

## **Sustainable business models for public charging points**

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### **Abstract**

This paper is an investigation into the optimal scenario for the placement and operation of public charging points for electric vehicles. The points will be placed in semi-large Dutch municipalities during 2013 up to 2015 and operated until 2020. Different cost-, income- and organisation measures are combined using scenario planning, showing the financial impact on the budget of the charging point operator. Interviews held with involved stakeholders on the measures and scenarios reveal their opinions and preferences. Combining the analyses leads to a recommendation on optimal measure combinations to stimulate the placement and operation of public charging points.

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### **1 Introduction**

The transportation sector is gradually changing from a fossil fuel based sector to a green, durable fuel transportation sector, including electric vehicles. There are obstacles that inhibit a successful growth of electric vehicles in the Netherlands. One of these obstacles is the limited amount of public charging points. The municipalities of the four largest cities in the Netherlands organised public tenders to place such points. Furthermore, a cooperation of Dutch distribution system operators (DSO) called e-laad placed 2500 free points all over the Netherlands. E-laad announced in September 2012 to end the placement of public points [1]. The last points will be placed in 2013. Without the support of e-laad, municipalities outside of the four largest cities do not have procedures for the financing, placement and operation of public charging points. As a result, no public charging points are being placed currently. The problem discussed in this research is stated as:

*There is currently no long-term viable business case for the placement of public charging points in the majority of Dutch municipalities, inhibiting the stimulation of electric mobility.*

Due to the recent state of this problem, there is not much research available on this subject. The research that is available is often outdated, due to the very dynamic market development. Some research has been very valuable. For instance, research performed by the national government on possible cost changes and the required law changes [2] and research performed by Movares on the extended private grid connection [3]. This report elaborates on the financial impact of the changes and on collecting and analysing the opinions of stakeholders on the changes. Furthermore this research contributes to solving the stated problem by also analysing income and organisational measures. Similar to the cost measures a financial and stakeholders' analysis is held. The research question answered in this research is therefore stated as:

*'What is the optimal combination of cost-, income- and organisation measures to stimulate the placement of public charging points, for the benefit of electric vehicle users?'*

## 1.1 Research objective

The objective of this research is:

*To develop scenarios for a long-term viable business case with a positive budget in 2020 for the placement of public charging points to stimulate electric mobility.*

These scenarios can be used to advise the involved stakeholders on the measures to be taken in the near future and their impact on the budget. The social importance of this research is to establish measures that stimulate the placement of public charging points and therefore stimulate the use of electric vehicles. The scientific importance is to reveal the financial effects of the combination of different measures and the assessment of these measures and combinations by involved stakeholders.

## 1.2 Research boundaries

The research is restricted to semi-large Dutch municipalities with around 200.000 inhabitants. The public charging points will be placed in 2013, 2014 and 2015 and be operated until at least 2020. The points will be in use during this entire period. Costs for removing the points are not taken into account. The measures applied focus on the financial impact for the operator. All measures applied start when the points are placed and remain active during the entire period of operation until 2020.

## 1.3 Paper structure

The paper will first describe in chapter 2 the research model and methods used in the research. Secondly, chapter 3 reveals the findings of each part of the research. Next, chapter 4 will give the overall conclusions. Finally, chapter 5 provides discussion points on the research itself and possibilities for future research.

## 2 Method

To answer the research question several methods are used. See figure 1 for the research model.

The research model is divided into three parts. Each part consists of several steps, visualized as the white boxes. General morphological analysis is used to identify the most important parameters and values in the first part [4]. The second part uses the method of scenario planning following the steps developed by Mercer [5]. This research will focus on normative scenarios that investigate how to reach a certain target. Qualitative interviews are held with 14 involved stakeholders to assess the parameters and mini-scenarios. Combining this information with a financial analysis leads to three final scenarios. An extensive description of the scenarios has been written. The scenarios are analysed by identifying the issues arising through information gathered in the interviews, a financial analysis and a sensitivity analysis. The third part gives the conclusions and discussion points.

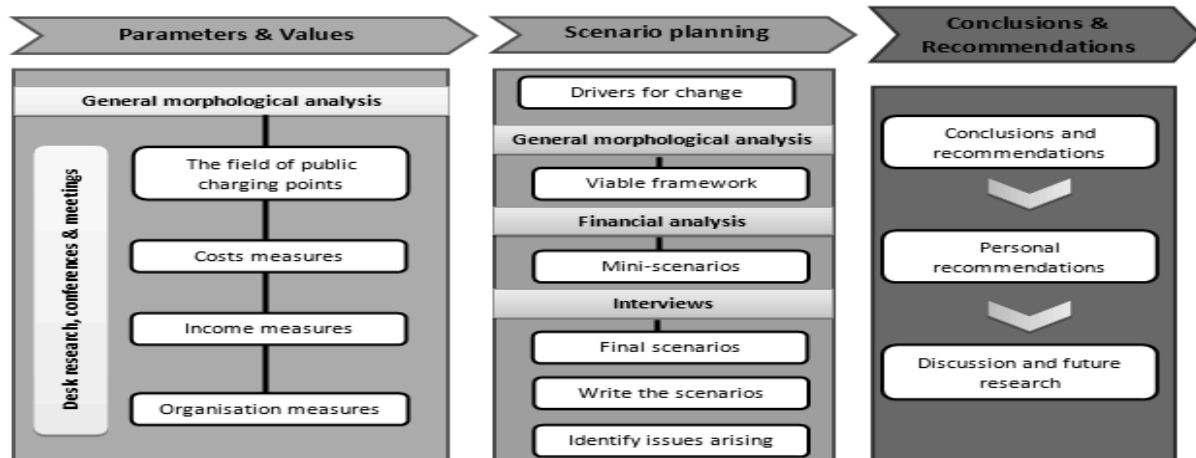


Figure 1. Research model

### 3 Findings

To answer the research question, first the most important parameters and values must be identified. These will be given in chapter 3.1. Chapter 3.2 will give the findings based on scenario planning.

#### 3.1 Parameters & values

##### 3.1.1 The field of public charging points

The research focuses on the Dutch market. In the Netherlands public charging points are placed on municipal grounds by an operator. The operator places and maintains the points, enabling users to charge their vehicle at the points. Each user is subscribed to a service provider. The service provider issues a charging pass to users. When electricity is charged at a charging point, the charging costs are recouped by the operator by billing the service provider who in turns bills the user. Operators and service providers cooperate on interoperability through a platform called eViolin [6]. Users apply for a public charging point at an operator. The operator needs permission from the municipality to place and operate the point at the requested location.

This report focuses on alternating current charging points with mode 2 type 3, based on the current European trends and technology [7]. Only stations with one or two charging points are placed. The points are placed in semi-large municipalities, assuming that 50 points will be placed in both 2013 and 2014 and 100 points in 2015. They will be in use until at least 2020.

Based on trends in the electric vehicle market the amount of plug-in hybrid vehicles (PHEV) in the Netherlands until 2020 is set at 75% of the total electric vehicle market [8]. Full electric vehicles (FEV) will take in 25% of the electric vehicles used in the Netherlands until 2020.

Differentiation is made between locations with over 7 hours of available charging time like residential areas and work places, locations with less than 7 hours of charging time like parking areas near supermarkets and locations with less than half an hour of charging time like locations at high ways. This last group requires stations that use direct current and is therefore not taken into account in this research. It is assumed that the points assessed in this research will be placed for

90% in locations with over 7 hours of charging time and 10% in locations with less than 7 hours of charging time. For the first group 3,7 kW points are sufficient. For the second group 11 kW points are appropriate. Figure 2 shows the groups.

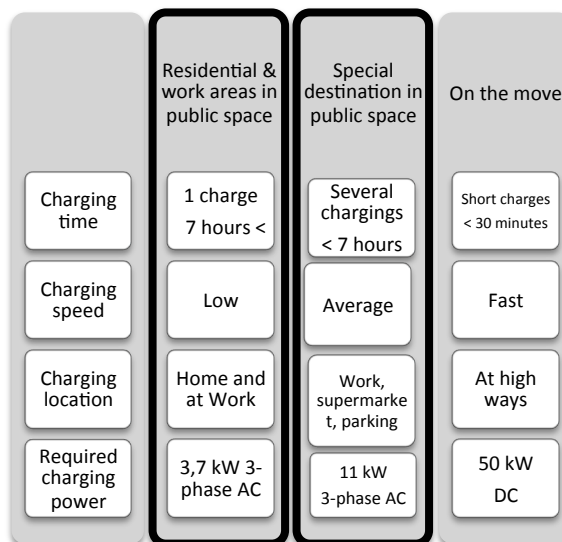


Figure 2. Focus groups and charging power

The circled groups are taken into account.

Based on the average amount of kilometres driven by Dutch vehicles in 2012 [9]; the assumption that PHEV can drive for 70% on electricity [10]; the assumptions that European FEV and PHEV use on average 20 kWh/100 km [11]; and the expected volume of 75% PHEV and 25% EV until 2020, results in an average of 2000 kWh charged per year per electric vehicle, see table 1.

It is presumed that each user will charge this amount of 2000 kWh/year at a public charging point. Data from existing points reveals that 2000 kWh per point per year can be achieved. Based on expected growth of electric vehicle usage, the amount charged per point will rise with 5% per year.

##### 3.1.2 Cost measures

There are many possible measures to lower the costs involved in placing and operating public charging points. The choice is made to focus on cost measures, which are currently most discussed by involved stakeholders [2]. Distinction is made between measures that require a practical interference and measures that require interference by changing the law.

EV	KM per year	KM % on electricity	KM/year on electricity	kWh /km	kWh/year	Percentage PHEV and EV	Average kWh/year/EV
FEV	13.300	100%	13.300	0,20	2660	25%	2061,5~2000
PHEV	13.300	70%	9.310	0,20	1862	75%	

Table 1. Average kWh/year/EV

Cost measures	Description
<b>Practical measures</b>	
<b>Placement cooperation</b>	Operator takes over municipal construction works and if possible the construction works of the distribution system operator. This results in a reduction of €200,- per public charging station.
<b>Extended private grid connection</b>	Connect station with existing grid connection. The owner of the connection owns the station. Only 3,7 kW points are placed. The hardware is reduced with €1000,- per station. The construction costs are €700,- per station. Grid connection costs are zero.
<b>Meter - Change requirements</b>	The measuring device is changed and simplified. Yearly costs paid to the distribution system operator remain the same. Hardware costs are reduced with €50,- per station.
<b>Law related measures</b>	
<b>Meter - Remove meter device</b>	The meter is removed from the distribution system operator. Other meters in the stations must be improved, resulting in non-changing hardware costs. No operational rent has to be paid.
<b>Large-scale consumer</b>	A network of public charging stations in one geographical area and belonging to one operator is qualified by the law as one large-scale consumer. As a result the energy tax can be consolidated, paying a lower tax rate for large quantities of energy. The tax rebate is only granted for one object and not for each object, due to all points qualified together as one object.
<b>New connection category</b>	A new connection category allowing smart grid options, like controlling the charging time, capacity and costs can prevent high peaks in energy usage. Cost for this new connection category can therefore be lowered. A 25% discount on grid costs is established.

### 3.1.3 Income measures

Income is generated by selling electricity to service providers who in turn sell it to users who charge their electric vehicle at a public charging point. Income for the operator can also be generated by receiving discounts on rents,

subsidies or a revolving fund. Parties that provide these measures can be, for instance, the government, banks, distribution system operators and car manufacturers.

Income measures	Description
<b>Discounted interest rate</b>	Discount of 5% or 3% on interest rate bank loan. Government guarantees the investment
<b>Public subsidy</b>	Public parties subsidize the capital expenditures of the operator. Subsidy is either 25 %, 50%, 75% or 100%
<b>Revolving fund</b>	Public and private parties start a fund for the capital investments. Operator repays between 2016 and 2020. Interest rate not included. Fund is either 25%, 50%, 75% or 100%
<b>Higher energy price</b>	The energy price for the service provider ranges between € 0,27 and €0,59 /kWh in order to be comparable to private charging while it will be lower than driving on fossil fuels
<b>Implementing starting rate</b>	A starting rate per transaction between € 0,- and € 1,-. It is expected that on average users charge 10 kW per transaction.

### 3.1.4 Organisation measures

There are many options for stakeholders to cooperate in the organisation of placing and operating public charging points. This research focuses on cooperation on establishing the

station's specifications and the price per charged kWh. The parties involved are the operator and the public parties.

Organisational measures	Description
Specifications	Either public parties or the operator
Set the price	Either public parties or the operator

## 3.2 Scenario planning

To answer the research question of reaching the most optimal combination of cost-, income- and organisational measures, the method of scenario planning is used. The scenarios are constructed using the steps developed by Mercer [5]. Each of the following paragraphs will describe one of the steps in chronological order.

### 3.2.1 Drivers for change

The drivers for change are the fixed and variable parameters and values described in chapter 3.1. The measures are considered the parameters. The attributes and cost changes of the measures are the specific values of the parameters.

### 3.2.2 Viable framework

There are many different combinations possible between the different parameters and values. To reduce the options, a framework is established. The framework developed using general morphological analysis. Using a cross-consistency matrix, combinations of parameters and values that are inconsistent are removed. There are three types of inconsistency involved [12]: purely logical contradictions, empirical constraints and normative constraints.

An example of a logical contradiction occurs when the public parties subsidize over 50% of the capital expenditures, while the operator sets the specifications. An empirical constraint is having a 100% subsidy and a 100% fund. Normative constraints include for instance the rule to always have a positive budget for the operator in 2020. The normative constraints are revealed in the scenarios by executing a financial analysis in Excel, using the function 'scenario management'.






It is possible to use none, one or several measures in one scenario. To reduce the amount of possible scenarios, rules are established to fit the set framework. The rules are set in a certain order of importance, based the research objective as stated in chapter 1. This will help selecting six mini-scenarios.

#### Rules for construction mini-scenarios

1. Focus point of the scenarios is each having a different combination of cost measures.
2. The scenario must comply with framework.
3. A positive business case for the operator is reached in 2020.
4. The revolving fund is paid back in 2020.
5. The lowest price for users is pursued.
6. The lowest possible costs for public parties.
7. Preferable no extreme debts.
8. Choose configuration with the highest profit.
9. When scenarios have too great an overlap, one of the values can be changed in order to investigate the influence of the parameters and values.

### 3.2.3 Mini-scenarios

The analysis based on the rules described in the previous chapter results in six mini-scenarios, see table 2. In the mini-scenarios the starting rate is not taken into account. For the cost measure 'Meter device' it is assumed that the meter is changed and the rent set to zero. These parameters and values changed during the research, due to new acquired information.

Variable	Description
	Placement cooperation
	Extended private grid connection
	Meter - Change requirements
	Large-scale consumer
	New connection category

















	Costs measures	Income measures				Organisation measures	
		Rate	Subsidy	Revolving fund	Energy price	Specifications	Price setter
1	-	-	+ 100%	-	0,27	Public parties	Public parties
2		-	-	-	0,44	Operator	Operator
3	  	5%	-	- 75%	0,27	Operator	Public parties
4	   	-	+ 50%	-	0,35	Public parties	Operator
5	    	5%	-	- 100%	0,27	Operator	Operator
6	  	-	+ 50%	-	0,35	Public parties	Operator

Table 2. Mini-scenarios

In order to construct final scenarios, the mini-scenarios, parameters and values are tested on financial impact and stakeholders' preference. To test the stakeholders' preferences, qualitative interviews are held with 14 involved stakeholders. By executing qualitative interviews, the research can respond to new developments and give new insights that were not available when establishing the mini-scenarios. This is needed due to the fast evolving research field within the market of public charging points. The financial- and interview analysis of the mini-scenarios and parameters revealed the following aspects:

For stations without any of the measures used in the mini-scenarios it is most beneficial to place 100 stations with two 3,7 kW points compared to stations with two 11 kW points or 90 stations with one 3,7 kW & 10 stations with 11 kW points, see figure 3. In figure 3 'CAPEX' stands for capital expenditures and 'OPEX' for operation expenditures. 'CAPEX station' includes the hardware and placement costs and 'CAPEX management' stands for the costs needed to organise the project. 'OPEX station' entails the yearly costs paid to the distribution system operator, while the 'OPEX management' stands for the management and maintenance costs.

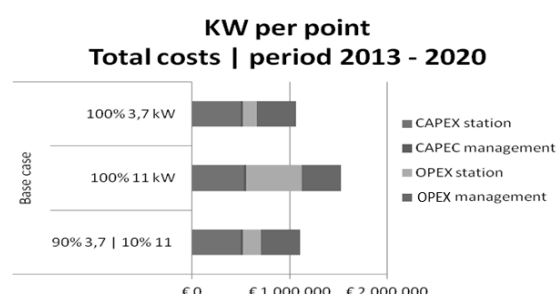


Figure 3. Total costs without mini-scenario measures

Most stakeholders prefer stations with two 3,7 kW points on locations with low to regular usage, while placing 11 kW points on locations with high usage. The research will therefore focus on 90% 3,7 kW points and 10% 11 kW points. Furthermore most stakeholders find a usage of 2000 kWh per year more realistic then 3000 kWh per year. And most stakeholders prefer the introduction of a starting rate.

Each stakeholder has its own preferences on costs- and income measures to implement. Matrixes are constructed, combining an average of these opinions with the financial impact of the measures on the total costs or cumulative budget in 2020 for 90% stations with two 3,7 kW points & 10% stations with two 11 kW points. All these have a usage of 2000 kWh/year. Figure 4 and 5 reveals the stakeholders' preferences on several cost- and income measures and the financial impact of the measures on the budget. The stakeholders' preferences range between 1 and 5, indicating the level of preference, see table 2.

Figure 4 shows that the large-scale consumer is most advised due to stakeholders' preferences and financial impact. Extending the private grid connection has most financial impact, but some stakeholders foresee practical problems in establishing the measure, for instance in cooperation from the municipality. Changing the meter and cooperating in placement is preferred, but has limited financial impact. It is therefore advised to not put too much effort in establishing these measures. Based on the interviews it is advised to investigate the new connection category and simultaneously implement a new meter. Figure 5 shows that subsidies are financially influential, but not preferred by stakeholders, while a fund is preferred, but has low financial impact. Based on the interviews it is advised to never subsidize or fund the capital investments for 100%, because then the financiers had better act as operator themselves. Subsidies should never be the end goal of financing public charging points, because it does not stimulate a sustainable business case or innovation. Rents are considered interesting, but stakeholders doubt if banks are willing to cooperate on the given terms.

Furthermore the interviews revealed that reticence exists relative to the current cooperation with municipalities and distribution system operators. Cooperation with both parties consumes too much effort, time and money. For municipalities this is caused due to the lack of fitting procedures on licenses and parking policy. For the DSO this is due to the long time period of 18 weeks in which the grid connection must be made.

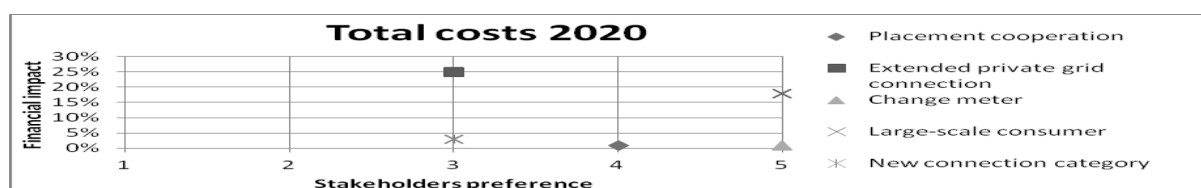


Figure 4. Financial impact and stakeholders preferences on cost measures

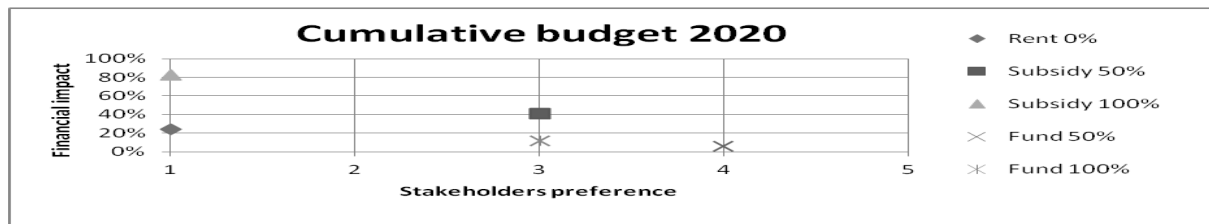


Figure 5. Financial impact and stakeholders' preferences on income measures

X- axe value	1	2	3	4	5
Description	Least preferred	Not preferred	Neutral	Preferred	Very preferred

Table 3. X-axe description

Figure 6 shows the impact of subsidies, price per kWh and kWh charged per year per point on a scenario resulting in a cumulative budge of €0,- in 2020. Charging stations with two points of 3,7 kW are used and no cost measures are included. The graphs show that with consumer prices of €0,50 /kWh, no starting rate and an average use of 2.000 kWh/point/year the business case is neutral. With some cost measures the consumer price can come down to about € 0,35/ kWh.

Figure 7 is similar to figure 6, only differing in including a fund instead of a subsidy. It can be seen that at a use of 2000 kWh/year a starting rate of €1 euro can lower the price per kWh with €0,10, compared to having no starting rate. From both figures it can be concluded that above 3000 kWh per year the influence of subsidies and revolving funds is limited, that prices per kWh steeply rise when less than 2000 kWh is charged per year and that starting rates are very influential on the cumulative budget in 2020.

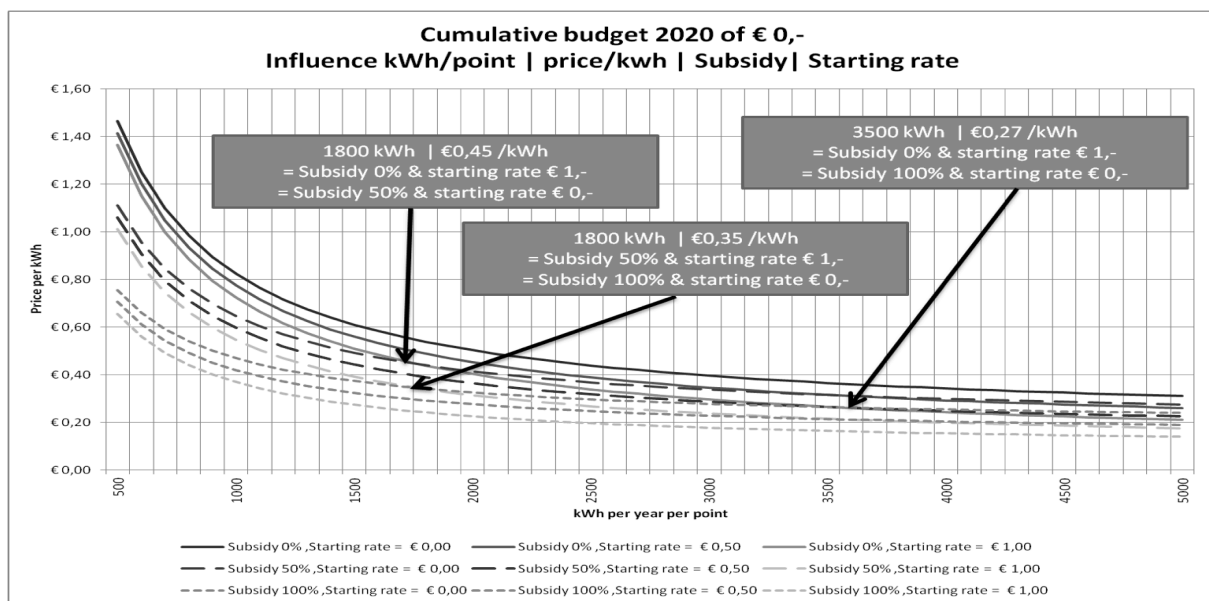


Figure 6. Cumulative budget 2020 of €0,- with subsidy and/or starting rate



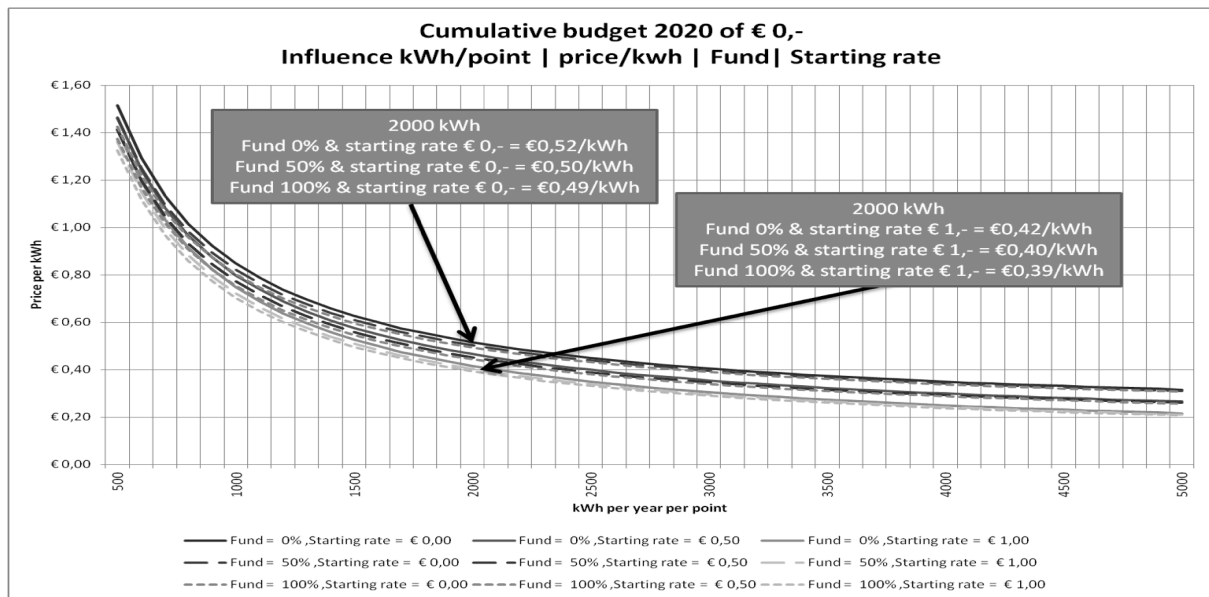


Figure 7 Cumulative budget 2020 of €0,- with fund and/or starting rate

### 3.2.4 Final scenarios

Based on the analyses three final scenarios are constructed, see figure 8. The highlighted measures are applied in the given scenario.

Government in control:

AC2 kW / point	Costs measures	Income measures			Energy price	Organisation measures	
		Rate	Subsidy	fund		Specifications	Price setter
3,7	Placement	0%	0%	0%	0,27	Government	Government
	Meter		25%	25%			
	New connection	2%	50%	50%			
11	Large user		75%	75%	Starting rate	Operator	Operator
	Extended connection	5%	100%	100			

User in control:

AC2 kW / point	Costs measures	Income measures			Energy price	Organisation measures	
		Rate	Subsidy	fund		Specifications	Price setter
3,7	Placement	0%	0%	0%	0,27	Government	Government
	Meter		25%	25%			
	New connection	2%	50%	50%			
11	Large user		75%	75%	Free   0,40	Operator	Operator
	Extended connection	5%	100%	100			

Operator in control:

AC2 kW / point	Costs measures	Income measures			Energy price	Organisation measures	
		Rate	Subsidy	fund		Specifications	Price setter
3,7	Placement	0%	0%	0%	0,27	Government	Government
	Meter		25%	25%			
	New connection	2%	50%	50%			
11	Large user		75%	75%	Starting rate 1,00	Operator	Operator
	Extended connections	5%	100%	100%			

Figure 8. Final scenarios with the highlighted measures being applied

### 3.2.5 Write the scenarios

An extensive description is written of the final scenarios. As shown in figure 8 each scenario has

a different stakeholder in control. In the first scenario the government is in control. They change the law enabling a new grid connection category and large-scale users. Since they have most control on setting the specifications and price, the government subsidizes the capital expenditures of the stations with 75%. Due to these measures the price per kWh is set at €0,30. In the second scenario the user is in control by only placing stations that are connected to an existing grid connection, extending this connection. The owner of the grid connection subsidizes 50% of the capital expenditures, while not paying extra energy costs. Other users pay extra for the energy charged. The government sets some strict restrictions on specifications, while the operator has some freedom in other specifications. In the third scenario the operator is in control. A high price per kWh is implemented. The operator receives a fund of 75% of capital expenditures from public and private parties. Between 2016 and 2020 this fund is repaid, making the operator independent of public investments.

### 3.2.6 Identify issues arising

Comparing the scenarios on qualitative and financial aspects reveals that each scenario has its own benefits and downsides. The financial analysis reveals that the scenario 'Government in control' has most influence on the total costs over the period 2013-2020, due to lower energy costs caused by consolidation of the energy tax. The cost reduction in 'user in control' is mainly caused by not paying any grid costs and lower management costs, see figure 9. The effect of the income measures in each scenario reveals that the



scenario ‘operator in control’ has the most stable development in costs. See figure 10 for the income, expenditures and cumulative balance of scenario ‘operator in control’. It is expected that after 2020 the profit will steeply rise due to repayment of the fund.

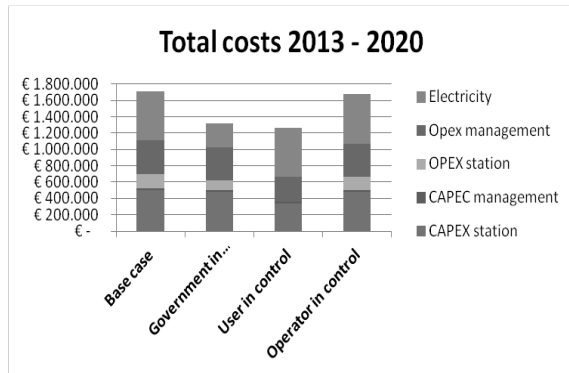


Figure 9 Total costs final scenarios

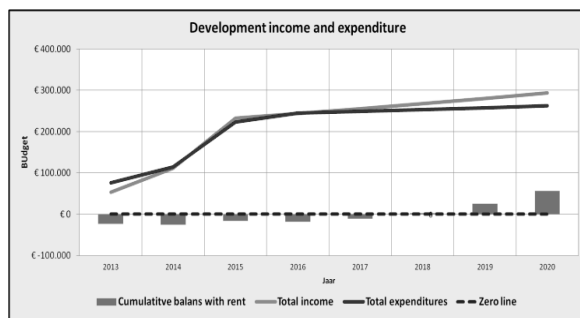


Figure 10 Financial development 'operator in control'

The interviews revealed that opinions of stakeholders differ on kW per point, kWh per year, configuration of the stations and the management and maintenance costs. A sensitivity analysis analyzes the influence of these ‘fixed’ parameters on the cumulative budget in 2020 by changing their values. It is revealed that placing only stations with 11 kW points significantly affects the budget, making the scenario very unprofitable in 2020. Changing the amount of kWh charged per year from 2000 kWh to 3000 kWh significantly raises the final budget. Lowering the management and maintenance costs with €400 per station per year, also significantly influences the final budget. It can be concluded that placing 3,7 kW points instead of 11 kW points is preferred, due to the impact on the budget; points are preferred to be placed when high usage is expected; and high benefits can be gained by optimizing the maintenance and management costs.

Since the scenarios each have their benefits and downsides and they are highly sensitive to changes in ‘fixed’ parameters, one optimal

scenario cannot be chosen to apply in all cases in all municipalities.

Which scenario is most preferred, depends mainly on the budget that the municipality is willing to invest, the control the municipality wants to have on specifications and price and on the expected usage per point/year.

## 4 Conclusions

The research and analysis revealed that at this moment not all public points are profitable to operate, but by combining certain measures, a positive business case can be established. By analyzing the three final scenarios, it is concluded that a combination of the scenarios complies with the preferences of most stakeholders. The scenario planning, financial analysis and sensitivity analysis showed that the measures are profoundly interlinked and must be seen as part of a whole. Overall, the research reveals that small differences in parameters significantly influence the budget of the business case. However, predictions on these parameters are uncertain, due to the fast developments in the field of electric mobility. As a result, business cases implemented during this period of development and innovation are linked with high risks, but also with interesting opportunities that are worth investing in.

The main conclusions on optimal measure combinations are the following:

- ❖ Only place charging stations with two points of 3,7 kW and a minimum usage of 2000 kWh per year per point.
- ❖ Shorten municipal procedures for licenses and parking policy to a maximum of 4 weeks.
- ❖ Focus on cost measures: extended private grid connection and large-scale consumer.
- ❖ Raise the price per kWh to a minimum of €0,30 and implement a starting rate.
- ❖ Let the operator set the price, while staying within a maximum set by the government in order to protect the user.
- ❖ If the municipality has the financial means: subsidize points with low usage.
- ❖ Otherwise: optimize procedures and allow market initiatives.

## 5 Discussion

By combining costs, income and organisational measures, an overall view of the current market is given. The parameters, values and opinions used in the research are however subject to uncertainties due to the very dynamic market developments. This is for instance shown by

stakeholders changing their opinion during the research on placing 3,7 kW or 11 kW points. As a result this research can only give an indication of the market at this moment in time.

The results, however, can be very well used for further discussion. Discussions on this subject are much needed, since points must be placed on short notice. Procedures are needed now, because when no points are placed, this can negatively affect the image users have of electric mobility. In the current economic situation, it is not expected that municipalities will give high subsidies. Operators, however, are willing to take the financial risk, provided municipalities fasten their procedures for placing objects in the public space. If municipalities set the specifications, law changes are implemented and prices are raised, a sustainable market can be developed and expanded without public investments. Municipalities should provide the framework and let the market fill in the rest.

## 5.1 Future research

Future research could focus on the specifications set by municipalities, the interaction between operators and service providers, the behaviour of users in case of more differentiation between market models and the optimal division between alternating and direct current charging points, which in our opinion are complementary to each other.

It is also interesting to investigate some other measures mentioned by the interviewees. These measures were left out of this research' scope, including subsidizing the usage instead of the points, reducing the subsidies through the years or implementing an energy tax per charged kWh.

Finally it is recommended to further stimulate the implementation of private and semi-public charging points. These include lower costs and no governmental interference, making them cheaper and easier to implement. Using semi-public charging points at offices is especially recommended, because electric vehicles can charge here during the day. This optimizes smart grid usage with decentralized energy production, enabling electric vehicles to be part of a bigger electricity transition network, playing a vital role in future smart grid applications.

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