DESIGN PROJECT

SolarRoof 3

Memo 1: Technical design

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Introduction and scope

This memo outlines the technical scope for the proposed intervention of a solar roof covering an open parking terrain in Rotterdam. The solar panels will be accompanied by a local smart grid enabling the generated electricity to be used, stored and distributed locally. With the aim to take some of the pressure from the main electricity grid. The Municipality of Rotterdam plans to cover six open parking terrains with solar panels in 2020 (de Jonge Baas, 2019). To choose the best location for this design project the following criteria have been taken into account: The size of the parking terrain (which should be larger than 10000 m^2, as this is specified by the client), the amount of shadow from surrounding objects (since shadow has a significant effect on solar energy yield) and the presence of a large energy user in the area which could potentially be connected to the local smart grid. Based on these criteria P+R Kralingse Zoom has been selected, as it is the only considered location, that is larger than 10000 m^2 and has a large energy user nearby. However, it is likely some trees will need to be removed to profit optimally from the solar roof. The Erasmus University is located near the parking terrain Kralingse Zoom, and will be connected to the PV system through a local smart grid.

Future technical context

The ambitions of the Municipality of Rotterdam, to use open spaces in the city to generate solar energy, shows that future energy production of the city will be more decentralized (Alstone, Gershenson & Kammen, 2015). This provides an opportunity to work with more local smart grids to help decrease the stress on the main grid and provides room for endeavours as described in this memo. Stedin expects a significant increase of EVs in Rotterdam over the coming years (Stedin, 2017). This requires an increase in charging points throughout the city, enlarging the relevance of adding charging points at the parking terrain in Kralingse Zoom. Furthermore, the Erasmus University gets a significant share of its energy from wind farms, buying renewable energy credits for more than 16500 MWh. Besides this they have solar panels installed on rooftops of EUR buildings (EUR, n.d.). In the future they intend to increase their renewable energy usage, and therefore fits well with our solar roof initiative.

Design choices

While designing the technical system multiple decisions had to be made that influence the remainder of the design process. The choice of location was one of these decisions. Furthermore, the fact that the system should be able to charge EVs and that it will be connected with the Erasmus University are two other important choices. These decisions limit the design space, because they restrict the number of possible solutions. Even though it can be very beneficial to keep all options open, choices have to be made at certain points in the design process, to narrow down the scope. These three choices are the most influential decisions that already have been made.

Desired performance

To determine the desired performance of the system a functional analysis is performed. The selected functions that the technical design should be able to perform are the following: to store electricity, to charge and discharge the storage unit, to generate electricity from solar energy, to distribute electricity (to the university, to the EV charger and from and to the storage), to charge electric vehicles, to process information and to hold the solar panels in place. In addition there are some non-functional properties that are important. The most essential non-functional properties are: cost-efficiency, durability, sustainability availability and acceptability.

These functions will be performed by different subsystems, although all the subsystems need to have the non-functional properties. The identified subsystems that together perform the above functions are: the PV system (generates electricity), the construction system (holds PV system in place), the storage system (stores energy), the distribution system (distributes electricity flows), the information system (gathers, stores and processes information) and the car charging system (charges vehicles). The interactions of the different subsystems with their relations are shown in figure 1. The dotted lines in the figure below are out of scope for this project.

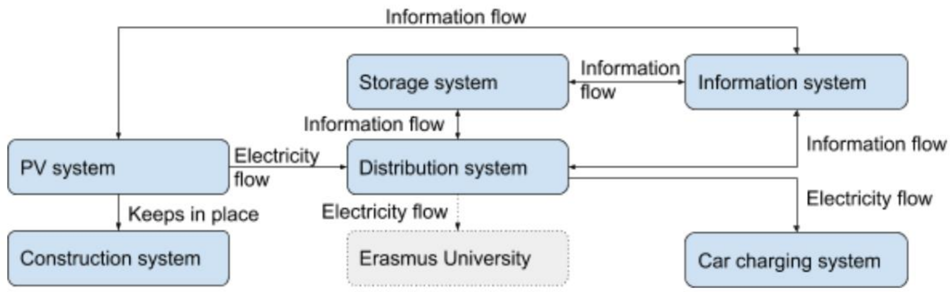

Figure 1: Subsystem interactions

Requirement analysis

Based on the functional and non-functional analysis a requirement breakdown structure has been made. The table below gives an overview of the most important requirements, structured per function.

Table 1: Requirement Breakdown Structure

Function	Requirement
To store electricity	High storage capacity [MW]
To charge and discharge the storage unit	High round trip efficiency [%] High power in/output [MW]
To generate electricity from solar energy	High yield [€] Sufficiently large area [yes/no]
To distribute electricity	Bi-directional power flow [yes/no] Sufficient metering points [yes/no] 230V connections [yes/no] 50Hz connection [yes/no]
To charge electric vehicles	High amount of charging connections [#]
To hold the solar panels in place	Meets safety standards [yes/no]
To process information	Adequate information gathering, storing & distributing [yes/no] Meets privacy standards [yes/no]
(non-functional) Property	**(Non-functional) Requirement**
Cost-efficiency	High EROI [integer] High yield [€] Low capex [€] Low opex [€]
Durability	Long lifetime [years] Water resistant [mm/u] Snow resistant [cm/u] Hail resistant [mm] Wind resistant [beaufort]
Sustainability	Meets circularity standards [yes/no]
Availability	Centrally located [m] Openly accessible [yes/no]
Acceptability	Perceived as harmonic with landscape [%]

Quick and dirty sketch

Based on the functions a general means-end analysis is performed. For each requirement one possible means have been selected in order to be able to make an initial sketch of one possible technical design. It is important to point out that this initial sketch is definitely not a final solution, it is merely a possibility to show what a potential solution could look like. In the following figure a quick and dirty sketch of this design is shown. In this design the electricity is stored using EV's that are connected with rapid chargers. Furthermore, the solar panels are monocrystalline and the distribution cables are below ground. This system is held in place using a frame.

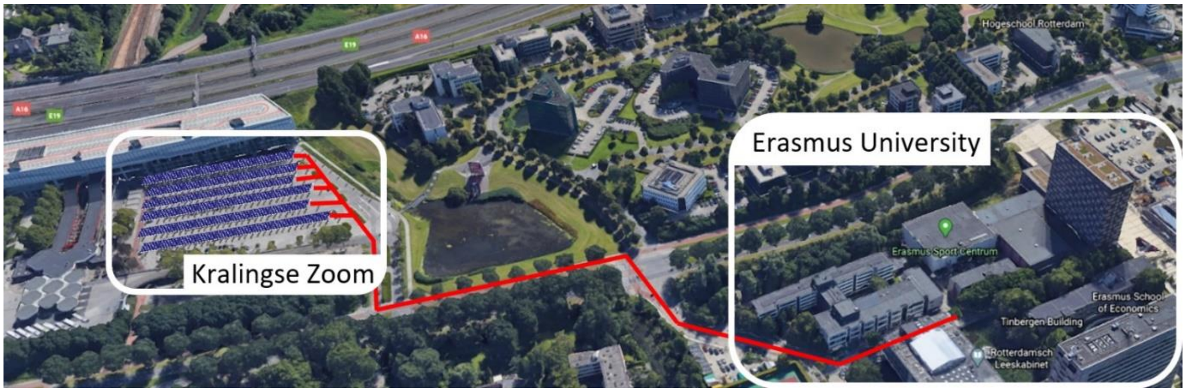

Figure 2: Quick and Dirty Design Sketch

Conditions to realise the design

To be able to realize the design there are certain conditions that have to be met. One of these conditions is the need for a permit in order to be able to build the technical system. During the process of acquiring this permit potential opponents will have the opportunity to object (Rotterdam.nl n.d. (1)). Therefore it is important that the final design maintains a harmonic landscape with the rest of the city. Furthermore, since shadow has a very high impact on the total yield of solar panels (Ibrahim, 2011), it is most likely that some trees have to be removed. Also for this process a permit should be acquired (Rotterdam.nl n.d. (2)). Again there is a possibility for objection by opposing parties and in order to cater to the needs of opponents like Milieudefensie, a plan with additional investments in the surrounding nature might have to be made.

Conclusion

In this memo the technical scope of the intervention is presented. This technical design outlines a design for a solar roof covering an open parking terrain. The solar panels will be integrated with a local smart grid enabling the generated energy to be used, stored and distributed locally. With the aim to take some of the pressure from the main electricity grid. For this design project the location P+R Kralingse Zoom has been chosen, which is near the Erasmus University. Furthermore, the solar PV system will also include some form of electricity storage and be able to charge EVs. With a functional analysis the most important functional and non-functional requirements have been derived. Furthermore, subsystems were identified and an initial sketch of a possible solution was given with the use of a means-end analysis. This knowledge will be used as the technical foundation that the final design will be built upon.

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DESIGN PROJECT

SolarRoof 3

Memo 2: Institutional design

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Introduction

Along with the intervention of technical artefacts (namely the solar park) in the broad socio-technical context, new transactions emerge among different stakeholders and relevant coordination issues need to be addressed. In this memo, these transactions and coordination issues are categorized into three different phases, respectively 'Before the start of construction', 'During construction' and 'After construction'. In all three categories it is essential to have knowledge of and comply with in-use laws and regulatory rules. Furthermore, to fulfil the performance of the technical design, an institutional design is required to modify or create coordinating institutional arrangements (Correljé, 2020). This memo will cover the institutional analysis using the IAD framework and identify the most critical coordination issues concerning the implementation of a solar park on an open parking terrain within the municipality of Rotterdam (Kralingse Zoom).

Institutional context

In the first phase, institutions concerning the ground/area and relevant environmental regulations need to be met. For investigating the ground/area of the open parking terrain with the desire to build a roof based solar park, two formal institutions related to the technical architecture (Ménard, 2014) are very important:

1. **PFAS norms**: PFAS is the collective name for over 6000 chemical substances that can be found in the ground. These substances can raise risks for human health and for the environment as well. Therefore the Rijksinstituut voor Volksgezondheid en Milieu (RIVM) created a norm that needs to be met before construction can take place at a certain location. (Ministerie, 2019). The maximum limit to which the ground level of PFAS can be is 0.1 microgram per kg ground (Kistenkas, 2019). Therefore the design process should include an agreement between the project manager and the municipality. This agreement should state the wellbeing of the environment on the open parking terrain, before construction. According to investigation of The Municipality of Rotterdam and DCMR Milieudienst Rijnmond (Gemeente, 2019), the grounds at Kralingse Zoom 50 has the status 'Pot. verontreinigd' which means that the location UBI value is less than 100 (CBS, 2005). This value indicates that the ground/area is sound enough in order to build on it.
2. **MER (milieueffectenrapportage) review**: Besides estimating the quality of the ground, a review of the environment is also important. Therefore a MER should be generated. This will result in a clear overview of the impact that such a project can have on the environment and therefore the stakeholder that is responsible for the construction can also be held liable for negatively influencing the environment (Elings, 2011).

The second phase includes the technical design of the project as well as the building of the roof based solar park. During this phase the focus is on specific technical characteristics (Ménard, 2014). Institutions cover safety regulations, building permits, possible transfers (new allocation) of property rights, regulations regarding electric vehicles and compatible charging stations and possible liability arrangements when damage is done by the solar park on other properties. Most safety regulations are registered in the NEN2443 (Normcommissie, 2013) and are openly available. For making the parking terrain available to electric vehicles and for including charging points, there are no special guidelines nor regulations concerning safety rules, due to the fact that the technology is relatively new (Instituut, 2020). Concerning the ownership of the parking terrain, there are several alternatives possible, but the most likely alternatives are a full transfer of ownership rights (economically and lawfully) or a ground lease where the municipality will remain lawful owner, but the operator will become the economic owner. (N. Pattiwael, personal communication, May 16, 2020)

For the third and last phase, the operational rules should be in place, such as the rules for dispatch of generated electricity, tariff setting and revenue allocation. Agreements between stakeholders are necessary for determining how to use the generated electricity, how the costs and benefits are allocated, and who will be allowed to the parking area.

Institutional analysis - IAD framework

The abovementioned regulatory voids implicate the necessity of institutional arrangements, especially in the last and part of the second phase. Referring to the Williamson scheme (Williamson, 2000), the design space mainly focuses on the second and third layer, i.e. formal institutions for general objectives and governance for specific purposes. The IAD framework (Ostrom, 2010) is utilized to further elaborate on the specific case, as shown in Figure 1.

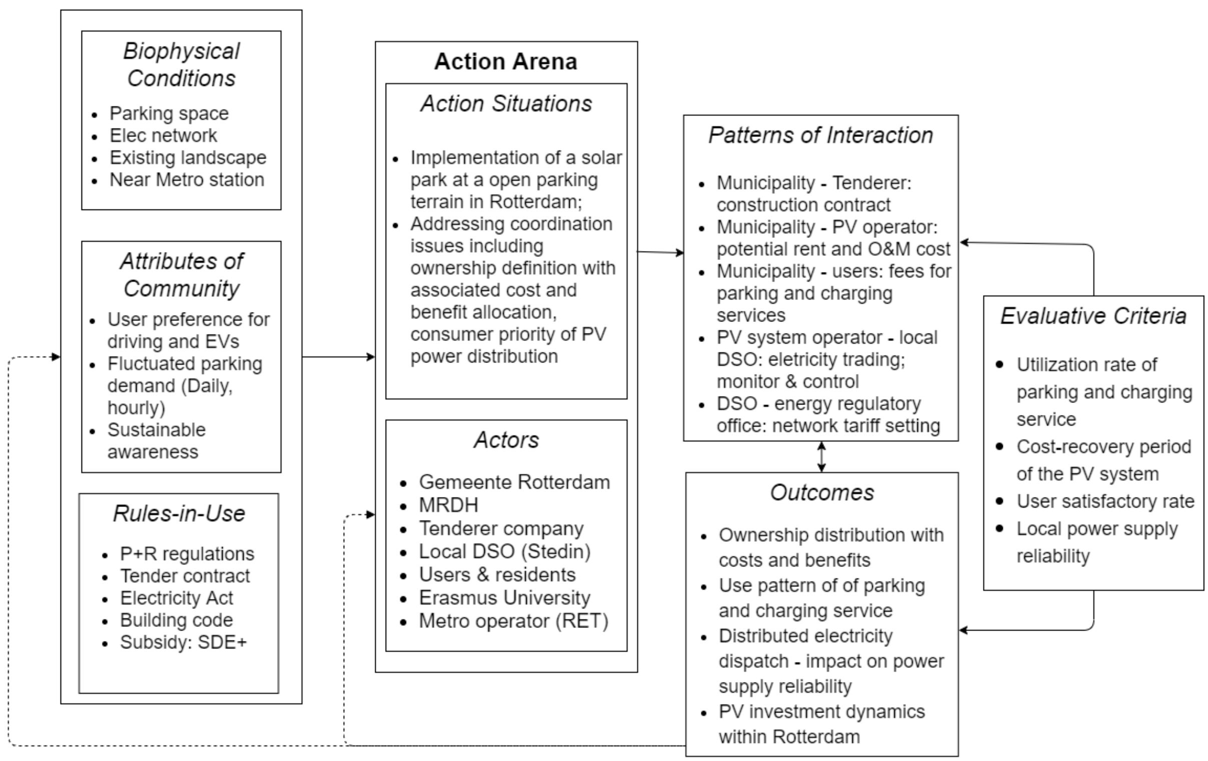

Figure 1: Application of IAD framework on the solar park case

Referring to the technical design choices, the Kralingse Zoom parking terrain is chosen as the target case. This is a P+R terrain next to a metro station. Together with the surrounding neighbourhood and facilities (including university and companies) and underlying electricity infrastructure, the biophysical conditions are constructed. The relevant regulations include building code, electricity act, subsidy mechanism (SDE+), P+R parking rules and tender contract. The dynamic preference for driving of electric vehicles influences the use of the parking terrain and the electricity generated from the solar park. This interaction becomes more complex when considering daily & hourly parking demand variation and integration with the local smart grid. Besides the use pattern of the parking and charging service, the power supply reliability of the local grid is affected due to the variable and uncontrollable solar generation. In general, several transactions occur among the stakeholders (further elaborated on in the third memo):

1. **Between The Municipality of Rotterdam and Tenderer company**: construction contract for the solar park.
2. **Between The Municipality of Rotterdam and the PV system operator**: the PV system supplies. electricity to the parking terrain (owned by the municipality); potential rent and O&M cost.
3. **Between The Municipality of Rotterdam and users**: fees for parking and charging services.
4. **Between the PV system operator and electricity users**: energy trading.
5. **Between the PV system operator and the local DSO**: besides the electricity selling revenue and network tariff, the variable injection from the PV system to the local grid needs to be monitored and controlled to safeguard the reliability of the electrical power system.
6. **Between the PV system operator and Ministry (EZK & Fin)**: subsidy and tax mechanism.
7. **Between the local DSO and the energy regulatory office**: to cope with increased distributed energy sources, DSO needs to make technical adjustments and grid expansion, that requires a higher network tariff regulated by the Autoriteit Consument en Markt.

More specific transactions are related to the ownership and dispatch model of the solar park, which will be discussed more in one of the upcoming memos. The internal structure of the action situation is illustrated in Figure 2 in the Appendix. The institutional design has to reconcile various interests of stakeholders, accommodate the technical design of the energy management system and synthesize information of user pattern and weather conditions, in order to roll out the solar park across Rotterdam.

Coordination issues

Both the parking terrain and generated electricity could be regarded as common pool resources (high subtractability of use and difficulty of excluding potential beneficiaries), which lead to social dilemmas in need of institutional efforts (Ostrom, 2010). The most critical coordination issues identified, are listed below:

1. **The ownership of the solar park**: various potential mechanisms exist including public (The Municipality of Rotterdam), private (Tenderer company or other commercial parties), public-private partnership, collective ownership by residents. The ownership distribution is closely connected with the cost & benefit allocation from the investment and O&M cost to electricity selling revenue and potential subsidies.
2. **The dispatch of generated electricity**: the application scenarios could be classified into integrated dispatch and dedicated dispatch. The integrated scenarios indicate the connection with the local grid that usually requires grid expansion or distributed storage solutions. The dedicated dispatch involves certain players to be the major consumers, for example, the charging stations, metro station, Erasmus University Rotterdam, which implicates the possibility of a defected system.

Conclusion

This memo is set as a starting point for institutional design regarding the implementation of a solar park at the Kralingse Zoom parking terrain. The existing regulations to comply with are explained in terms of three phases, i.e. before the start of, during and after the construction of such PV systems. Along with the institutional analysis supported by IAD framework, the most critical coordination issues are identified as the PV system ownership and electricity dispatch. As for the next step, the Alignment scheme (Ménard, 2014) that connects technology and institutions will be utilized to design the institutional arrangement, this will be done in one of the upcoming memos.

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Appendix

Figure 2 illustrates the internal working parts of the given action situations. The involved stakeholders based on various standing hold different interests and resources, and thereby take various actions. The interactions among actor positions, information about user demand and generation profile, and control over energy management system and process management link to the final outcome associated with net cost and benefits.

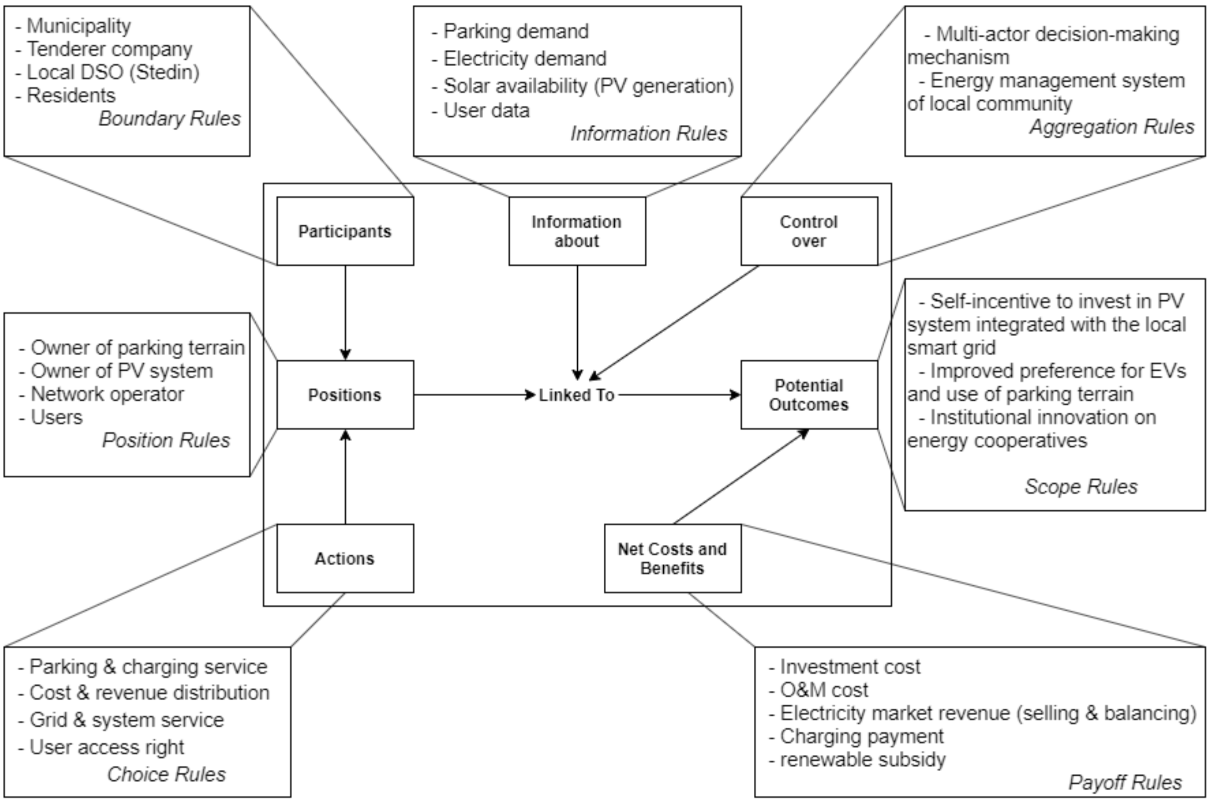

Figure 2: Internal structure of the action situations

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Memo 3: Stakeholder design

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Introduction

This memo builds upon the two previous memos. A stakeholder analysis is used to derive the different coalitions that correspond with the three project phases and will help to shape the process design. In this process, the Municipality of Rotterdam is the initiator. The municipality started a market consultation that will be followed by a tender to build solar roofs over open parking terrains in the city (De Jonge Baas, 2019). As discussed in the technical design memo the parking terrain selected for this project is P+R Kralingse Zoom.

Stakeholder overview

A stakeholder analysis is performed, the various stakeholders for this project and their interests are presented in the following table.

Table 1: An overview of all stakeholder and their interest

Stakeholder	**Interest**
The municipality of Rotterdam	The Municipality wants to reduce the greenhouse emissions in the city by 50% in 2030 (Municipality of Rotterdam, 2020). One way to accomplish that is to stimulate renewable energy. Solar roofs above parking terrains is one initiative of the municipality in the transition to a sustainable future (De Jonge Baas, 2019).
Contractor of the solar park	The contractor participates in the tender for building the solar park (De Jonge Baas, 2019). The contractor that will eventually win the tender will be deeply integrated in the project and will aim to make a profit.
Operator of the solar roof	One operator will exploit the solar park once it is built. The operator will be a commercial party that rents the solar park from the municipality (N. Pattiwael, personal communication, May 14, 2020)
Stedin	The local DSO in Rotterdam is responsible for the electricity distribution throughout the city. Stedin prefers this project to be connected to its own local grid, since it aims to reduce the pressure on the main grid. Stedin wants to ensure a reliable energy supply (Stedin, 2020) and at the same time wants to stimulate renewable energy initiatives (H. Fidder, personal communication, May 11, 2020).
TenneT	TenneT is owner of the high voltage grid and responsible for reliable and safe electricity transport (TenneT, 2020). The solar park will have influence on the supply and demand of electricity on the parking terrain and at the Erasmus University and therefore TenneT also is a stakeholder.
Erasmus University	Erasmus University has the ambition to become one of the most sustainable universities of the Netherlands (Erasmus University, 2020). Therefore they would be interested to use energy locally generated by the solar park. They will be connected to the local smart grid, so that the university can use the electricity generated by the solar system.
Users of the parking terrain	People who park their car on the parking terrain, want enough parking space and if they have an electric vehicle, enough charging stations.
Local residents	People living around the parking terrain care about landscape aesthetics and don't want the solar park to negatively influence the aesthetics of the area. However, the amount of people that live close by is minimal.
The RET	The RET is the local public transport company in Rotterdam. The RET has interest in an attractive P+R that will encourage people to park and take public transport from there.
The Metropole Rotterdam The Hague	The MRDH has a program called 'Sustainable Mobility', this initiative would contribute to this program and their goals (MRDH, 2020).

The performed stakeholder analysis is based on the aforementioned actors. Subsequently, the power and interest of each actor is determined. From this analysis it can be concluded that the stakeholders with the most power and interest are: the operator of the solar panel roof, the municipality of Rotterdam, Stedin and the Erasmus University. Therefore, a total of four stakeholders will form a coalition in order to make the project a success.

Coalition of stakeholders

The process towards an operating solar roof located at the P+R Kralingse Zoom can be divided into three phases, as described in memo 2. The phases are 'Before the start of construction', 'During construction' and 'After construction'.

For the first phase, the municipality will tender the construction of the solar roof (de Jonge Baas, 2019). This tender forms the formal relation between the operator and the municipality since there will be a transfer in property rights. The municipality will retain the right to alienate (abusus), the operator will gain the right to make revenue from the solar park (usus fructus) (N. Pattiwael, personal communication, May 14, 2020). During this first phase, the municipality and the operator will negotiate and agree upon the rent the operator will pay to the municipality.

For the second phase, the operator and the municipality will discuss with Stedin whether to connect the solar park to the local grid. As DSO, Stedin is responsible for the connection of the solar panels. Thus the operator and Stedin will form a formal relation where it is noted how the solar park will be connected and what costs come paired with this.

For the third phase, the municipality, the Erasmus University, the operator and Stedin will be in a coalition and allocate the generated electricity, the costs and the revenues that come along with the project. A formal relation is created where these actors discuss how they will handle the various possible scenarios of electricity supply and demand by the roof based solar.

The main design dilemmas

While conducting the technical, institutional and stakeholder analyses, multiple issues and dilemmas came to light that stakeholders will need to deal with. These dilemmas arise from stakeholders having contrasting views and different perspectives towards the project. The most important dilemmas are described below, it is also noted if these dilemmas concern the technical, institutional or process aspect of the design.

Dilemma 1: *Achieving the right balance between sustainability and revenue* **(T,I,P)**
The goal of the operator will be to generate as much revenue as possible. The goal of the municipality is not solely a monetary concern, but this is also about generating electricity in a sustainable manner and at the same time keep the costs for using the P+R as low as possible in order to incentivize people to use the nearby public transportation. Furthermore, also the University wants to have affordable electricity on the one hand and sustainable electricity on the other.

Dilemma 2: *Main grid connection versus local grid connection* **(T,I)**
The trade-off between a relatively easy connection to the main grid versus the design of a local grid for less pressure on the main grid. This dilemma is being raised during the formal relation between Stedin and the operator. For the operator it is easiest to connect the solar park to the main grid and generate revenue by supplying it to the retail market. For Stedin it is important that the main grid is relieved from pressure. Therefore it will be beneficial for Stedin to connect the solar park to a local (smart) grid instead of the main grid. This could create difficulties and costs for the operator. Questions that arise if you are

not connected to the main grid are: How much backup storage do you need? What do you do if there is no sun for a long time? Do you always want to be able to charge cars? How to deal with the cost structure?

Dilemma 3: B*alancing the allocation of costs and benefits between actors* **(I,P)**
The trade-off between allocation of costs and benefits is one of the dilemmas that became apparent during the institutional analysis. As discussed during the institutional analysis this dilemma is closely related to the ownership distribution of the system. On the one hand there are investment, operation and maintenance costs that are still to be made, and on the other hand there are the revenues to be made from the system. It is very important that these costs and revenues are divided in such a way that all the partners from the coalition are satisfied.

Process structure and design principles

All three dilemmas require different process structures to negotiate and eventually align contrasting views and perspectives. It is important that all dilemmas have been discussed and most decisions and agreements are made before the actual start of building the technical system. The following section gives a brief indication of process rules that are important in order to reach consensus on the illustrated dilemmas.

For the first dilemma it is important to make sure that the right balance is achieved between sustainability and revenue. In order to achieve this, it is the municipality and the operator that have to come to a formal agreement. Because this dilemma is about differences in values of the municipality (sustainability) and the operator (making profit), it is important to make sure that these core values are protected and that both parties get the chance to promote their interests.

To reach consensus on the second dilemma, there needs to be a uniform understanding of the consequences of being connected to the main grid, or operating as a standalone local grid. Therefore, the negotiation process should be transparent, this requires Stedin and the operator to share all relevant information. Stedin should disclose the pressure it expects on the grid, would the solar project be connected to the main grid. While the operator should communicate the difficulty and costs it expects from operating as a local grid.

To solve the third dilemma, the coalition needs to balance between allocation of costs and benefits. Therefore it is important that everybody is honest and open about their expected and realized costs and revenue. All relevant information should be shared.

The first two dilemmas addresses the diverse interests between the municipality and the operator and between DSO and the PV operator, which implicates the necessity of 'protection of core values' and 'openness' during the negotiation process. The involved parties should be allowed to express their values and not commit to the result (De Bruijn, 2010). The third dilemma addresses the financial incentives of both short-term and long-term across all the stakeholders, which is essential to avoid free-riding behaviour and contribute to a stable cooperation. Therefore, openness needs to be safeguarded for a fair cost allocation (De Bruijn, 2010).

Conclusion

This memo proposes the stakeholder coalition and derives the main dilemmas in each of the three phases (i.e. Before-the start-of-, During- and After- construction). It gives an indication of process rules that are important in order to reach consensus on the illustrated dilemmas. The design principles 'protection of core values' and 'openness' will have to be kept in mind throughout the process.

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DESIGN PROJECT

SolarRoof 3

Memo 4: Complexity of design challenge

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Introduction

With this memo a bridge will be created connecting the technical, institutional and process design. The original problem statement served as a starting point (seen in the Appendix). Hereafter, this memo will describe the most relevant aspects of each artefact and possible issues that occur when integrating these artefacts. Besides, the original problem statement is revised based on the issues and complexities that arise with each artefact. It is important to note that after personal communication with the municipality of Rotterdam, we learned that the municipality has made different development plans for P+R Kralingse Zoom, the initial location. Therefore, the location has been altered to P+R Meijersplein.

Artefacts

Based on the problem statements, three artefacts are designed and analysed, namely technical, institutional and process artefacts. Many aspects of the design project are either complex or complicated. The definition of complex and complicated that is used in this research stems from Snowden (2003): "An aircraft is a complicated system; all of its thousands of components are knowable, definable and capable of being catalogued as are all of the relationships between and among those components, while human systems are complex. A complex system comprises many interacting agents, an agent being anything that has identity." For this research the focus is laid on the complexity of the project. In the following paragraphs these three artefacts will be elaborated on and the main complexities that came to light during the analyses will be discussed.

Technical artefact

The technical artefact to be designed is a PV system on top of an open parking terrain in the municipality of Rotterdam (P+R Meijersplein) covering an area of 15.000 m2. The artefact has to be modular in design and able to distribute, store and generate electricity in an efficient manner and it needs to be in line with the aesthetics of the environment. Additionally, it has to be able to charge electric vehicles. This means that the car charging subsystem has to be connected to the main grid, to guarantee that you are able to charge EVs, also in periods of low irradiation (Pattiwael & Dullaert, personal communication, 2020).

Based on the analysis of the technical artefact there are some complicated technical aspects, but they can't be classified as complex. This is because the project is already done a number of times in other places in other situations (morrensolar.nl, n.d.) and because it does not have many interactions. However, there are some very complex choices to be made that influence the technical artefact, these choices are complex since the choice process consists of interacting actors. These are related to who the operator will be. This will influence the amount of storage needed or if you want to be able to feed electricity back into the grid. Because the Dutch electricity law dictates that only electricity suppliers are allowed to sell electricity, feeding back electricity to the grid will have to be done with the help of an electricity supplier (like Eneco) (consuwijzer.nl, n.d.). Therefore the operator most likely will be the major energy consumer or an electricity supplier (Pattiwael & Dullaert, personal communication, 2020).

Institutional artefact

The institutional artefact includes the ownership of the technical artefact and it includes the allocation of costs, benefits and electricity of the technical artefact. The complexity of the institutional artefact is related to the two coordination issues that were identified in the institutional analysis. The first coordination issue is related to the ownership of the PV system. As mentioned in the previous paragraph there are a couple of options. The institutional artefact depends on which of the options it will be, along with the interest that potential operators show in the tender of the project, which will be expected in the start of 2021 (Pattiwael & Dullaert, personal communication, 2020). However, according to Dutch law not all actors are allowed to sell electricity. Therefore depending on which actor will become the operator, the electricity must be consumed by that actor or could be sold to various actors (consuwijzer.nl, n.d.). The second coordination issue relates to the dispatch of the generated electricity and is connected with the first coordination issue. When the owners of the solar park will be one (or a combination of multiple) electricity consumer(s) that are close to the PV system it is assumed that the produced electricity will be used by the same party. However, because these consumers are not allowed to sell electricity the charging of electric vehicles would still have to be done by the grid and therefore a grid connection is still needed. A second option is that an electricity supplier becomes the operator of the PV system, in this case the operator is allowed to sell electricity with the purpose of charging EV's, or make personalised agreements with the consumers nearby. But in periods of low irradiation a grid connection for the EVs is still required.

The institutional artefact consists of a set of institutions that make sure that the mentioned coordination issues are solved and that the ownership of the PV system, the task and the responsibilities of the concerned actors are clear. The institutional framework is not dependent on the location of the roof based solar system, therefore the institutional artefact is modular and thus applicable to varying situations.

Process artefact

The process artefact should connect all important stakeholders and bring them to an agreement in order to make the project a success complying with the principles of Openness and Protection of core values (De Bruijn, 2010). The tender model is proposed by the municipality, which requires that a potential operator is willing to conduct a modular design and apply that to multiple parking-terrain-based solar parks. The choice of tender company will implicate which stakeholders are involved, which should form a coalition and which stakeholders should be excluded from some decisions. The complexity rises from the fact that not all stakeholders have similar perspectives on the various aspects of the project and that not all stakeholders should be involved in all the process steps of the project.

The process artefact should be designed in a way that the actions of each stakeholder will commit to the process rather than the result (De Bruijn, 2010) and that it is modular to be applicable to various situations. It is important that the process artefact will converge the actions of each stakeholder iteratively towards a common goal concerning the main dilemmas, including balance between sustainability and revenue, type of connection with the grid, and cost & benefit allocations. The process artefact will formulate a timeline addressing the three phases of the project, namely before, during and after construction. But the process design of all three phases should be coordinated and facilitated before the actual start of project implementation. The main focus of the process artefact will be on the tender (before construction phase), since this is the decision that shapes the whole project.

Complexity in integrating these artefacts

The nestedness of technical challenges, coordination issues and dilemmas showcases the complexity of the integrated design project. From the perspective of the municipality, it is desirable to have one party responsible for the rollout of solar parks across all the parking terrains, which will decrease the burden of the municipality drastically. However, this would most likely only be possible for a party that already is an electricity producer, since not everyone is allowed to sell electricity. Alternatively, the large electricity consumers in the industrial and commercial sectors could be both operators and users in order to fulfil their sustainable goals. However, this would require a case-by-case engagement from the municipality, which implicates huge workload and lower speed of roll-out. Furthermore, the above mentioned scenarios could lead to different technical designs with regard to stand-alone or grid-connected systems, with/without storage and operation management. The different technical challenges are closely linked to the various solution spaces of institutional arrangements and agendas of negotiation processes, which addresses ownership, electricity dispatch and financial settlements of the solar park. Because of different standings and interests, the involved stakeholders could leverage their sources and behave strategically to influence the process which could lead to diverse outcomes. Furthermore, under the radical uncertainty, it is more complex to fulfil the requirement of modularity aiming for fast roll-out. These complexities necessitate the harmonised iterations and integration of technical, institutional and process designs

Conclusion

Based on the analyses of the first three memos the different technical, institutional and process artefacts are clarified and specified in this fourth memo. The complexities within each artefact and within integrating these three artefacts are described. Based on this the problem statement is revised. This memo will be used as a starting point for the Integrated Programme of Requirements in the next memo. These requirements will be used to derive means and will constitute the design space.

Revised problem statement

The municipality of Rotterdam aims to become the leading municipality in renewable energy in the Netherlands (Binnenlandsbestuur, 2019). Therefore, it is seeking to increase its share of renewable electricity production. This will be partly accomplished by building modular solar PV systems on top of open parking terrains, where ‘P+R Meijersplein’ will serve as a benchmark.

The PV system shall be integrated with a local (smart) grid so that the generated energy can be consumed or stored for later consumption by a nearby consumer (TU Delft, 2020). The solar roof shall cover 15.000m2 and shall have charging points for Electric Vehicles that will be connected with the main grid. Furthermore, the design shall be successfully realized at the latest before 2030. The design shall be compliant with the current legal framework and shall include institutional arrangements concerning the ownership and electricity dispatch of the system. The technical and institutional design shall be accompanied by a process design that connects all important stakeholders and brings them to an agreement concerning the institutional and technical arrangements of the system.

The design should maintain a harmonic landscape within the city (Girot, 2012), be used as efficiently as possible and fulfil more than one function. Also, it should meet current circularity standards and be available to all inhabitants of the municipality of Rotterdam (Gemeente Rotterdam, 2019). Furthermore, it should be scalable and modular in such a way that the final design could be applied to other locations with a minimum amount of adaptations. Lastly the technical, institutional and process artefacts should fit well together and should be able to complement each other. The final design will be tested on these objectives in order to measure how well it fulfils the needs of the municipality.

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Appendix A: Original (initial) problem statement

The Municipality of Rotterdam is seeking to increase the penetration of renewable electricity at open parking terrains before 2030. This goal is set in order to achieve the bigger goal being the leading municipality in renewable energy in the Netherlands (Binnenlandsbestuur, 2019).

The PV system shall be integrated with a local (smart) grid so that the generated energy can be used, stored, and distributed (TU Delft, 2020). It shall cover 10.000 - 40.000 m2 and be in line with the legal framework.. Furthermore, the design shall be successfully realized at the latest before 2030.

The design should maintain a harmonic landscape within the city (Girot, 2012), be used as efficiently as possible and fulfil more than one function, meet circularity standards and be available to all inhabitants of the Rotterdam population (Gemeente Rotterdam, 2019). The final design product will be tested on these objectives in order to measure its effectiveness.

Appendix B: Location choice

The location that was originally chosen for this research was P+R Kralingse Zoom. Based on personal communication with N. Pattiwael and D. Dullaert on the 19th of May some new information has come to light. The location that was chosen in the first memo, the ‘P+R Kralingse Zoom’ is not suited for a project with a lifetime of minimal 16 years. The lifetime of 15 years is a minimum to achieve a positive business case. The department ‘Area development’ already has other plans for this location. However, there is another location that is suitable, namely ‘P+R Meijersplein’, with similar technical, institutional and geographical aspects. Due to the similarity, the analyses of the previous memos are still applicable to the new location.

The involved stakeholders which are of most relevance, meaning they have a relatively high amount of power over the project and relatively a lot of interest in the project's success, are the municipality of Rotterdam, the PV system operator, potential large consumers and Stedin. Where the PV system operator could be any or a combination of the following: An electricity producer like Eneco, or the ING, the RET and any of the other businesses close by. This means the Erasmus University is no longer considered as a stakeholder.

DESIGN PROJECT

SolarRoof 3

Memo 5: Integral program of requirements

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Introduction

In this memo, the integrated program of requirements for the technical, institutional and process artefact is illustrated and motivated. Hereafter, the key dilemmas in meeting these requirements are identified and the trade-offs that need to be made are discussed.

Integrated program of requirements

Input from important stakeholders, Stedin and the Municipality of Rotterdam, has been used to make objective trees for each aspect of the design, these were used to formulate a comprehensive list of requirements. In the coming section an overview of the higher level (non)functional requirements of all three aspects of the design is given, the requirements are motivated and some examples of lower level requirements are illustrated. The complete list of lower level requirements with rationale can be found in appendix A. Although the P+R Meijersplein is used as a pilot case, the requirements are applicable to other parking terrains in Rotterdam as well.

Requirements for the technical design

This section illustrates the higher level technical requirements, elaborating upon the initial list of objectives and requirements provided in memo 1.

- **Produce electricity effectively:** One of the main requirements of the system is to produce electricity effectively. To ensure this the system needs to: Produce a high energy yield, making the project more profitable and increasing the renewable energy penetration. Ensure a high EROI, producing more energy than it costs. Ensure a low CAPEX and low OPEX, to be able to make a return on investment.
- **Store electricity effectively:** The system should provide a high charging and discharging rate, high round trip efficiency and high storage capacity to store electricity effectively. This would improve the flexibility of the system, make the system more profitable and enable the system to absorb energy fluctuations.
- **Distribute electricity efficiently:** To save costs and energy the distribution system should provide an efficient electricity connection between all subsystems (PV system, storage system, car charging system and large user). It should provide a bi-directional power flow connecting the storage system to the distribution system.
- **Process information adequately:** To ensure the storage charge/discharge system works optimally, the information system needs to provide fast gathering, storing & distribution of information. Furthermore, the information system should meet privacy standards.
- **Ensure a high degree of modularity in the technical design:** To make the design scalable, all the subsystems (PV system, distribution system, storage system, information system and car charging system) should be made modular.
- **Ensure durability and safety**: To make sure the solar roof construction meets safety standards and to ensure a long life time improving the profitability of the project, the design needs to be durable and safe.
- **Ensure inclusion:** One of the main goals of the municipality is that all citizens can profit from new interventions, therefore only public parking terrains can be considered and the roof should be high enough for all types of cars.
- **Perceived as harmonious with landscape:** In order to comply with the goals of the municipality and to satisfy the inhabitants with the design, it needs to be harmonious with the landscape.
- **Provide a sufficient number of EV charging points:** To make sure people are able to charge their EV if they want to, there should be enough charging points available.
- **Meet circularity standards:** To support the vision of the municipality the project needs to be sustainable and should therefore meet circularity standards.

- **Implement solar roofs at parking terrain between 10000 and 40000 m2:** In order to make the design modular, all parking terrains considered should be comparable in size.

Requirements for the institutional design

The list of requirements for the institutional design is developed according to six higher level requirements which are illustrated below.

- **Ensure compliance with local laws and regulations:** For the design to be legal it needs to meet aesthetics standards and adhere to electricity law. Furthermore, a building permit, environmental permit and operating license need to be requested and received.
- **Provide effective monetary benefits allocation:** For the design to be beneficial to all stakeholders, it needs to ensure that operator costs are covered by revenue, provide low EV charging tariffs and provide a low electricity usage tariff for the large user.
- **Provide a clear tender formulation:** To support and guide potential operators in the tender, the project goal and program of requirements should be clearly defined. Furthermore only a limited number of requirements should be predefined to enlarge the solution space and stimulate creativity.
- **Ensure a high degree of modularity in the institutional arrangement:** To make the institutional arrangement for the solar park at P+R Meijersplein usable for multiple parking terrains in Rotterdam, it should be modular. Therefore, the parking terrains should be owned by the municipality, there should be one operator and one large energy user at all parking terrains and the mode of electricity allocation should be uniform.
- **Provide an efficient allocation of energy:** To make sure that people are able to charge their car when they wish to. Furthermore, to provide an electricity flow to the large user and to store the remaining electricity mitigating intermittency.
- **Agree upon a long term commitment between stakeholders:** To ensure the operation period exceeds the payback period of 16 years. Furthermore, to allow for a long enough operation period, it is important to make certain there are no development plans for the area. Finally, to ensure commitment of all relevant parties coalitions should be formed for every phase of the project.

Requirements for the process design

The process design aims at dealing with the stakeholder dilemmas illustrated in memo 3. The structure of the process design is developed according to three higher level requirements which are illustrated below. The process requirements focus on the 'before construction phase', elaborating on the tender process. However, in the tender process some decisions will have to be made for the 'during' and 'after construction phase'. The tender process aims for a modular design for multiple parking-terrain-based solar parks.

- **Ensure a high degree of openness:** To make sure parties trust each other and all parties feel involved openness should be safeguarded throughout the process. Therefore, it is important to ensure transparent exchange of information, an unbiased and structured process and to bring and keep all relevant actors at the table.
- **Ensure core value protection of all stakeholders:** To make sure that all parties that take a risk by participating in the process are offered sufficient protection, their core values have to be protected and a safe environment has to be established. This can be achieved by committing to the process rather than to the result, by allowing parties to postpone their commitments and establish exit rules.

- **Provide an effective tender process:** this is needed to make sure; everyone gets a fair chance, the winner is determined in a non-biased way, all stakeholders are on the same page, and to eventually enable the best potential operator to win.

Requirement dilemmas and trade-offs

While integrating the requirement of T, I, P, three critical dilemmas are identified and analyzed, which implicates trade-offs either at the design table or at the negotiation table.

Project cost vs performance & service quality: On the one hand it is beneficial that the electricity tariffs for charging cars and large consumers will be low. This will only be possible when the construction costs will also be low, since the operator needs to recover this by revenue of selling the electricity or by saving in the energy bills. On the other hand it is also beneficial for all stakeholders that the project has a long lifetime and high performance. In order to provide high service quality such as sufficient EV charging points, meet circularity standards for more sustainability, however, this requires higher investment costs. This creates a trade-off between paying more for a better design or paying less for a (almost) sufficient design. The municipality will determine the balance within this trade-off and specify in the program of requirements in the tender.

Ensure a high degree of modularity in the institutional arrangement vs ensure a high degree of openness*:* modularity is an essential factor for fast rollout and implicates the preference for a long-term power purchase agreement between one operator and one large customer, to reduce the complexity. However, this preference excludes most commercial parties and empowers certain big players to steer huge influence during the negotiation process, which could lead to suboptimal outcomes for social welfare. The tradeoff between modularity and openness need to be considered at the design table to decide the involved stakeholders and negotiation agenda.

Define a limited number of requirements for the tender vs ensure core value protection of all stakeholders: on the one hand a limited number of requirements is preferable to enlarge the solution space and stimulate creativity. On the other hand, a limited number of requirements also gives the potential operator freedom to chase self-interest rather than incorporating the core values of all stakeholders. The trade-off is balanced by the municipality who decides how much the project will be constricted and what opportunities for the operator will be kept open. The principle of core value protection needs to be monitored and safeguarded in the negotiation table to cope with strategic behaviors and lead to un-biased agreement for all the stakeholders.

Conclusion

In this fifth memo the integrated program of requirements is drafted, the full list including the rationale can be found in the appendix. Furthermore, the main dilemmas that arise within these requirements were explained. The main dilemmas are the project cost versus the performance, modularity versus openness and a limited number of requirements in the tender versus the protection of core values. These dilemmas will be kept in mind when different possible solutions are compared with each other. The integrated program of requirements will serve as a starting point to come up with different means that will make up the final solution space.

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Appendix A: Complete list of requirements

In this appendix consists of the list of technical, institutional and process requirements. Constraints are indicated with (c).

Requirements technical design

Higher level requirement: Produce electricity effectively

Requirements/constraint	Rationale
Produce high energy yield	In order to make the project more profitable and increase the renewable energy penetration the yield should be high.
Produce high EROI	In order to make the project add to the renewable goals it should deliver more energy than it costs
Ensure low CAPEX	To make sure the profit is profitable capital expenditure should be low
Ensure low OPEX	To make sure the profit is profitable operational expenditure should be low

Higher level requirement: Store electricity efficiently

Requirement/constraint	Rationale
Provide high charging and discharging rate	High charging and discharging rate improves the flexibility and therefore added value of the storage
Provide high round trip efficiency	High round trip efficiency means the storage unit will be more profitable since more energy is used
Provide high storage capacity	To be able to store a large amount of energy and therefore be able to absorb large fluctuations

Higher level requirement: Distribute electricity efficiently

Requirement/constraint	Rationale
Provide an efficient connection from the PV system to the large user	To make sure more energy is used and profits are higher
Provide an efficient connection from the PV system to the storage system	To make sure more energy is used and profits are higher

Provide an efficient connection from the PV system to the car charging system	To make sure more energy is used and profits are higher
Provide an efficient connection from the storage system to car charging system	To make sure more energy is used and profits are higher
Provide an efficient connection from the storage system to large user	To make sure more energy is used and profits are higher
Provide an efficient connection from the main grid to car charging system	To make sure more energy is used and profits are higher
Enable a bi-directional power flow between storage and distribution system	To be able to charge and discharge electricity
Have sufficient metering points	To be able to correctly allocate costs and benefits to all users and consumers
Have 230V & 50 Hz connections (c)	To be able to connect the system with the regular electricity grid

Higher level requirement: Process information adequately

Requirement/constraint	**Rationale**
Ensure fast gathering, storing & distribution of information	To make sure the storage, charge/discharge system work optimally
Meets privacy standards (c)	Violation of privacy standards will result in the system not being used by consumers

Higher level requirement: Ensure a high degree of modularity in the technical design

Requirement/constraint	**Rationale**
Ensure the PV system can be setup at multiple locations	To make sure the PV system can be implemented at other parking terrains
Ensure the distribution system can be setup at multiple locations	To make sure the distribution system can be implemented at other parking terrains
Ensure the car charging system can be setup at multiple	To make sure the car charging system can be implemented at

locations	other parking terrains
Ensure the information system can be setup at multiple locations	To make sure the information system can be implemented at other parking terrains

Higher level requirement: Ensure durability and safety

Requirement/constraint	**Rationale**
Ensure long life time	To improve the profitability of the project
Ensure high weather resistance	To make sure the system will have a long lifetime
Make sure solar roof construction meets safety standards (c)	To avoid unsafe situations

Higher level requirement: Ensure inclusion

Requirement/constraint	**Rationale**
Ensure chosen location is a public parking terrain	To adhere to the municipalities goal of including all inhabitants
Ensure the roof is high enough for all car types (c)	So that people with other car types won't be excluded from the system

Remaining requirements/constraints:

Requirement/constraint	**Rationale**
Perceived as harmonious with landscape (c)	In order to be compliant with the goals of the municipality and that the inhabitants will be satisfied with the design
Provide a sufficient number of EV charging points	To make sure people are able to charge their EV if they want to
Meet circularity standards (c)	To adhere to the view of the municipality and make sure the project is sustainable
Implement solar roofs at parking terrain between 10.000 and 40.000 m2 (c)	To comply with the wishes of the client and to be able to make the design modular

Requirements institutional design

Higher level requirement: Ensure compliance with local laws and regulations

Requirements	**Rationale**
Meets aesthetics standards (c)	The municipality has aesthetics standards to maintain the aesthetics of the city. The solar park should be in compliance with those.
Adheres to electricity law 1998 (c)	The electricity law 1998 describes that certain parties can sell electricity to third parties.The institutional arrangement should be in compliance with this law.
Request and receive building permit (c)	To be able to build the solar park, the operator should request and receive a building permit from the municipality
Request and receive environmental permit (c)	To be able to realize the solar park, the operator should request and receive an environmental permit from the municipality
Request and receive operating license (c)	The operator should request and receive an operating license from the owner of the parking terrain, the municipality

Higher level requirement: Provide effective monetary benefits allocation

Requirements	Rationale
Ensure operator costs are covered by revenue (c)	To make the project a success a viable and sustainable business model is needed so that the operator can cover its costs
Provide low electrical vehicle charging tariff	To incentivise people to charge their car at the parking terrain, low charging tariffs should be provided
Provide low electricity usage tariff for large user	To make it attractive to a large energy user to buy the solar power relatively low usage tariffs should be provided

Higher level requirement: Provide a clear tender formulation

Requirements	Rationale
Define the project goal clearly in the tender	The project goal of the municipality should be clearly defined in the tender to allow bidders to fulfil the goal
Define a clear programme of requirements for the tender	In the tender, the municipality should make clear what requirements it has for the solar park to guide potential operators in the tender application
Define a limited number of requirements for the tender	To allow a large number of potential operators and a large number potential solutions, the amount of requirements should be limited

Higher level requirement: Ensure a high degree of modularity in the institutional arrangement

Requirements	Rationale
Subject parking terrains should be owned by municipality (c)	To make the institutional arrangement for the solar park at P+R Meijersplein usable for multiple parking terrains in Rotterdam.
There should be one operator for all solar roofs at open parking terrains owned by the municipality	To make sure the institutional arrangement is also applicable on other parking terrains and the operator should be the same party.
There should be a large local energy user at every solar park location	To relieve stress on the distribution network you want to make sure that there is a large energy user nearby, this could also be a couple of medium large energy users or a group of consumers acting as unity.
Make the model of electricity dispatch uniform	At the solar park, the energy should be allocated in the same way, to make it easily applicable to other solar parks

Higher level requirement: Provide an efficient allocation of electricity

Requirements	Rationale
Ensure an agreement reliable EV charging	To make sure that people that want to charge their EV are always able to. The electricity could be either from the solar panels or the main grid depending on the ownership model.

Ensure that as much as possible of the remaining electricity goes to the large user	The large user makes institutional arrangements to be able to profit, therefore the electricity should flow to the large user.
Store last remaining electricity	To mitigate intermittency due to the fluctuating energy production of solar power remaining energy should be stored

Higher level requirement: Agree upon a long term commitment between stakeholders

Requirements	Rationale
Agree on a long-term contract for a minimum operation period of 16 years (c)	To ensure the operation period exceeds the estimated payback period of 16 years
Ensure operation period does not clash with area development plan (c)	To allow for a long enough operation period it is important to make sure there are no development plans for the area
Form coalitions for every phase of the project	To ensure commitment of all relevant parties coalitions should be formed for every phase of the project

Process requirements

Higher level requirement: Ensure a high degree of openness

Requirement/constraint	Rationale
Ensure transparant exchange of information	To adhere to the core value of openness and to make sure parties trust each other
Ensure an unbiased and structured process	To adhere to the core value of openness and to make sure every party feels involved and knows what they are up to
Bring and keep all relevant actors at the table	To adhere to the core value of openness and to make sure no-one feels excluded

Higher level requirement: Ensure core value protection of all stakeholders

Requirement/constraint	Rationale
Protect core values of all parties	In order to make sure that all the parties that take risks by participating in the process are offered sufficient protection the core values have to be protected (De Bruijn & Ten Heuvelhof, 2010)
Commit to the process rather than to the result	By committing to the process rather than to the result creates safety and space which leads to a better process overall (De Bruijn & Ten Heuvelhof, 2010)

Allow parties to postpone their commitments	To make sure you don't create points of no return. And to make sure that parties commit to the final package of commitments instead (De Bruijn & Ten Heuvelhof, 2010)
Establish exit rules	Exit rules create safety and space which will nourish cooperation and decision making (De Bruijn & Ten Heuvelhof, 2010)

Higher level requirement: provide an effective tender process

Requirement/constraint	**Rationale**
Consult all relevant stakeholders for programme of requirements	To make sure that all stakeholders are on the same page they have to be consulted about the programme of requirements beforehand.
Ensure a transparent evaluation of tender applications	In order to give everyone a fair chance the tender evaluation process should be transparent
Use effective scoring methods for tender winner determination	In order to make sure the winner is not determined in a biased way
Provide and adhere to established timeline	To give all applicants an indication of the planning and make sure that they know what to expect
Allow all potential operators to bid for the tender	To make sure no party is excluded

DESIGN PROJECT

SolarRoof 3

Memo 6: Results of Generation and Selection phases

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Introduction

This memo presents the results of the generation and selection phases of the design project. Morphological charts are utilized for each T-I-P artefact to propose means for each function and generate several alternatives. Then the design team ranks alternatives and selects the best one using the Analytical Hierarchy Process (AHP), a more elaborate explanation can be found in Appendix A. How the chosen designs meet the programme of requirements is explained to support the selection. This memo proceeds as follows: The process design is described and elaborated upon, the technical design scheme is illustrated and two institutional contracts are drafted.

Process design

Based on an expert meeting with Dr. H.G. van der Voort the scope of the process design is slightly changed. For the process artefact it is decided to focus primarily on the tender process, since this is the most complex and interesting part, and the Municipality of Rotterdam is still highly involved in this. For these reasons the process requirements have been revised. For the revised list of process requirements please see appendix B.

The most important functions of the process, necessary to fulfil the requirements, are depicted in the morphological charts in Appendix C. The morphological chart is used to generate different design alternatives.. The different alternatives are illustrated below:

Open process design: The first option characterizes itself as the most 'open' process. With a limited number of requirements and many potential operators can participate and creativity is stimulated. However, it is also the most time-consuming.

Closed process design: The second option is characterized by a 'closed' process. It minimizes the design space by the extensive existing list of technical requirements. It is a negotiated tender, with a short time frame and the preferred operator is approached from the start.

Energy producers only process design: The last option is a combination of the first and second option. In this option the list of requirements is reconsidered. However, only energy producers are approached and there will be negotiations with multiple potential operators.

Evaluation of alternatives

Based on the new list of requirements the following objectives are identified: high degree of openness, steady progress, high amount of clarity and high degree of connectivity. These objectives are used to rank and score the different alternatives derived by the morphological chart.

Based on the defined objectives, using the AHP method, the 'Energy producers only process design' is considered to be the most suitable. The results of the AHP method can be found in Appendix F.

This design can be seen as a midway in between the two other options. Therefore scores reasonable to good on all objectives. Furthermore, because of the high amount of scheduled meetings and the use of a predefined scoring method, it specifically scores very well on the clarity and connectivity objectives. Therefore, this option is the superior alternative.

The following table shows how the chosen process design meets the process requirements.

Table 1: How the process design meets the Programme of Requirements

Higher level requirement	How option meets Programme of Requirements
Provide a structured progress	Because of the timeline and the scheduled meetings the process is structured
Ensure a high degree of openness	Because only the energy producers/retailers are approached the process is not fully open at the start. Hereafter, the process is transparent and unbiased and therefore relatively open during the remainder of the process.
Effectively Identify potential operators	Approach the big energy producers/retailers in the Netherlands, among which Vattenfall, Essent, Engie, CCI, Delta, EDF, Eneco and E.ON. After which a financial check of all potential operators is done. However, not all potential operators can bid on the tender.
Effective identification of preferred operator	By deciding upon a predefined scoring method the preferred operator can be identified easily and transparently.
Create clarity surrounding the requirements of the project	By evaluating the requirements together with all stakeholders clarity surrounding the project requirements is created.
Structured and successful negotiation with preferred operator	The negotiation phase in the third month will be structured with 3 negotiation rounds where there will be agreed upon the institutional and technical design.

Mock-up of the process design

As a mock-up for the process design a timeline has been constructed that shows the most important characteristics of the tender process. The month before the start of the tender will be specifically elaborated upon below.

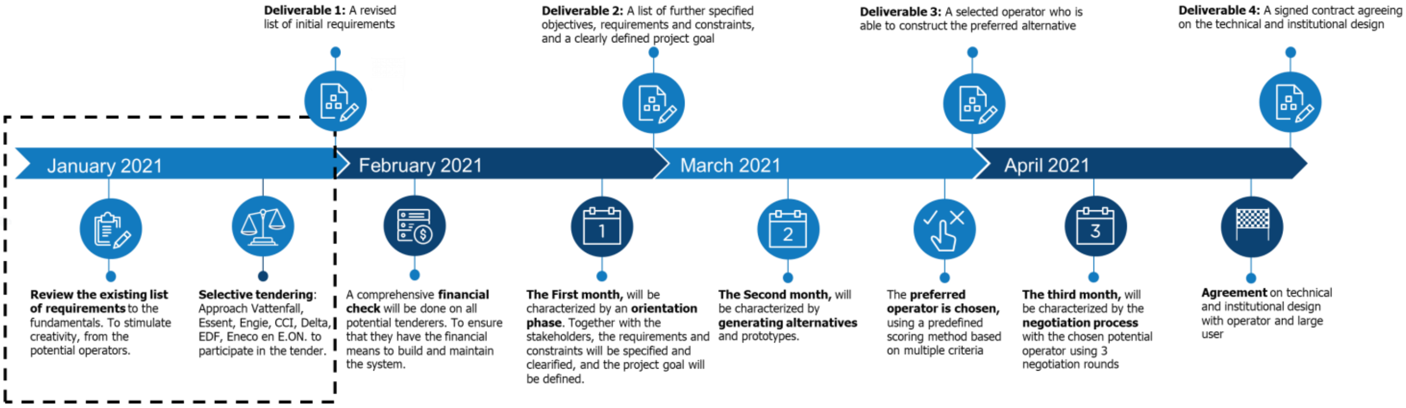

Figure 1: Timeline of the tender process

The tender process is pretty much predefined and the complexity of the process design is most interesting in the month before the start of the tender: during reconsideration of the requirements and while approaching the energy producers. Therefore, a more detailed process design for the month before the tender is formulated.

The sustainability department of the Municipality, has already developed initial technical requirements for the tender. These requirements are reconsidered by including different viewpoints and by engaging some of these stakeholders for realization of the project.

Because all stakeholders are very different and have different amounts of power and degree of involvement, the complexity is relatively high. To deal with this complexity the process is divided in four different rounds. Where the invited stakeholders and the process rules in every round are based on the characteristics of the stakeholders and the specific goal of the round. In every round the department of sustainability leads the discussion. A schematic view of this process is given in the following figure and table.

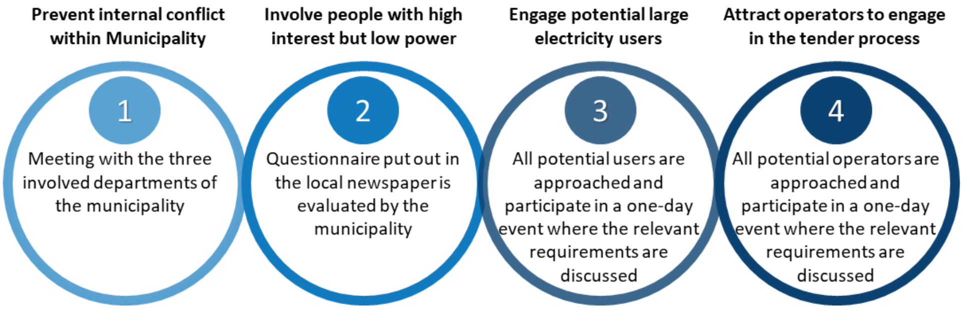

Figure 2: The four rounds of the process before the start of the tender

Table 2: Specifics of the process design of the month before the tender

	Round 1	Round 2	Round 3	Round 4
Stakeholders involved	Municipality: • Dep. area development • Engineering bureau • Dep. sustainability	• Dep. sustainability • Anyone that is interested	• Dep. sustainability • ENGIE • Potential large electricity users	• Dep. sustainability • Potential operators
Goal	Making sure there is no internal conflict within the Municipality	To involve people with high interest but low power	To engage potential large electricity users	To engage potential operators
Design principle	The core values of parties are protected	All relevant parties are involved in the decision-making process	Parties commit to the process rather than the result	Parties commit to the process rather than the result
Process rules	• Two representatives per stakeholder • Finalised requirement list must be approved by all parties	• Everyone can reply. • Questionnaire is open for 2 weeks • All replies must be evaluated by the municipality afterwards	• Two representatives per stakeholder • Anyone may suggest requirements • Municipality has to consider all suggestions afterwards	• Two representatives per stakeholder • Anyone may suggest requirements • Municipality has to consider all suggestions afterwards

Technical design

For the technical design, the same method for generation and selection of alternatives is used. Appendix D depicts the morphological chart for the technical design. Using the possible means, four alternatives have been generated. These alternatives are discussed below, after which the most suitable option is chosen.

The economical alternative: This alternative chooses the most commercialized products and simplified control system to fulfil the minimum requirements. The thin-film solar cell is the cheapest one (€ 150/panel) due to a relatively low efficiency (7-10%) and local component control is picked for electricity dispatch (Zonne-paneel, 2019; Customenergy, 2019). Electrical vehicles (EVs) also served as storage to balance the demand but with slow charging units.

The green choice alternative: The emphasis of the green choice alternative is to select highly recyclable materials, reduce life-cycle carbon footprints and impose less impact on the existing landscape. Wood structure is eco-friendly and exhibits an aesthetic harmony with the surrounding landscape. The sophisticated multi-agent energy management information system is deployed to optimize the car charging and electricity dispatch and perform demand side management (Manbachi,2018).

The innovative niche alternative: As for the innovative niche alternative, state-of-the-art technologies and sophisticated energy management information system are integrated to achieve the best technical performance. Monocrystalline solar cells with a high efficiency of 20% are installed on the highly recyclable steel roof (Customenergy, 2019). The multi-agent energy management information system controls and integrates rapid charging of EVs and kinetic energy in a rotating flywheel to balance between the intermittent PV generation and user demand.

The intermediate alternative: The intermediate alternative balances the commercial feasibility and technology innovation. The polycrystalline solar cell is a mature technology with a efficiency of 15% but with 25% lower price compared to the monocrystalline one

(Zonne-paneel, 2019; Customenergy, 2019). The lithium-ion battery is proved to be a promising distributed energy storage solution with a high modularity (Berrueta, 2019). The control components are located closely to the relevant assets so that they receive and process data for local optimization. Compared to centralized control, local control avoids the long-distance communication cost and use of more advanced metering infrastructure (Manbachi,2018).

Evaluation of alternatives

No conflicts between the four alternatives and system constraints exists, which enables all the alternatives to enter the evaluation phase using the AHP method. The used criteria were derived with the help of the objectives tree. The results of the AHP method are shown in Appendix F. It is clear that the intermediate alternative ranks the best overall. Specifically, it performances the best in terms of durability and safety, modularity and inclusiveness, ranks the 2nd on the cost, and ranks the 3rd on efficient electricity production & storage and landscape harmony. Table 3 verifies that the chosen design fulfils the system requirements.

Table 3: How the technical design meets the Programme of Requirements

Higher level requirement	How option meets Programme of Requirements
Produce, store and distribute electricity effectively	The polycrystalline solar panel, Li-ion battery and local control components fulfil the functions of production, storage and distribution; the chosen technologies balance between the efficiency and costs, and their effectiveness is endorsed by their wide implementation all over the world.
Process information adequately	The local control components receive and process data from PV panels, storage, charging vehicles and consumers to optimize the electricity dispatch.
Ensure a high degree of modularity	The chosen commercial products are easily accessible on the commercial market at an acceptable price and exhibit a high modularity and extensibility with standardized control topology .
Ensure durability, safety	The chosen technologies are mature in terms of PV panels, battery and roof material with a life-expectancy time of over 20 years.
Perceived as harmonious with landscape	The polycrystalline solar cells with a typical blue diamond-shaped look are installed on the highly recyclable steel roof to ensure the aesthetic harmony with surrounding landscape.
Provide a sufficient number of EV charging points	Sufficient fast chargers are deployed on the parking terrains to reduce charging time per vehicle and provide service to more users.

Mock-up of the technical design

Figure 3 showcases a mock-up of the technical design scheme. The charge controller tracks the maximum power point of the PV array to deliver the maximum available amount of electricity. The inverter transforms direct current into alternating current in order to supply the load. The dispatch priority of generated electricity is: electric vehicles, large electricity user load, and storage in the Li-on batteries in the case of a surplus. The charging and discharging state of battery banks are optimized by the local controller to balance between variable PV generation and system demand. Besides, the main grid also backs up the charging service reliability.

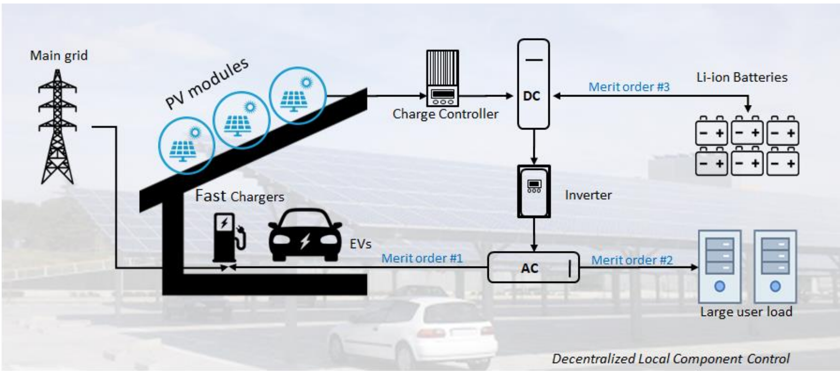

Figure 3: Technical design scheme

Institutional design

To obtain an adequate institutional design a morphological chart is constructed in which the three main functions of the institutional design are stated. For each function various means are constructed and these are combined into three alternatives, a 'rigid', 'flexible' and 'mixed' alternative. Appendix E depicts the morphological chart for the institutional design. The alternatives are discussed below, after which the most suitable option is chosen.

Rigid institutional design: The first alternative characterizes itself as the most rigid institutional design. With mainly predefined electricity and monetary allocations there is limited wiggle room left. This option is the most straightforward to implement.

Flexible institutional design: The second alternative is characterized by its flexibility. It enables every actor to adapt to the ideal situation and gain the highest amount of total welfare. However, this alternative is most time-consuming because of the significant room for negotiations and has the highest amount of transaction costs.

Mixed institutional design: The third alternative has a mixed feature, which is a balance between the other two options. This alternative has room for negotiations, but also has lower transaction costs and an easier agreement design than the flexible alternative.

Evaluation of alternatives

After concluding that there are no conflicts between the three alternatives and system constraints, the AHP method is used to evaluate the alternatives. Four criteria are chosen with a corresponding weight: Effective monetary benefits allocation (0.3), high degree of modularity (0.4), efficient allocation of electricity (0.1) and long term commitment between stakeholders (0.2). Because the purpose of the design is to be scalable to different parking terrains in the city, a high degree of modularity is the most important criterion. The second most important criterion is the effective monetary benefits allocation. This is needed to be able to make a business case of the project. The results of the AHP method are shown in Appendix F.

From the analysis the 'mixed alternative' seems to be most suitable. The mixed alternative scores best on the effective monetary benefits allocation and long term commitment. Furthermore, the mixed alternative scores average on the other criteria but never has the lowest score, whereas the other two alternatives do score lowest sometime. Table 4 shows how the chosen design adheres to the institutional requirements.

Table 4: How the institutional design meets the Programme of Requirements

Higher level requirement	How option meets Programme of Requirements
Provide effective monetary benefits allocation	Since there is no maximum profit indicated for the operator, the operator can set the tariffs so that the monetary benefits cover their costs effectively. Because the tariffs are predefined the transaction costs will remain low.
Ensure a high degree of modularity in the institutional arrangement	A high degree of modularity is established by the flexibility in the agreement between the operator and the large electricity user. If another solar park is realized, this flexibility makes the negotiation between the operator and new large users easier. The DBFM agreement between the municipality and the operator limits the modularity but is needed for a viable business case.
Provide an efficient allocation of electricity	By choosing for a specified order of generated electricity allocation, based on absolute power instead of percentages, a more clear allocation will occur.
Agree upon a long term commitment between stakeholders	The long term commitment is guaranteed in the DBFM agreement between the municipality and the operator, since the minimum duration is 16 years.

Mock-up of the institutional design

The mock-up of the institutional design consists of two different contracts: A Design, Build, Finance and Maintain contract (DBFM) between the Municipality and the operator and a Power Purchase Agreement (PPA) between the operator and the large user.

Design, Build, Finance and Maintain contract

For the long term arrangement between the Municipality of Rotterdam and the system operator a DBFM contract is drafted and can be found in Appendix G. This DBFM contract contains the most important institutional arrangements between these two actors. The main topics are as follows:

Obligations and duration: The obligations of the system operator and the obligations of the municipality in terms of technical and physical aspects of the design as well as the property rights allocation and duration of the project.
Financing: The financial agreements which allocate the costs of the physical design, the revenue which will be generated by selling the produced electricity and the monetary flow that comes paired with the allocation in property rights.
Contract revisions: Agreements on the possibility to bilaterally revise the contract will be accounted for and needs to be signed by both parties.
Final provisions: Ensuring that the contract and agreements are all compliant to Dutch law and legislation.

Power Purchase Agreement

For the allocation of the electricity generated, a PPA is drafted. This PPA addresses the financial and physical agreements of the system operator, ENGIE - who will be responsible for the electric vehicle chargers - and the large electricity consumer. The PPA is available in Appendix H. The main topics discussed in the contract are the following:

Type of production unit: PV solar park, located on the P+R Meijersplein, Rotterdam.
Length of the contract: The length of this contract will be 16 years with every year a possibility of a bilateral change of contract.
Possible termination of contract: The contract will contain a unilateral termination possibility for the electricity supplier in case the buyer does not meet his obligations.
Bandwidth: When producing electricity from a variable renewable energy source is important that no bandwidth agreements are made in the PPA. For solar energy fluctuations can cause significant differences in expected energy production and the real production. It is not desirable to be held accountable for the difference in volumes than was contractually established as expected annual volume. Therefore no bandwidth agreements are made in the contract.
Malfunction, maintenance: In times of malfunction or maintenance, there will be no electricity supplied and sold. The electricity supplier cannot be held monetary liable for loss of electricity supply when unexpected errors occur. Maintenance will be paid for by the electricity supplier.
Imbalance, profiling: Potential imbalance will be paid for by the electricity supplier. If the generated electricity is more than demanded by the large electricity consumer, the supplier will pay for it and keep it stored on the site.
Payment: It is important to have the payment moment close to the production period, to avoid payment issues. Therefore, the payment will be done the month following the production month.
Pricing method: APX monthly unweighted: As pricing method the 'APX month unweighted' will be used. In this construction all APX hourly prices of the month will be divided by the number of hours in the month. The average price is then multiplied by the monthly production.

Conclusion

In this memo different alternatives for the process, technical and institutional designs were generated. Hereafter the best designs were chosen with the help of the AHP method and mock-ups of the chosen designs were shown. In the next memo a proof of concept will be given of each mock-up.

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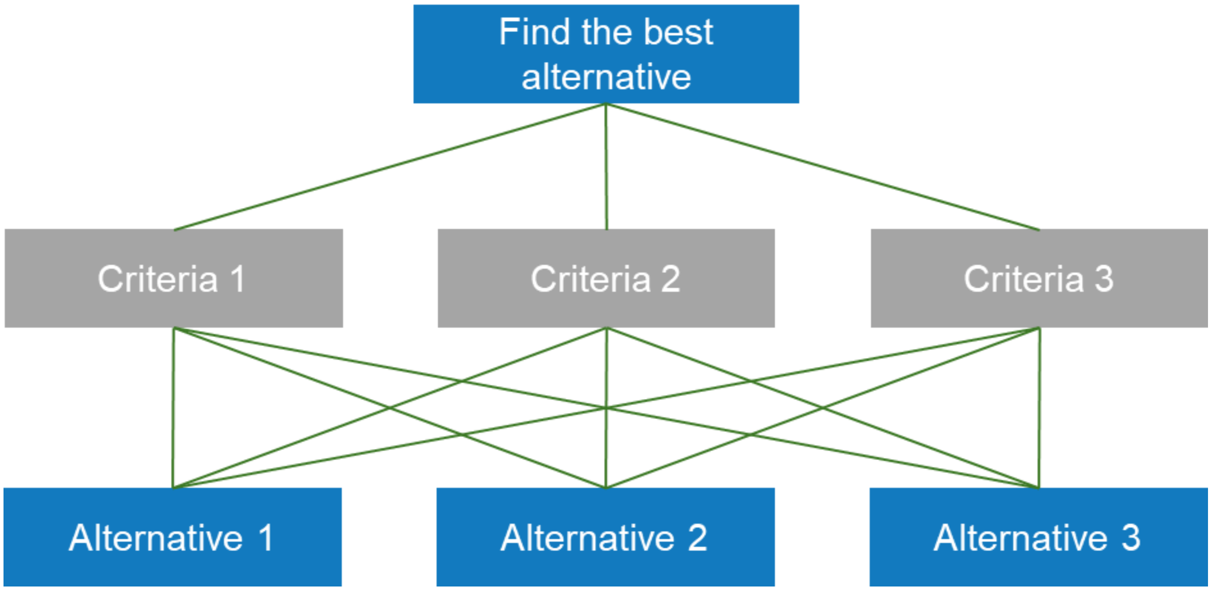
Appendix A: Analytical Hierarchy Process



"*The analytic hierarchy process is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology*". Specifically, the alternatives are compared to each other for each criterion using a preference scale, which generates the criteria preference matrix. Different weights are assigned on each criteria to obtain the preference vector. In the end, the outcome of both is combined in order to gain a final ranking of the alternatives.

Appendix B: Revised process requirements

Provide a structured process: To make sure the involved parties know what they're up to the process should be structured. This can be done by providing effective meetings and presentation possibilities and by defining the project goal clearly in the tender and by providing and adhering to a timeline.

Ensure a high degree of openness: To make sure parties trust each other and all parties feel involved openness should be safeguarded throughout the process. Therefore, it is important to ensure transparent exchange of information, an unbiased and structured process and to bring and keep all relevant actors at the table.

Effectively identify potential operators: To make sure that all the potential operators are identified and that you don't exclude potential operators from the process. Therefore it is important that all potential operators are allowed to bid for the tender, that all relevant stakeholders are consulted for the programme of requirements and that a comprehensive financial check on the potential operators is performed.

Effective identification of preferred operator: to identify the most suitable operator, it is important to make sure the winner is determined in an unbiased way. The evaluation process should be transparent to ensure all participants have a fair chance in the tender process.

Provide clarity surrounding the requirements of the project: To support and guide potential operators in the tender, the programme of requirements should be clearly defined. Furthermore only a limited number of requirements should be predefined to enlarge the solution space and stimulate creativity. Also all stakeholders should be informed with the requirements.

Structured and successful negotiation with preferred operator: to ensure that all requirements set out by the municipality are met, and a clear division of roles and responsibilities is made, it is important that an agreement is reached concerning the final technical and institutional artefact.

Higher level requirement: Provide a structured process

Requirement/ constraint	Rationale
Define the project goal clearly in the tender	The project goal of the municipality should be clearly defined in the tender to allow bidders to fulfil the goal
Provide effective meetings and presentation possibilities	To ensure structure and progress throughout the tender
Provide and adhere to established timeline	To give all applicants an indication of the planning and make sure that they know what to expect

Higher level requirement: Ensure a high degree of openness

Requirement/constraint	Rationale
Ensure transparent exchange of information	To adhere to the core value of openness and to make sure parties trust each other
Ensure an unbiased and structured process	To adhere to the core value of openness and to make sure every party feels involved and knows what they are up to
Bring and keep all relevant actors at the table	To adhere to the core value of openness and to make sure no-one feels excluded

Higher level requirement: Effectively Identify potential operators

Requirement/constraint	Rationale
Allow all potential operators to bid for the tender	To make sure no party is excluded
Perform comprehensive financial checks on potential tenderers	To make sure that the potential operator is financially strong enough

Higher level requirement: Effective identification of preferred operator

Requirement/constraint	Rationale
Use effective scoring methods for tender winner determination	In order to make sure the winner is not determined in a biased way
Ensure a transparent evaluation of tender applications	In order to give everyone a fair chance the tender evaluation process should be transparent

Higher level requirement: Create clarity surrounding the requirements of the project

Requirement/constraint	Rationale
Consult all relevant stakeholders for programme of requirements	To make sure that all stakeholders are on the same page they have to be consulted about the programme of requirements beforehand.
Define a clear programme of requirements for the tender	In the tender, the municipality should make clear what requirements it has for the solar park to guide potential operators in the tender application
Define a limited number of requirements for the tender	To allow a large number of potential operators and a large number potential solutions, the amount of requirements should be limited

Higher level requirement: Structured and successful negotiation with preferred operator

Requirement/constraint	Rationale
Agree on the final technical artefact to be designed	To ensure that the designed artefact meets all the requirements that are set from the municipality.
Agree on the final institutional artefact to be designed	To ensure a clear division of roles and responsibilities, in combination with cost/revenue allocation, in later stages of the project

Appendix C: Morphological charts process design

Morphological chart Open design:

Process function	Mean 1	Mean 2	Mean 3
Assemble list of requirements	Use existing list of technical requirements	Reconsider existing list of requirements	Down scale existing list of requirements to the fundamentals
Identify potential operators	Approach energy producers/retailers (selective tendering)	Notify that potential operators are able to enlist for the tender (open tendering)	Negotiated tendering
Provide structure to the process	3 month process with weekly check in meetings with final presentation	6 month process with monthly check in with final presentation	1 month process with only a final presentation
Choose the preferred operator	Choose based on lowest cost	Use a predefined scoring method based on multiple criteria	Choose based on energy yield
Negotiate with the preferred operator	Use predefined amount of 'negotiation rounds'	Only give a 'take-it-or-leave-it' option	Negotiate for as long as necessary to reach consensus.

Morphological chart Closed design:

Process function	Mean 1	Mean 2	Mean 3
Assemble list of requirements	Use existing list of technical requirements	Reconsider existing list of requirements	Down scale existing list of requirements to the fundamentals
Identify potential operators	Approach energy producers/retailers (selective tendering)	Notify that potential operators are able to enlist for the tender (open tendering)	Negotiated tendering
Provide structure to the process	3 month process with weekly check in meetings with final presentation	6 month process with monthly check in with final presentation	1 month process with only a final presentation
Choose the preferred operator	Choose based on lowest cost	Use a predefined scoring method based on multiple criteria	Choose based on energy yield
Negotiate with the preferred operator	Use predefined amount of 'negotiation rounds'	Only give a 'take-it-or-leave-it' option	Negotiate for as long as necessary to reach consensus.

Morphological chart Energy producers only design:

Process function	Mean 1	Mean 2	Mean 3
Assemble list of requirements	Use existing list of technical requirements	Reconsider existing list of requirements	Down scale existing list of requirements to the fundamentals
Identify potential operators	Approach energy producers/retailers (selective tendering)	Notify that potential operators are able to enlist for the tender (open tendering)	Negotiated tendering
Provide structure to the process	3 month process with weekly check in meetings with final presentation	6 month process with monthly check in with final presentation	1 month process with only a final presentation
Choose the preferred operator	Choose based on lowest cost	Use a predefined scoring method based on multiple criteria	Choose based on energy yield
Negotiate with the preferred operator	Use predefined amount of 'negotiation rounds'	Only give a 'take-it-or-leave-it' option	Negotiate for as long as necessary to reach consensus.

Appendix D: Morphological charts technical design

The economical alternative:

Technical function	Mean 1	Mean 2	Mean 3
Produce electricity	Monocrystalline solar cells	Polycrystalline solar cells	Thin-film solar panels
Store electricity	Car battery	Lithium-ion battery	Flywheel
Distribute electricity	Local smart grid	Local grid	Connected to the main grid
Process information	Centralized control	Local control	Multi-agent system
Ensure durability and safety	Wood construction	Steel (highly recyclable)	Concrete / cement
Charge cars	Rapid chargers	Fast chargers	Slow units

The green choice alternative:

Technical function	Mean 1	Mean 2	Mean 3
Produce electricity	Monocrystalline solar cells	Polycrystalline solar cells	Thin-film solar panels
Store electricity	Car battery	Lithium-ion battery	Flywheel
Distribute electricity	Local smart grid	Local grid	Connected to the main grid
Process information	Centralized control	Local control	Multi-agent system
Ensure durability and safety	Wood construction	Steel (highly recyclable)	Concrete / cement
Charge cars	Rapid chargers	Fast chargers	Slow units

The innovative niche alternative:

Technical function	Mean 1	Mean 2	Mean 3
Produce electricity	Monocrystalline solar cells	Polycrystalline solar cells	Thin-film solar panels
Store electricity	Car battery	Lithium-ion battery	Flywheel
Distribute electricity	Local smart grid	Local grid	Connected to the main grid
Process information	Centralized control	Local control	Multi-agent system
Ensure durability and safety	Wood construction	Steel (highly recyclable)	Concrete / cement
Charge cars	Rapid chargers	Fast chargers	Slow units

The intermediate alternative:

Technical function	Mean 1	Mean 2	Mean 3
Produce electricity	Monocrystalline solar cells	Polycrystalline solar cells	Thin-film solar panels
Store electricity	Car battery	Lithium-ion battery	Flywheel
Distribute electricity	Local smart grid	Local grid	Connected to the main grid
Process information	Centralized control	Local control	Multi-agent system
Ensure durability and safety	Wood construction	Steel (highly recyclable)	Concrete / cement
Charge cars	Rapid chargers	Fast chargers	Slow units

Appendix E: Morphological charts institutional design

The rigid agreements:

Institutional Function	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
Allocate monetary benefits	Contract with predefined tariffs for car charging and electricity use	Car charging and electricity use tariffs can be set and changed by the operator	Contract that specifies a maximum amount of profit for the operator	Contract that specifies no maximum amount of profit for the operator	
Allocate the electricity generated	Allocate the electricity using predefined percentages	Set a predefined order to who has the right to use the electricity	Local trading market: bidding mechanism		
Arrange long term commitment between stakeholders	DBFM agreement for a minimum of 16 years for operator	Contract for a minimum of 16 years between operator and large electricity user	Contract for a to be agreed on years between operator and large electricity user	Annual check-up meeting with municipality and operator with possible contract revisement	Annual check-up meeting with operator and users with possible contract revisement

The flexible agreements:

Institutional Function	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
Allocate monetary benefits	Contract with predefined tariffs for car charging and electricity use	Car charging and electricity use tariffs can be set and changed by the operator	Contract that specifies a maximum amount of profit for the operator	Contract that specifies no maximum amount of profit for the operator	
Allocate the electricity generated	Allocate the electricity using predefined percentages	Set a predefined order to who has the right to use the electricity	Local trading market: bidding mechanism		
Arrange long term commitment between stakeholders	DBFM agreement for a minimum of 16 years for operator	Contract for a minimum of 16 years between operator and large electricity user	Contract for a to be agreed on years between operator and large electricity user	Annual check-up meeting with municipality and operator with possible contract revisement	Annual check-up meeting with operator and users with possible contract revisement

The Mixed agreements:

Institutional Function	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
Allocate monetary benefits	Contract with predefined tariffs for car charging and electricity use	Car charging and electricity use tariffs can be set and changed by the operator	Contract that specifies a maximum amount of profit for the operator	Contract that specifies no maximum amount of profit for the operator	
Allocate the electricity generated	Allocate the electricity using predefined percentages	Set a predefined order to who has the right to use the electricity	Local trading market: bidding mechanism		
Arrange long term commitment between stakeholders	DBFM agreement for a minimum of 16 years for operator	Contract for a minimum of 16 years between operator and large electricity user	Contract for a to be agreed on years between operator and large electricity user	Annual check-up meeting with municipality and operator with possible contract revisement	Annual check-up meeting with operator and users with possible contract revisement

Appendix F: Results of the AHP scoring method

Results for the process design:

	Criteria				
Preference vector	0,25	0,25	0,25	0,25	**Total Ranking**
Alternative	Open	Progress	Clarity	Connectivity	
Open	0,70	0,14	0,17	0,48	0,37
Closed	0,07	0,57	0,35	0,16	0,29
Energy producers	0,23	0,29	0,48	0,64	0,41

Results for the technical design:

	Criteria							
Preference vector	0,25	0,15	0,1	0,15	0,05	0,05	0,25	**Total Ranking**
Alternative	Efficient electricity production	Efficient electricity storage	Highly durable and safe	High degree of modularity	Highly inclusive	Harmonious with landscape	Low costs	
Economical	0,083	0,218	0,242	0,267	0,128	0,148	0,362	0,222
Green choice	0,333	0,218	0,113	0,200	0,128	0,353	0,214	0,235
Innovative niche	0,333	0,296	0,323	0,200	0,352	0,295	0,174	0,266
Intermediate	0,250	0,269	0,323	0,333	0,391	0,205	0,250	0,277

Results for the institutional design:

	Criteria				
Preference vector	0,30	0,40	0,10	0,20	**Total Ranking**
Alternative	Monetary	Modularity	Allocation	Commitment	
Rigid	0,14	0,14	0,57	0,45	0,25
Flexible	0,29	0,57	0,14	0,13	0,35
Mixed	0,57	0,29	0,29	0,49	0,41

Appendix G: Mock-up DBFM Contract

DBFM contract

This agreement is dated the 1st of May, 2021.

The municipality of Rotterdam (the **Client**)

and

Operator (**Contractor**)

agreed on the following:

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1 OBLIGATIONS AND DURATION

1.1 Obligations Contractor

a) The Contractor must:
   (i) Realize the technical design of the solar park that the Contractor and Client have agreed on in the tender process

   (ii) Realize the technical design of the solar park within the timeframe the Contractor and Client have agreed on in the tender process

   (iii) Ensure the required maintenance of the solar park determined by the duration of this contract

b) All incurred costs to realize the commitments mentioned above are for own account, except for the case that this contract expressly determines differently.

1.2 Obligations Client

a) The Client must:
   i) Give the Contractor the right to build and maintain the solar park on the P+R Meijersplein location
   ii) Give the Contractor the right to acquire revenue generated by the exploitation of the solar park
   iii) Remain exploiting the parking terrain itself
   iv) Fulfill all other obligations stated in this contract

1.3 Duration

This contract enters into force on the 1st of May, 2021 and ends on the 1st of May, 2037, unless agreed on revisements determines determination of this contract.

2 FINANCING

2.1 Costs

a) All cost related to the construction of the project are fully to be paid and accounted for by the Contractor.
b) All cost related to the operation of the project are fully to be paid and accounted for by the Contractor.
c) All cost related to the maintenance of the project are fully to be paid and accounted for by the Contractor.

2.2 Revenue

a) The operator is entitled to all revenue acquired by selling the generated electricity. This entails:
   i) Electricity sold to large consumer(s).
   ii) Electricity sold to charge Electric Vehicles.

2.3 Rent

a) The monthly rent that the Contractor has to pay the Client over the duration of the project is set at €0,00 (zero).

2.4 Damage

a) Any damage to the property of the Client, not as a logical result of construction the project, is to be repaired or accounted for by the Contractor.

3 CONTRACT REVISIONS

a) It is possible to revise the contractual arrangements as stated in in this contract only if the Client and the Contractor are both in favour of revision of the contract.

4 FINAL PROVISIONS

a) Dutch law is applicable to this agreement.

MUNICIPALITY OF ROTTERDAM:	**OPERATOR:**

Appendix H: Mock-up PPA Contract

Power Purchase Agreement

between:

System operator (**"Seller"**); and

Engie (**"Buyer A"**); and

Large electricity Consumer (**"Buyer B"**).

(referred to jointly as the **"Parties"** and individually as a **"Party"**)
(Large electricity Consumer and Engie referred to jointly as the **"Buyers"** and individually as a **"Buyer A / Buyer B"**)

on the date ____ (**"Signature Date"**), where the commercial terms of this individual power purchase agreement are set forth below, and the general provisions of which are set forth below, and which incorporate by reference herein, and form a part hereof.

SECTION A: COMMERCIAL PROVISIONS

1. SETTLEMENT AND TOTAL SUPPLY PERIOD

1.1 The Total Supply Period shall be:

[ ] The period commencing on the later of (i) 00:00 CET on the first day immediately following the Commercial Operation Date, and (ii) 00:00 CET on *[specify date]* ___________________, and expiring on the termination or expiry of this Agreement in accordance with its terms

2. ELECTRICITY

2.1 Contract Quantity: The **"Contract Quantity"** of electricity: All generated electricity will be supplied with the purpose to charge EV's and thus be firstly supplied to 'Buyer A'. The (potential) remainder of the supply will be offered to 'Buyer B'. The quantity will be based on a '**0 kWh contract**', where only generated electricity can be transacted.

2.2 Pricing: The **"Electricity Contract Price"** is based on the APX monthly unweighted pricing method.

2.2(a) Monthly average price, variable for all periods: ***[APX Monthly Unweighted]*** __EURO/kWh;

[ ] The average Market Price for a Calculation Period, being the (unweighted) sum of all hourly prices published by the Electricity Reference Price Source in a Calculation Period divided by the total number of all hours in that applicable Calculation Period for which a price is published by the Electricity Reference Price Source; or

; and

The **"Electricity Reference Price Source"**: *[Day-ahead market price]*

; and

The **"Calculation Period"**: *[1 month]*

3. GENERAL PROVISIONS & FACILITY

"Delivery Period" of electricity: [ ] continuously if available

"Facility": *[P+R Meijersplein solar park]*

Facility generation type: *[PV solar energy]*

"Capacity": *[0.715 MWp]*

Physical address of Site: *[P+R Meijersplein]*

"Delivery Point": *['Buyers']*

Location of Metering Device: *[P+R Meijersplein]*

"Network Operator": *[Local network operator]*

"Metering Entity": *['Seller']*

If "*Provisions of this Agreement on Balancing Services*" are specified to apply in Section B of Part I (*Individual Terms*):

"Balancing Responsible Party":

Where the Delivery Point is on the Network or within Buyer's property: *[specify one option]*

[ ] the Seller.

shall be Balancing Responsible Party up to the Delivery Point

"Balancing Costs": *Will be paid for by the Seller. It can store the overcapacity of electricity and therefore repay the costs by selling the stored electricity at another moment in time.*

SECTION B: ELECTIONS FOR THE PURPOSES OF PART II (GENERAL PROVISIONS)

§ 1

Construction and Commissioning of Facility

§ 1.1 Construction and Commissioning:

The **"Scheduled Commissioning Date"** is: 1st of May, 2021

§ 1.2 Late Commissioning Date:

[ ] § 1.2 shall apply;
otherwise § 1.2 shall not apply

The **"Late Commissioning Date"** is: 2nd of May, 2021

The **"Daily Liquidated Damages Amount"** is: 10.000,- EURO

§ 2

Remedies for Failure to Deliver and Accept Certificates

§ 2.1 Right to Refuse Electricity:

[ ] § 2.1 shall apply;
otherwise § 2.1 shall not apply

§ 3

Special Provisions Applicable to the Financial Settlement

§3.1 Price Differential:

The Price Differential shall be calculated by:
[ ] the Seller; or
[ ] the Buyer

§ 3.2 Deemed Delivery Volume:

The **"Deemed Delivery Volume"** is: Expected generated capacity based on day-ahead calculation models

§ 4

Non-Performance Due to Force Majeure

§ 4.1 Definition of Force Majeure:

[ ] The definition of **"Force Majeure"** shall not apply as written in § 4.1 but shall instead be as follows:

otherwise the definition of **"Force Majeure"** shall apply as written in § 4.1

§ 4.2 Right to Refuse Electricity:

[ ] § 4.2 shall not apply;
otherwise § 4.2 shall apply

§ 5

Term and Termination Rights

§ 5.1 Expiration Date:

The Expiration Date is: *1st of May, 2037, 00.00 CET*

§ 5.2 Termination for Material Reason:

[ ] Termination Amount shall not be payable as a result of an event of Force Majeure which occurs in accordance with § 5.2 (*Long Term Force Majeure*);

otherwise Termination Amount shall be payable as a result of an event of Force Majeure which occurs in accordance with § 5.2 (*Long Term Force Majeure*)

§ 6

Calculation of the Termination Amount

§ 6.1 Termination Amount:

Where the Buyer is the Terminating Party, the following shall apply to the Buyer:
[ ] § 6.5 (*Termination Amount Payment*); (EURO)

Where the Seller is the Terminating Party, the following shall apply to the Seller: *[specify one option]*
[ ] § 6.2 (*Mark-to-Market Termination Amount*);
[ ] § 6.3 (*Outstanding Debt Termination Amount*); or
[ ] § 6.4 (*Alternative Termination Amount*):

§ 6.5 Termination Amount Payment:

The Termination Amount shall be due and payable 1 Business Days after the Termination Date and contain 1000.000,- EURO

§7

Invoicing and Payment

§ 7.1 Payment: Payments will be transferred on the 1st of every month.

§ 8

Performance Assurance

§ 8.1 Application:

[ ] § 8shall not apply;

otherwise § 8 shall apply

§ 9

Confidentiality

§ 9.1 Confidentiality Obligation:

[ ] § 9 shall not apply;

otherwise § 9 shall apply

§10

Malfunction and Maintenance

§ 10.1 Malfunction & Maintenance: During malfunction of the electricity production, distribution or storage, the electricity supplier cannot be held monetary liable for loss of electricity supply when unexpected errors occur. Maintenance will be paid for by the electricity supplier.

§ 11

Miscellaneous

§ 11.1 Notices and Communications:

(a) **TO SELLER:**

Notices & Correspondence

Address:
Telephone No:
Fax No:
Attention: *[Job Title]*
Invoices
Fax No:
Attention: *[Job Title]*
Payments
Bank account details

(b) **TO BUYER A:**

Notices & Correspondence

Address:
Telephone No:
Fax No:
Attention: *[Job Title]*
Invoices
Fax No:
Attention: *[Job Title]*
Payments
Bank account details

(c) **TO BUYER B:**

Notices & Correspondence

Address:
Telephone No:
Fax No:
Attention: *[Job Title]*
Invoices
Fax No:
Attention: *[Job Title]*
Payments
Bank account details

SECTION C: AMENDMENTS TO PART II (GENERAL PROVISIONS)

[This section may be used to include additional provisions and local requirements such as on balancing, licencing requirements, or Delivery requirements for Certificates, as well as recitals to set out the economic balance between the Parties, in particular in relation to a Change in Law in accordance with § 16 (Change in Law)]

Executed by the duly authorised representative of each Party effective as of the Signature Date.

[SELLER]	***[BUYER A]***	***[BUYER B]***
[Name of Signatory/ies]	*[Name of Signatory/ies]*	*[Name of Signatory/ies]*
[Title of Signatory/ies]	*[Title of Signatory/ies]*	*[Title of Signatory/ies]*

DESIGN PROJECT

SolarRoof 3

Memo 7: Proof of Concept

Liu, Ziyi	5006430
Stam, Roelof	5191521
Van Rossum, Rik	4375408
Verheijen, Maurits	4346556
Wolters, Anouk	4476239

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This memo illustrates a 'proof of concept' for the technical, institutional and process design. First, for the technical artifact, literature and a simulation tool are used to gain insights in technical and economic feasibility of the proposed design. Furthermore, for the institutional artifacts, expert meetings and relevant literature are used to proof that the artifacts are suitable for our case. Lastly, for the process design, a serious game is played to identify potential shortcomings of our process artifact.

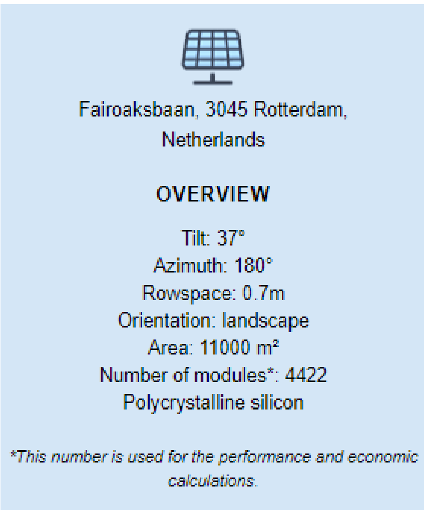
Technical design

The proof of the technical design of the best alternative, as concluded from the previous memo, will be substantiated by firstly analyzing the technical and physical aspects of the design supported by literature, followed by a preliminary simulation.
The technical design balances the commercial feasibility and technological innovation to meet the programme of requirements. The polycrystalline solar cell is a technology with an efficiency of only 15%, but its costs are 25% lower than that of the monocrystalline solar cell (Zonne-paneel, 2019; Customenergy, 2019). The lithium-ion battery is proved to be a promising distributed energy storage solution with high modularity (Berrueta, 2019).

The control components are located near the relevant assets so that they receive and process data from the PV panels, storage, charging vehicles and the consumers to optimize the electricity dispatch. Compared to centralized control, local control avoids the long-distance communication cost and the use of more advanced metering infrastructure (Manbachi,2018). The use of fast chargers could reduce the charging time per vehicle and therefore provide service to more users. Over a 20-year lifetime it is expected to safeguard the durability and ensure the cost recovery. Overall, the various physical aspects of the technical design are easily accessible at an acceptable price and the electricity management system has standardized control topology, which indicates high modularity and extensibility.

Simulation as proof of concept

A preliminary simulation is conducted to prove the technical and economic feasibility with the Dutch PV Portal 3.0 (Klement, 2020). Figure 1 presents the key input parameters including the optimal module tilt and the right azimuth for the Netherlands. A maximum of 4422 solar modules could be installed on the terrain P+R Meijersplein, hence the yearly power generation is estimated at 1.04GWh (Figure 2). If the total generated electricity would be used for charging EV's, taking Nissan Leaf with a battery of 40 kWh for 270 km as an example (Nissan, 2020), the solar park would be able to charge 26000 Nissan Leafs for a total 7,020,000 km per year.



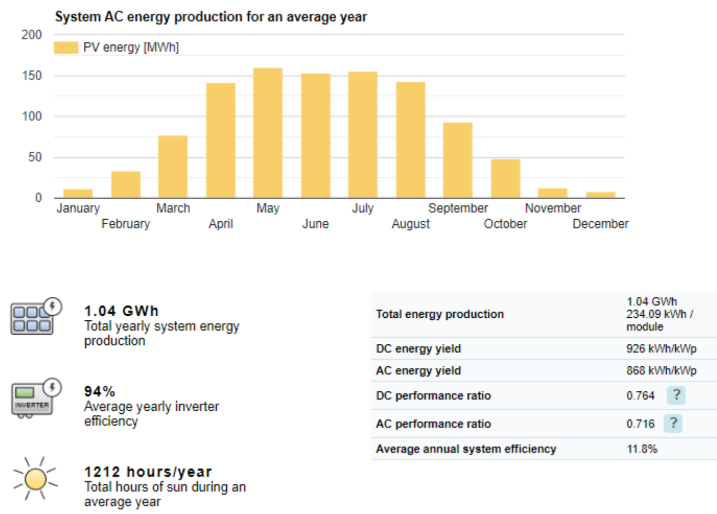


Figure 1: Input parameters (left); Figure 2: Monthy power generation (right)

Figure 3 illustrates the yearly monetary flow during an operation period of 25 years. The required initial investment is approximately €1.03 million and when in operation, the payback period is predicted between 10-15 years based on the discount rate and current electricity market price.

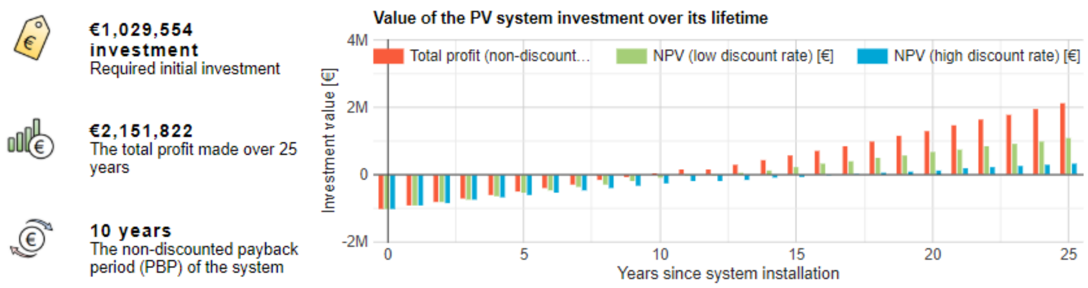


Figure 3: Financial evaluation of the solar park

This initial simulation shows that the payback period is compatible with the minimum operation time of the project. Based on this it can be concluded that the project would be feasible and with that this proof of concept is successful.

For further research, a more sophisticated model could be built in order to optimize the operation of the battery bank and the electricity dispatch based on real customer load profiles, considering the efficiency of all the electrical components, simulate the human behaviors for parking and charging, and execute a financial analysis with the PPA contract price.

Institutional design

In memo 6 two contracts have been selected as most important institutional artefacts. These contracts were the Design, Build, Finance and Maintain-contract (DBFM) and the Power Purchase Agreement (PPA). Literature and case examples are used to show that these contracts fit the purpose of the institutional design.

Proof of concept: DBFM contract

From an expert meeting with a representative from the Municipality of Rotterdam, we gained insights in their expectations and main concerns regarding the design project (N. Pattiwael, personal communication, May 14, 2020). Based on this meeting it became apparent that a DBFM contract is a must-have institutional artifact.

For this project, a longer exploitation period (a minimum of 16 years with a preference for 25-30 years) is desired (N. Pattiwael, personal communication, May 14, 2020). This would make it possible to improve the profitability of commercial parties and to achieve the 2030 solar energy goal (750MW) of the Municipality. Furthermore, minimal restrictions are preferred by the parties that participated in the market consultation of the Municipality (market parties). This fits with the characteristics of the DBFM contract because a DBFM contract aligns the interests of the municipality and operator, while providing the operator with freedom to maximize his knowledge and creativity, and mitigates the workload of the municipality (Rijkswaterstaat, 2020). These kind of contracts are increasingly applied in the Netherlands and other European countries (Arts, 2007). DBFM contracts lead to more sustainable infrastructure development because the linked contract stages of design, construction and maintenance incentivize lifecycle optimizations. (Lenferink et al., 2013).

Several cases show that more experts could be employed in DBFM contracts to focus on the specialized tasks, and a wider public support could be achieved due to the close coordination between different stages of the planning lifecycle (Lenferink et al., 2013). The DBFM contract could empower the operator to formulate a modular design and roll-out similar solar parks across Rotterdam.

Proof of concept: PPA contract

The market parties see the opportunity to sell the electricity to third parties or electric charging points behind the meters, which corresponds with the design project (N. Pattiwael, personal communication, May 14, 2020). After an expert meeting with Aad Correljé, we decided to use a PPA contract. In order to guarantee the long-term commitment for the dispatch of generated electricity among the PV system operator, the charging point operator and the large consumers. The PPA provides financial certainty for all parties, which reduces the investment risk for the operator and market price fluctuation for the consumers (RWE, 2020). The used PPA is a physical PPA, in which the producer delivers power directly from the generator to the EVs and the large electricity user, at a PPA price. Surplus power can be stored in lithium-ion batteries. Physical PPAs have been widely implemented in the renewable energy market all across the world (Rachit, 2019), which demonstrates its feasibility and effectiveness in terms of electricity dispatch and cost allocation.

The following existing successful experiences provide support for the proposed institutional design:

- Light Energy and SAAone together developed a 1 MWp solar park in combination with a DBFM-contracted highway project over a period of 20 years (Alink, 2014).
- Google signed its third PPA in Europe for a datacenter in Eemshaven with Eneco's onshore wind farm in Delfzijl Noord that includes a total output of 175 GWh for 10 years from 2016 (Eneco, 2014).

Both the DBFM and the PPA are well suited to support the modular roll-out. They clearly define the rights and duties to safeguard the long-term commitments among the parties. To further strengthen the proof of concept for this particular design, a pilot project could be facilitated to validate the concept of the institutional design.

Process design

The first part of the process design, the reconsideration of the technical and institutional requirements, is subject to this proof of concept and is tested with the use of a serious game in which the process is simulated. The tender process follows a strict concept, that is described in the Aanbestedingswet 2012 ('Aanbestedingswet 2012', 2019). This process is applied in the Netherlands very often, which indicates that this concept has already proved to work. Therefore the tender process is not part of this proof of concept. The proof of concept of the process of the reconsideration of the requirements will be obtained by playing a serious game.

Serious game

The purpose of the serious game is to check whether the process design will function the way it is designed to function and could possibly result in a desired outcome. The process provides a clear overview of which stakeholders will discuss the technical and institutional requirements. The process is shaped by 4 rounds in which different actors participate each round. The representative of the Municipality, department of Sustainability, will be attending every round and leads the discussions.

During each round a discussion will take place where all physically present stakeholders get the opportunity to speak their minds and act opportunistically. This way, the process can be evaluated to see if the result is a success. If some part of the process is not successful, this will be used as a learning moment and a change to the process will be iterated. Hereafter, the serious game will be played once more to see if the change results in a successful process.

The set up

The process consists of four rounds. The first round is a meeting with three departments of the municipality. The second round is only a questionnaire, therefore this round is not simulated in the serious game. The third round consists of the following stakeholders: the department of sustainability, ENGIE and potential large users (ING wilgenplas and the RET). The fourth round consists of the department of sustainability and energy producers (ENGIE, Nuon Vattenfall and Eneco). During every round, each participating party is represented by one person of the design team.

The process rules that are drafted in memo 6 are adhered to during the game. Furthermore, the municipality department of sustainability leads all meetings.

Key takeaways from playing the game

Playing the game gave insight in the way our process was designed. During the first time we played the game, we noticed some things that were not specified enough and were not considered in the initial process design. We noticed that the requirements that are up for discussion sometimes were not relevant for the parties that participate in that specific round of the process, and this hindered the flow and successfulness of the process. Furthermore we also noticed that it is not possible and feasible to arrive at a consensus during the meeting with all involved parties considering all requirements.

Based on the above learnings, we made some adjustments to the process design. First of all, in every meeting the municipality department of sustainability decides upon which requirements are relevant for the specific involved parties and then during the meetings only these relevant requirements are discussed. Secondly, the municipality department of sustainability considers all suggestions but after the meeting decides themselves if the requirements are to be changed and why, in order to stimulate progress during the meetings. The first meeting however is an exception. During this meeting consensus still has to be realised, because it is very important that there are no internal conflicts within the municipality.

After these adaptations were made the game was played once more. With these adaptations everything went a lot smoother. With these adaptations we concluded the process design to be successful and we have iterated the changes we made in the final process design.

Conclusion

Based on the proof of concepts of the three different design artefacts we conclude that the artefacts will most likely be successful once implemented. For the technical design a simulation showed the technical and economic feasibility of the design and it showed that the payback period is compatible with the minimum operation time of the project. For the institutional design, literature and already existing projects showed that a DBFM and a PPA contract are very applicable to our case. The serious game of the process design showed that the process works.

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DESIGN PROJECT

SolarRoof 3

Memo 8: Communication package

Liu, Ziyi	5006430
Stam, Roelof	5191521
Van Rossum, Rik	4375408
Verheijen, Maurits	4346556
Wolters, Anouk	4476239

Gemeente Rotterdam

Dear Sir/Madam,

On behalf of the Municipality of Rotterdam, department Sustainability, I send you this letter to invite you to an initial meeting regarding the realization of a roof based solar park at P+R Meijersplein. The Municipality of Rotterdam aims to become the leading Municipality in solar projects. Whit this invitation we invite you to join our journey to a sustainable Rotterdam. In this first meeting we intent to introduce the project and evaluate the initial list of requirements. This invitation letter is sent to you, because as a leading electricity producer in the Netherlands, you have been identified as a potential operator for the solar park.

After earlier meetings with other stakeholders where the initial program of requirements written by the Municipality of Rotterdam, department Sustainability, have been re-considered, we would like to invite you to following meeting:

When: **15 - 01 - 2021**

Time: **9:30 AM - 17:30 AM**

Where: **De Rotterdam, Wilhelminakade 179, 3072 AP Rotterdam**

This meeting will inform you about the intent of the project and the possible role for your company in this. Further, the program of requirements for the tender will be re-considered with the attendees. All potential operators of the solar park, including your company, will receive the opportunity to comment on the program of requirements and suggest revisions. Who will be the operator will be decided on by a tender, for which you will be invited at the end of the meeting.

Attached to this letter, you will find information in preparation of this first meeting. This includes the agenda for the meeting, an impression video of a parking terrain solar park, the technical and institutional requirements that will be re-considered during the meeting, the timeline of the process and a simulation that proves the economic feasibility. All of which will also be presented during the meeting.

I am looking forward to your reaction and if you are interested to participate in this meeting and be a potential operator for the solar park. For the meeting, two representatives of your company may be present. Please be so kind to RSVP on this invitation and as side note, it is requested to inform us who will be representing your company at this meeting. For any further information, please contact me.

Yours sincerely,

Sylvia de Jong

Department of Sustainability
Municipality of Rotterdam

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1. Agenda

Dear Sir/Madam,

This meeting will include information regarding the roof-based PV Solar Park at P+R Meijersplein in Rotterdam. During this meeting, the role of the operator will be explained, the technical design of the PV system and distribution network will be discussed as well as the relevant institutional framework. To finalize the meeting, there will be a discussion regarding the requirements of the solar park in which your feedback will be considered. Therefore, your input and participation of this meeting could directly have impact on the requirements for the project in the tender.

All attending actors:

- Municipality Department of Sustainability
- Representatives of electricity producers

Agenda

Friday 15th of January 2021

Starting 9:30 AM

9:30 Opening of meeting
9:35 Introduction parking terrain solar park project
10:00 Elaborate on the role of the operator
10:15 Announce the timeline of the process towards realization

11:00 Coffee break

11:15 Announce relevant Institutional framework
11:30 Discussion: re-consider institutional requirements

12:30 Lunch break

13:15 Discussion: attendees may propose new institutional requirements
14:15 Elaborate technical design space

14:45 Coffee break

15:00 Discussion: re-consider technical requirements
16:00 Discussion: attendees may propose new technical requirements
17:00 Final questions and comments
17:15 Handing out invitations to the tender
17:20 Closing of the meeting

2. Code of conduct

Article 1 | General rules during the meeting:

1. The chairman maintains the order during the meeting and will take the lead.
2. The chairman is a representative of the Municipality of Rotterdam, department Sustainability
3. If a speaker allows abusive or inappropriate expressions or disturbs order in any way, he shall be called to order by the chairman. The same applies if a speaker deviates from the subject in the chairman's opinion.
4. The chairman is authorized not to include in the report a representation of any offensive or inappropriate expressions used by a speaker for which that speaker has been raised during the meeting.
5. In order to maintain order, the chairman may adjourn the meeting for a time to be determined by him and - if order is disturbed again after reopening - close the meeting.
6. The chairman is authorized, if order is disturbed in any way by the audience, those who do this, or have all the auditors leave.

Article 2 | Task of the chairman during the meeting the chairman is responsible for:

1. Conducting the meeting;
2. Maintaining order;
3. Giving members the opportunity to express their views on the subject under discussion
4. Formulating the questions and conclusions in the meeting;

Article 3 | Failure to attend a meeting

A member who is unable to attend the meeting should report this to the chairman before the start of the meeting.

Article 4 | Setting the agenda

The agenda shall be determined by the chairman at the start of the meeting

Article 5 | Taking the floor

1. Attendees may ask the floor during the whole length of the meeting
2. In the discussion rounds, the chairman gives the floor to every potential operator in a random order

3. Impression video of a parking terrain solar park

The attached video gives an impression of what a solar park on top of an open parking terrain could look like. This video belongs to Perdaman Advanced Energy. The video can be accessed by clicking on the figure below, if this does not work the link to the video is provided below.

https://www.youtube.com/watch?v=zbd4L1TMg3M

4. Requirements that are to be reconsidered

The requirements that are to be revised and discussed during the meeting are shown in the next tables. The requirements are split up into two categories: the technical requirements, which consider the technical design that is to be realized and the institutional requirements, which consider the institutional arrangement that has to be constructed. These requirements have been narrowed down to make sure that only the relevant requirements for potential operators are shown. Lastly, constraints are noted with '(c)'.

These requirements could sometimes be conflicting or difficult to adhere to. This is the main reason why they are still up for discussion. The requirement of modularity is one of the main requirements of the Municipality and we know this could be hard to achieve. However, we want to stress out that a higher degree of modularity reduces future costs and therefore is important to the success of the project.

Furthermore, requirements that cost money but do not result in generating revenue, like adhering to certain standards or maintaining a harmonious landscape, can also be conflicting. Therefore we want to discuss these with all potential operators.

Requirements technical design

Higher level requirement: Produce electricity effectively

Requirements/constraint	Rationale
Produce high energy yield	In order to make the project more profitable and increase the renewable energy penetration the yield should be high.
Produce high EROI	In order to make the project add to the renewable goals it should deliver more energy than it costs

Higher level requirement: Store electricity efficiently

Requirement/constraint	Rationale
Provide high charging and discharging rate	High charging and discharging rate improves the flexibility and therefore added value of the storage
Provide high round trip efficiency	High round trip efficiency means the storage unit will be more profitable since more energy is used
Provide high storage capacity	To be able to store a large amount of energy and therefore be able to absorb large fluctuations

Higher level requirement: Distribute electricity efficiently

Requirement/constraint	Rationale
Provide an efficient connection from the PV system to the large user	To make sure more energy is used and profits are higher
Provide an efficient connection from the PV system to the storage system	To make sure more energy is used and profits are higher
Provide an efficient connection from the PV system to the car charging system	To make sure more energy is used and profits are higher
Provide an efficient connection from the storage system to car charging system	To make sure more energy is used and profits are higher
Provide an efficient connection from the storage system to large user	To make sure more energy is used and profits are higher
Provide an efficient connection from the main grid to car charging system	To make sure more energy is used and profits are higher
Bi-directional power flow between storage and distribution system (c)	To be able to charge and discharge electricity
Sufficient metering points	To be able to correctly allocate costs and benefits to all users and consumers
230V connections, 50Hz connection (c)	To be able to connect the system with the regular electricity grid

Higher level requirement: Process information adequately

Requirement/constraint	Rationale
Ensure fast gathering, storing & distribution of information	To make sure the storage, charge/discharge system work optimally
Meets privacy standards (c)	Violation of privacy standards will result in the system not being used by consumers

Higher level requirement: Ensure a high degree of modularity in the technical design

Requirement/constraint	Rationale
Ensure the PV system can be setup at multiple locations	To make sure the PV system can be implemented at other parking terrains
Ensure the distribution system can be setup at multiple locations	To make sure the distribution system can be implemented at other parking terrains
Ensure the car charging system can be setup at multiple locations	To make sure the car charging system can be implemented at other parking terrains
Ensure the information system can be setup at multiple locations	To make sure the information system can be implemented at other parking terrains

Higher level requirement: Ensure durability and safety

Requirement/constraint	Rationale
Ensure long life time	To improve the profitability of the project
Ensure high weather resistance	To make sure the system will have a long lifetime
Make sure solar roof construction meets safety standards (c)	To avoid unsafe situations

Higher level requirement: Ensure inclusion

Requirement/constraint	Rationale
Ensure the roof is high enough for all car types (c)	So that people with other car types won't be excluded from the system

Remaining requirements/constraints:

Requirement/constraint	Rationale
Perceived as harmonic with landscape (c)	In order to be compliant with the goals of the municipality and that the inhabitants will be satisfied with the design
Provide a sufficient number of EV charging points	To make sure people are able to charge their EV if they want to
Meet cicularity standards (c)	To adhere to the view of the municipality and make sure the project is sustainable

Requirements institutional design

Higher level requirement: Ensure compliance with local laws and regulations

Requirements	Rationale
Meets aesthetics standards (c)	The municipality has aesthetics standards to maintain the aesthetics of the city. The solar park should be in compliance with those.
Adheres to electricity law 1998 (c)	The electricity law 1998 describes that certain parties can sell electricity to third parties. The institutional arrangement should be in compliance with this law.

Higher level requirement: Provide effective monetary benefits allocation

Requirements	Rationale
Provide low electrical vehicle charging tariff	To incentivize people to charge their car at the parking terrain, low charging tariffs should be provided
Provide low electricity usage tariff for large user	To make it attractive to a large energy user to buy the solar power relatively low usage tariffs should be provided

Higher level requirement: Ensure a high degree of modularity in the institutional arrangement

Requirements	Rationale
There should be one operator for all solar roofs at open parking terrains owned by the municipality	To make sure the institutional arrangement is also applicable on other parking terrains and the operator should be the same party.
Make the model of electricity dispatch uniform	At the solar park, the energy should be allocated in the same way, to make it easily applicable to other solar parks

Higher level requirement: Provide an efficient allocation of electricity

Requirements	Rationale
Ensure an agreement reliable EV charging	To make sure that people that want to charge their EV are always able to. The electricity could be either from the solar panels or the main grid, but there should always be electricity to charge cars.
Ensure that as much as possible of the remaining electricity goes to the large user	The large user makes institutional arrangements to be able to profit, therefore the electricity should flow to the large user.
Store last remaining electricity	To mitigate intermittency due to the fluctuating energy production of solar power remaining energy should be stored

Higher level requirement: Agree upon a long term commitment between stakeholders

Requirements	Rationale
Agree on a long-term contract for a minimum operation period of 16 years (c)	To ensure the operation period exceeds the estimated payback period of 16 years

5. Timeline of the tender process

The timeline below gives an overview of the activities and deliverables throughout the tender process. We are now in the initial phase, as is indicated with the dotted box in figure 1.

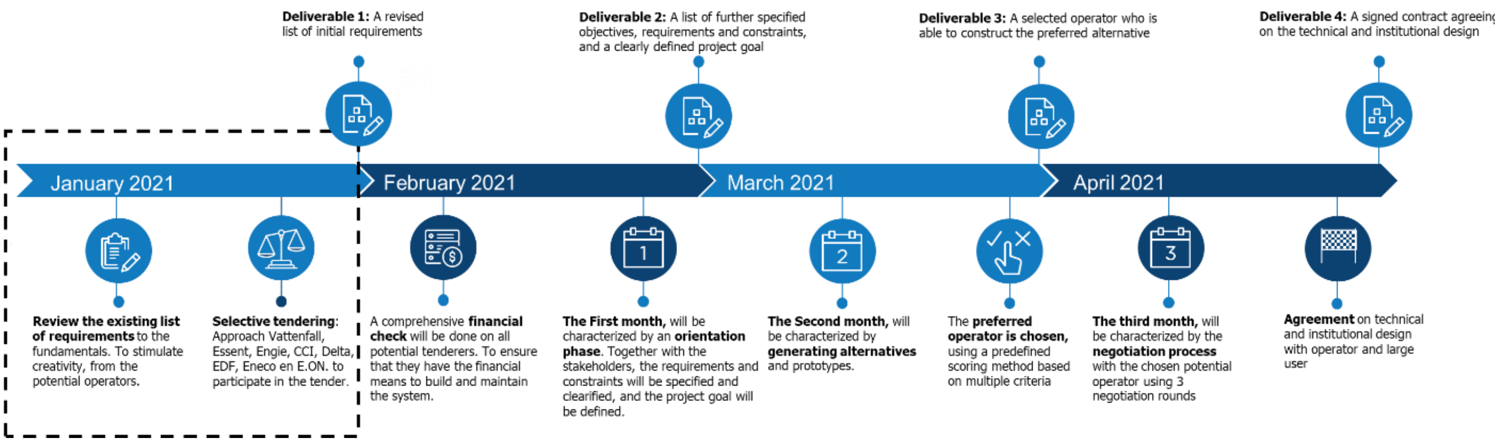


Figure 1: Timeline of the tender process

All invitees are invited to participate in the tender. The admission deadline for the tender is 15th of February 2021. Further details for the admission process will be handed out at the end of the initial meeting. Hereafter alternatives can be generated based on the list of requirements that is to be finalized with the help of this meeting. The preferred operator for the project is chosen in the last week of March. In April the Municipality and the chosen operator will discuss the specifics and will agree on the technical and institutional designs. The large consumer, that will consume most of the generated electricity, will also be part of these negotiations.

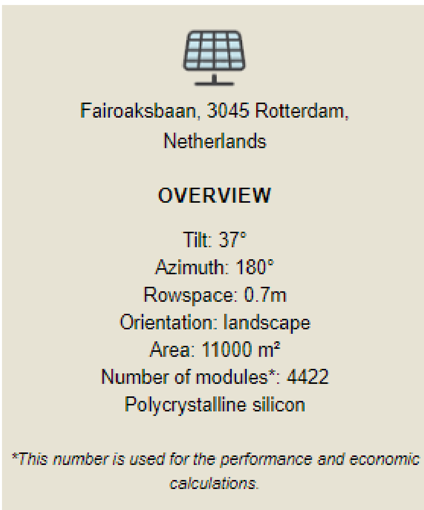
During this tender process weekly meetings will be held where potential operators can ask questions and show the progress of their application. These meetings will always be held on Thursdays in the afternoon. Below an initial list of dates with all the meetings and their main subject is given.

Monday 15 February: Submission deadline for the tender process.
Monday 22 February: The Municipality notifies all parties if they are allowed to participate in the tender process based on the financial check.
Thursday 4 March: The first meeting of the generation phase, requirements will be discussed and example of final design made by the Municipality is presented.
Thursday 11 March: Second meeting of the generation phase, Municipally is available for questions.
Thursday 18 March: Third meeting of the generation phase, potential operators present their final proposed design.
Thursday 25 March: Fourth meeting of the generation phase, Municipality announces the winner of the tender process and elaborates on the reasoning.
Thursday 1 April: First meeting of the negotiation phase, operator meets potential large consumers.
Thursday 8 April: Second meeting of the negotiation phase, operator and potential large consumers negotiate over the institutional design.
Thursday 15 April: Third meeting of the negotiation phase, operator and large consumer come to an agreement.
Thursday 22 April: Last meeting of the negotiation phase, operator, Municipality and large consumer sign the institutional agreement.

6. Simulation to prove economic feasibility

To illustrate the possible revenues and to prove the economic feasibility a simulation in conducted with the Dutch PV Portal 3.0.

Figure 2 presents the key input parameters including the optimal module tilt and the right azimuth for the Netherlands. 4422 solar modules can be installed on the terrain P+R Meijersplein, hence the yearly power generation is estimated at 1.04GWh (Figure 3).



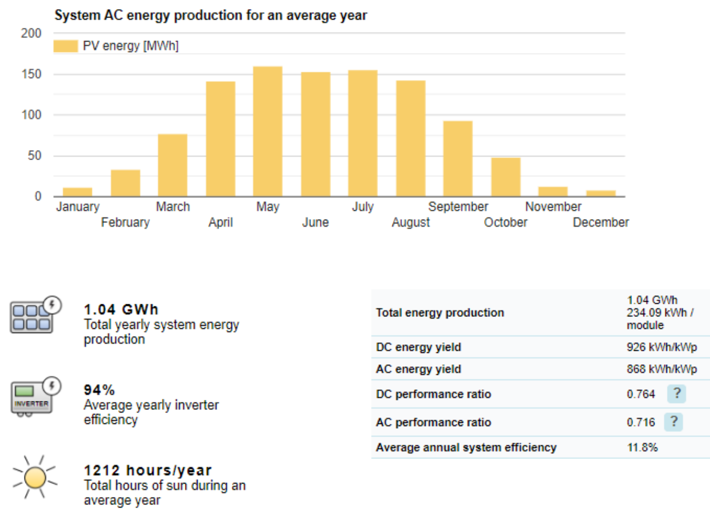


Figure 2: Input parameters *Figure 3: Monthly power generation*

Figure 4 illustrates the yearly monetary flow during an operation period of 25 years. The required initial investment is approximately €1.03 million and when in operation, the payback period is predicted between 10-15 years based on the discount rate and current electricity market price.

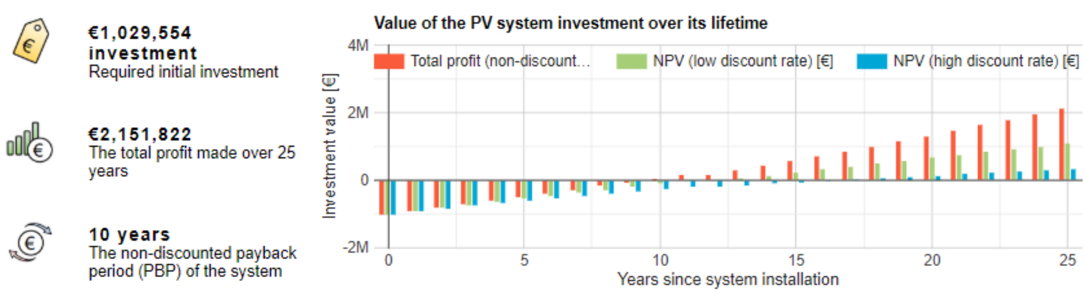


Figure 4: Financial evaluation of the solar park

This shows that the project has potential to be highly profitable with a lifetime up to 25 years.