Techno-economic Feasibility of Pathways for an Electric Transition for Petrol Stations

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June 25, 2021

Abstract

The energy transition is one of the main drivers of change for many businesses, especially, for petrol stations. It is well-established that the increase in the number of electric vehicles (EVs) and in the demand for charging places is a real challenge. The objective of this research is to create a future outlook of the petrol station that considers implementing electric chargers. It is important for petrol stations to eliminate the risk of a decrease in customer demand due to the switch of car owners to EVs. Three pathways are proposed in this research with consideration of different types of chargers and renewable energy (RE) source. To determine the best pathway, a Simple Multi-attribute Rating Technique (SMART) of multicriteria analysis was used. The scoring of the criteria is performed by considering technical and economical inputs of the pathways. The results suggest that a pathway with DC chargers and RE source is the best alternative out of the three considered pathways. Moreover, this visionary research helps to shape the business idea of a platform through Business Model Canvas and stakeholder analysis. In the platform, the petrol station owners have a variety of proposed scenarios for electric transition on a simple set of input data. The limitations of this investigation are based on the assumptions that were made along with the research.

Contents

1 Introduction

Nowadays, e-mobility plays a significant role in preserving climate change, because it facilitates one of the scenarios of sustainable energy transition. The contribution of the transport sector to the global greenhouse gas (GHG) emissions is impactful. However, by putting forward electrification of transport the amount of emissions can be reduced [1].

The current market of electric vehicles (EVs) experiences significant growth, this is motivated by the ambitious goal in the Netherlands of selling only EVs by 2030 and move towards carbon-free urban mobility [2]. To satisfy the usage demand of EVs there needs to be enough charging possibilities for their owners. At this moment, there is growing popularity of EVs charging stations. However, the increase consumption of private chargers at home is much higher, than increase of implementation of public chargers [3]. Another point of concern is that conventional fossil fuel vehicles are becoming less and less attractive as a mean of transportation [4]. Except of growing number of EVs around the world, electrification process has been happening to preserve the nature and environment and to contribute to sustainability goals. Hence, it leads to increase introduction of ancillary services, such as microgrid implementations to make power distribution efficient and satisfy the demand of the loads connected to it [5, 6].

All these aforementioned points can have a vital impact on the future of petrol stations. Thus, the prospective of electric transition of the current petrol stations into EV charging stations have to be analysed. The main points of concern with such transition is meeting energy demand of the EV charging system that depends on total frequency of EV's daily visits, user experience of the owners of electric vehicles, costs and revenues, etc. Also, increasing penetration of renewable energy (RE) is a key to sustainable energy transition, according to Sustainable Development Goal 7, target 7.2 [7]. Thus, RE sources can be considered for electric transition of petrol stations as well.

In this paper, the literature review on importance of electric transition of the petrol station is described and an explanation on the types and standards of chargers are provided. Next, the pathways of electric transition are introduced following by the technical and economical inputs that are considered for the pathways. To able to choose the best pathway out of three, multicriteria analysis has to be applied that consists of five steps. At the final step, sensitivity analysis of the outcome is performed. Eventually, the results are given to select the best pathway based on the technical and economical inputs. What is more, the business case was investigated by stakeholder analysis and formation of Business Model Canvas. The paper is finalized with the discussion and conclusion.

2 Literature review

In this section, the usefulness of the electric transition of petrol stations is discussed based on the research that was done before. In addition, the classification and types of chargers are described that can be used for this investigation.

2.1 Importance of electric transition of the petrol stations

Through a literature research it was investigated that petrol stations are one of the common options of placing EV chargers. In the article on assessment of EV charging infrastructure with help of analytical tools, it was found that intensity distribution of petrol stations and electric charges are correlated by 75.7%, meaning that locations at which they are placed coincide [8]. Thus, it points out that it is quite common to place chargers at the petrol station or in the close proximity to it. In another research that involves statistical evaluation, it was shown that preferable locations for fast chargers are motorway service stations, workplaces and petrol stations. Also, the respondents of the investigation pointed out that for battery electric vehicles (BEV) desirable locations for fast chargers are again motorway service stations and petrol stations [9].

However, several papers concluded that petrol stations might be not the most favorable location for EV chargers. In a two-level multicriteria analysis method of locating EV charging stations in urban surroundings, the authors found out that location of the electric charging stations close to P + R facilities or in high-density areas is more preferable than petrol stations. It is worth to point out that the research supports short trips made by EV due to research environment (e.g. in the cities) [1]. Another investigation was done to predict popularity of EV charging infrastructure in the cities. It was discovered that from geographical point of view, the main predictor of location of chargers is the amount of supermarkets, businesses, restaurants, hotels, etc. This research does not recommend against placing EV charging stations at the petrol station if it is located near aforementioned places [10].

Finally, feasibility of powering electric charging system with solar modules has been the subject of the investigated research. The outcomes have shown that solar panel system connected to grid is more profitable to the owner compared to grid-only or off-grid solar panel system. However, the PV-grid system was also sending electricity to the grid, in case there were no demand for charging and that is how profit was generated [11].

2.2 Chargers for Electric Vehicles

As it was already mentioned before, the rapid growth of EVs requires proper infrastructure of chargers to be built around the country. In this section, types and standards of chargers are described. Also, an explanation is given on which type of chargers is the most applicable for the electric transition of petrol stations.

It is important to differentiate that Europe and USA have different standards for chargers (IEC 61851 and SAE J1772 standard, respectively). The main difference between the standards lies in the different current and power outputs of each type of EV charger. European standard is applicable for this research, which consist of four charging modes. In these papers [12, 13], there were summarized different modes of charging and their various power outputs. Furthermore, the type of electric chargers is also essential to differentiate, such as private (domestic), semi-public and public [3]. For this investigation, the interest lies in the public high power chargers with 3-phase AC connection (Mode 3) and with DC connection (Mode 4), where both provide more than 22 kW of output power. Mode 1 and Mode 2 are not considered here due to its usage mostly as a domestic or semi-public chargers that supplies less than 22 kW of power and long charging duration compared to Mode 3 and Mode 4 [3, 12]. What is more, the petrol stations relate to the public chargers only in the scope of this research.

2.2.1 Technical aspects of AC and DC charger

From a technical perspective, with AC chargers, AC to DC happens on-board of the car through inverter. With DC fast chargers the conversion from supplied AC to DC is performed off-board of electric car (inside the DC charger). From the DC fast charger, DC is passed to the car battery directly and it avoids being converted (and lose power) from AC to DC inside the car. It simply bypasses the on-board inverter of the EV. That is why the power that is supplied by DC charger to EV can be almost ten times higher compared to the other modes of charging [14].

However, DC fast chargers are not compatible to all the EVs that are being sold on the market due to maximum input power of 50 kW for older EVs that DC can supply [15]. What is more, DC fast chargers are not being widely implemented compared to AC charging stations, because of the high cost of implementation [16]. This leads us to consider both AC and DC chargers to be implemented at the petrol stations.

3 Methodology for choosing electric transition

An approach to deciding on the best alternative for the electric transition of the tank stations is discussed in this section. At first, the pathways of implementation of electric transition are discussed. Next, the common technical and economical inputs for each of the pathways are listed and characterized together with the assumptions that were made based on the prior research. Finally, multicriteria analysis is introduced as a decision-making tool to select the pathway that will be implemented at the petrol station.

3.1 Pathways of electric transition of petrol stations to public charging stations

With consideration of the reasoning provided in the literature review about different charging modes 3 and 4 and public type of electric chargers, I would like to introduce three pathways that are studied for the electric transition of the petrol stations. Based on these proposed pathways the best solution can be identified.

3.1.1 Pathway 1

In this pathway, commercial EV charging system is considered that can be implemented in case that electric transition happens today at the petrol station. The overall system block diagram is depicted on the Figure 1 below.

To begin with, the definition of the microgrid needs to be addressed. Microgrid represents a distributed network that includes various components, starting from broader components, such as any resources of energy, loads, energy storage system and ending with more distinct components, like cables, power inverters, controllers, etc. With these components, microgrid is responsible for the energy management to supply and distribute the demand correctly between the items of microgrid [17].

Thus, for the Pathway 1, the AC chargers are used and the energy demand is distributed between the connected electricity grid, energy storage system and grid-connected PV system. They are connected through power inverters in AC microgrid configuration. Of course, AC microgrid consists of more details, however, for the scope of this research, it is sufficient to show only the system block diagram of the Pathway 1, where components are generalized. The details of configuration were inspired from these research papers [18, 19].

At this point in time, 3-phase AC chargers of charging mode 3 classification are widely used around the Netherlands and that is reason of them being implemented here, compared to the fast DC chargers which plan to penetrate the market in the near future [2]. The maximum value of output power of AC charger found in the literature review is 43 kW charger and this value was taken for this research [12].

3.1.2 Pathway 2

Pathway 2 provides future outlook of the EV charging system. The main difference from the previous example is that DC fast chargers and other components in DC microgrid configuration are going to be used here, instead of 3-phase AC chargers and certain components in AC microgrid configuration. The vision of the Pathway 2 of EV charging station is shown in the Figure 2. The output power of the fast DC charger of 50 kW was taken from the Thesis paper of my colleague on electrical implementation of DC fast chargers inside the petrol station.

3.1.3 Pathway 3

In the first two pathways, there was a need to implement RE source for the charging stations. In this pathway, the case of full dependence on energy demand being delivered by the grid providers is taken into account. Moreover, the same AC charger and components implemented in AC microgrid configuration are

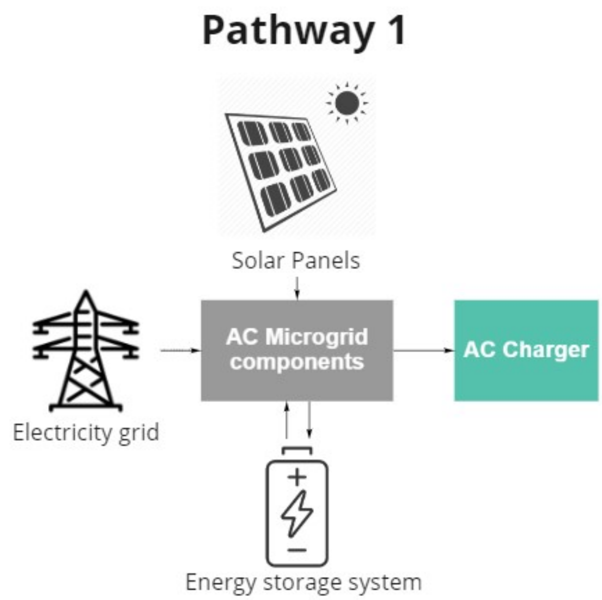


Figure 1: Pathway 1 of the electric transition of petrol stations

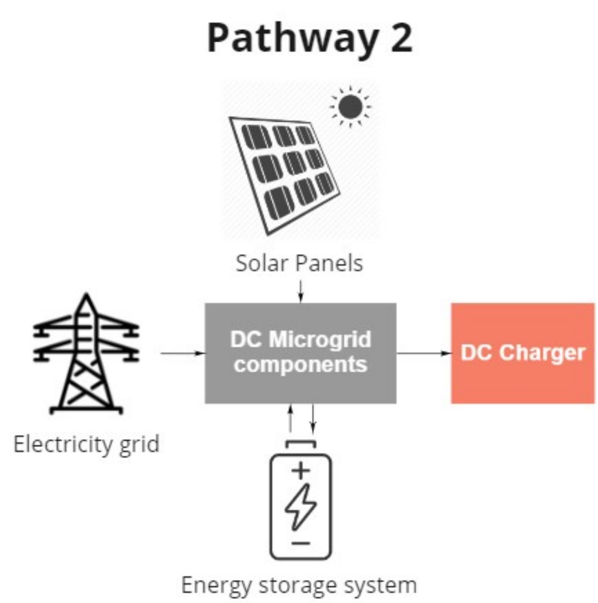


Figure 2: Pathway 2 of the electric transition of petrol stations

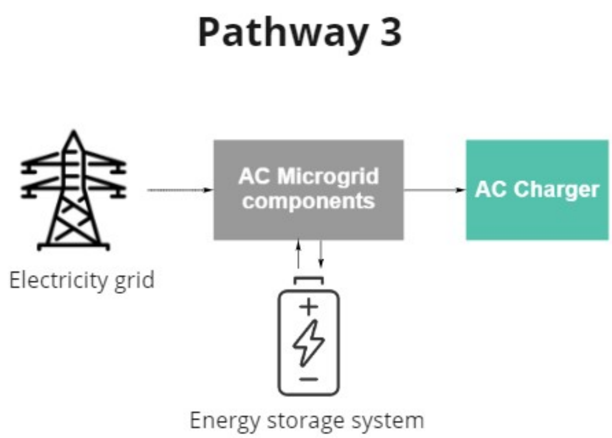


Figure 3: Pathway 3 of the electric transition of petrol stations

used here as it was proposed before in Pathway 1. Of course, components in AC microgrid composition that are relevant to PV modules were discarded. Pathway 3 is shown in the Figure 3:

3.2 Common inputs to the pathways

Each of the pathways require more or less similar inputs. In this research, these inputs are served as tuning parameters to discover the best alternative out of the three pathways that are considered with help of multicriteria analysis that is discussed in the next subsection 3.5. There is differentiation made between technical and economical inputs. The critical points that have to be determined with both of the inputs are energy demand from the grid and RE (if applicable), distribution of energy between grid and RE, financial feasibility of the pathways and the charging time of the EVs, more information about it can be found in the section 3.5 later on.

Table 1. Technical and Economical inputs to the pathways

Input	Value	Units
Technical Inputs		
Average monthly solar irradiance (from January to December) [20]	770, 1460, 2620, 4110, 5500, 5550, 5420, 4710, 3010, 1660, 860, 540	$[W/m^2]$
Average monthly temperature (from January to December) [20]	12.96, 13.08, 14.02, 15.29, 17.00, 18.87, 21.18, 21.95, 21.31, 18.91, 15.84, 13.06	$[°C]$
Average monthly sunshine hours (from January to December) [20]	2, 2, 4, 5, 7, 7, 6, 6, 5, 3, 2, 1	[hours]
Single solar panel size [21]	1.7	$[m^2]$
Battery capacities of EV [22]	47.5, 95, 36, 32, 64, 37.9, 52, 64, 95, 84.7	$[kWh]$
State-of-charges (SOCs) of EV battery	10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85	[%]
Charger power outputs	43 (AC) and 50 (DC)	[kW]
Charging sessions per week	27	-
Number of charging sessions	3 and 6	-
Economical Inputs		
Annualized costs of the system	depends on the pathway	[Euros/year]
Weighted average cost of capital (WACC)	5	[%]
Energy rates in the Netherlands [23]	0.095	[Euros/kWh]
Charging costs for customers [24]	0.4 (AC) and 0.6 (DC)	[Euros/kWh]

In the Table 1 above, there were listed all the values that are considered as tuning parameters of this research. In the next subsections 3.3 and 3.4, the explanation behind each value in the table and selection of the best values of certain inputs are provided. However, it is essential to point out the most critical assumptions that were made to select these inputs:

1. The lifespan of the project is considered from 2021 until 2030 for the scope of this research. The reason to choose 2030 has to deal with objectives of Coalition Agreement made in the Netherlands [25]. Thus, the analysis of costs and revenues is shown until 2030.

2. The area that solar panels can cover at the petrol station is assumed to be 150 m^2 that considers the size of the roof of the petrol station and the shop next to it.

3. The average driving distance per day in the Netherlands of 38 km [22] is similar to the one that was shown in the study of charging behaviour of EV owners in Berlin 37 km [26]. Thus, the difference of 1 km was neglected

and the results of the investigation of charging behaviour are used in this research.

4. The assumption was made that throughout a year the number of charging sessions per month is the same. Furthermore, throughout a year the demand for charging stays the same.

5. During the charging session, it was assumed that EVs are being charged until 80% due to linear behavior of the battery. After exceeding 80% and reaching 100% the battery of EV has non-linear behaviour [27]. The change in charging behaviour after SOC is higher than 80% can be observed in the results section 5.2.

6. It was assumed that this research is only done for battery electric vehicles (BEVs) due to limitations of input power that can be delivered to plug-in hybrid electric vehicles (PHEVs) [14].

7. There were no considerations made with regards to the time of the day that EVs are entering to charge. Meaning that energy demand from EVs per day and month treated as a constant value.

Other assumptions are present in the description of the inputs in the subsections below.

3.3 Technical Inputs

The following are the technical inputs for the pathways and some of them are based on the assumptions described above and the others introduce new assumptions. One should note here that all the technical inputs cannot be varied to make a final decision on the best pathway. Hence, the values that are shown in bold represent the approximated fixed value of certain inputs.

- **Solar insulation (Irradiance and temperature).** The daily average irradiance and temperature per each month throughout the year starting from January until December was taken (and that is the same order as it is shown in the Table 1). This choice helps us to derive the energy that can be supplied from the solar panels. In the research paper [28], it was discovered that differences in irradiation influence current of the solar panel, but it doesn't have an impact on voltage. However, temperature has the profound effect on voltage, while current is not being influenced. To make sure that accurate value of output can be derived, both irradiance and temperature have to be considered. Calculations were made based on the model proposed in the book [29]. Before we are going into the expressions to compute output power of PV panel, it is crucial to mention that Standard Test Conditions (STC) are the conditions at which each solar panel is tested. Now, the selected solar panel for this research has an efficiency of 22.1% and output power of 390 [W] [21].

Let us first start with calculations of output power of PV module based on Global Horizontal Solar Irradiance [20]. It is important to say that current calculations show only the power at a given instant, in order to calculate daily average of solar irradiance, it has to be multiplied by the daily hours of sunshine at each month of the year that was placed in the Table 1 above.

$$P_{mt} = (\frac{G_t}{G_{STC}}) * P_{STC} \tag{1}$$

, where P_{STC} = module power at STC [W], $G_{STC} = 1000$ $[W * m^{-2}]$, $G_t = 1$ $[W * m^{-2}]$ at time t, P_{mt} = module output power at G_t [W].

Next, the output power based on the temperature has to be computed in the following way:

$$P_{mT} = P_{STC} * C_p * (T_m - T_r) \tag{2}$$

Where C_p = module power temperature coefficient provided by the data sheet $[\frac{\%}{^{\circ}C}]$, T_m = operational temperature at a location $[^{\circ}C]$, T_r = module reference (STC) temperature $[^{\circ}C]$, P_{mT} = change in module power at temperature T [W].

Eventually, it is time to combine both of the expressions together to calculate the output power of a single solar panel based on the irradiance and temperature at a given instant:

$$P_m = P_{mT} + P_{mt} \tag{3}$$

As a last thing, the power at a given instant was multiplied by the amount of daily average sunshine hours of each month throughout the year starting from January until December as it is shown in the Table 1.

Exactly this model was put into the MATLAB to perform calculations on solar power output. The only thing is left here is to assume the size of the area that is used at the tank station. Referring to the assumption made in the previous subsection of the coverage area of solar panels, where the solar panel system covers the roof of the petrol station. It can help us to compute the amount of solar panels that is needed for this project.

- **Battery capacity of EV.** To determine battery capacity of the BEVs the 10 most purchased BEV models in the Netherlands were chosen to determine the average size of the battery. Next, the probability was calculated of each of the BEV models [22]. Following that, randomly generated data sample of 1000 samples was made based on probability of each electric car. Finally, to determine the most probable value of the battery capacity, a median of the sequence was taken. The reason to choose the median over the mean is that a bell curve of normal probability distribution was skewed in a plot. The outcome was positively skewed and due to skewness median is better choice over the mean [30]. **The median value was calculated to be 47.5 [kWh].**

- **State-of-charge (SOC) battery of the customer's EV**. Each car that stops by the charging station usually has a various state of charge of their batteries. The charging behaviour of EV owners found in the succeeding research [26], which shows probability of the SOC of the battery of incoming EV. In the same way as with computations of batter capacity of EV in the item above, the state-of-charge of the batter was derived. In this case, the mean was used due to slight difference between median and mean. Moreover, the graph of normal distribution is really close of being symmetrical [30]. **The mean value of SOC is 45.12%.**

- **Average number of charging sessions per week.** This input is related to the energy demand of both grid and RE source, since depending on charging sessions per day the appropriate energy demand can be derived. Firstly, in the research of charging behaviour of EV owners, it was discovered that they charge 3.1 times a week for assumed average driven distance of 37-38 km per day [26]. Secondly, the amount of BEVs and the percentage of BEV owners that charge at public fast chargers was derived. The approximate number of BEVs is taken based on the national report on EV adoption, where the number of BEVs is 174 801 in the Netherlands.

  Next, in yet another report of the national charging infrastructure agenda [2], it was discovered that the amount of publicly fast charged EVs is 11%. Thus, 11% was taken from the total amount of BEVs and the result is 19 228 BEVs charge on public fast chargers. The number of fast chargers in the Netherlands is 2187. Eventually, we can derive that for the amount of fast chargers and the amount of electric cars that charge publicly, there are 8.79 BEVs per fast charger. Finally, returning to the discovered number of charging sessions per week (3.1) and approximated number of BEVs per fast charger (8.79). The total amount of charging sessions per week is 27.25 (rounded up to 27). To calculate the total number of charging sessions per month, **27 charging session per week** was multiplied by 4, which gave result of **109 charging sessions per month**. In order to calculate the number of charging sessions per day, the master thesis were used [22], where distribution of chargers per week can be found. Based on that it was assumed that the maximum percentage of cars that can come to a charger per day is equal to 18% of 27.25 charging sessions per day, which equals to 4.9 charging sessions. In the similar manner the lowest number of cars per day is 3. Thus, the values that were taken as a range are **from 3 to 5 BEVs per one charger** that come daily.

- **Number of chargers at the petrol station.** According to the Transport and Environment report [31], there are 17 fast chargers per 100 km, which means that there is one charger for each 5.88 km assuming linear distribution of the locations of chargers. Now, let us take into account the value of average driven distance in the Netherlands and divide it by the distance of location of chargers: $\frac{38[km]}{5.88[km]} = 6.46$ chargers per charging pool needs to be present to satisfy the number of EVs. The value of chargers were rounded up and 6 chargers per petrol station was taken as a value. Another research in the same paper [31] has shown that there are 7 EVs per fast charger for 100 km. Using the same reasoning as was used above leaves us with 2.66 chargers per petrol station to satisfy driven distance of 38 km. In this case, the amount of chargers was taken as 3. For further research of the pathways, **6 chargers** are considered at the petrol station, while the case of using 3 chargers is explicitly mentioned, if it is used.

These inputs are crucial for determining possibilities of each of the pathways.

Especially, all the technical inputs are used to determine the energy demand that is required from the chargers at the petrol station. Energy demand can be computed starting by using the charger output power for the specific pathway and the number of chargers. That is followed by the amount of BEVs that come to the chargers, their estimated battery capacity and SOC value at the moment of arrival to recharge. This strategy of calculations assesses roughly the expected value of energy demand. Furthermore, the input from RE source has an effect on the requirement from the energy that needs to be supplied from the grid as well.

3.4 Economical Inputs

Here are represented economical inputs for the pathways:

- **Annualized cost of the system (ACS).** It refers to the sum of annualised capital costs (ACC), annualised operational costs (AOC). ACS consist of other parameters as well, such as capital recovery factor (CRF), annualised maintenance cost (AMC) and yearly fuel cost (AFC) [32]. However, both CRF, AMC and AFC were not taken into consideration due to simplification of the research. The equation for calculation of ACS is provided 4 below for the next 9 years (from 2021 until 2030):

$$ACS = \sum_{n=1}^{9}[ACC + AOC] \tag{4}$$

  ACC referes the one-time purchase, for instance, of new equipment. In our case, it relates to acquisition of solar panels [21], chargers for EVs [12], storage battery [33], microgrid components, inverters and installation costs that are involved with it. It can be seen that certain values of costs were found in the literature. However, the readers need to be advised that installation costs, microgrid components and inverters costs were simply assumed. The total list is shown in the Figure 4 of the table.

  One should note here that AOC involves a payment for the energy consumption from the grid.

- **Weighted average cost of capital (WACC).** Although CRF was not included, there are still considerations were made with regards to the time value of money and any loans that company has taken with help of

Assumed costs for this research

	Pathway 1	Pathway 2	Pathway 3
Solar panel system	€ 27.081,00	€ 27.081,00	€ 0,00
AC charger	€ 2.500,00	€ 0,00	€ 2.500,00
DC charger	€ 0,00	€ 15.000,00	€ 0,00
Inverters	€ 1.600,00	€ 1.600,00	€ 1.600,00
Storage battery for 160 kWh	€ 18.020,00	€ 18.020,00	€ 18.020,00
Microgrid	€ 5.000,00	€ 5.000,00	€ 5.000,00
Equipment installation costs	€ 48.000,00	€ 78.000,00	€ 33.000,00
Total:	€ 102.201,00	€ 144.701,00	€ 60.120,00

Figure 4: The table of costs that are assumed for this research. References to some of the values are mentioned in the description of this figure.

WACC. This economical input helps to bring calculations closer to the real situation and considers the inflation possibilities in the future [34]. The value of WACC was assumed to be **5%**.

- **Energy rates in the Netherlands.** There is a difference in energy rates that have certain value for homes and businesses. In this case, charging station is in the business category and thus, the price is being lower at **0.095 [euros/kWh]** [23].

- **Charging cost for customers per charging session.** It is crucial to know this input to derive potential revenue out of the model. Due to differentiation in the pathways between AC and DC chargers, it was assumed to keep both prices of **0.4 [euros/kWh] for AC charger** and **0.6 [euros/kWh] for DC charger** [24].

3.5 Multicriteria analysis

In this section, multicriteria analysis approach that is undertaken in this research is described. Multicriteria analysis (MCA) is a decision making tool that helps to evaluate several different decisions and solutions based on the identified criteria. Next, preferences between these criteria are evaluated to which extent pre-determined objectives are achieved. The objectives are made to emphasize the preferable outcome that MCA needs to achieve [35]. There are exists multiple types of MCA, such as Simple Multi-attribute Rating Technique (SMART), multi-attribure utility theory (MAUT), analytical hierarchy process (AHP), etc. However, for this research emphasis was made on SMART, because it is one of the most commonly used types of MCA in practice and it helps to deal with uncertainty, which is present in this visionary research. Moreover, SMART is used for decision making on evaluation of the performance of several attributes and determining the best solution for the problem [36]. This choice of the type of MCA was also confirmed by the expert (PhD student) in decision making from BMS faculty at University of Twente. Interesting point to realize is that each type of MCA uses the same tool, such as performance matrix. It is a table that consists of criteria or attributes. It also gives space for evaluation of performance of these attributes. As it was already mentioned above, the evaluation of criteria is based on how close the objectives are met. The performance matrix assessment consists of two stages, namely scoring and deriving weights of attributes [35]. More information on details of scoring and weighing is described in subsection 3.5.3 below.

One can ask about inclination of the outcome to the preferences of the decision-maker. This can be resolved by establishing criteria that have mutually independent preference, meaning that judgment of one criteria can not effect the judgement of another criteria. Otherwise, the outcome is biased towards preferences of the decision-maker, indeed. Next, the steps of multi-criteria analysis were generalized from two sources [35] and [36] as follows:

1. Establishing the decision context and the objectives.
2. Identify options and criteria.
3. Measure the performance of the alternative choices of the criteria (Scoring strategy).
4. Weights of criteria and derivation of the overall results.
5. Sensitivity analysis of the results.

The following subsections are examining the details of MCA steps.

3.5.1 Establishing the decision context and the objectives

The decision context was already partially described above with introduction of the pathways in the subsection 3.1. However, the main idea here is to present the objectives that have to be achieved with help of MCA.

Objective 1: Find the appropriate pathway for the electric transition of petrol stations.

Objective 2: Analyze the possibility to power EV charging station with help of RE source.

Objective 3: Determining the techno-economic suitability of the electric transition of the petrol station.

3.5.2 Criteria identification

It was suggested that one of the means of finding criteria for MCA is through examining information sources [35]. Next, the criteria were analysed on their quality whether they are complete, redundant and mutually independent of preferences [36]. The first two analysis of qualities of criteria are quite self-explanatory and the last one was described in the section 3.5 above. Moreover, the selected criteria were shown to the industry expert for validation as well to prove their relevance. It is time to introduce selected criteria:

- Energy usage ratio between the grid and RE
- Net Present Value (NPV) of the pathway until 2030
- Time to charge EV for customers

Next, the reasoning behind each of the selected criteria is described below.

Energy usage ratio between the grid and RE was chosen to show possibility of outsourcing certain amount of energy (approximated amount is determined in the Results section 5) from the grid to RE sources. It was inspired by the paper [37], where Energy Ratio was considered as a performance indicator on the appropriate location of the EV charging station. This criterion helps to achieve the objective of RE implementation at the charging station and in line with governmental regulations in the Netherlands [25].

Net Present Value (NPV) of the pathway until 2030, Net Present Value (NPV) tells us the value of all the cash flows after the certain period of time (our period is until 2030). It encompasses revenue, costs, time value of money, etc. Of course, in research all the parameters that have an influence on NPV were not considered, for instance, taxes [38]. This criterion tells us by how much costs outweigh the benefits and whether payback for specified period of time is attractive enough for the owners of the petrol station.

Time to charge EV for customers, it refers to the time that customers willing to spend on the petrol station while charging. It is a crucial factor for attracting the customers and ensuring proper user experience for them.

3.5.3 Measurement approach of the performance of the criteria

At first, to make a decision of the most rated attributes, one has to follow normalized approach. The criteria are scored on the scale from 1 to 10 to determine their relevance to the proposed objectives. Next, all of the criteria that were selected are easily quantifiable. Hence, a direct rating needs to be created to make sure that marginal preferences between criteria of decision maker are taken into account. It is important to point that evaluation happens based on the interval scale between criteria in the same way as Fahrenheit and Celsius temperature scales are being compared [36]. In direct rating, initial set of values for scores was made by the researcher. It is derived from the MATLAB calculations of inputs that are shown in the Results section 5. Here is the description of application of direct rating for each criterion.

For Energy usage ratio between grid and RE, the desired ratio was derived from the Climate Agreement made by the government of the Netherlands. In general, the Netherlands would like to achieve 49% reduction in carbon emissions by 2030. The approach that was taken is to calculate the reduction that needs to be made for the biggest five sectors to get to 49% reduction. One of them is electricity sector, where a strong encouragement of using 49% of Renewable

Energy (RE) sources as a basic package and that has to be accomplished by 2030 [39].

Thus, with application of direct rating the score of 10 was given to the pathway, where energy supply of 49% comes from RE source. Starting from there, a linear proportionality is used to derive the scores for all other variables up until the score of 1.

Net Present Value of the pathway. To start with, the NPV was computed by the following formula for the period from 2021 to 2030:

$$NPV = \sum_{n=1}^{9} [\frac{R_t}{(1+i)^t}] \tag{5}$$

Where R_t = net cash flow during one period of t, i = WACC and t = number of time periods.

Next, the computation details of the costs and revenues are described.

With regards to costs, there were computations made with regards to costs based on the input variables that were introduced before. As it was already discussed in the subsections 3.3 and 3.4, energy demand helps to find the operational costs (AOC) per month. For the *capital costs*, purchase costs of chargers, storage batteries, microgrid, transmission cables, inverters and solar panel system (for the Pathway 1 and 2 only) are involved. Moreover, in capital costs there is a presence of costs for installations of microgrid and solar panels, which were mentioned in Figure 4.

In terms of the revenue, the computations were made based on the charging prices, where for the Pathways 1 and 3 (AC charger) the price of charging was selected as 0.4 [euros/kWh]. For the Pathway 2, the price was chosen as 0.6 [euros/kWh] due to DC charging.

Finally, based on the values of NPV the score of 1 was assigned to the lowest NPV of the selected pathways and score of 10 was assigned to the highest NPV value which rounded up to closer value. Due to consideration of only 3 pathways the scoring turns out to be less reliable. Thus, to make scoring more robust, the variation in the number of chargers was included to make the scoring. Now, the scoring is made with application of both three chargers for 3 pathways and six chargers for 3 pathways, having six options to make a scoring work reliably.

For time to charge EV for customers. Here the average value of time to charge your EV was taken to be 33 minutes, since it is the average time that people take for their lunch break in Europe [40]. It is not possible to apply linear proportionality here as it was done with energy ratio, because of the minimum charging time of available DC chargers on the market is 15 minutes [41]. Thus, as an assumption the maximum time was taken to be 45 minutes that people would like to stay at the tank station. This case is given a grade of 1. Next, the lunch break time of 33 minutes is given the grade of 5, while the 15 minutes receive a grade of 10. The other scores are assigned based to their proximity to aforementioned scores.

3.5.4 Weights of criteria and derivation of the overall results

Here, the weights of the criteria are given and required computations of the outcome are discussed. The initial weights were assigned by me as a researcher in consideration of the scale from most influencing criteria to least influencing criteria [36]. This is done in order to evaluate the sensitivity of the weighting criteria on the outcome.

Energy usage ratio between grid and RE	30%
Net Present Value of the pathway	40%
Time to charge EVs for customers	30%

Next, to calculate the value of the criterion for a certain pathway can be found in the simple equation of [36]:

$$Value = Score * Weight \tag{6}$$

Afterwards, the total value of the pathway is calculated by summing all the values of criteria of each pathway. The pathway that has the highest total value is the best option for an electric transition. More information on derivation can be seen in the results section of this report 13.

3.5.5 Sensitivity analysis

The relevance of sensitivity analysis boils down to examination on how robust are the proposed criteria with help of scenarios. For example, the uncertainty in the weights of criteria might be troubling for decision maker [35, 36].

Thus, several scenarios of sensitivity analysis are proposed here:

- Amendments in weights of criteria.
- Change of output power of AC chargers from 43 kW to 22 kW for the Pathway 1 and 3, due to the feedback received from the industry expert.
- Consideration of the total number of the EV fleet, including BEV and PHEV. One should note here that this has an effect on AC chargers only, since DC chargers cannot charge PHEV [15].

The main idea of sensitivity analysis is to assist the decision maker in understanding the problem that he or she is trying to solve and to help in selection of the best pathway to follow.

4 Business Case creation

This section describes relevant aspects of creating a business case, which consists of stakeholder analysis and Business Model Canvas. I came up with an idea for facilitation of the electric transition of petrol stations. The initial idea was to evaluate business viability of electric transition for a single petrol station to be able to estimate whether this transition makes sense. However, two factors that needs to be satisfied to be able to prove that it makes sense to perform electric transition. First of all, aforementioned governmental regulations are supporting this transition [25,39]. Next, the business needs to make a profit after a certain period of time to function properly and it can be seen in Results 5 whether this is the case. The latter being as an assumption that is validated in the next section. Now, I propose to make an amendment in the business idea, because the current business idea does not have a scalable solution. It refers only to a single petrol station that will perform only one-time action after which the business idea becomes irrelevant for them.

The newly proposed business idea considers creation of the data analysis platform that can facilitate the electric transition for many tank stations. On the platform, a petrol station owner can input the data that is known to him, which is mentioned in the subsection 3.2. Eventually, the data that is being processed and in the same way as in this research, the pathways are proposed to the petrol station owners, which are evaluated by the decision making tool, such as MCA. The more customer use our platform with their unique dataset, the higher the probability that the outcome is reliable. The owner of such a platform will be a StartUp that works closely with the stakeholders described further. With this business idea broader range of the petrol stations can be covered.

4.1 Primary stakeholder analysis

To begin with, the definition of the stakeholder needs to be given. The stakeholder can be anyone that has an engagement or interest and he or she has certain consequences with the success or failure of the project. Also, stakeholders can influence the project flow and determine whether it is relevant to proceed or not. In this research, the attention has to be put on the primary stakeholders, which have the most power and influence on the outcome of the project. To determine that the power/influence grid that is proposed in this source is used [42]. The outcome of stakeholder analysis can be seen in the Results section 5.6.

4.2 Business Model Canvas

Business Model Canvas (BMC) offers a unique possibility to show all the elements that have to be taken care of while setting up a venture. From the general overview, BMC is separated into groups related to the main areas of business, such as infrastructure, offer, customers and financial viability. These groups are represented by nine building blocks of BMC, namely customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost infrastructure. With the application of this business model, it is possible to inspect all the aspects of business feasibility of the electric transition of petrol stations into EV charging stations [43].

5 Results

In this section, the results are shown starting with the outcome of calculations of energy demand for the petrol station, results of techno-economic suitability. Following that, MCA results are given with the performed sensitivity analysis. Ending with proposed business case that is discussed by means of primary stakeholder analysis and BMC.

5.1 Finding distribution between grid and RE source based on the inputs

The results of energy supply and demand are shown below for the Pathway 1. The other pathways were analysed in the similar manner and the results of each of them can be seen in the MCA subsection 5.4. The energy supply is described by the solar panel system calculations, while energy demand is characterized by combination of the technical inputs. Eventually, the energy supply and demand is compared.

5.1.1 Energy supply from solar panel system

The energy supply was found by modelling the solar panel system and its output based on irradiance and temperature. The expression for modelling can be found in the subsection 3.3. The power output was modelled and plotted with help of MATLAB to determine average power output of a solar panel output system that covers an area of 150 m^2, while a single solar panel has an area of 1.7 m^2. At the end, the total number of solar panels in the system is around 85. The outcome can be seen in the Figure 5 below.

5.1.2 Energy demand from EVs

With regards to energy demand, it was determined through combination of parameters described in the previous section 3.3. The step-by-step procedure of calculations is described here:

1. A selected charger with output power for a certain pathway, which is either 43 kW for AC or 50 kW for DC chargers.

2. Use the determined value of battery capacity in the subsection of technical inputs 3.3.

3. The EVs are being charged until 80% of SOC of their batteries. However, the SOC of incoming electric cars is being varied from 10% to 70%.

4. Consider the number of incoming electric cars being from 3 to 5 at the petrol station per day and 109 charging sessions per month.

5. A for-loop was made to encounter both change in SOC values of incoming EVs and the number of EVs per day.

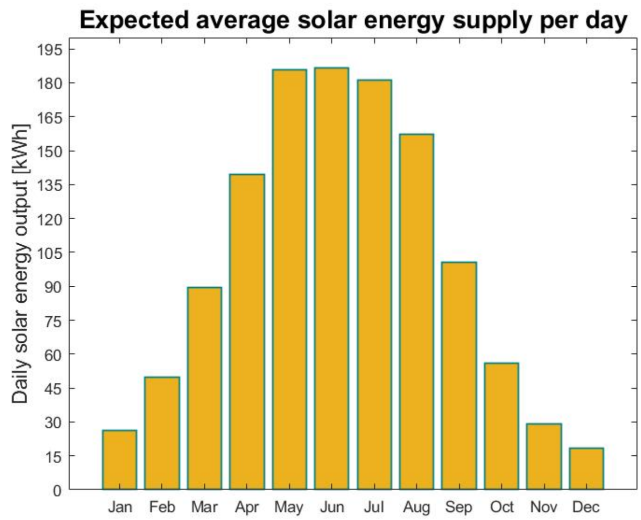


Figure 5: Plot of daily average solar energy supply of the solar panel system for each month shown for the whole year.

6. The results were plotted.

It is important to note that the approximated value of SOC of battery of entering electric cars is known (which is 45.12%) and it was plotted together with other SOC values. However, the energy demand was plotted to encounter different SOCs to understanding the maximum energy demand that is possible. The Figure 6 above shows the energy demand per day with regards to SOC of the battery and the number of entering EVs.

Furthermore, the plot for monthly energy demand was made to show the energy demand for 109 charging session per month. For the fixed value of SOC of 45.12% of EV battery that needs to be charged until 80% of its battery capacity, the energy demand per month is 1806 [kWh].

5.1.3 Combination of energy demand and supply

Eventually, with fixed technical input values mentioned above, the graph was plotted of energy demand and supply for the Pathway 1 both for daily and monthly case. With regards to daily case the number of EVs was taken as maximum (5 cars per day) with SOC of 45.12% to show the worst-case scenario. The Figure 7 shows the results of it.

Also, the percentages were found of dependence between the grid and RE source. At first, the average energy demand that is required for the chargers was calculated by summing energy demands of the months. Secondly, the same calculation procedure was done for the energy supply that is given by the solar

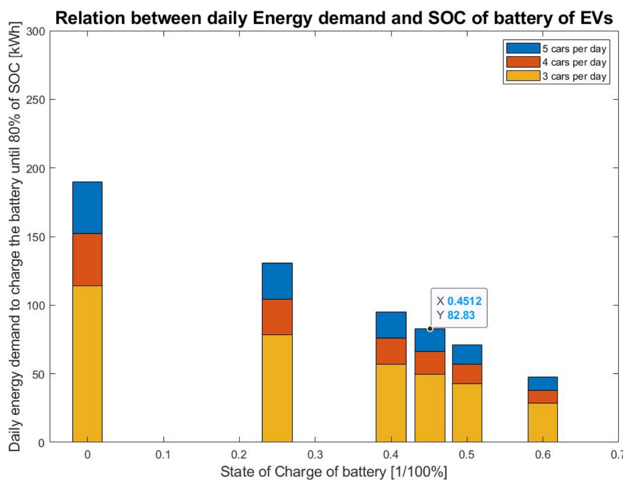
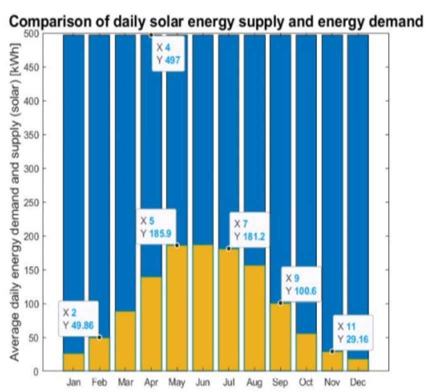


Figure 6: Expected daily energy demand to charge entering EVs until 80% of their battery capacity at a single electric charger. *Note:* the plot shows varying SOC value of entering EVs that are charged until 80% of their battery capacity.



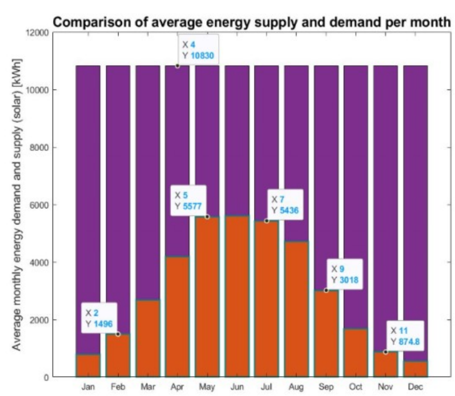


Figure 7: Comparison of expected energy demand and supply for different periods of time. *On the left:* Expected daily maximum of expected energy demand and supply from solar panels. *On the right:* Expected monthly energy demand and supply.

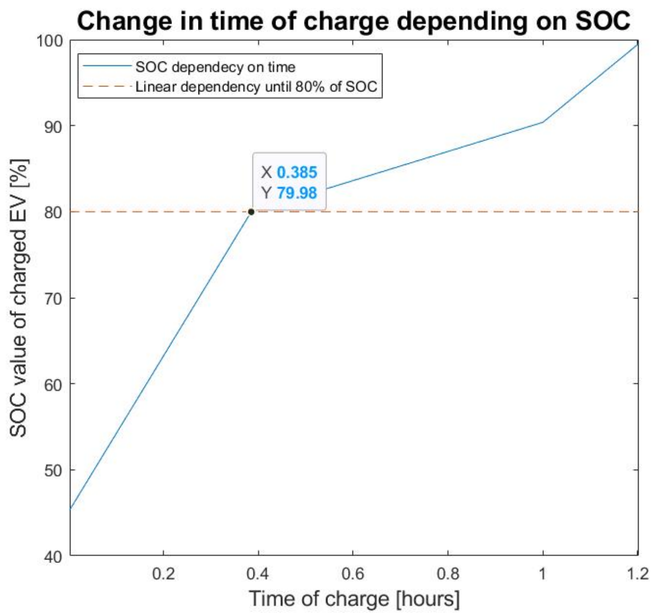


Figure 8: Charging time of incoming EV with the fixed value of SOC (45.12%)

panels. Now, by finding yearly values of energy demand and supply, the percentage of distribution can be found. Finally, the table below shows the percentages of distribution between the grid and RE source for each of the pathways.

Table 2. Results of energy distribution between grid and RE

Pathway 1	Pathway 2	Pathway 3
28.41%	28.26%	0%

These derived values are used in multicriteria results in subsection 5.4.

5.2 Time to charge EV

In order to determine the time of charge of EVs. The graph of charging time that is compared to the SOC of EV battery was plotted in the Figure 8 above. It is important to note that the value of SOC is being fixed at 45.12%, when EV enters to the charger. The figure shows not only the charging time of EV for the Pathway 1, but additionally shows the reason of not choosing EV being charged until 100%, but until 80%.

In the similar manner the plots were made for the other pathways, where EVs are charged until 80% and the results are shown below.

Table 3. Charging time of EV represented for each pathway

Pathway 1 and 3	Pathway 2
23.1 [minutes]	19.8 [minutes]

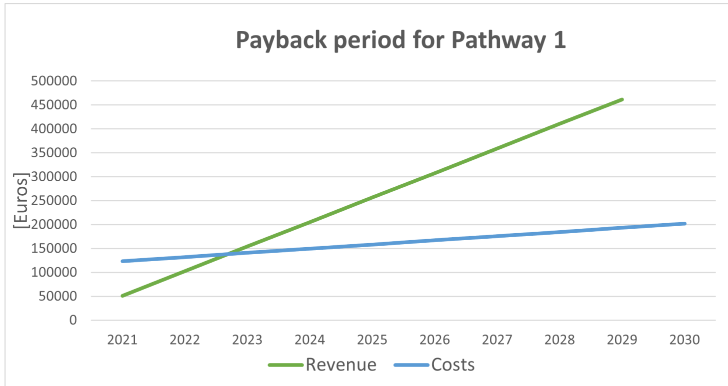


Figure 9: Payback for the period from 2021 until 2030 of the Pathway 1

Eventually, charging time of EV is used at the multicriteria analysis in subsection 5.4.

5.3 Techno-economic suitability results

To determine techno-economic suitability, the computations were made of the Net Present Value (NPV). Also, payback period graphs for each of the pathway are included in this subsection.

Starting with payback period graphs, where the revenue and cost were compared for the period of 9 years. It is important to note that no revenue is expected for the first year (for 2021), since there are only costs involved for implementing the system in reality. Firstly, the graph for payback period of the first pathway is depicted in the Figure 9 above.

Secondly, the payback period for the second pathway is shown in the Figure 10 and thirdly, the same plot is made for the third pathway that is shown in Figure 11.

Eventually, it is known that payback does not encounter amendments in the time value of money and involvement of loans and so on. The results considered more reliable with computations of NPV for the same time period. In the table below these results are demonstrated. Moreover, only the case with 6 chargers can be observed, the other results with the same pathways and 3 chargers are shown in the Figure 12 of distribution of scores.

Table 4. NPV values of each of the pathways

Pathway 1	Pathway 2	Pathway 3
1519429 [euros]	1600476 [euros]	1533982 [euros]

At this moment, all the criteria are found and it is time to give them appropriate scores that were found in the previous section 3.5.3.

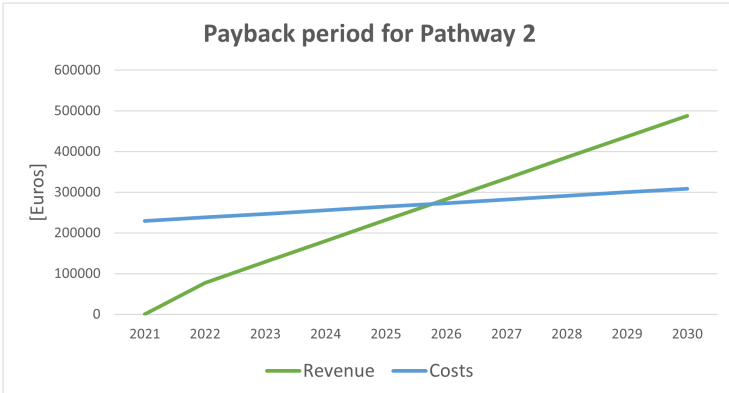


Figure 10: Payback for the period from 2021 until 2030 of the Pathway 2

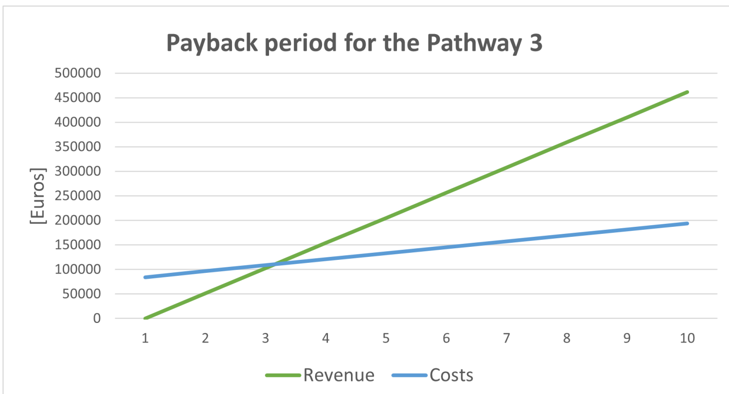


Figure 11: Payback for the period from 2021 until 2030 of the Pathway 3

Scoring of the criteria

Score	Normalization	Grade for the distribution of energy	Grade for the Net Present Value	Grade for the time of charging of EV
10	100	49	1700000	15
9	90	44,1	1600000	17
8	80	39,2	1500000	20
7	70	34,3	1400000	22
6	60	29,4	1300000	25
5	50	24,5	1200000	30
4	40	19,6	1100000	33
3	30	14,7	1000000	35
2	20	9,8	900000	40
1	10	4,9	800000	45

Figure 12: Scoring distribution of criteria based on the results and previous assumptions.

Multicriteria analysis of electric transformation for petrol station

Criteria:	*Rank Relative %*	Pathway 1	*Score 0 to 10*	*Weighed Score*	Pathway 2	*Score 0 to 10*	*Weighed Score*	Pathway 3	*Score 0 to 10*	*Weighed Score*
Energy usage ratio between grid and RE [%]	30,00%	28,41 % of RE	6	180	28,26 % of RE	6	180	0 % of RE	1	30
Net Present Value of the pathway [euros]	40,00%	€ 1.519.429,00	8	320	€ 1.600.476,00	9	360	€ 1.533.981,00	8	320
Time to charge EVs for customers [minutes]	30,00%	23,1 min.	7	210	19,8 min.	8	240	23,1 min.	7	210
Total:	100,00%	*Total amount of points:*		710	*Total amount of points:*		780	Total amount of points:		560

Figure 13: Results of multicriteria analysis

5.4 Multicriteria calculations

Multicriteria analysis was performed with determined scores and weights for each of the criteria. The scores distribution is presented in the Figure 12 of the table. Some of the values were possible to determine since methodology subsection 3.5.3 and the unresolved one was possible to find after the results were explored. The results that were found in the result section relate to the criterion of *NPV of the pathway until 2030*. The values were rounded up to the highest closest decade.

The picture of the final table with the results can be found in the Figure 13.

Also, the total values of criteria were plotted to determine the best outcome. The Figure 14 shows the outcome and it can be seen that Pathway 2 is the most preferable in this case. Furthermore, all the objectives that are described in establishment of decision context of MCA are met.

However, one can ask a question about the accuracy of this decision making process. Reliability can be assured by performing a sensitivity analysis, which is the topic of the next subsection.

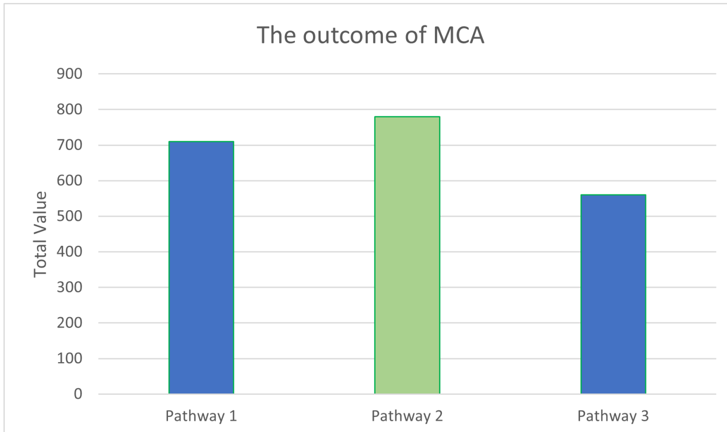


Figure 14: Comparison of the aftermath of the total values of multicriteria analysis. The winner of the multicriteria analysis is depicted in light green colour

5.5 Sensitivity analysis

After MCA was performed, it is time to validate the results with help of sensitivity analysis. Three scenarios are considered.

In the scenario 1, let us imagine a situation, where the petrol station cares more about their customer's experience and NPV, rather than distribution of energy. In that case, the weights are changed in the following manner:

Energy usage ratio between grid and RE	20%
Net Present Value of the pathway	40%
Time to charge EVs for customers	40%

The results for scenario 1 are depicted in the Figure 15 in the blue colour.

For the scenario 2, the value of the output power of the AC chargers was changed from 43 kW to 22 kW, according to the feedback of two industry experts that were interviewed. This is the only assumption that was changed and all other inputs stayed the same. Thus, in the results of MCA, the change happened for the time to charge to 80%, that increase from just 23.1 minutes to 45.2 minutes. All other criteria have not changed in their scoring results. The aftermath of scenario 2 can be observed in the same Figure 15 in the orange colour.

For scenario 3, the number of EVs was increased by considering not only BEVs but also PHEVs. Now, the total fleet consists of 280486 EVs. As a reminder, this change applies only for the pathways with AC chargers, meaning only to Pathway 1 and 3. By following the calculations shown in the assumptions of subsection 3.3, one can discover that daily coming cars have changed from 5 to 8 per day for 280486 incoming EVs. This has a profound effect on the energy demand, distribution of energy between the electric grid and RE source and

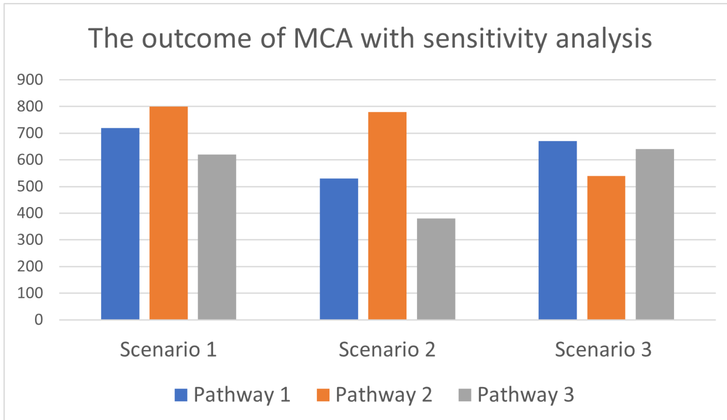


Figure 15: Three scenarios of the sensitivity analysis of the pathways

NPV. Furthermore, it has effected the scoring that was shown in Figure 12 for NPV criteria, because of enormous difference in NPV compared to the previous scoring option. Thus, the scoring of NPV criteria was adjusted. The obtained results of all the calculations have shown that the total value has changed and it effects on the winner of the multicriteria analysis. In scenario 3, the winner is Pathway 3. The result of scenario 3 is depicted in the same Figure 15 in grey color.

Hence, after the change in weights of the criteria and considering the amendments in values of two of the assumptions, it was discovered that variation in the results of the winner of MCA occurs as well. For the scenarios 1 and 2, the clear winner is Pathway 2, while for the scenario 3, the clear winner is Pathway 1. It can be seen that Pathway 3 has the lowest scores out of the three pathways in almost all the scenarios.

Thus, for decision makers to be confident in their choice, they have to be solid on the outcome that they are willing to achieve at the end of the investigation.

5.6 Business Case Results

In this subsection the results of the Business case creation can be seen. However, it is worth to mentioned that the assumption that was made in the previous section 4 of Business case is validated. A petrol station generates a profit within the proposed time period in this research as it was observed in 5.3. Thus, the business idea with the platform can be discussed in the results.

5.6.1 Primary stakeholder analysis results

The stakeholder analysis is performed for the proposed platform. As primary stakeholders, three candidates are considered, such as customers, partners and regulators. The customers are the owners of petrol stations and installation

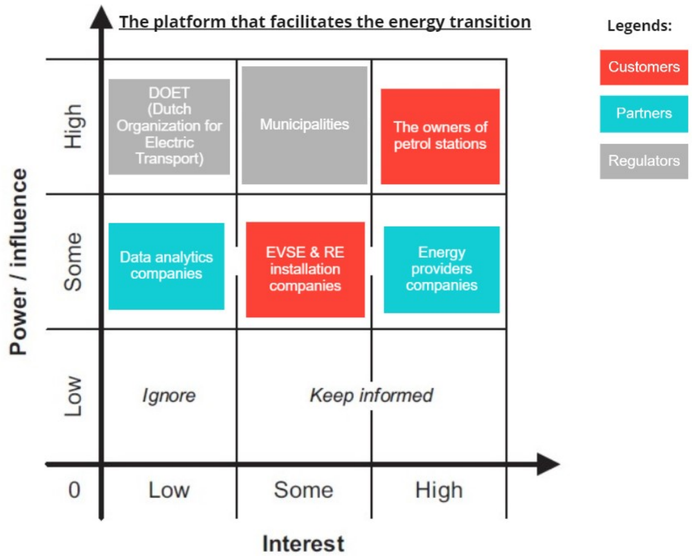


Figure 16: Stakeholder diagram of power and influence. [42]

companies that can be promoted on our platform. Our partners are the companies that help with customization of data analytics, energy providers that can offer our platform to their customers and installation companies of Electric Vehicle Supply Equipment (EVSE) and RE equipment. Finally, the regulators are the municipalities in which the petrol station is functioning and governmental institutions responsible for the energy transition.

Next, the aforementioned stakeholders were placed on the stakeholder power/influence grid that is shown in the Figure 16. It is important to note that only primary stakeholders are listed here. In reality, the list is much more extensive.

5.6.2 Business Model Canvas results

The nine building blocks of BMC are described here.

- **Value Proposition.** One of the main values that this new company or Startup delivers to its customers is helping with energy transition and meeting the governmental goals with regards to climate change and CO_2 reduction. With use of our platform customers receive several scenarios on how their transition will look like, whereas engineering company provides only one or two solutions to their customers. By considering electric transition scenarios through the platform our customer (petrol stations) can increase the range of their own customers.

- **Customer segment.** The main customers for our platform are petrol stations and oil and gas companies that own petrol stations. The distant customers are the EVSE suppliers, energy providers and installation companies.

- **Channels.** The best type of channel is the balance between some of the types. In our case, we consider our own and partner's channels, since we need to delivered many unique details. The steps to describe the channels proposed in the Business Model Generation book [43] are followed. Awareness is done through the government, energy network operators or our own outreach to the petrol stations. Evaluation is based on the reduction of carbon emissions throughout the year and achievement of break-even point for the platform. Purchase is performed through the platform that connects to all other partners that we work together with. Delivery happens by providing data set and showing several pathways of the development of their solution. Design and engineering of electric transition of their petrol station and evaluation of their case. After sale consists of facilitation of the connection between customer and maintenance company.

- **Customer relationships.** They are based on the self-service and co-creation. For the self-service point of view the customers fill-in the data themselves into the platform and after processing of data they can see the outcome. Co-creation part involves, because with the new dataset the platform gets better at its service.

- **Revenue Streams.** It represents the cash that the company generates. The type of Revenue Stream is transaction revenues resulting from one-time customer payment. The main revenue stream is through usage fee that petrol station pays. Usage fee might be dynamic due to the complexity of the solution. Moreover, due to possible promotion of producers of EVSE with petrol stations that are evaluating electric transition with help of the platform. The fee is taken for their representation on our platform.

- **Key resources.** This block describes the most critical assets needed for our business model to perform efficiently. The main key resource is known as intellectual according to [43], due to established partnerships and unique databases that the platform collects.

- **Key activities.** Every company has their own particular set of actions that they need to perform to keep their venture going. A combination of both platform and problem-solving activities (acting as a consultancy and service organization by providing solutions). It requires developing the data analysis of our platform to come up with the best alternative. Improving customer experience through listening to their feedback and so on. It can be generalized into more general key activities, such as platform management, service provisioning and platform promotion.

- **Key partnerships.** It describes crucial partners or suppliers that are involved into our business model. Buyer-supplier relationship (BSR) is considered in this research. BSR is one of the best way to optimize and

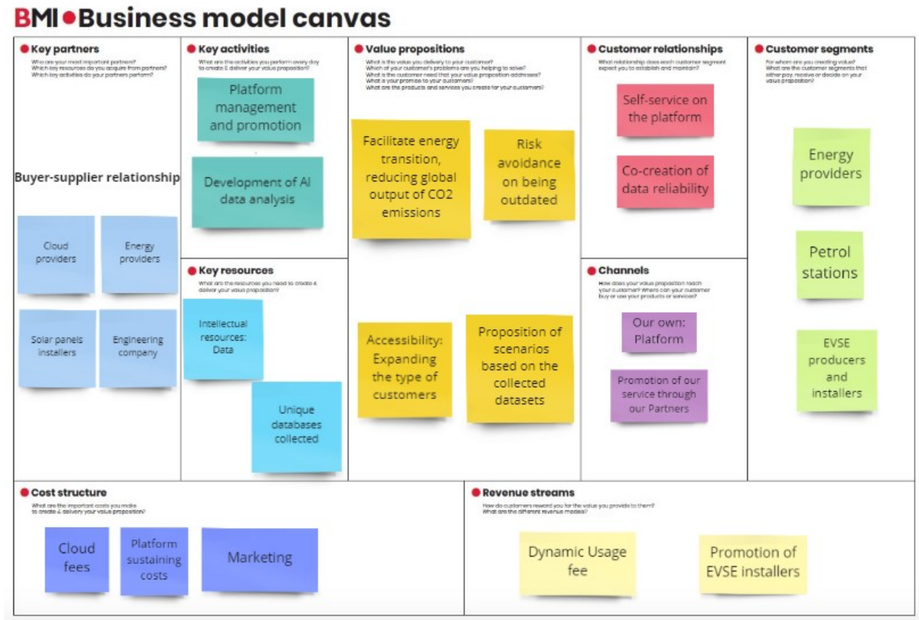


Figure 17: Completed Business Model Canvas for the proposed idea

have a scalable solution to outsource or allocate the development of a resource that is important for the business [43]. Our partners were already mentioned in the stakeholder analysis above and generalized here as well: cloud providers, energy providers (they have interest in selling more of their energy), solar panels installers (promotion of them on our platform), companies that specialize in data analytics, engineering companies.

- **Cost Structure.** These are the costs involved to sustain the business. Value-driven model of costs due to the personalized system for the customers and the high price of the development. The costs include cloud fees, data analytics, costs related to sustaining the platform, marketing (outreach to customers).

Eventually, all of the nine-building blocks are shown on the Business Model Canvas that can be seen in the Figure 17.

6 Discussion and Further Investigation

For the discussion of this report, one has to mention that this research is based on the assumptions that may influence the outcome of the investigation. Let us start by describing limitations and enhancement points about both technical and then economical inputs. Finally, improvement points and constraints for MCA and its sensitivity analysis are mentioned.

With regards to technical inputs, the number of incoming EVs considering PHEV and BEV needs to be taken into account. However, it has to be studied whether PHEV owners prefer to charge at the petrol stations at all, this can be a crucial factor whether PHEV and BEV needs to be considered. Another point of discussion is the output power of the DC charger (50 kW) is also taken at the minimum based on the results of the investigation provided by the Thesis work of my colleague. What is more, the constant energy demand is assumed throughout the day and month, which is different case compared to reality. To improve this research, the variability in energy demand needs to be implemented. Next, item of concern of this investigation refers to the battery capacity and SOC of the battery. With help of probability theory, the most probable battery capacity and its SOC of EV battery were found. However, with the introduction of variation of these two parameters the outcome can be different. Moreover, the number of chargers at the petrol station was assumed based on the amount of chargers per 100 km, where each charger is distributed on equal distance from each other and that have the same flow of customers per day and month. Regarding the energy supply, the assumption on the available area for the solar panel system was assumed here and as a matter of truth, it depends on the area that petrol station roof occupies, which is slightly different for almost all the petrol stations.

In terms of economical inputs, the prices for installation of the equipment and purchasing price of inverters were assumed. The other costs were found through papers and it can be slightly various compared to the prices in reality. With calculated Net Present Value, there were not all the parameters considered, such as taxes and debts. To improve the economical values of the research, there has to be a discovery about the taxes, incentives and fines in the Netherlands to have a clear pictures on the NPV.

With multicriteria analysis the number of criteria might change depending on the key performance indicators that petrol stations placed for themselves. However, both technical and economical inputs can be helpful in providing a score for the new criteria.

In sensitivity analysis, the broader evaluation of scenarios can be made by changes in the inputs, which are described in this section.

7 Conclusion

To conclude, this visionary research has shown possibilities for an electric transition for the petrol stations into EV charging stations. By the extensive literature review, it was discovered that petrol stations are in the top three places of locations to place charging pools. Also, it was validated that there is a need for the electric transition of petrol stations.

There are many ways on how electric transition can be made and that is why three pathways were treated here. For these pathways, the technical and economical inputs were selected from the literature research that helped to shape the scores for the multicriteria analysis. By following SMART type of multicriteria analysis, the criteria were identified, such as energy distribution between grid and RE source, NPV of the pathways until 2030 and the time that it takes to charge EV. The way to determine the total value of the pathways was based on combination of scoring and weighing. Afterwards, the results have shown that Pathway 2 has the highest total value, compared to others. However, during the validation of reliability of the results of multicriteria analysis through sensitivity analysis, the validation of the Pathway 2 came under the question after the change in the amount of incoming EVs.

Several scenarios were analyzed for sensitivity analysis. In scenario 1, the change in weights of criteria has proven that Pathway 2 still has the highest total value. In scenario 2, more common output power of AC chargers was taken into account that still gave the preference to Pathway 2 in the outcome. In scenario 3 of sensitivity analysis, different input value of the incoming EVs to the petrol station with consideration of BEV and PHEV had an effect on the results, which lead to the Pathway 1 to be the winner. Thus, it can be concluded that the most critical parameters that embraces several technical and economical inputs in itself and that change the outcome of multicriteria analysis is the energy demand and output power of the chargers, which has an effect on final total value of criteria. By the end of sensitivity analysis, the Pathway 2 considers to be the best out of the three due to the final results of calculations of MCA and the highest total value score in two out of the three scenarios considered for MCA. One should note here that Pathway 3 was the least preferable by both the outcome of MCA calculations and sensitivity analysis. Hence, the use of RE source in the pathways is highly suggested.

Eventually, the business idea was proposed that allows this research to be continued and implemented in reality. It permits the petrol station owners to have a variety of proposed scenarios for electric transition one a simple set of input data. This business idea was analyzed with help of Business Model Canvas to have a clear overview of the processes that are required. Also, stakeholders were mapped as customers, partners and regulators on the power and interest graph. All of it gave a closer look on the future development of this business idea and it has its chances to be in demand due to powerful driver that is considered by the governments all around the world, which is energy transition.

Acknowledgment

This paper has benefited greatly from the guidance and support of Dr Prasanth Venugopal as well as Dr Jelena Popovic.

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