Assessment of smart grid implementations at business parks in the Netherlands

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Word count: 18,990

Abstract

The energy transition in the Netherlands is developing rapidly. Business parks aim to contribute by utilizing their roofs for solar installations, but stumble upon the more frequently occurring phenomenon of grid congestion. To make the electricity grid efficient, the implementation of a smart grid seems promising. However, little is known on the stakeholder specific effects of implementing a smart grid. Moreover, knowledge on how this might vary for different business park configurations is lacking. In this research a sequential mixed methods approach is taken to constitute a utility score for all the relevant stakeholders and for a total of 180 different configurations. First, the criteria, and corresponding importance, on which the relevant stakeholders assess the implementation of a smart grid are retrieved through interviews. An exception is made for business owners, which are surveyed. The resulting criteria are subsequently classified into criteria that are qualitatively assessed and quantitatively assessed. Scoring of the qualitative criteria is done by expert interviews and literature research. Scores of the quantitative criteria are calculated by means of a mixed integer linear programming model, in which three optimisation scenarios are simulated for all 180 business park configurations. These optimisations are a cost minimisation, grid dependency minimisation and a minimisation of the required connection capacity. Finally, a multi criteria analysis is used to combine the scores for each stakeholder into a utility score. The results show that the implementation of a smart grid for the average configuration is beneficial for all stakeholders. The largest gains in utility are the effect of either a cost or connection capacity minimisation.

Contents

1. Introduction

1.1 Societal background

Reducing CO_2-emissions is of crucial importance in combating climate change. Therefore, the Netherlands has set the ambitious goal to decrease their CO_2-emissions with 95% in 2050 in comparison to 1990 levels (Rijksoverheid, 2019). One of the largest emitters is the electricity sector, being the second largest emitter after the industrial sector (CBS, 2020). Moreover, the electricity consumption is expected to increase, as the projected pathways towards emission reduction in other sectors typically entail major electrification trends (Hers, Oliveira Machado Dos Santos Lamboo, 2021). Therefore, the electricity sector is, and will be, at heart of the Dutch energy transition and should thus strive for as much renewable production as possible.

Last decade there has been a large growth in the generation from renewable sources, resulting in an annual share of 27% of renewable electricity in 2020 (CBS, 2021). Part of this large uptake is due to the increased deployment of solar PV (Kausika et al., 2015). An example is the various business parks in the Netherlands that both see the financial benefit of, and want to make a social contribution by, installing renewables. These business parks typically have large rooftops, which can accommodate significant renewables capacity. However, due to the intermittent nature and increased penetration of renewables the grid capacity is stressed (NetbeheerNederland, 2019). Consequently, the grid operators lack transport capacity to accommodate new grid connections or upgrade existing ones and, subsequently, solar PV installation projects are queued (NetbeheerNederland, 2019).

The most obvious solution to this problem is strengthening the grid, but this is an expensive and time-consuming process. On top of that, grid congestion already is a frequent problem (Pesiwarissa, 2022). It is therefore evident that a timely solution is required to accommodate the desired number of renewables in the future. An alternative to strengthening the grid is to coordinate local loads and assets in a smart manner, resulting in a decrease of the amount of electricity that is exchanged with the grid (Barsali et al., 2015). In the existing literature there are several concepts that fit this description. The most common ones are microgrids, smart grids and energy hubs. All of these are integral solutions that locally couple *production, storage,* and *conversion* of energy with *demand*. Throughout this research the following definition of a smart grid business park is used: A business park equipped with an advanced metering infrastructure that allows businesses to exchange production and demand profile information and alter loads by means of storage and demand response. Due to the electrification trend the scope of this research is narrowed down to just the electricity grid.

1.2 Scientific background

In the Netherlands, the ministry of economy and climate called for a study amongst all grid operators on the required nationwide infrastructure to reach the goal of 95% CO_2-reduction in 2050 (Werkgroep Integrale Infrastructuurverkenning 2030 -2050, 2021). The results of this research underlined that major expansion of the grid is required. However, the shortage of technical employees and long lead time for tenders due to long decision-making processes make it challenging. Furthermore, this study recognizes the potential of storage in smart grids and claims that under optimal circumstances a reduction of 40 – 65% in desired grid capacity can be achieved (Werkgroep Integrale Infrastructuurverkenning 2030 -2050, 2021).

Luo et al., (2014) conclude that local exchange of energy can increase the utilization of distributed renewable production. Besides, it reduces the cost of energy in comparison to the conventional situation where it is purchased from the grid. Other studies confirm the possible reduction in energy costs and indicate a possible load reduction on the main grid (Ehjaz et al., 2021; Wang et al., 2020). In addition to local exchange, storage and flex capacity can provide main grid load reductions. Storage and flex capacity provide mechanisms by which load profiles can be altered to minimize traffic from or to the grid. Storage provides benefits by periodically storing energy during peak production, whilst releasing it at later times when electricity exchange with the grid is less (NetbeheerNederland, 2019). Flex capacity consists of appliances that can alter their energy consumption to either increase or decrease the net demand (Morales-España et al., 2022).

1.3 Problem definition

The literature shows that the implementation of smart grids at business parks can be beneficial. However, despite the expected benefits, in practice smart grids are rarely implemented at business parks. The current literature addressed the financial aspect of implementing smart grids. Furthermore, studies either evaluate the smart grid system as a whole or evaluate the potential benefits of implementing smart grids for a specific case study. Nevertheless, the current literature has a few shortcomings. Firstly, it focusses on a system perspective and thereby neglects the individual interests of the involved stakeholders. Secondly, the focus is placed on the financial incentives and thereby neglects non-financial aspects that should be considered for the adoption of a smart grid at business parks. Thirdly, most of the studies are concerned with a specific case study and do not consider the various possible configurations of smart grids. Due to these shortcomings, the current literature does not provide sufficient knowledge to understand the bottlenecks for implementing smart grids at business parks. All the above taken into consideration, this research centres around gaining insight in how to stimulate the diffusion of smart grids at business parks, leading to the following research question:

What is the effect of implementing smart grid business park configurations on the utility of the involved stakeholders?

1. What challenges hamper the adoption of smart grids at business parks?
2. What are the general business park configurations?
3. Who are the stakeholders involved in adopting smart business parks?
4. What criteria construct the utility of each stakeholder?

The remainder of this research is structured as follows. In the next section a background on smart grids is provided, giving a preliminary answer to the first three sub questions. The setup of this research is sequential, with a split in qualitative and quantitative research. First the qualitative methodology and results are discussed. Then, the qualitative results are used to structure the quantitative methodology. Thereafter, the quantitative and combined results are discussed. Lastly a discussion and conclusion are provided.

2. Theory

2.1 The Dutch electricity grids

Since the implementation of the Electricity Act in 1998, the Dutch electricity market has liberalized (Van Damme & Zwart, 2003). To serve the liberalization, the market was unbundled and split up into several functions (Tanrisever et al., 2015). One is all commercial activities regarding the production of electricity. Another one is the operational management of the networks. The latter is executed by in total 9 network operators, which were appointed a licence by the Dutch government. This was appointed because the provision of infrastructure for electricity transport is seen as a natural monopoly. By ensuring third party access to the infrastructure, the rest of the electricity supply chain is enabled to freely compete with each other (Tanrisever et al., 2015). As a result, also the retail market was liberalized and all consumers can choose their own electricity supplier (Linderhof et al., 2003).

To make sure the operational management of the public grid is done in a fair manner all regulations are laid down in so called codes. The most important ones are the grid code and tariff code. In the grid code all regulation concerning the functioning of the grid, connecting parties to the grid and transport over the grid are defined (ACM, 2022b). In the tariff code the cost structure that DSOs can charge for providing grid connections and transporting electricity are laid down (ACM, 2022c).

The electricity grid in the Netherlands is conventionally designed in a centralised manner, where production follows demand (Linderhof et al., 2003). In other words, electricity is generated in large power plants, which coordinate their production based on demand. After production, the electricity flows through the transmission network and distribution network to the consumer (NetbeheerNederland, 2019). The high voltage transmission network is the backbone of the Dutch electricity grid and is owned and operated by transmission system operator (TSO). After transport on the transmission network, the distribution system operators (DSO's) operate the final transport to the consumer by means of the distribution grid (NetbeheerNederland, 2019).

To make sure production and demand are in balance, balance responsible parties (BRP's) exist. A BRP manages at least one connection to the grid and is responsible for forecasting their net demand as well as the quantity that will be transported and communicates this with the TSO (TenneT, 2022). If the actual net demand deviates from the forecasted demand the BRP is held responsible for this imbalance and is obliged to pay imbalance costs (Tanrisever et al., 2015). The height of these costs is dependent on the amount of imbalance and the market price of electricity during the imbalance period.

As renewables penetrate the market the described system experiences several difficulties. First, the electricity production of renewables is highly dependent on weather conditions, making accurate forecasting of electricity production challenging (Sweeney et al., 2020). Second, due to the intermittent nature of renewables, there often is a mismatch between supply and demand (Sovacool, 2009). Lastly, the production of electricity becomes increasingly decentralised (Buth et al., 2019). This results in electricity not only being withdrawn from the grid, but also injected to the grid. As a result, the grid capacity of the conventional infrastructure cannot always accommodate the desired amounts of electricity transport (Mir Mohammadi Kooshknow & Davis, 2018). This phenomenon is referred to as congestion.

2.2 Challenges of integrating smart grids at business parks

Although the implementation of smart grids at business parks seems promising, there are several barriers that need addressing before implementation is possible. These challenges can be distinguished into four categories: technical, financial, organisational, and regulatory.

Technical

The main challenge of implementing smart grids at existing business parks lies within its metering infrastructure. To effectively manage the system in real-time all components should be equipped with scalable two-way communication infrastructure (Ancillotti et al., 2013). Currently, most businesses in the Netherlands are in possession of a smart meter, that measures the total consumption of a grid connection (Van Aubel & Poll, 2019). However, these meters are merely sending information and only entail consumption on company level. To enable efficient distributed command-and-control functionalities, as is desired in a smart grid, companies should be equipped with two-way communication infrastructure. Besides the advanced metering infrastructure, appliances require intelligent electronic devices, so that demand is controllable at asset level (Ancillotti et al., 2013).

Organisational

The implementation of smart grids requires significant changes of existing relationships and interactions of all actors (Lösch & Schneider, 2016). The shift from a system with centralised actors to a local self-organising system needs new organisational arrangements. Such changes introduce adaptation processes, which influence the operations of the concerned actors (Rohde & Hielscher, 2021). Presently, the organisation from a contractual viewpoint of the business park is suboptimal (Deloitte, 2020). This has two causes. First, the management of energy is not the priority on the agenda of most companies. Second, the amount of companies on a business park is often too large to effectively align all preferences (Deloitte, 2020). Moreover, there is a lack of proper standardised contracts, cooperation forms and implementation scenarios (Ancillotti et al., 2013). Especially the agreements between all companies concerning the operational management and ownership of the system are important.

Financial

The financial challenges of implementing smart grids at business parks relate to the investment upfront and the division of benefits and costs amongst actors. Currently the investment costs for the required technical infrastructure are high and whether these cost are renumerated by the received benefits is uncertain (Jackson, 2013; Römer et al., 2012). This uncertainty is mainly due to the (social) benefits being distributed over multiple actors, making it unsure if the investing actor recoups its full investment (Römer et al., 2012). Besides the high investment upfront, the lack of standardised contracts, cooperation forms and implementation scenarios results in inability to properly address the required financial structures for the implementing smart grids(Rohde & Hielscher, 2021).

Regulatory

The main regulatory concern of implementing smart grids at business parks in the Netherlands evolves around the principal-agent problem between DSO's and business parks. Whereas the companies are likely to aim for cost minimizations, the DSO strives for stable grid operations and reduction in required transport capacity (de Wildt et al., 2019). Therefore, there will always be a conflict of interest, no matter who oversees the smart grid operation. Nonetheless, workarounds to this challenge exist. This could for example be done with indirect financial incentives from the DSO to consumer. By implementing time based financial incentives an equilibrium could be created where costs for businesses are minimal and grid operation is stable (Movares, 2014). However, the tariff code is currently too strict for DSOs to freely adapt their cost structures of grid connections. Furthermore, there is a clear distinction between publicly regulated grids and private grids. The public grids are regulated by the DSOs and private grids are managed by individuals behind the meter. Hence, the current grid code does not allow for the use of public grid in privately regulated smart grids (ACM, 2022b).

2.3 Business Park types

In total there are 3900 Business Parks in the Netherlands and they range in size from 1 to 2300 acres (IBIS, 2022). As a result of historical area development five types of business parks can be distinguished (Hanze, n.d.). The main difference between them is their geographical integration and the commercial activities of the settled entities. An overview of the different types and a short description is provided in Table 1.

Table 1: Business Park types overview.

Business Park type	**Description**
High-Quality	High-Quality business parks are intended specifically for companies with production and/or research and development activities. Because of the high level of employment these parks are multi-modally accessible.
Industrial	Industrial sites are distanced from cities and the area is characterised by environmental exceptions, so that environmentally polluting business activity can take place.
Logistics	Logistic hubs are located near highways and often more distanced from cities, so that the available land area is large.
Maritime	A business park is considered a maritime business park when it is formed around a harbour.
Mixed	Area's intended for regular commercial activities. Often near a city and characterised by multi-tenant buildings.

2.4 Smart grid configurations

There are multiple stakeholders involved and each smart grid configuration results in differences in benefits for each stakeholder (Kumar & Bhimasingu, 2015). This section elaborates upon the different operational and technical configurations a smart grid business park can have. The configuration of a smart grid business park can differ in both its operational management and technical configuration. The latter can be seen as the technical composition of electric components at a business park and encompasses the amount of renewable production and demand response (Brown et al., 2010).

The operational management consists of the objective function that is given to the energy management system, which determines the manner in which all loads are managed (Kim et al., 2015). The objective function entails the goal to which decision-making in the system is calibrated. Examples are a minimisation of costs, a minimisation of the peak in grid exchange and the maximisation of renewable production utilisation. Based on the objective function of the system, loads can be managed in several ways (Kim et al., 2015). The system should at all times provide power to the businesses, however the amount of demand response that is activated and the amount of grid power and renewable production that is used to fulfil this constraint varies for each objective function (Nasir et al., 2021).

2.5 Congestion management

Depending on the aggregated load profile of a business park, grid congestion occurs when the physical infrastructure is insufficient. DSOs should manage congestion and the use of flexibility mechanisms can aid them in this process. Flexibility mechanisms can be distinguished into implicit and explicit mechanisms (SEDC, 2016). Implicit flexibility mechanisms are expressed as an incentive to which users can respond. An example is the implementation of tariff structures to indirectly manipulate the load profiles of consumers (Fonteijn et al., 2021). Explicit flexibility mechanisms entail hard commitment of demand-side flexibility, which can be traded on balancing markets (Fonteijn et al., 2021).

At present the only flexibility mechanisms implemented in the Dutch regulatory framework consist of local and integrated markets where flexibility is traded, bilateral agreements between DSO's and aggregators and a relatively small network tariff for each grid connection. Nonetheless, congestion is becoming an increasingly urgent problem, which is why various flexibility mechanisms are presently under debate (ACM, 2021).

2.5 Relevant stakeholders and multi attribute utility

Multiple stakeholders are involved in implementing a smart grid at a business park. An overview of the stakeholders and their relationship to smart grids is given in Table 2.

Table 2: Overview of stakeholders and their interests.

Stakeholder	Interest
Business parks/ business owners	Adoption of smart grids at business parks can achieve lower energy costs and make the system operate more efficient.
DSO's	The implementation of smart grids at business parks can enhance grid operations by reducing transport, therefore alleviating congestion. This could be a feasible alternative to strengthening the grid.
Dutch government	The Dutch government has the responsibility for achieving climate targets. Smart grid business parks can help by replacing fossil fuel electricity generation with distributed renewable generation.

Local authorities	Local authorities are responsible for the regional energy strategy. Smart grids at business parks could provide opportunities in developing these strategies.
Regulator	The regulator must make sure that energy systems operate conform regulations. When making changes to the energy system the regulator must oversee that this happens in a legal manner.
Developers of decentralised energy systems	This stakeholder provides the required infrastructure for the implementation of smart grids at business parks
Developers of storage and flex assets	This stakeholder provides solutions that can contribute to matching supply and demand over time.
Aggregators	Aggregators could help business parks retrieve value from their storage and flex assets. This is for example done by operating on the imbalance market.

The utility of a stakeholder is according to the Multi-Attribute Utility Theory (MAUT) a combination of scores for multiple attributes of a complex problem (Jansen, 2011). Each attribute is essentially a criterion that can be assigned importance by means of a weighting. Furthermore, these criteria can be both quantitative and qualitative (Min, 1994). MAUT assumes that when comparing alternatives, a stakeholder is presumed to have a preference for the option with the largest utility (Jansen, 2011). Applying this theory to the implementation of smart grids at business parks, the alternatives are the different scenarios of smart grid implementation. For example, one alternative is the reference scenario without a smart grid and another one is after the implementation of a smart grid, with the objective of minimising costs. Each alternative has different scores in criteria for each stakeholder. Moreover, the importance (weighting) that is given to criteria can vary based on the preference of the stakeholder. Consecutively, each scenario has a corresponding utility for each stakeholder.

3. Method

To answer the research questions a multi criteria analysis is performed through a mixed-methods approach. In total this research consists of two consecutive steps. The first step is to answer the fourth sub-question to identify the criteria for each relevant stakeholder. The second step is to use the quantitative criteria of the first step as performance indicator in a stakeholder-based python model. As these steps are consequential the method and results of each step are provided separately. Therefore, first a qualitative method is described, followed by the qualitative results. Thereafter, a quantitative method is provided, finishing with the overall results. This process is illustrated in Figure 1.

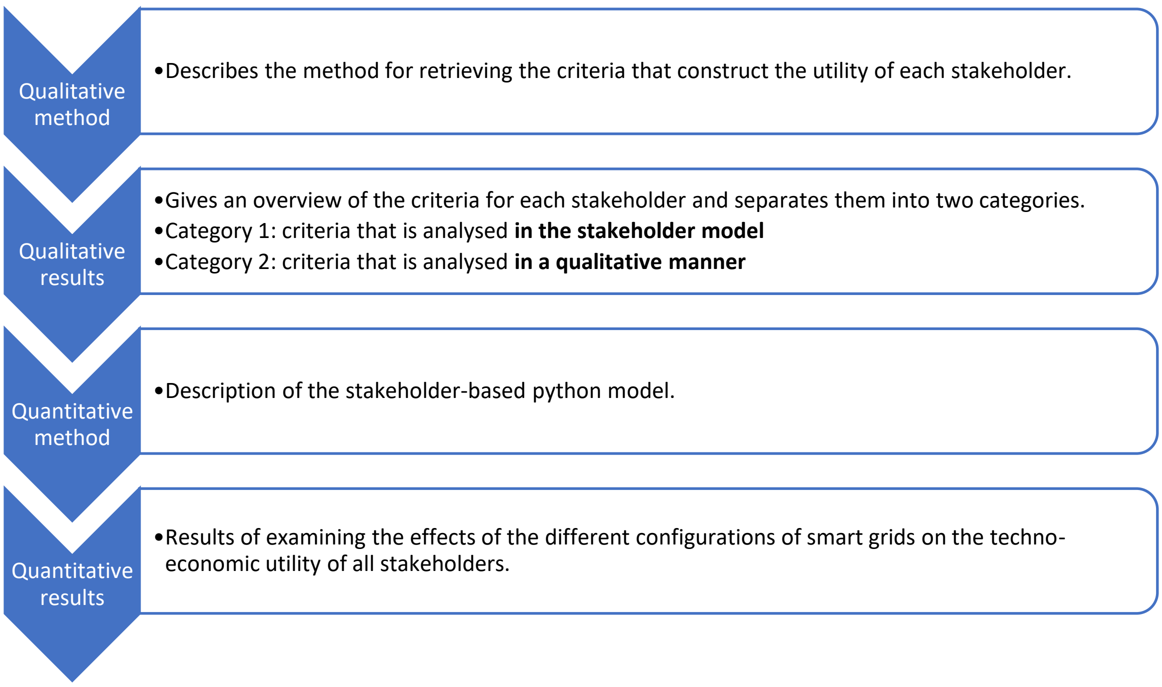

Figure 1: Overview of the sequential setup of this research

3.1 Qualitative methodologies

This section provides the method for retrieving the criteria that construct the utility of each stakeholder. An overview of the relevant stakeholders is already given in Table 2. The retrieval of criteria is done by a combination of interviews and a survey. All stakeholders, except business owners, are interviewed. The criteria of business owners are obtained through a questionnaire. The reason for this division is that there are many more business owners in the Netherlands than there are of the other stakeholders. By sharing a survey among business owners, instead of interviewing them, the scope of respondents is enlarged.

3.1.1 Stakeholder interviews

The stakeholder interviews are used to gain insight in the criteria and considerations regarding the implementation of smart grids at business parks for each stakeholder. An overview of the parties that are interviewed is given in Table 3. In total 8 interviews are held. As the retrieval of criteria has an exploratory nature, the interviews are conducted in a semi-structured manner. This entails there is an overview of topics that should be covered in the interview, but that there is freedom for additional questions on the go. Furthermore, each stakeholder is asked to rank their interests, so that a weight to each criterion can be given.

Table 3: Overview interviewees

Organisation type	**Organisation**
DSO	Liander, Enexis (x2)
Aggregator	Spectral
Regulator	ACM
Dutch government	NPRES
Local authority	NPRES
Storage and flex developer	Semper Power
Smart energy system developer	Firan

The Dutch government and local authorities are both represented by the national programme for regional energy strategies (NPRES). The Netherlands is split up into 30 geographical regions, each with its own regional energy strategy (RES). The national programme is driven by the national climate goals and translates these into developments on a regional level. Therefore, the NPRES represents a combination of the criteria for both national and regional authorities.

3.1.2 Business owner's survey

In addition to the interviews, surveys are conducted at business owners. The survey is used to examine their willingness to participate in a smart grid, retrieve their criteria for implementing a smart grid, and retrieve the weighting of each criterion. The survey is made and sent through Qualtrics, using the Utrecht University license. In total the survey is sent to a random sample of 500 businesses located at business parks throughout the Netherlands. These are obtained from the IBIS database on business parks in the Netherlands (IBIS, 2022). An overview of the questions is given below.

Question 1: Are you be willing to participate in a smart grid?
Possible answers:

- Yes
- No
- I'm in doubt, because [text field for explanation]

Question 2: Rank the following aspects of your energy system from most important to least important. The most important is at the top.
Possible answers:

- Costs
- Sustainability
- Time consumption
- Possibility to expand
- Robustness
- [Open entry] x 2

For the answers of the second questions an additional description is given to make sure all respondents have the same perception of each answer. The additional description for each answer is provided in Table 4. Furthermore, the order in which the answers are displayed is randomised for each respondent to eliminate any nudging. Lastly, two open entry fields are included to give respondents the opportunity to provide additional criteria.

Table 4: Description of answer possibilites for survey question 2.

Answer	Description
Costs	Total costs for electricity
Sustainability	The total emissions of the electricity that is consumed
Time consumption	Total time that is spent on being able to consume electricity
Possibility to expand	The grid connection capacity that is available when a business owner wants to upgrade its grid connection. For example, when expanding business activities or installing solar panels.
Robustness	The ability of a power system to maintain a good power quality in case of disturbances. For example, when voltage dips occur.

3.1.3 Criteria distinction and analysis

The criteria that come forth from the interviews and surveys are separated into two categories. The first category consists of criteria that have a quantitative nature. This entails that the effect of implementing a smart grid can be expressed in quantitative scores for these criteria. Therefore, these criteria are included in the quantitative stakeholder-based model. The method for this model is provided in section 5. The second category consists of criteria for which the effect of implementing a smart grid is best done in a qualitative manner. Examination of these criteria is done based on expert information from the interviews in combination with literature research.

4. Qualitative results

In this section an overview of the results of the interviews and survey is given. Furthermore, for each criterion is specified whether the effect of implementing a smart grid is analysed in the quantitative stakeholder-based model, or it's analysed on in a qualitative manner. The analysis of the qualitative criteria is also carried out in this section.

4.1. Interview results

There are several stakeholders that each have their own incentives for implementing a smart grid. These stakeholders are best divided into two subgroups. The first group entails the stakeholders that have direct or indirect influence on the objective of the smart grid. The second group of stakeholders are market parties that provide services for smart grid. Therefore, they provide services according to the preferences of the first group. Nonetheless, they benefit of the implementation of smart grids in general as this is their primary business. Based on the interviews an overview of stakeholders and their interest is given below. An exception to this is the business owners, whose incentives were obtained through a survey. The results of the survey are given in section 4.2.

4.1.1. Influential stakeholders

In this section a short overview of the considerations of each stakeholder that has influence on the configuration of a smart grid is given. Elaborate summaries of the interviews are given in Appendix A. Furthermore, the resulting criteria are provided. Lastly, it is specified whether the criterion is analysed quantitatively or qualitatively.

DSOs

Grid congestion is occurring more and more frequently and the DSOs struggle to keep up with the requests for extra connection capacity. As their primary business is to connect parties to the distribution grids, they aim to have the required connection capacity available to do so. Furthermore, grid connections should be realised within a reasonable timeframe. Lastly the solution to grid congestion should be universally scalable to the entire service area of a DSO so that it can be always applied. The resulting criteria are:

Grid dependency (Free connection capacity)	***Quantitative***
Timing of the solution for grid congestion	***Qualitative***
Scalability of the solution	***Qualitative***

NPRES

To achieve the goals set in the climate agreement the national authorities aim to increase the amount of renewable energy production. To do so there should be enough connection capacity for hosting more renewable electricity. As grid congestion is currently hampering the adoption of renewables, the timeframe in which it can be solved is also important. The optimal combination is a holarchic structure in which local 'pockets' become as little dependent on the centralised grid as possible. Lastly, the NPRES concludes that in an ideal scenario the electricity price should be more constant and affordable for consumers. The resulting criteria are:

Grid dependency (Free connection capacity and Total volume)	***Quantitative***

Timing of the solution for grid congestion	***Qualitative***
Electricity price developments	***Qualitative***

Regulator

The regulator must make sure that the developments of electricity systems are within the boundaries of regulation. To be able to check whether systems are within regulatory boundaries the criteria are captured in article 36 of the electricity law (ACM, 2022a). This article dictates that the electricity system should be robust, promote trade within the electricity market and easy to use for consumers. Furthermore, it must enable DSOs to provide a good quality of service and operate in a transparent, non-discriminatory, and cost-reflective manner. The latter one basically entails a fair operation of the system for all partaking parties. The resulting criteria are:

Robustness	***Qualitative***
Promote trade	***Qualitative***
Ease of use	***Qualitative***
DSO service quality	***Qualitative***
Fairness of operation	***Qualitative***

4.1.2. Service providing stakeholders

These stakeholders have in common that they only have a single objective, which is as much adoption of smart grids as possible. The reason for this is that their business is to provide services to smart grids. Therefore, they have no criteria that are important for evaluating the implementation of smart grids, but are stakeholders, nonetheless.

Aggregator / Energy Service Company (ESCO)

- Provide services in line with the preferences of other stakeholders. Larger adoption of smart grids results in more revenues for this stakeholder.

Storage and flex capacity developers

- Their business is to implement smart grids. Thus, more adoption is more revenues for this stakeholder.

Smart energy systems developers

- Their business is to implement smart grids. Thus, more adoption is more revenues for this stakeholder.

4.2. Survey results

This section provides an overview of the survey results. In total there are 87 respondents, of which all answered the first question and 81 ranked the criteria in the second question. Beginning with the first question, 86% of the respondents is willing to participate in a smart grid, 10% is not, and 4% is in doubt. The main reason that is provided for being in doubt is that previous research concluded that partaking in a smart grid is not beneficial.

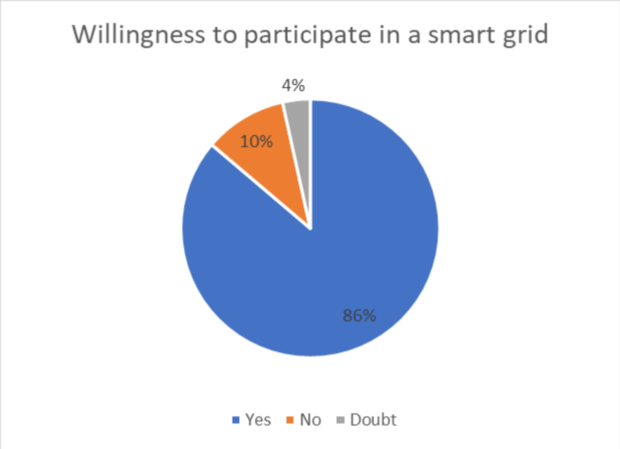

Figure 2: Overview of the answers on the first survey question.

The second question of the survey asked the respondents to order criteria from most important to least. In Figure 3 the frequency by which each criterion is occurs at each rank is displayed. For example, robustness is most frequently ranked most important. Followed by costs, sustainability, time consumption and possibility to expand respectively.

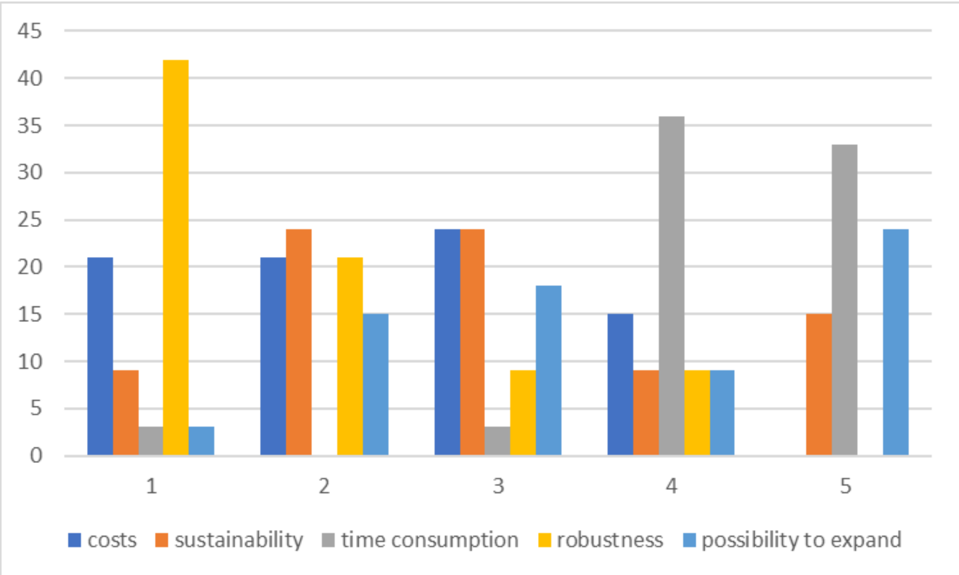

Figure 3: Overview of the answers on the second survey question.

To give a weighting to each criterion the frequency with which each criterion occurs at each rank is multiplied by the respective rank. The criterion with the lowest score then is the most important and the criteria with the highest score the least. Normalizing the scores gives a weighting to each criterion. The resulting weights are shown in Table 5.

Table 5: Normalized weightings of business owners' criteria.

Weighting	Summation	Normalised
Costs	195	0.23
Sustainability	240	0.19
Time consumption	360	0.13
Robustness	147	0.31
Possibility to expand	318	0.14

Besides the suggested criteria in question two, one respondent provided an additional criterion. This respondent also found it important to score its energy system on innovativeness. Because it is only one respondent that provided an additional criterion, the weight of this criterion is so minor that it is negligible. Therefore, the resulting criteria are:

Costs	***Quantitative***
Sustainability	***Quantitative***
Free connection capacity	***Quantitative***
Time consumption	***Qualitative***
Robustness	***Qualitative***

5. Quantitative methodologies

To examine the effects of implementing smart grids on the score of the quantitative criteria of all stakeholders a python model is constructed. In total four scenarios are simulated in this model. One to simulate the reference scenario before implementing a smart grid and three scenarios after the implementation, each with its own optimization objective. With the implementation of a smart grid, it is assumed that all companies on the business park have a contract with an aggregator and the aggregator manages the smart grid for them. This assumption is justified based on the interviews. Amongst almost all stakeholders it is agreed that this is the best way to implement a smart grid. By doing so, the business park becomes a singular entity.

5.1. Quantitative criteria

Section 4.1.1 gives an overview of the criteria that the influential stakeholders indicated to be important. This section provides an overview of these criteria and the performance indicators, by which the effect of implementing a smart grid is measured. Table 6 presents an overview of the quantitative criteria and a description of the corresponding performance indicators. These performance indicators are incorporated into the stakeholder-based python model. For the grid dependency and sustainability criteria the same performance indicator is used. This is the self-sustainability, which entails to what extent the business park can maintain itself by independent effort. This is expressed in total volume (kWh) that is exchanged with the grid, no matter the direction. A lower volume means less dependency on the grid. Similarly, a lower value is the result of an increase in self-consumption. Therefore, more of its self-generated solar electricity is consumed, making the park more sustainable.

Table 6: Quantitative criteria overview and corresponding performance indicators.

Criteria	**Performance indicator**
Costs	Total annual costs. This is a combination of electricity costs and connection costs.
Free connection capacity	Annual connection capacity that is required.
Grid dependency	Self-sustainability
Sustainability	Self-sustainability

5.2. Business Park configurations

To be able to draw general conclusions for the implementation of smart grids at business parks it is necessary to examine the full spectrum of possible configurations. In the theory it is mentioned that in the Netherlands there are five types of business parks. Furthermore, each business park can be equipped with a differing amount of solar production, different amounts of flexible load that is available, and different sizes of batteries. Each of these dimensions is elaborated below.

Business Park types and aggregated profiles

In total there are five types of business parks in the Netherlands that can be distinguished. Each of these types is characterised by different commercial activities that are present at the park. To analyse all five types, an average sized business park of that type is used as a casus. An overview is given in Table 7.

Table 7: Case studies for each business park type.

Business Park type	Casus	City	Size (ha)
High Quality	Laakhaven – Centraal	Den Haag	16.0
Industrial	Kulkweg – De Haak	Rotterdam	16.3
Logistics	Pijnacker – Nootdorp	Ruyven	35.2
Maritime	Koningin Wilhelminahaven	Vlaardingen	26.6
Mixed	Ypenburgse – Poort	Delft	11.0

To construct an aggregated consumption profile the floor area of each commercial activity is first multiplied by the average annual consumption per square meter and then multiplied by a normalised profile for that commercial activity. This process is depicted in equation 1. Multiplying the fraction with the annual consumption of a company gives the consumption for each timestep. As the business park is comprised of companies with differing standardized consumption profiles, it is expected that the aggregated profile illustrates a stochastic profile corresponding to a more realistic aggregated profile.

$$Aggregated\ profile_t = \sum_i m^2{}_i * \theta_i * \gamma_{i,t} \quad (eq\ 1.)$$

Where,

Parameter	Description
$m^2{}_i$	Square meters of commercial activity i that is present at the business park
θ_i	Average annual energy consumption per square meter for commercial activity type i
$\gamma_{i,t}$	Fraction of annual energy consumption of commercial activity i, that is used at timestep t

The commercial activities that are distinguished and their corresponding average annual electricity consumption per square meter is given in Table 8 (CBS, 2019). The difference between a small, medium, and large office is the total floor area of the entity. A floor area smaller than 500m^2 is a small office, 500 – 5000 m^2 is a medium office, and anything larger than 5000m^2 is considered a large office.

Table 8: Overview of average annual electricity consumption for all commercial activity types.

Commercial activity	Average annual consumption	Unit
Industry	326	kWh/m2/year
Warehouse	50	kWh/m2/year
Small Office	55	kWh/m2/year
Medium Office	65	kWh/m2/year
Large Office	80	kWh/m2/year
Restaurant	175	kWh/m2/year
Retail	80	kWh/m2/year
Hotel	85	kWh/m2/year

The normalised profiles are constructed based on the open energy data initiative database (OEDI, 2022). This database contains consumption profiles for each commercial activity type in the United States, divided by county. Data from the United States is used because no detailed data was available on consumption profiles of the Dutch market. On top of that, the profiles from the US market overlap with the commercial activities of the Dutch market, allowing for easy extrapolation. To match the climate of the Netherlands the profiles of the Seattle County are used to construct normalised profiles. The profiles in this database provide the total consumption of each timestep for all buildings of each commercial type. First the consumption profiles of each commercial activity type are summed into an aggregated profile. Converting this into a normalised profile is done by dividing the aggregated consumption of each timestep by the total annual consumption.

Solar profiles

It is assumed that only solar PV can be installed on the rooftops of the business park. However, the installed capacity may vary for each business park. This is included in the model by differentiating the rooftop area that is covered with solar panels. In order to do so the pvlib library in python is used (F. Holmgren et al., 2018). There is a reference situation where 0% of roof area is covered and three situations with 25%, 50% and 75% coverage respectively. The panels are installed in a typical south facing orientation with a tilt of 30 degrees.

The radiation data that is used is from the KNMI station located in de Bilt and for the year 2018, which is the most recent year with close to average annual radiation amounts. The solar panel that is used in the model is the Trina Tallmax DE17(M) and the inverter is the Sungrow SG110CX V112. Both are based on the technology that is offered in recent tenders for solar installations at roofs of business parks. The solar panels have a peak power of 450 watts and the nominal efficiency of the inverter is 98.5%. The datasheets concerning benchmark performances of both technologies are included in Appendix B and C.

Battery sizes

The business parks can also have some battery capacity installed. To consider the full range of possibilities, each park is modelled with three battery sizes. These entail no, a small, and a large sized battery. To make a universal comparison between business parks The sizes of the battery are dimensioned based on the annually measured peak load of a business park. A small battery has a power rating equal to 10% of the peak load, and a large battery 30%. The batteries are ¼c batteries, meaning the power rating is a fourth of the battery capacity.

Flex profiles

Lastly, each business park has assets that can be used in demand response schemes. Which assets, and the quantity in which they are present can differ for each park. Common assets that are feasible for demand response contribution are electric vehicles, cooling, electric heating and sometimes aquifer thermal energy storage (ATES). To consider the full spectrum of flexible loads, three flex profiles are constructed. This approach is to model several flex profiles, which set the power limit for each timestep by which the load can be altered up or down. To construct these profiles, it is assumed that a certain percentage of the load is flexible. This is in accordance with the approach De La Nieta et al., (2018) take in their paper. The three flex profiles for each business park type are:

- $P_{flexmax,t}$ = 5% * Aggregated $load_t$

- $P_{flexmax,t}$ = 10% * Aggregated $load_t$
- $P_{flexmax,t}$ = 15% * Aggregated $load_t$

5.3. Model description

The model is used to simulate four scenarios. One reference scenario and three scenarios after the implementation of a smart grid. These three scenarios each have their own optimization objective that is programmed into the energy management system. The optimization objective and the corresponding constraints determine the operational management. Therefore, each optimization objective yields different techno-economic outcomes. An overview of the optimization objectives and the corresponding constraints is given in section 5.3.2. The model executes the four scenarios for all possible configurations of business parks, as described in section 5.2. In total this results in 180 model runs for each optimization, containing 5 business park types, 4 solar profiles, 3 battery sizes and 3 flex profiles. The model simulates a period of a year, with a granularity of an hour. In the reference scenario it is assumed that there already is cooperation of the parties at the business park and electricity is purchased collectively at variable prices. However, the resulting grid exchange is not managed smartly, which is why the grid exchange is the aggregated demand minus the solar production.

5.3.1. Input data

In this section an overview of the input data of the model is given. First the timeseries data is discussed. Thereafter, an overview of the fixed inputs is given.

Timeseries input

In total there are 4 timeseries inputs. A description and its source of each timeseries is given in Table 9. All timeseries inputs have the kWh/h unit, except for the electricity price, which is in €/kWh.

Table 9: Overview of timeseries input data.

Timeseries (label)	Description	Source
Consumption profile (P_{dem})	Aggregated profile of all entities that are established at a business park.	See section 5.2
Solar profiles (P_{pv})	Generation profile of the installed solar capacity at the roofs of the business park.	See section 5.2
Flex profiles ($P_{flexmax}$)	The maximum of aggregated load that is flexible in each timestep.	See section 5.2
Electricity price (C_{elec})	The hourly electricity day ahead price of 2021. This is the price that is used for electricity bought/sold from the grid.	(Nord Pool, n.d.)

Fixed inputs

The fixed inputs for the model consist of the floor area of each commercial activity, the roof area, the battery sizes, and the costs of the grid connection. The floor area of each commercial activity present at a business park is obtained from BAG. BAG is the Dutch Key Register of Addresses and Buildings (Kadaster, 2022). The roof area of each business park is retrieved from (Cyclomedia, 2022), for which Over Morgen has a paid subscription. The determination of battery sizes is explained in section 5.2. The cost structure for grid connections consists of two components. The first one is a standard tariff that is paid for each kW of contracted transport capacity and is billed annually. The second component is a monthly price that is charged for the measured peak in transport capacity and has a flat tariff in €/kW. Data for these costs is retrieved from the largest Dutch DSO's (Enexis, 2022; Liander, 2022; Stedin, 2022). The average prices of the 3 DSOs are given in Table 10.

5.3.2. Optimization objectives

After the implementation of a smart grid the energy management system can be given an optimization objective. This optimization objective formulates the operational management by which the energy management system controls all loads and assets in the system. Based on performance indicators for the quantitative criteria, as described in section 5.1, there are three different optimization objectives. The first one is a minimization of the costs, the second a minimisation on the grid dependency in terms of total volume, and the third one a minimisation of grid connection capacity that is required. Furthermore, due to physical limitations of the electrical energy system, there are some constraints that must be set. These constraints are the same for each of the optimisation objectives. An overview of the optimisation objectives and corresponding constraints is given below. First an overview of the parameters used in the optimisations is given in Table 10. An overview of the decision variables is provided in Table 11.

Table 10: Overview of the parameters that used in the optimizations.

Label	Parameter description	Value	Unit
Δt	Length of a timestep	1	hour
T	Number of timesteps in a year	8760	hours
d	Day, consisting of 24 timesteps	1	day
D	Subset of total days in a year	1	days
eff_{ch}	Battery charging efficiency	94	%
eff_{dis}	Battery discharge efficiency	94	%
SoC_{min}	Minimum state of charge	20	%
SoC_{max}	Maximum state of charge	100	%
SoC_0	Initial state of charge at the first timestep of the year	50	%
C_{mpeak}	Monthly peak price	1.74	€/kW
C_{ctc}	Contracted transport capacity costs	21.53	€/kW
Cap_{batt}	Capacity of the battery	-	kWh
PR_{batt}	Power rating of the battery	-	kW
$P_{gridmax}$	Limit on power exchange with grid	-	kW

The Cap_{batt}, PR_{batt} and $P_{gridmax}$ parameters have no specific value. This is because they differ for each business park configuration. A description of the battery parameters is provided in section 5.2. The maximum power that can be exchanged with the grid is equal to the absolute maximum value of grid exchange that occurs in the reference scenario.

Table 11: Overview of the decision variables for all optimizations.

Label	Variable Description	Unit
P_{ch}	Power charging the battery	kW
P_{dis}	Power discharge from battery	kW
P_{flex}	Amount of flexible power that is used to adjust demand	kW

The first optimisation objective is to minimise the total annual costs. This is predominantly desired by the business owners of a business park, can be concluded from the survey results. The costs consist of the electricity costs plus the costs that are paid for the grid connection.

$$Optimization\ objective = \ minimize\ COST_{total}\ \ (eq\ 2.)$$

$$COST_{total} = \left(\left(\sum_{t=1}^{T} C_{elec,t} \ * \ \Delta t \ * \ P_{grid,t}\right) + \left(\sum_{m=1}^{M} P_{peak,m} \ * \ C_{mpeak}\right) + \left(\sum_{y=1}^{Y} P_{ctc,y} \ * \ C_{ctc}\right)\right)\ (eq\ 3.)$$

Where,

Parameter	Description	Unit
$C_{elec,t}$	Electricity price at timestep t	€/kWh
$P_{grid,t}$	The power that is exchanged with the grid at timestep t	kW
Δt	Length of a timestep	h
$P_{peak,m}$	Monthly peak in absolute values of grid exchange in that month	kW
C_{mpeak}	The costs per kW of monthly measured peak	€/kW
$P_{ctc,y}$	The capacity of grid connection for which an annual contract is agreed upon with the DSO. This is automatically set to the yearly peak in absolute values of grid exchange.	kW
C_{ctc}	The costs per kW of contracted transmission capacity	€/kW

The second optimisation objective is to maximise the self-consumption of the generated solar electricity. Or in other words, to minimize the grid dependency in terms of total volume. This is desired by both the national authorities – to become less dependent on a centralised grid – and business owners – to have a more sustainable image.

$$Optimization\ objective = \ minimize \sum_{t=1}^{T} \Delta t \ * \left|P_{grid,t}\right|\ \ (eq\ 4.)$$

Where,

Parameter	Description	Unit
$P_{grid,t}$	The power that is exchanged with the grid at timestep t	kW
Δt	Length of a timestep	h

The last optimisation objective is a robust optimisation in which the goal is to minimize the required grid connection capacity. This is done to have as much free connection capacity on the grid as possible. The DSOs are aiming for this, so that they have connection capacity available for new connections or to upgrade existing ones. This is also supported by the local authorities as they desire a strong business climate, which requires connection capacity to be available when companies want to establish themselves or expand their business.

$$Optimization\ objective = \ minimize\ \max_{t\ \in T}\{|P_{grid,t}|\} \quad (eq\ 5.)$$

Where,

Parameter	Description	Unit
$\max_{t\ \in T}\{\lvert P_{grid,t}\rvert\}$	Maximum value of the absolute grid exchange, occurring at any t in the total set of timesteps in a year (T).	kW

Each of the optimisation problems formulated above are exposed to a set of constraints. The set of parameters and constraints is similar for each optimisation problem. First, the solar production, battery and grid power should meet the by response adapted demand at each time step.

$$P_{pv,t} + \ P_{grid,t} + P_{dis,t} - P_{ch,t} = \ P_{dem,t} + P_{flex,t} \quad \forall t\ \in T \quad (eq\ 6.)$$

In this constraint P_{grid} is positive when power is withdrawn from the grid and negative when power is injected. Similarly, P_{flex} is positive to increase demand and negative when it is adjusted down. P_{ch} is the power that enters the battery to charge it and P_{dis} the power that the battery provides when discharging.

Besides that, the power should be in balance, the battery also needs to be properly managed. In the model the state of charge of the battery is measured at the end of a timestep. Hence, the discharge and charge must be subtracted and added accordingly. This process is depicted in formula 7 for the first timestep and formula 8 for the rest of the timesteps.

$$SoC_{t=0} = SoC_0 + \frac{P_{ch,t=0} *\ \Delta t * eff_{ch}}{Cap_{batt}} - \frac{P_{dis,t=0} *\ \Delta t}{Cap_{batt} * eff_{ch}} \quad (eq\ 7.)$$

$$SoC_t = SoC_{t-1} + \frac{P_{ch,t} *\ \Delta t * eff_{ch}}{Cap_{batt}} - \frac{P_{dis,t} *\ \Delta t}{Cap_{batt} * eff_{ch}} \ \ \forall t\ \in \{1, \dots, T\} \ \ (eq\ 8.)$$

Furthermore, the battery must not discharge further than 20% of its maximum capacity and not charge further than 100%. These percentages indicate the boundaries of the state of charge.

$$SoC_{min} \leq SoC_t \leq SoC_{max} \;\; \forall t \quad (eq\ 9.)$$

The power with which the battery can either charge or discharge in a timestep is limited by the power rating of the battery and must be non-negative. This constraint is given in equation 10 and equation 11.

$$0 \leq P_{ch,t} \leq PR_{batt} \;\; \forall t \quad (eq\ 10.)$$
$$0 \leq P_{dis,t} \leq PR_{batt} \;\; \forall t \quad (eq\ 11.)$$

Like the battery there are some constraints for the flexibility of the demand response. It is required that the sum of flex power in each day must be 0. This is done because all flex assets at business parks roughly have a timeframe in which they operate no longer than a day. This is done in a simplification effort for the model. If each asset that can provide flex is modelled separately, with its own more accurate time constraints, the model would be too complex to run. This comes with the following constraint:

$$\sum_{t=1}^{t=24} P_{flex,t} * \Delta t = 0 \quad \forall\, d \in D \quad (eq\ 12.)$$

Furthermore, the demand cannot be adjusted by more than which is set by the flex profiles that are constructed for each business park type.

$$-P_{flexmax,t} \leq P_{flex,t} \leq P_{flexmax,t} \;\; \forall t \quad (eq\ 13.)$$

Lastly, power exchange with the grid is limited by the maximum withdrawal and injection the business park can have.

$$-P_{gridmax} \leq P_{grid,t} \leq P_{gridmax} \;\; \forall t \quad (eq\ 14.)$$

5.4. Solving optimisations, system overview

To solve the optimisations problems that are formulated in the previous section a multi-integer linear programming (MILP) solver is used. The solver that is used is the python based linear solver of Gurobi (Gurobi, n.d.). There are three decision variables that are determined by this solver. These variables are the flexible load and the power with which the battery is either charged or discharged. Due to the power balance constraint both variables have their effect on the power that is exchanged with the grid. Therefore, the main outcomes of each optimisation concern performance criteria related to the grid power. Their relation is depicted in Figure 4.

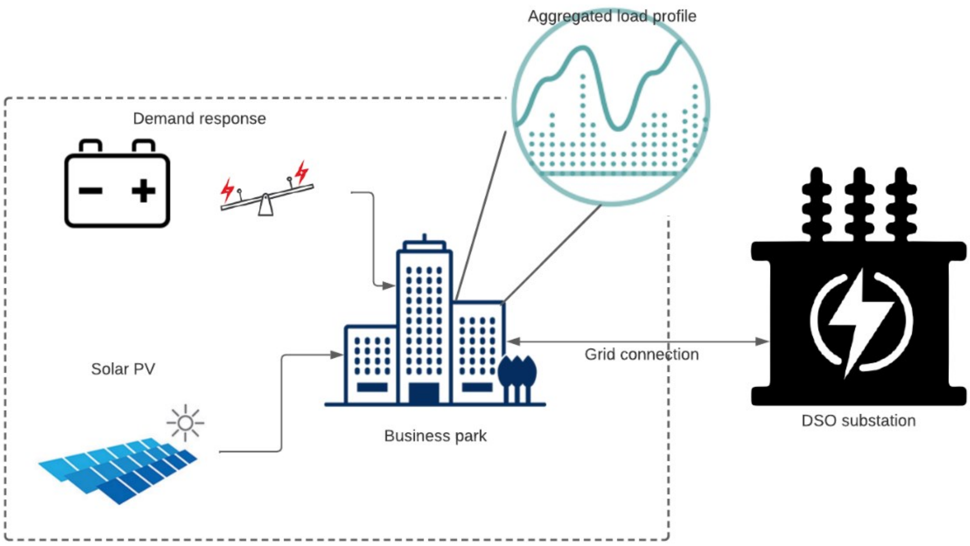

Figure 4: Simplified overview of the energy system of a business park.

To measure the effects of implementing a smart grid on the quantitative criteria the performance criteria of section 5.1 are used. All of them relate to the grid exchange profile that is the result of each optimisation. In the next section is elaborated how the value for each criterion is calculated and how it should be interpreted.

5.5 Multi criteria analysis

In the last step the qualitative criteria from the interviews are combined with the techno-economic criteria resulting from the python model. This section describes how both criteria categories can be scored and combined into a single utility score for each stakeholder. In section 4 it is explained that there is a difference amongst stakeholders in the amount of influence they have when it comes to implementing a smart grid. Therefore, only the influential stakeholders are included in the multi criteria analysis. An overview of the example results for a single stakeholder is given in Table 12.

Table 12: Format for utility score calculation.

	Cost optimisation		**Grid dependency optimisation**		**Capacity optimisation**	
Criteria	weight	score	weight	score	weight	score
Criteria 1						
Criteria 2						
Criteria 3						
etc…						
Total Utility Change	$= \sum_{a=1}^{A} weight_a * score_a$					

For each scenario the utility score for each stakeholder is computed. This gives an answer to the main research question as it allows to examine the marginal gain or loss in utility for each stakeholder. Each scenario can be put into comparison to the reference scenario, but also against each other. This gives insight in the effects of implementing a smart grid at a business park, but also demonstrates the trade-offs between the possible configurations. An overview of the methods for scoring the criteria is given below. The method for attributing weights to each criterion is to rank all criteria, where the highest ranking gets the heaviest weight and vice versa (Munro, 2011). The ranking of the criteria for the influential stakeholders is asked in their interviews. An exception to this is the business owners, for which the ranking is asked in the survey. The resulting weights are given in section 4.2.

5.5.1. Qualitative criteria

All scoring of qualitative criteria is done by means of literature research and the expert interviews of the service providing stakeholders. The scoring is expressed by a Likert scale and represent either how beneficial or unfavourable the implementation of a smart grid is in comparison to the reference scenario. The reference scenario always scores neutral. A visual representation of this process is given in Table 13.

Table 13: Visual representation of liker scale scoring method.

Very Unfavourable (--)	Unfavourable (-)	Neutral (0)	Favourable (+)	Very Favourable (++)
0	0.25	0.5	0.75	1

5.5.2. Quantitative criteria

In this section it is elaborated how the score for each quantitative criterion is determined. To be able to compare them it is important to score them with the same scaling as the qualitative criteria, otherwise it would be comparing apples to oranges. Therefore, the scores of the quantitative criteria are also expressed in amount of change in comparison to the reference scenario. The reference scenario always scores neutral. Depending on how favourable or unfavourable each scenario is in comparison to the reference scenario the score varies between 0 and 1. In the model a total of 180 different business park configurations is simulated. To show the range of outcomes, the minimum, maximum, and average score are provided. Below an overview of the calculation of each quantitative performance indicator is given. These were already briefly mentioned and explained in section 5.1.

Costs

To include the cost criterion in the multi criteria analysis it is not enough to only look at the annual benefits. The initial investment is made by the business park, and thus it is best to express the cost criteria by means of the NPV. It is, however, assumed that the annual profits (benefits – costs) are constant over the lifetime of the system. The annual profits are the difference in costs between the optimisation scenario and the reference scenario. Equation 3 gives the formula for the total annual costs of a business park. Al-abri et al., 2022 indicates an investment cost of 1318.19 per building and a system lifetime of 10 years. As this is a private investment, a discount rate of 7% is assumed. Due to the constant costs and benefits the simplified NPV formula is used:

$$NPV = -n * 1318.19 + \frac{(B - C)}{\alpha} \quad (eq\ 15.)$$

Where, n indicates the number of participating companies, B the annual benefits, C the annual costs and α the capital recovery factor. The formula for calculating the capital recovery factor is given below.

$$\alpha = \frac{r}{1 - (1 + r)^{-t}} \quad (eq\ 16.)$$

Where, t represents the lifetime of the system in years and r is the discount rate. The NPV of the reference scenario is 0, therefore a negative NPV results in a negative score for this criterion. A positive NPV results in a positive score.

Free connection capacity

Currently the DSOs determine the required connection capacity on the peak of a consumption profile (Enexis & Liander, Appendix A). The percentage by which the peak in either consumption or injection can be lowered in comparison to the reference scenario thus is a good indicator for connection capacity that is freed up. A decrease in peak results in a positive score for this criterion, whereas an increase results in a negative score. The formula for calculating this score is as follows:

$$Percentage\ peak\ reduction = \frac{\max_{t \in T}\{|P_{grid,t}{}^{NEW}|\} - \max_{t \in T}\{|P_{grid,t}{}^{OLD}|\}}{\max_{t \in T}\{|P_{grid,t}{}^{OLD}|\}} \quad (eq\ 17.)$$

Grid dependency & sustainability

These criteria are discussed together as they share the same performance indicator. The performance indicator for these criteria is the self-sustainability of the business park, which basically entails to which extent it must depend on the grid. This can be expressed by the absolute volume of electricity that is exchanged with the grid. In the model a positive number for grid exchange represents withdrawal from the grid and a negative value grid injection. In case of grid injection an increase in the absolute value is the result of a decrease in self consumption of the solar generation. A decrease in absolute value shows that more of the solar production is self-consumed, being more sustainable. In case of grid withdrawal, the value for grid power is already positive. A reduction in this value means less consumption of grid electricity, which has a larger emission factor than on site solar production. The exact opposite holds for an increase in grid withdrawal. Therefore, a reduction in absolute value of grid exchange in both cases translates to an increase in sustainability and vice versa. The formula for calculating this score is given in equation 18.

$$Total\ volume\ exchanged = \sum_{t=1}^{T} \Delta t * |P_{grid,t}| \quad (eq\ 18.)$$

6. Quantitative Results

In this section an overview of the results from the stakeholder-based model is given. First, the resulting consumption profiles of all business parks are shown. Second, an overview of the solar profiles for each business park is given. Third, the results of the three different optimisation scenarios are elaborated. Lastly, the qualitative and quantitative criteria are combined into a final multi criteria overview for each stakeholder.

6.1. Normalised and business park profiles

6.1.1. Normalised profiles

The normalised profiles of each commercial activity are calculated as described in section 5.2. For the commercial activities an overview of both a winter and summer week is displayed. Roughly, all eight profiles can be classified into 3 sub-categories.

The first sub-category is shown in Figure 5 and entails the commercial activities with almost no activity during the weekends and high peak demands during weekdays. These peaks are largely within working hours, so between 08:00 and 17:00. As most of the annual consumption is during working hours, the consumption outside these hours is relatively low.

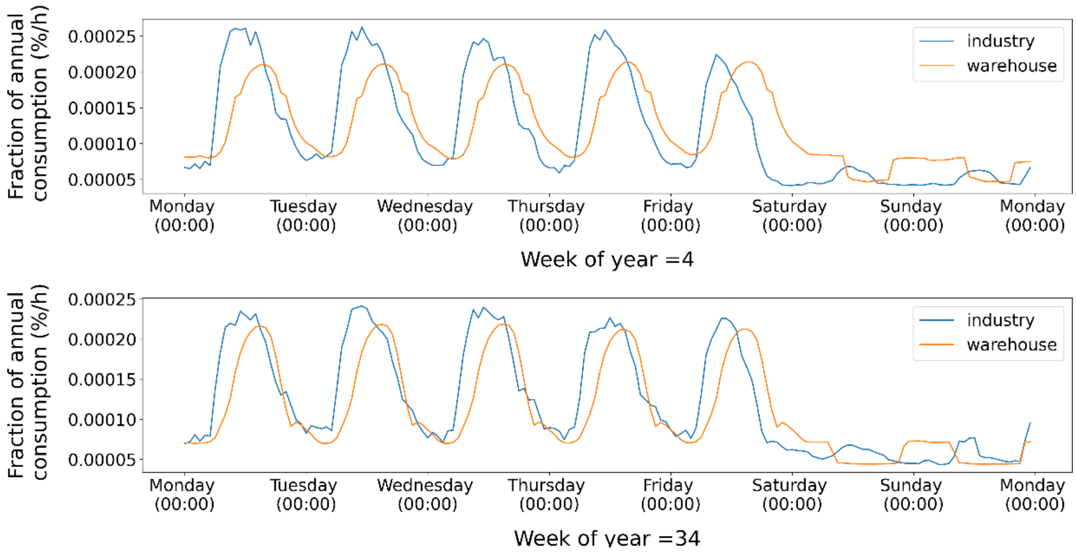

Figure 5: Normalized profiles of the industry and warehouse commercial activity.

The second sub-category consists of all office sizes and their profiles are shown in Figure 6. In comparison to the industry and warehouse category the peaks are a bit lower. The lower peaks are due to consumption in the weekend and a higher base consumption in comparison to the industry and warehouse category.

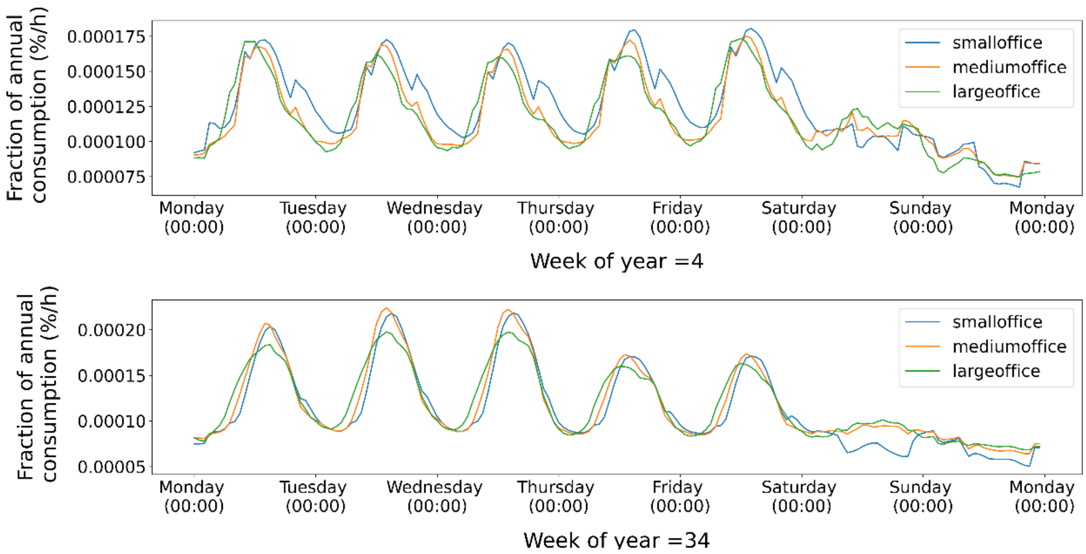

Figure 6: Normalized profiles for office commercial activity.

The last sub-category consists of commercial activities that have electricity consumption during weekends, as is depicted in Figure 7. This encompasses restaurants, retailers, and hotels. The total consumption is more evenly distributed over the days, resulting in lower peak demands. For restaurants it is seen that most of the consumption is during dining hours. Hotels show a pattern that somewhat resembles a household profile, with a morning and evening spike in demand.

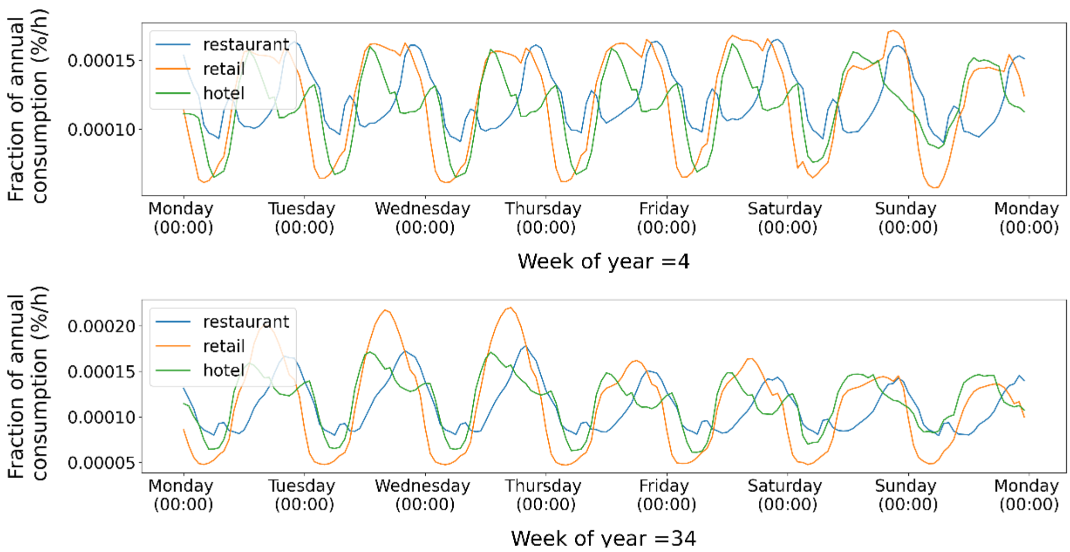

Figure 7: Normalized profiles of restaurant, retail, and hotel.

6.1.2. Business Park consumption profiles

Below an overview of the composition of each type of business park and its consumption profile is given. Table 14 gives an overview of the gross area, roof area, and composition of total floor area of each business park.

Table 14: Overview of the business park type compositions.

	Business Park type				
Unit: m²	*HQ*	*Industrial*	*Logistics*	*Maritime*	*Mixed*
Gross Area	160,000	163,000	352,000	266,000	110,000
Roof Area	81,222	63,307	130,558	56,145	40,469
Total floor area	**168,976**	**72,546**	**156,817**	**88,246**	**78,449**
Industry	*13,200*	*57,828*	*10,659*	*43,768*	*0*
Warehouse	*2,043*	*7,257*	*111,867*	*31,956*	*9,871*
Small office	*3,016*	*1,391*	*1,756*	*3,538*	*3,789*
Medium office	*14,283*	*5,035*	*6,531*	*3,854*	*21,338*
Large office	*45,335*	*0*	*7,050*	*0*	*7,223*
Restaurants	*2,198*	*0*	*0*	*2,358*	*704*
Retail	*88,901*	*1,035*	*18,954*	*2,772*	*26,160*
Hotel	*0*	*0*	*0*	*0*	*9,364*

High-quality business park

A high-quality business park is characterised by the presence of primarily retail companies and offices. Besides, most of the buildings are multi-tenant buildings. For example, in Figure 8 both large purple buildings resemble a shopping mall, in which a combination of retail parties is established. Also, most buildings have multiple floors, making it possible that the floor area is larger than the gross area. Furthermore, some industry, restaurants and a single warehouse are present.

Figure 8: Composition of commercial activities at the high-quality business park.

The resulting consumption profile for a winter and summer week of a high-quality business park is given in Figure 9. As retailers are also open on weekends it should be noted that there also is some consumption on Saturdays and Sundays. As most of the commercial activities of the occupants of this business park type are not energy intensive (see Table 8), the peak demand of individuals is small in comparison to other types of business parks. However, as the concentration of businesses is high, the aggregated peak demand is substantial, nonetheless. Typical characteristics are a peak demand of 3268kW, a continuous demand of 913kW and an annual consumption of 16.62 GWh.

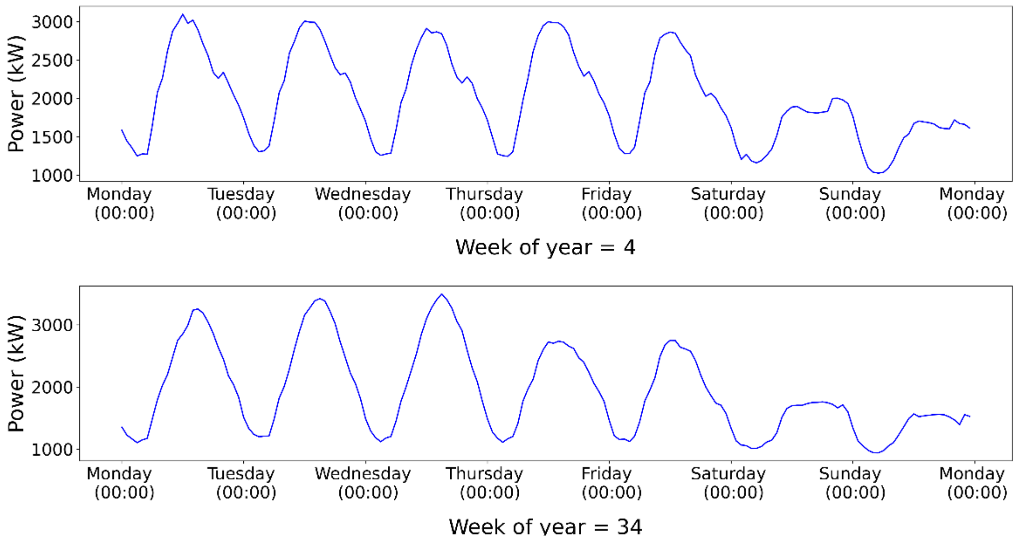

Figure 9: Consumption profile of the high-quality business park.

Industrial site

An industrial site mainly consists, as the name suggests, of companies with industrial activities. An overview of all occupants is given in Figure 10. Most buildings dedicated most of their floor area to industrial activities, in combination with space for a small or medium office. Furthermore, there is one retailer and one warehouse. The setup of the park is widespread, resulting in the total floor area being less than halve of the gross area of the park.

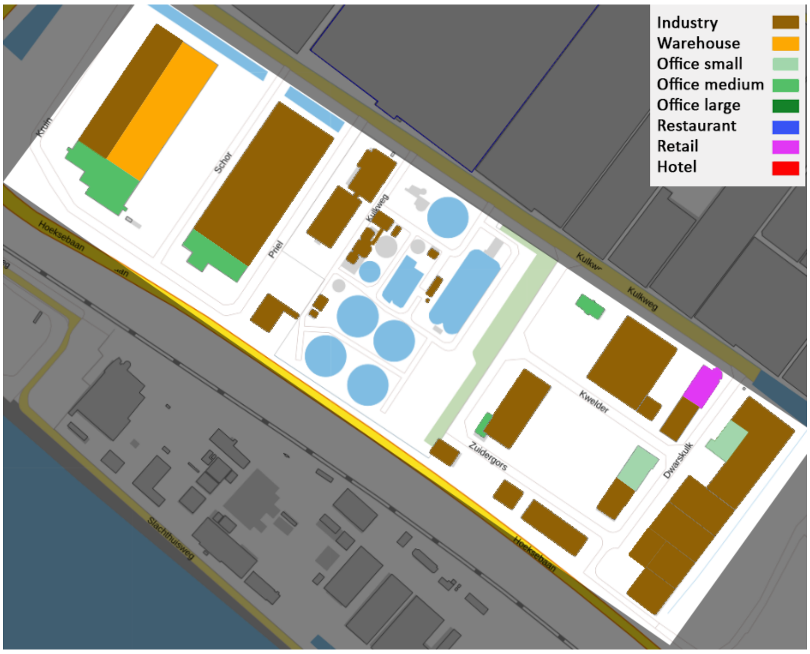

Figure 10: Composition of commercial activities at the industrial site.

The resulting consumption profile for a winter and summer week of an industrial site is given in Figure 11. Even though the total floor area of this park is the smallest, the electricity consumption of industry is most intense of all commercial activities, resulting in a high peak demand. In contrast to a high-quality business park there is little to no commercial activity in the weekends. Typical characteristics are a peak demand of 5173kW, a continuous demand of 764kW and an annual consumption of 19.70 GWh.

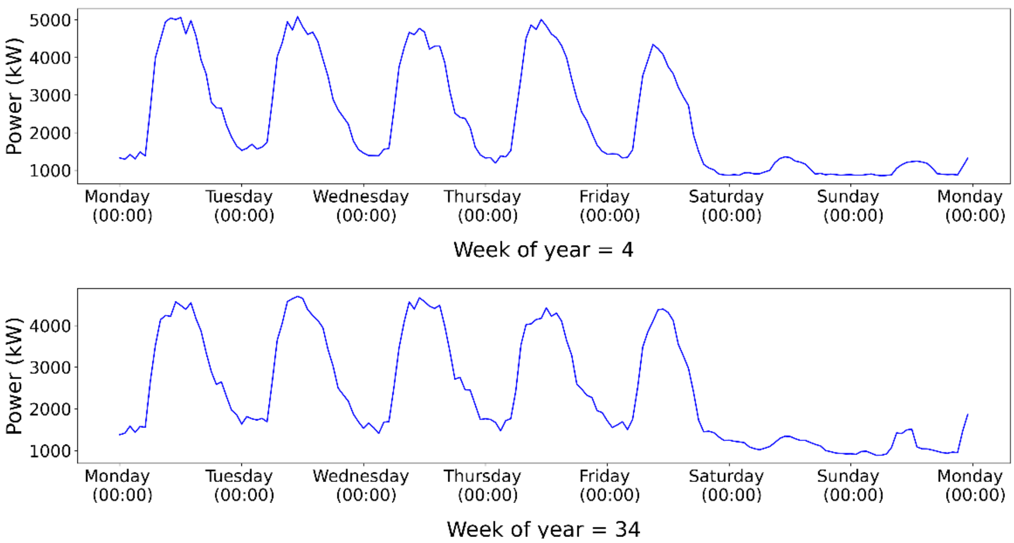

Figure 11: Consumption profile of the industrial business park.

Logistics Park

A logistics park is predominantly occupied by warehouses. The setup of the park is widespread, giving a relatively high ratio between gross area and total floor area. In addition, the logistics park is the largest park of the five business park types. Most buildings are single floored, which results in a roof area that is almost as large as the total floor area. Besides warehouses, there is retail, industrial and office activity present in small amounts.

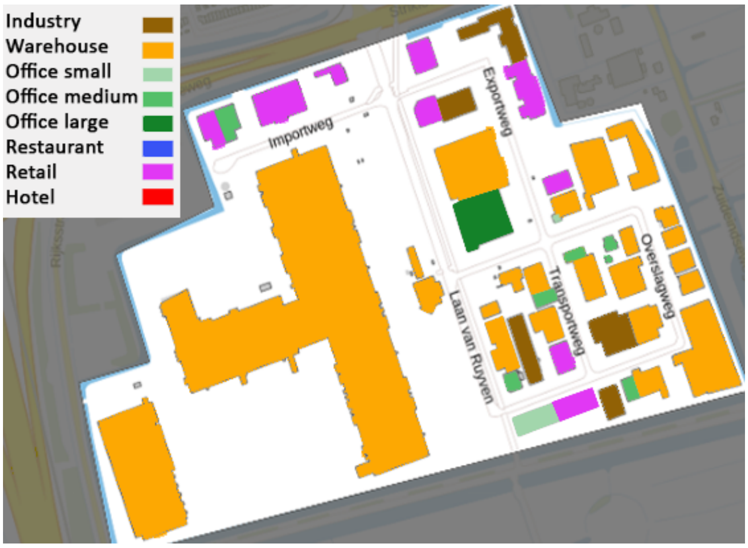

Figure 12: Composition of commercial activity of the logistic hub.

The resulting consumption profile for a winter and summer week of a logistics park is given in Figure 13. Like the industrial site there is little to no electricity consumption in the weekends. Albeit the specific electricity consumption of warehouses is low, the total floor area is relatively high in comparison to the other business park types. This results in a peak demand of 2619kW, a continuous demand of 560kW and an annual consumption of 11.67 GWh.

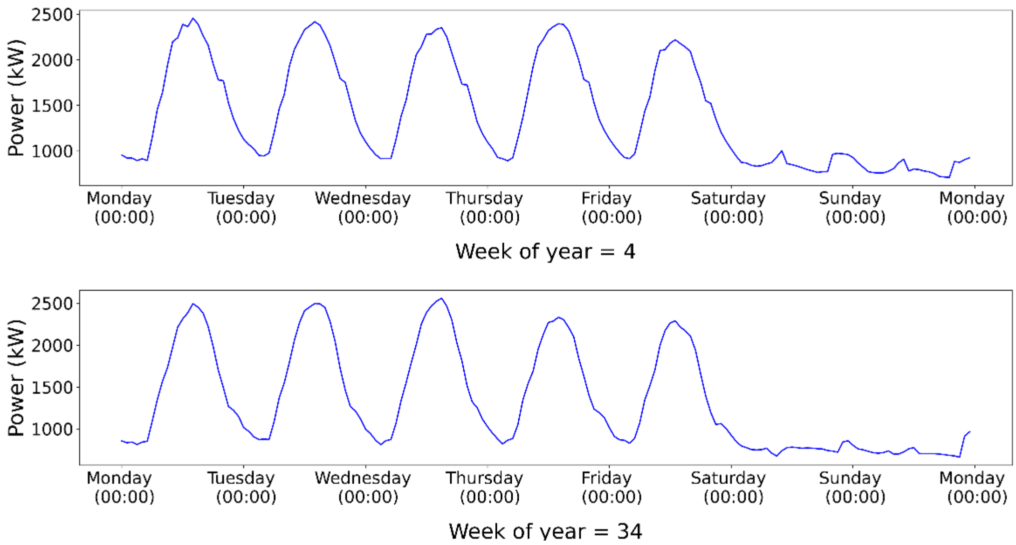

Figure 13: Consumption profile of the logistic business park.

Maritime

A maritime business park formed around a harbour is shown in Figure 14. This park consists mainly of industrial activity and warehouses. Besides, the harbour is included in the gross area, making the ratio between floor space and gross area relatively small. Furthermore, there is some retail, office and restaurants present at the park.

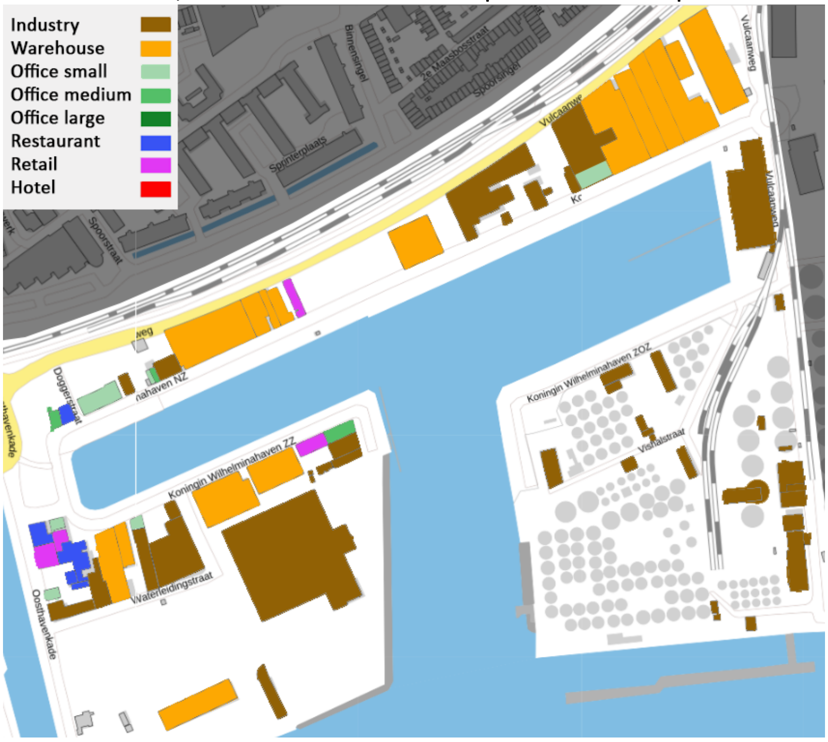

Figure 14: Composition of commercial activity at the maritime business park.

The resulting consumption profile for a winter and summer week of a maritime business park is given in Figure 15. As a large portion of the occupants consists of industry, the consumption profile has a similar pattern compared to an industrial site. However, the industry floor area is a bit smaller, resulting in a lower peak demand. The maritime park has a peak demand of 4232kW, a continuous demand of 729kW and an annual consumption of 16.95 GWh.

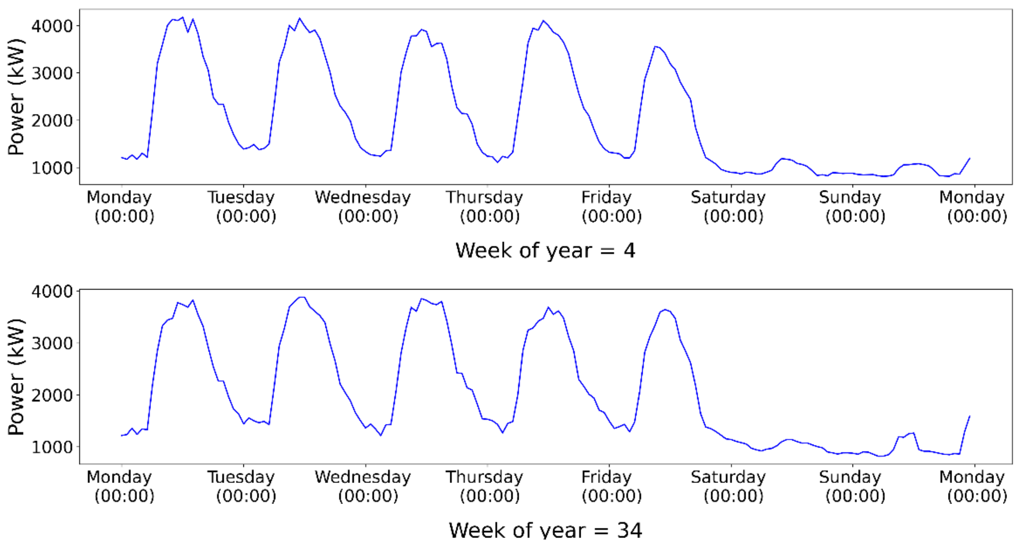

Figure 15: Consumption profile of the maritime business park.

Mixed

In similarity to the high-quality business park the mixed business park has a high variety of occupants. However, in contrast to the high-quality business park there is no industry, but there is presence of hotels. Furthermore, there is a large presence of all sizes office and retail. Lastly, there are some warehouses in the form of storage boxes for individuals and a restaurant.

Figure 16: Composition of commercial activity at the mixed business park.

The resulting consumption profile for a winter and summer week of a mixed business park is given in Figure 17. As the total floor area is one of the smallest of all five business park types and the electricity consumption intensity of the occupants is relatively low the peak demand of this park is the smallest of all. Like the high-quality business park there is commercial activity in the weekends, resulting in some electricity consumption. The mixed business park has a peak demand of 1239kW, a continuous demand of 382kW and an annual consumption of 5.68GWh.

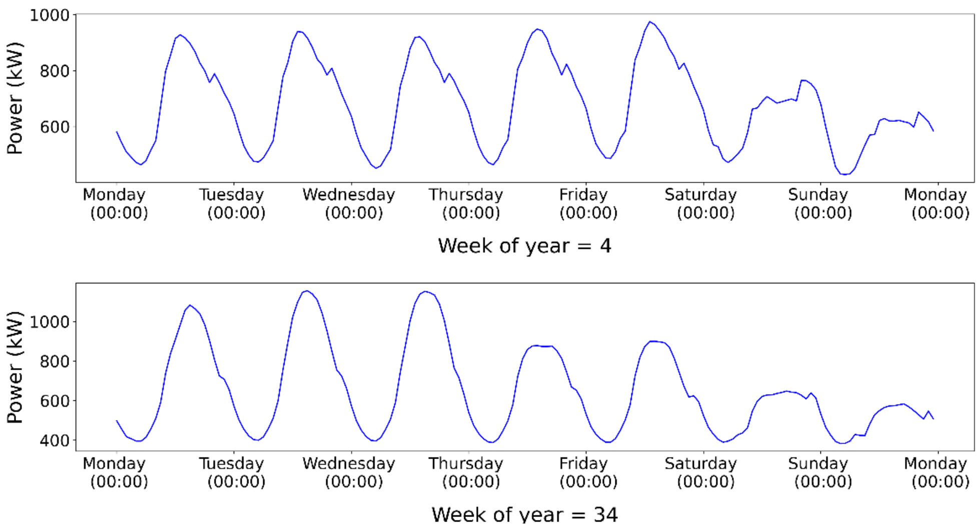

Figure 17: Consumption profile of the mixed business park.

6.2. Solar profiles and battery sizes

Solar profiles are constructed based on the percentage of roof area that is covered with solar panels. In total there are four percentages, being 0%, 25%, 50% and 75%. Figure 18 gives an overview of the solar profiles for all business park types, given that 50% of the roof area is covered. This is done for the 34th week of the year, which is a summer week. Table 15 also shows that the solar production of the logistics park is the largest, followed by the high quality, industrial, maritime, and mixed park respectively. The output of the 25% and 75% scenario is 0,5 and 1,5 times the power of the 50% scenario respectively due to the linear relation between power output and number of panels.

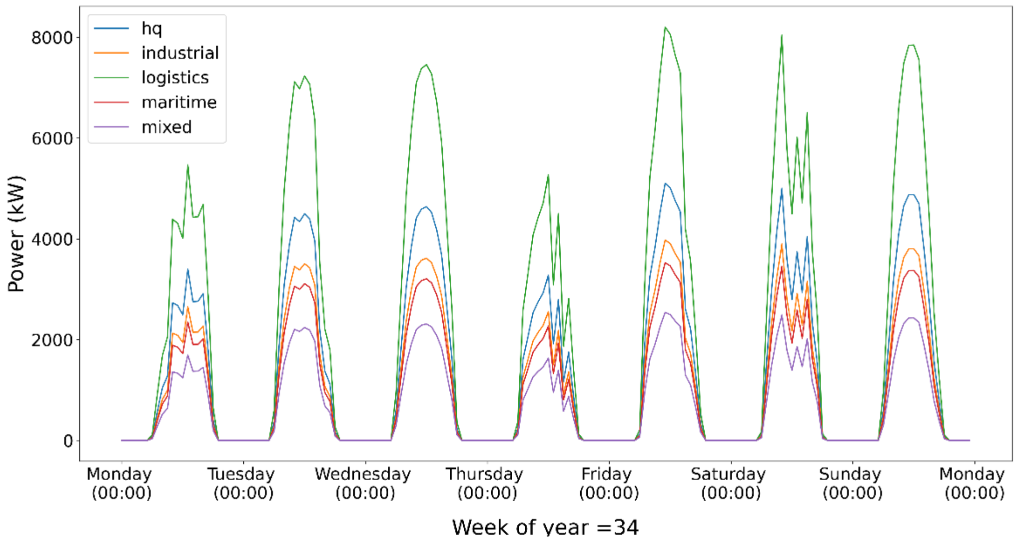

Figure 18: Solar production of all business parks, with 50% roof coverage.

An overview of the total annual production in GWh is given in Table 15.

Table 15: Overview of annual solar electricity production at each park (in GWh).

Business Park type	25%	50%	75%
High quality	4.72	9.45	14.17
Industrial	3.68	7.36	11.04
Logistics	7.59	15.18	22.77
Maritime	3.26	6.53	9.79
Mixed	2.35	4.71	7.06

The battery sizes are determined by the peak demand of each business park type. An overview of the battery power ratings in kW is given in Table 16. In line with the description of the consumption profiles in the previous section, the industrial park has the largest battery, whilst the mixed business park has the smallest.

Table 16: Overview of battery power ratings (in kW)

Business Park type	Small (kW)	Large (kW)
High quality	363	1,088

Industrial	517	1,552
Logistics	262	786
Maritime	423	1,269
Mixed	124	372

6.3. Optimisation results

This section provides an overview of the stakeholder-based optimisation model. Below, each of the optimisation scenario is elaborated upon and compared to the reference scenario. The performance indicators provide scores for the quantitative criteria, being the total annual costs, electricity volume exchanged with the grid, and necessary connection capacity. A total overview of these indicators is given in Appendix D. In Appendix E the percentage change in comparison to the reference scenario is given and transformed into a heatmap.

6.3.1. Cost minimisation

In this scenario the energy management system of the smart grid is given the objective to minimize costs. Depending on the business park configuration, the total annual costs decrease with a range of 2 to 104%. With larger availability of flexible load and larger batteries the cost reduction increases. The flexible load is redistributed over the day, so that the business park consumption increases when the electricity price is low and vice versa. Batteries capitalize on a similar price mechanism – storing electricity when the price is low and selling when the price is high. Looking at the state of charge of the battery for business park configurations without solar production and comparing it with the electricity this price arbitrage becomes evident. This process is depicted in Figure 19, where green highlighted periods indicate a charging battery due to low electricity prices and the orange periods indicate the opposite.

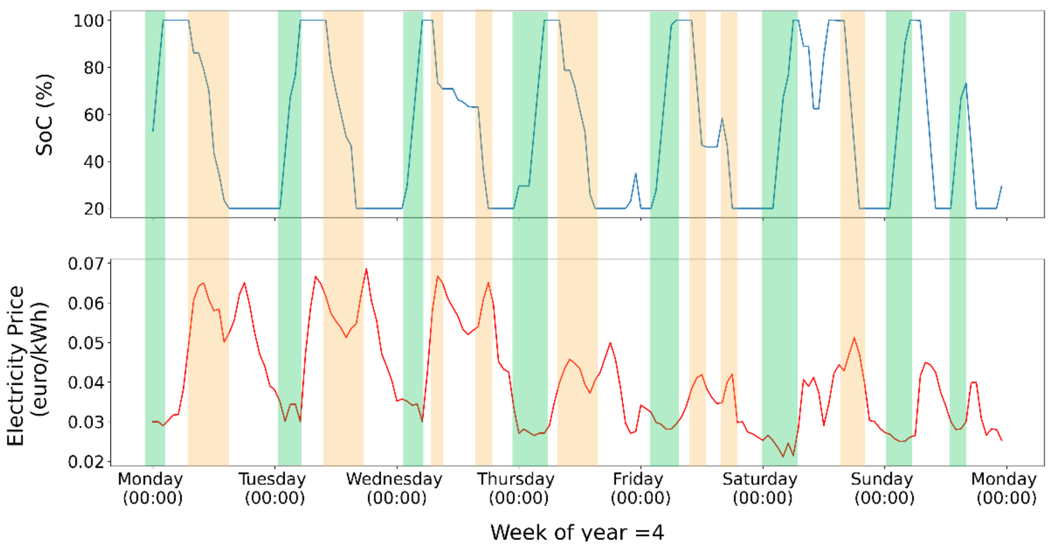

Figure 19: Relationship between battery state of charge and electricity price in the cost optimization scenario.

This mechanism can be similarly displayed for the interaction between activation of flexible load and the electricity price. Figure 20 provides an overview of the flexible load dispatch and its relation to the electricity price. It is then seen that the demand is increased (positive flexible load) when electricity prices are low, indicated by the green periods. The other way around, demand is decreased (negative flexible load) when electricity prices are high.

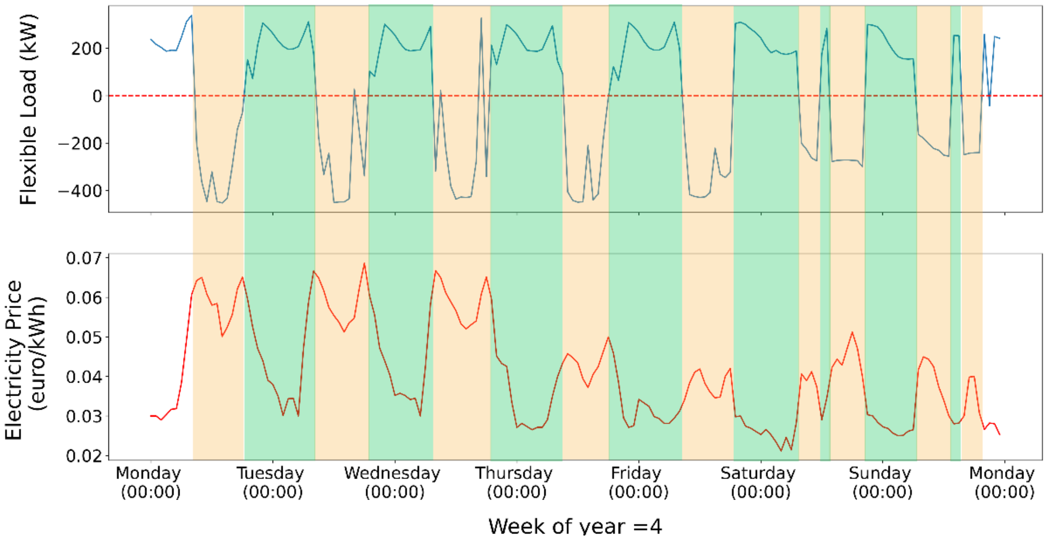

Figure 20: Relationship between flexible load and electricity price in the cost optimization scenario.

Furthermore, the total costs of the system consist of two components: the price for electricity that is consumed and the costs that relate to the grid connection. Figure 21 shows the ratio between connection costs and total costs of the reference scenario, with all 180 business park configurations on the x-axis. For most of the business park configurations the connection costs are 20 to 50% of the costs. An exception to this is the configurations with large quantities of solar PV. In these configurations the electricity costs are low due to solar production, resulting in high ratios. In the case of 75% roof coverage for the logistics park, the solar production results in negative electricity costs and even negative total costs. Because the connection costs in this case are positive a negative ratio is the result. Lastly, the costs do not differ for differing battery sizes and flexible loads, as these cannot be effectively used without a smart grid.

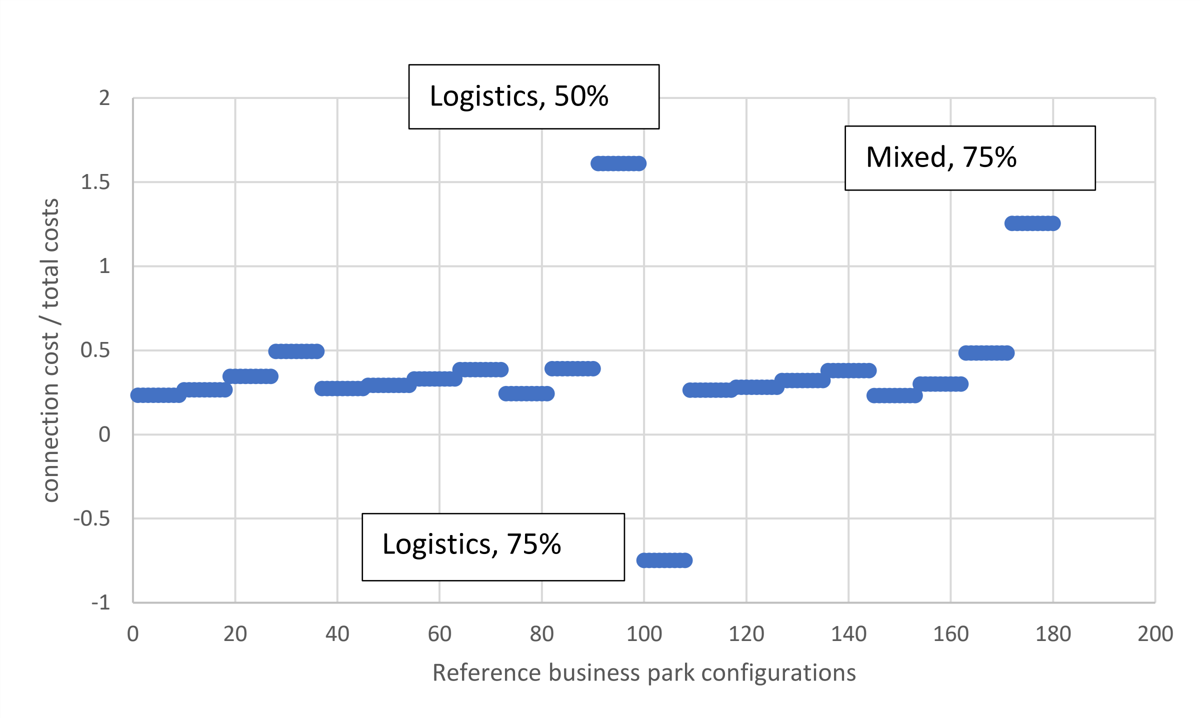

Figure 21: Ratio of connection costs in comparison to total costs.

Figure 22 shows a similar plot, but then for the ratio between the connection costs savings and total costs savings. The figure shows that for all configurations most of the savings are due to savings in connection costs.

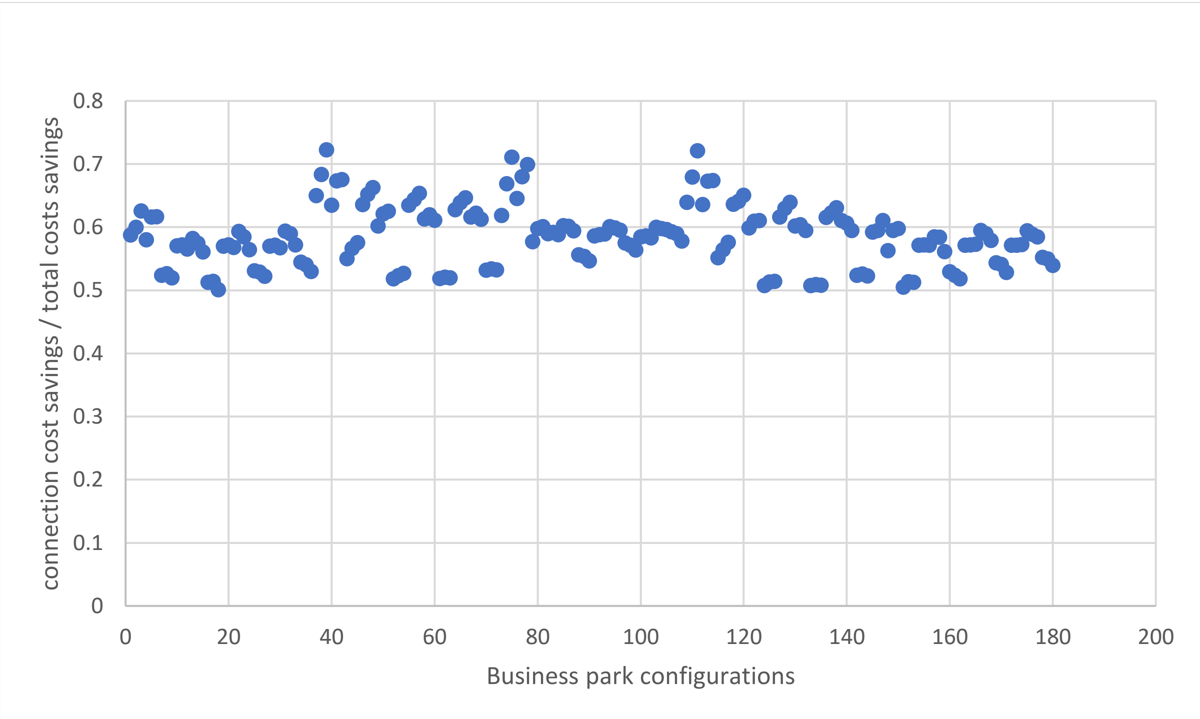

Figure 22: Ratio of connection costs savings in comparison to total costs savings.

When inspecting the effects of the cost optimisation on the required grid connection capacity it becomes evident that especially for the configurations with limited amounts of solar PV coverage the annual peak can be reduced by up to 25 – 30%. This is mainly due to the consumption profiles of the business parks having a similar pattern to the electricity price. Therefore, redistributing consumption to periods with lower prices also results in a lower peak demand and thus less required connection capacity.

For business park configurations with larger amounts of solar PV, the required grid capacity increases with more battery and flex capacity availability. This is the result of a summer day with large solar production, whilst the elecricity price is relatively high. An example is the high quality business park in combination with a large battery and 15% flexible load and 50% roof area coverage. Figure 23 is a visual representation of the effects that result in the need for increased grid capacity. The peak in required connection capacity for this configuration is on the 10th of june at 11:00, indicated by the black dotted line. As solar production is larger than demand, electricity is injected into the grid. On top of this injection, batteries also start discharging because the electricity price is high. Furthermore, the demand is adjusted downwards, resulting in less demand. All in all this leads to an increased injection into the grid and thus and increased need for connection capacity.

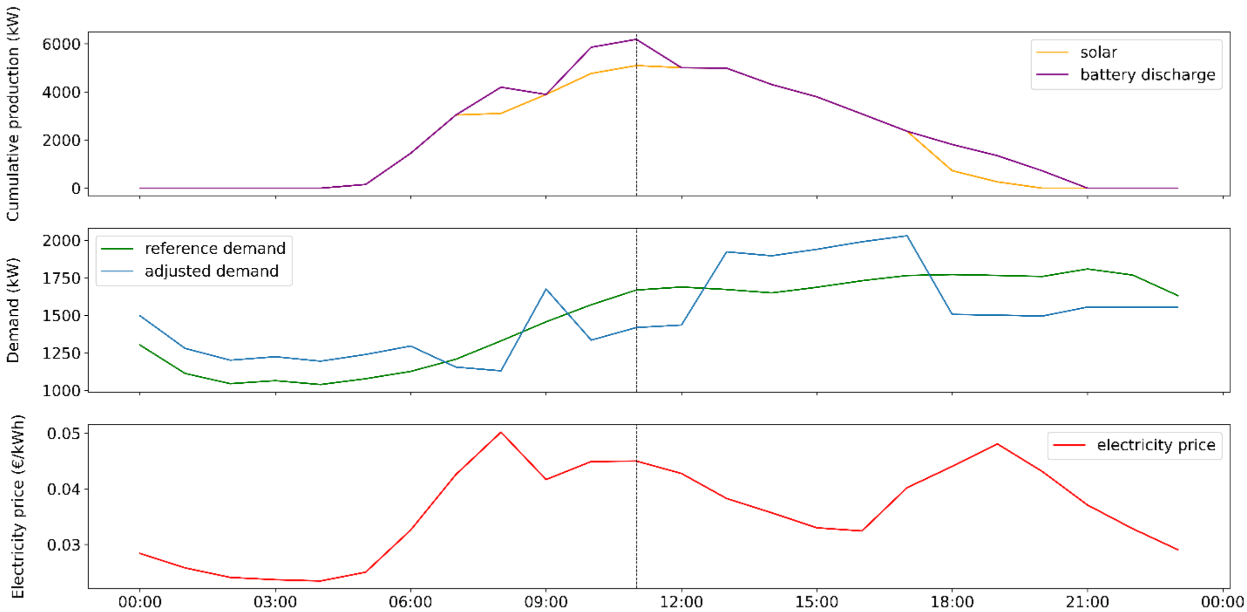

Figure 23: Visual representation of the effects that result in an increased grid capacity requirement. Graphs entail the high quality business park with 50% roof coverage, 15% flexible load and a large battery at June 10th.

Lastly, a cost optimisation does not have a significant effect on the volume of electricity that is exchanged with the grid. For the configurations with less solar PV production and either a small or large battery there is an increase in exchanged volume up to 9%. This is the effect of the price arbitrage that is captured by the battery. However, as there are round-trip efficiency losses, the total volume that is exchanged with the grid is increased to compensate for these losses.

For the park configurations where solar production on a typical summer day exceeds demand, a reduction in total grid exchange is seen. This indicates an increase in self-sufficiency. The reason for this increase resides in the combination of a battery and flexible load. A nice example to showcase those reasons is the logistics park with 50% roof coverage, a large battery, and 15% flexible load. An overview of the electricity flows on a typical summer day (July 2nd) of this park is provided in Figure 24. This figure shows that in the afternoon, when the electricity price is low, the battery is charged, and demand is increased. In this period, it is not beneficial to sell to the grid, and thus self-consumption of solar production is maximised. In the evening, when solar production is decreasing and the price is high, the demand is lowered. As the electricity price is high this electricity is not bought from the grid but withdrawn from the battery.

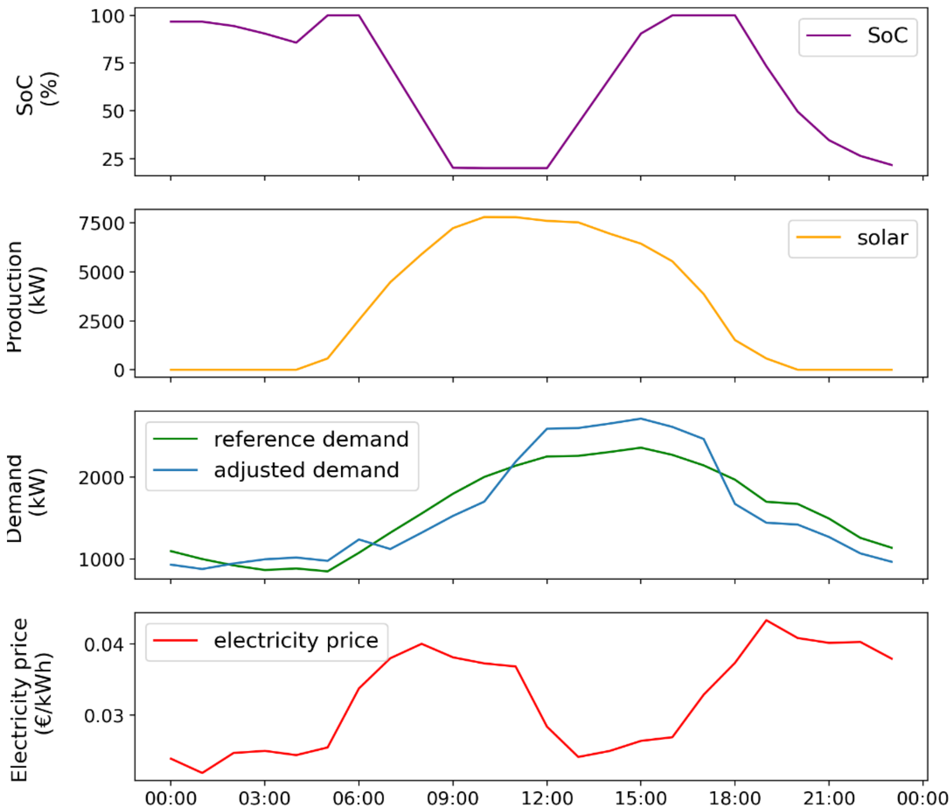

Figure 24: Overview of electricity flows for the logistics park with 50% solar panels, 15% flex load and a large battery (July 2nd).

6.3.2. Grid dependency minimisation

In this scenario the energy management system of the smart grid is calibrated to minimise the electricity volume that is exchanged with the grid. This entails both the electricity that is withdrawn from the grid in periods of net demand and electricity that is injected into the grid in periods of net production. To be able to decrease the volume that is exchanged with the grid in comparison to the reference scenario there must be solar production. This is affirmed by the total overview in Appendix E, where there is 0% change in electricity exchange with the grid for the business parks without solar production. Consequently, there is no change in required grid capacity and total annual costs.

In the configurations where there is presence of solar PV, the grid exchanged volume decreases with an increase in flexible load. It also decreases for increased availability of battery capacity. Whether the volume also decreases with an increasing amount of solar PV is dependent on the ratio between demand and production. For business parks where the solar production is much larger than demand, the grid dependency increases with increasing roof area coverage. Due to limit constraints on the battery and flexible load there is a limit to the absolute amount of electricity that can be redistributed over time. Any excess production beyond these limits is injected into the grid, resulting in increased grid dependency. An example can be found at the logistics parks. As this park is characterized by a relatively large roof area and is occupied by relatively low electricity intense habitants there is a lot of excess production during the summer. Therefore, the largest reduction in grid dependency is noticed at only 25% of the roof area being covered by solar panels. Because the industrial park has a higher peak demand and less roof area available for the installation of solar panels there is less excess electricity production. Therefore, the grid dependency for this park decreases as the installed amount of solar PV increases.

Furthermore, it is noticed that in this scenario the batteries and flexible load are only used when solar production exceeds demand. This is because no savings in grid exchange can be achieved. An example is the day with peak demand of the maritime park, with 25% solar, a small battery and 15% flexible load. An overview of the solar production and business park demand is given in Figure 25. The grey area is the amount of electricity that is withdrawn from the grid. Even if the demand profile is adjusted during the day, the grey area would remain the same. Therefore, there is no need to activate flexible load, as no grid exchange savings can be achieved. The same holds for the application of a battery. However, as a battery has some round-trip efficiency losses, this would only result in an increase of electricity that is exchanged with the grid. Furthermore, in this example the capacity of the grid connection is dimensioned based on the peak in demand. As there is no need to adjust demand, there also is no change in required connection capacity. This holds for all business park types with 25% solar, except for the logistics park. It also applies to the industrial and maritime park with 50% solar panel coverage of the rooftops.

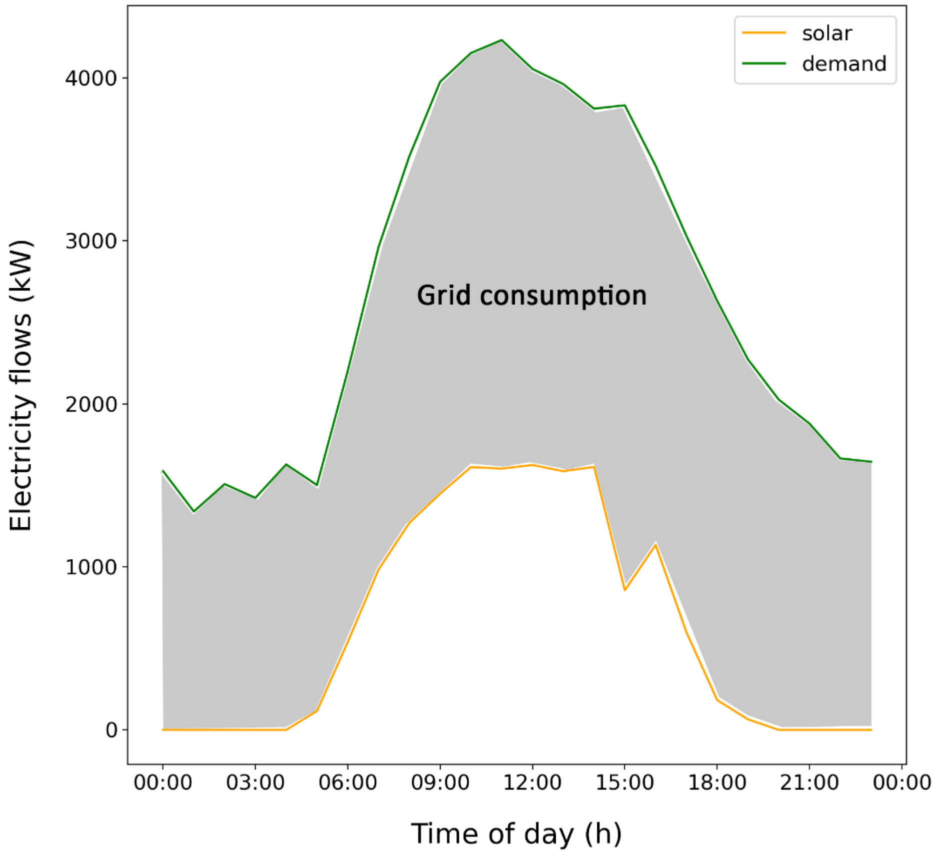

Figure 25: Overview of aggregated demand and solar production for the maritime park with 25% solar, a small battery and 15% flexible load.

An example where the grid connection capacity is determined based on the peak in solar production is the mixed park with 75% solar, a small battery and 15% flexible load. In Figure 26 an overview of the energy flows is given for a weekend day in summer, where there is lots of excess solar production. It is then seen that to minimise the exchange with the grid, the demand is lowered when there is no solar production and increased when there is. Due to the required grid capacity being determined by the amount of solar production that must be injected, the required grid capacity decreases. This effect is indicated by the black and red arrow, representing the reference and new grid capacity respectively. For the business park configurations where the grid connection capacity is based on solar injection into the grid, the required capacity is reduced by 2 – 16%.

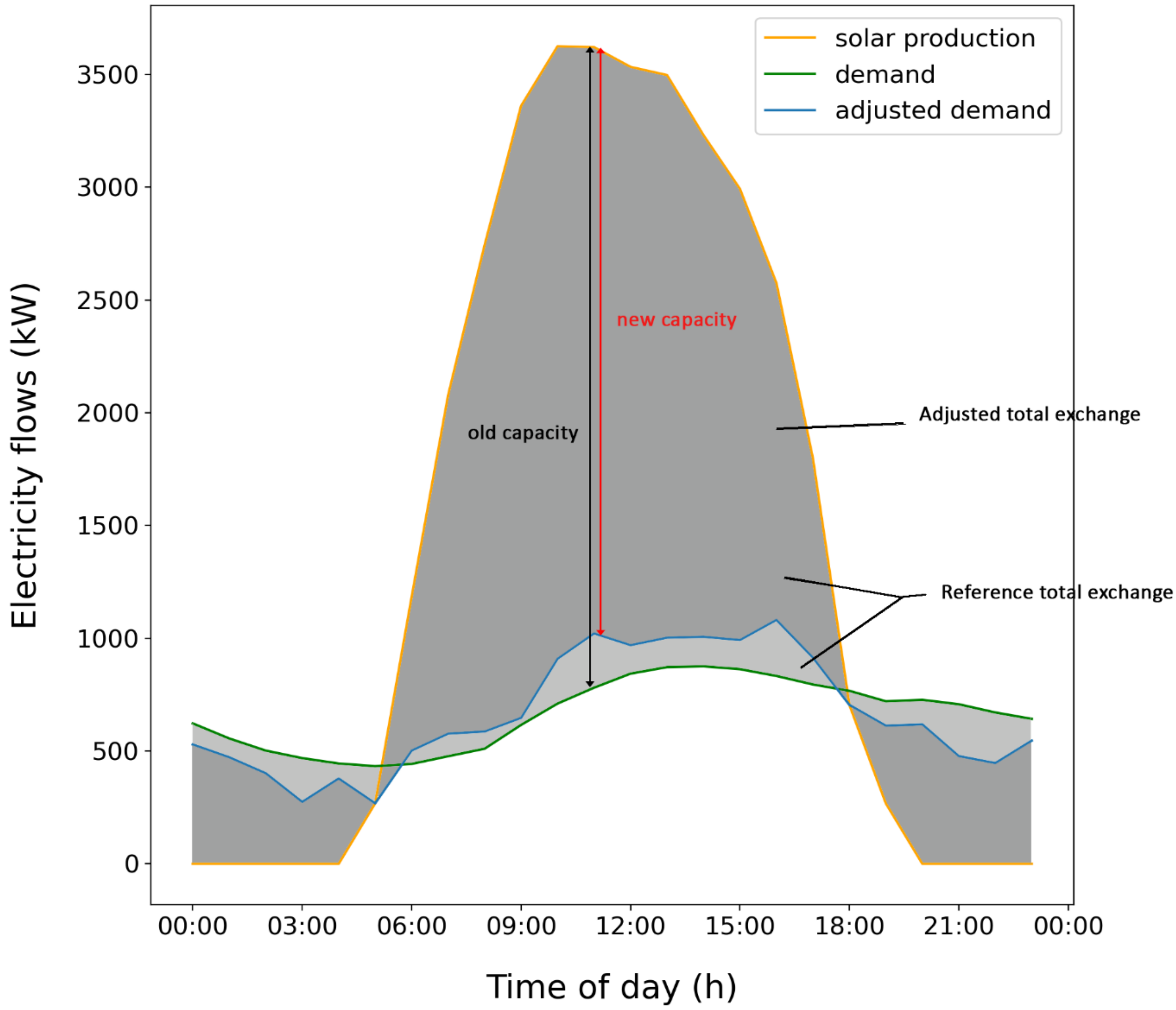

Figure 26: Overview of solar production, demand, and adjusted demand for a weekend day of the mixed business park with 75% solar, a small battery and 15% flexible load.

The costs in the grid dependency minimisation scenario do not change for the configurations without solar production. For all other configurations a grid dependency minimisation results in an increase in costs of 1 to 13%. The reason for this is twofold. The first reason resides within the use of batteries. In the case that the battery is used to redistribute electricity over time round-trip efficiency losses take place. The electricity that is lost would in the reference scenario been sold to the grid, resulting in lower costs. This effect is larger for the configurations with a large battery, as more electricity cannot be sold to the grid. The second reason relates to the timing of electricity use. In Figure 26 we have seen that demand during the day is increased and lowered when the sun does not shine. Because the average electricity price is higher during the day than in the night, the system saves less money on buying electricity from the grid than it loses from selling less electricity to the grid. This effect increases with increasing availability of flexibility (flexible load and batteries) within the system.

6.3.3. Connection capacity minimisation

In this scenario the energy management system is optimised for reducing the grid connection capacity that is required. As the connection capacity is determined by the annual peak, the objective is to lower the peak in power that is exchanged with the grid. The results indicate that when this optimisation objective is given to the energy management system the required grid connection capacity can be reduced by up to 30%. The mechanism by which this is achieved is depicted in Figure 27. This figure shows the annual peak demand of the high-quality business park without solar production, but with 15% flex and a large battery. It is seen that by adjusting the demand up and charging the battery in the morning the power from the grid is increased. In the afternoon the exact opposite is executed, respectively lowering the old peak demand to the new peak demand.

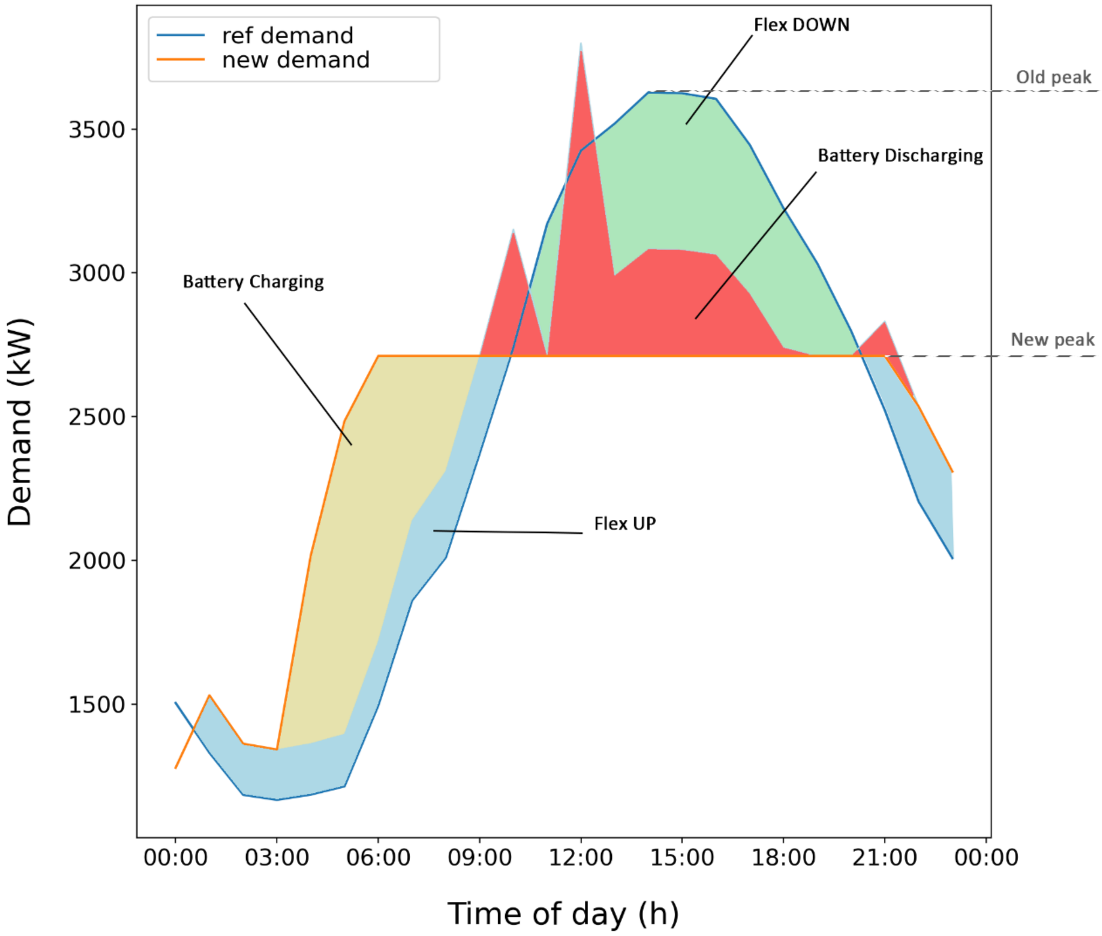

Figure 27: Visual representation of the mechanism that achieves a reduction in required grid connection capacity when peak is based on demand.

The percentage by which the peak can be decreased in comparison to the reference scenario increases with larger flexible load and larger battery capacity. This is logical as larger capacity of mechanisms that are capable of redistributing load over time, results in larger volumes being displaced, and thus a larger reduction in peak demand.

Furthermore, the reduction in required grid connection capacity reduces as the number of solar panels increases. However, this is only until the point where the required grid capacity is no longer determined by the peak demand, but by the capacity that is required for grid injection. At that point the absolute amount of electricity that can be redistributed remains the same, but the required grid capacity exceeds the originally required capacity – which was based on the peak in demand. In relative terms this is less of a reduction, which is why the percentage of reduction for some parks is less for configurations with large solar installations. This is for example the case for the mixed business park, where the percentage peak reduction is largest for the configurations with 25% roof area coverage. An overview of the peak reduction mechanism for configurations with large amounts of solar is given in Figure 28.

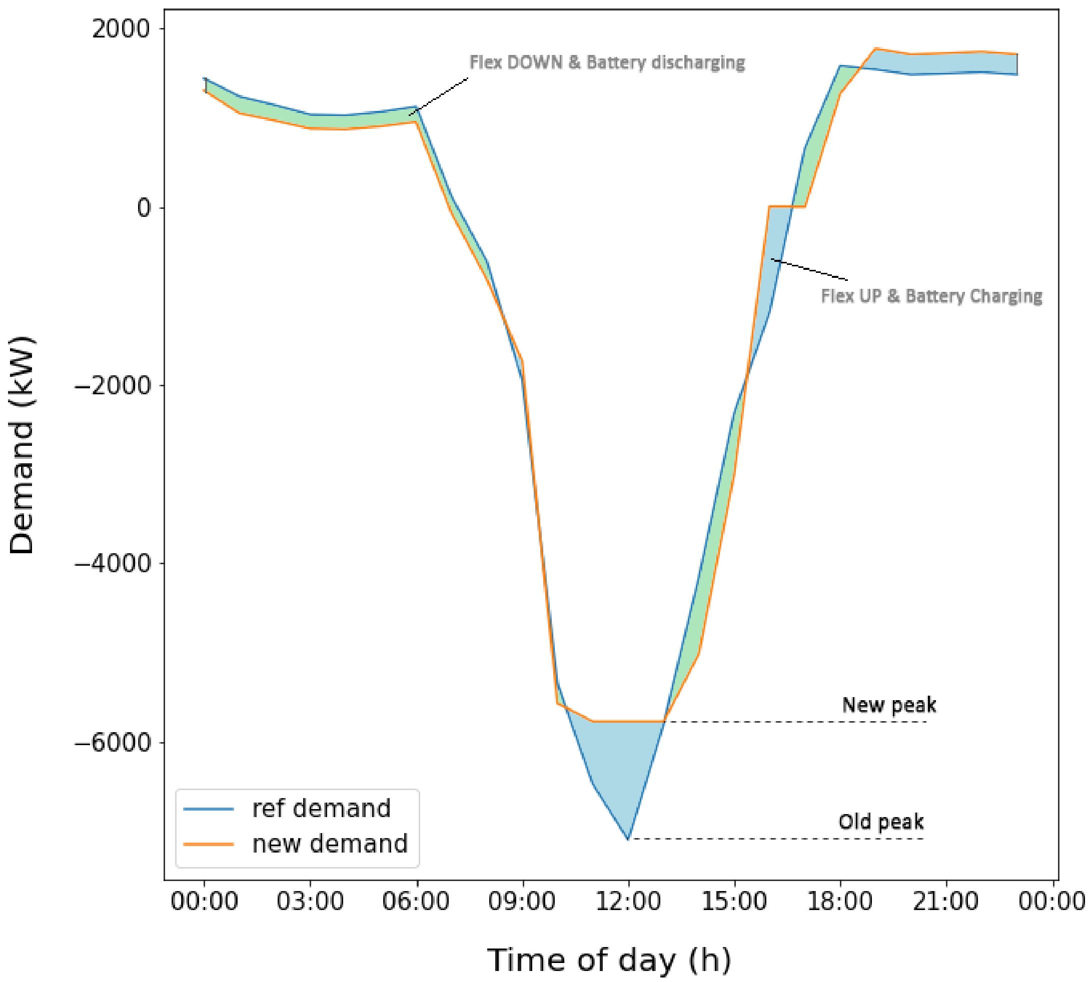

Figure 28: Visual representation of the mechanism that achieves a reduction in required grid connection capacity when peak is based on injection.

In this optimization it is noted that the costs of the business parks decrease for configurations where the required connection capacity is based on demand and increase for configurations where the required connection capacity is dimensioned for injection. A maximum increase of 20% is noticed, whilst the maximum decrease is 7%. As can be seen in the cost optimization scenario, over 50% of the total savings can be attributed to a reduction in connection costs. In this scenario the system is calibrated to reduce the required connection capacity and thereby reduce the connection costs. For the configurations with a grid connection dimensioned based on demand a reduction in costs is primarily a result of a reduction in connection costs.

Once the required connection costs are dimensioned based on the peak in grid injection a small increase in costs is noticed. This has two reasons. First, the capacity by which the peak can be adjusted remains the same. Therefore, the percentual reduction in peak is less, leading to a relatively smaller reduction in connection costs. Moreover, this reduction only applies to the summer months, which is why there only is a reduction in monthly capacity costs for half of the year. Second, in the configurations with high solar production, the batteries are used more extensively. This leads to larger round-trip efficiency losses, resulting in larger amounts of compensation electricity that is bought from the grid. In comparison to the reference scenario this effect in percentages is largest for the parks with relatively low annual demand as the amount of efficiency-losses are equally large for each business park type. Therefore, the percentual increase in costs is largest for the logistics and mixed business park.

Regarding the absolute volume of electricity that is exchanged with the grid, there is an increase (up to 12%) for the configurations where the annual peak is the result of grid withdrawal. In these configurations there is limited solar production and thus the battery is primarily used for the displacement of electricity as is shown in Figure 27. To compensate for the efficiency losses of the battery, extra electricity is withdrawn from the grid, leading to a small increase in the volume of electricity that is exchanged with the grid.

Concerning the configurations where the annual peak is the result of grid injection, there is a decrease in volume exchanged with the grid by up to 12%. This is the effect of reducing the electricity that is injected into the grid by means of charging the battery and adjusting demand upwards with flexible load. Outside peak sunshine hours the demand is then lowered by means of downwards flex adjustments and battery discharging. This leads to an increase in self-sufficiency and thus a decrease in total volume that is exchanged with the grid. This effect is already seen in Figure 26, where a minimization of grid dependency results in a smaller connection capacity requirement. In this scenario it is the other way around, where minimizing the required connection capacity results in a decrease of total volume that is exchanged with the grid. It should, however, be noted that reducing the required connection capacity is a matter of reducing the peak in grid exchange and thus only applies to certain periods of the year, whereas minimizing the volume that is exchanged with the grid applies to the whole year. Therefore, the reduction in volume that is exchanged with the grid is smaller in this scenario.

6.4. Multi criteria analysis

In this section a comparison between the different scenario's is made for each stakeholder. This analysis is executed by means of a multi criteria analysis, in which the different criteria of each stakeholder are scored. By giving a weight to each criterion and summing the multiplication of the weight and the score, a total utility score is calculated for each scenario. This process is explained in section 5.5. First the qualitative criteria are scored.

6.4.1. Qualitative criteria

An overview of all the qualitative criteria is given in Table 17. Thereafter, each criterion is elaborated upon and scored individually for each scenario. As mentioned in the methodology, the reference scenario is always scored neutrally (0.5). The ease of use and time consumption criterion are combined, as they closely relate to each other.

Table 17: Overview of qualitative criteria.

Criterion	**Stakeholders of interest**
Timing of solution for grid congestion	DSO, NPRES
Scalability	DSO
Electricity price developments	NPRES
Robustness	Regulator, Business owners
Promote trade	Regulator
Ease of use and time consumption for consumer	Regulator, Business owners
DSO service quality	Regulator
Fairness of operation	Regulator

Timing of solution for grid congestion

Grid congestion can be solved in multiple ways, but in essence it is a matter of having enough grid capacity available at the right time. Currently the DSOs reserve a static amount of capacity based on the peak of a consumer (Enexis, Appendix A). As shown in section 6.3 the implementation of a smart grid can result in the reduction of a peak and thus frees a bandwidth of connection capacity. Whether this bandwidth is enough to alleviate congestion is location dependent. However, the implementation of a smart grid enables DSOs to abandon the concept of a static capacity. This allows them to offer dynamic contracts, which might result in a better tuning of consumption profiles on a business park. Nonetheless, it is uncertain whether this is enough to alleviate congestion (Enexis, Appendix A). It is, however, certain that the implementation of a smart grid is typically faster than waiting for grid expansion, which is the reference scenario. The aggregator indicated that setting up a smart grid takes 1-2 years, whereas grid expansion can take up to 10 years (Spectral, Appendix A; KIVI, 2022). This criterion is characterised by two aspects; whether it is enough to solve congestion and the timing of implementation. The first aspect is uncertain, the second is favourable for the implementation of a smart grid. Therefore, the scoring of this criterion is as follows:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Timing for solving grid congestion	0.75	0.75	0.75

Scalability

For the DSOs it is important that the products which they provide are scalable. Their reference situation is the provision of grid connections, which are lawfully standardised in the code for grid connections and thus can be scaled to any business park. The implementation of a smart grid is not yet scalable to all business parks as not all assets have the required interfaces to be properly integrated (Firan, Appendix A). Albeit a matter of time before all interfaces are compatible, the application of smart grids is thus less scalable than the reference situation. This leads to the following scoring:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Scalability	0.25	0.25	0.25

Electricity price developments

This criterion is characterised by two aspects. The first aspect is the affordability of the electricity prices for consumers. The second aspect is the variability in electricity prices. An often mentioned benefit for consumers in smart grids is their ability to act upon price-signals, therefore lowering electricity costs (Print & Rights, 2015). In the cost optimisation scenario, a smart grid does so by alternating demand based on the electricity price. Therefore, this scenario has a small advantage in comparison to the reference scenario. In the other scenarios this is not the main objective of the energy management system, which is why there is no relative advantage. The electricity price in the Netherlands is determined by the national merit order (En:former, 2022). The variability in the electricity price is therefore determined at a national level. Implementing a smart grid on a business park is unlikely to have significant effect on the national merit order, and thereby the variability in electricity prices. Nonetheless, in theory a business park could form a local market, for which prices are established locally. This could result in more constant prices on a regional scale, but for now is primarily based on speculations. All the above results in the following scores:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Electricity price developments	0.75	0.5	0.5

Robustness

Another key characteristic of smart grids is their ability to increase power quality (Print & Rights, 2015). Due to the implementation of an advanced metering infrastructure the system is capable of effectively identifying the source of any voltage drops or outages. Moreover, smart grids help recover from these anomalies, and thus improve the supply quality (Innovation, n.d.). However, by adding an ICT based advanced metering infrastructure the system becomes vulnerable cyber components that could interrupt the operation as well (Zeynal et al., 2014). Therefore, the solution to one vulnerability results in the rise of another, effectively resulting in no gain in comparison to the reference scenario.

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Robustness	0.5	0.5	0.5

Promote trade

This criterion is the result of the initial split up of the electricity sector into regulated grids and a free market for trade. In the costs optimisation the objective of the system is to optimally make use of price differences. However, this is only half of the objective as the costs consist of both electricity costs and connection costs. In the dependency scenario the objective is to minimize the amount of electricity that in both directions is exchanged with the grid and thus minimize trade. The capacity scenario has no objective that is related to the trade of electricity. Taking the objectives of each scenario into consideration results in the following scores:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Promote trade	0.75	0	0.5

Ease of use and time consumption for the consumer

Managing and operating a smart grid is a complex process, which is generally not something to assign to business owners. It is therefore no wonder that all interviews agree that this task should be outsourced (Appendix A). This is a service which can be provided by an aggregator but could also be included in the services a DSO provides. However, in case of the latter one, legal changes are required to allow for this. In any case there is no longer any effort required from the business owners, besides the setup of the initial contract of cooperation. The scoring of this criterion is as follows:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
Ease of use and time consumption	1	1	1

DSO service quality

In the interviews with the DSOs it is mentioned that currently DSOs do not have a detailed enough insight in the consumption profile of individuals (Enexis, Appendix A; Liander, Appendix A). The implementation of smart grids provides them with these insights, allowing them to make better forecasts of the load profiles on sub-stations. Furthermore, it allows them to better utilise the free grid capacity, by providing products such as connections with dynamic capacities (Enexis, Appendix A). All in all, more detailed information of the electricity flows in a certain region enables the DSOs to provide more efficient products and services, resulting in the following scores:

Criteria	**Cost scenario**	**Dependency scenario**	**Capacity scenario**
DSO service quality	1	1	1

Fairness of operation

The same argument that applies to the service quality of the DSO applies to the fairness of operation criterion. Accurate insights in the consumption profiles of individuals enables system operation in a fair and cost-reflective manner. However, according to the CBS, already 59% of the companies is equipped with a smart electricity meter. This device already allows DSOs to accurately gather the consumption profiles of individuals.

Criteria	Cost scenario	Dependency scenario	Capacity scenario
Fairness of operation	0.75	0.75	0.75

6.4.2. Quantitative criteria

In the model a total of 180 different business park configurations is simulated. To show the range of outcomes, the minimum, maximum, and average score are provided. Furthermore, these scores are normalised on a scale of 0 to 1 so that they can be used in the final analysis.

Costs

For the costs criterion the optimization results (Appendix B), are only a part of the NPV calculation. The investment costs are dependent on the number of companies of a business park. In Table 18 an overview of the total investment costs for each business park type are given.

Table 18: Overview of investment costs for each business park type.

Business Park type	Number of buildings	Investment ($€_{2022}$)
High-Quality	20	26,363.80
Industrial	16	21,091.04
Logistics	34	44,818.46
Maritime	34	44,818.46
Mixed	14	18,454.66

The resulting minimum, maximum, and average NPV's for each scenario are given in Table 19. An overview of the NPV's for all business park configurations is given in Appendix F. The scores largely correlate to the profits that are noticed in the different optimisations. An explanation for the differences in profits for each configuration and optimisation is provided in section 6.3.

Table 19: NPV overview of the four scenarios.

Reference			Costs			Dependency			Capacity		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0	0	0	13.2	833	297	-236	-18.5	-72.6	-203	421	343

A normalised version of these scores is given in Table 20.

Table 20: Normalised scores based on the NPVs in Table 19.

Reference			Costs			Dependency			Capacity		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0.22	0.22	0.22	0.23	1.00	0.50	0.00	0.20	0.15	0.03	0.61	0.54

Free connection capacity

The scores for this criterion are extracted from the optimisation results. In specific from the 'peak' column of the heatmap in Appendix E, where the relative change in comparison to the reference scenario is provided. An explanation for the difference in scores is provided in section 6.3. Table 21 gives an overview of the minimum, maximum and average score for this criterion. Note that a reduction in peak in this case results in a higher score and vice versa.

Table 21: Overview of the percentage change in required connection capacity.

Reference			**Costs**			**Dependency**			**Capacity**		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0%	0%	0%	13%	-28%	-9%	0%	-16%	-2%	0%	-31%	-14%

A normalised version of these scores is given in Table 22.

Table 22: Normalised scores for the free connection capacity criteria.

Reference			**Costs**			**Dependency**			**Capacity**		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0.30	0.30	0.30	0	0.93	0.50	0.3	0.66	0.34	0.3	1	0.61

Grid dependency & Sustainability

As explained in section 5.5.2 the grid dependency and sustainability criteria can be scored by the same performance indicator. Like the previous criterion the score is directly extracted from Appendix E. In specific from the 'volume' column, which represents the absolute sum of electricity that is exchanged with the grid. Table 23 gives an overview of the minimum, maximum and average score for this criterion. As a reduction is desired, the max score is the largest reduction.

Table 23: Overview of the percentage change in total volume exchanged with the grid.

Reference			**Costs**			**Dependency**			**Capacity**		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0%	0%	0%	9%	-6%	0%	0%	-23%	-6%	12%	-12%	-1%

A normalised version of these scores is given in Table 24. Note that a reduction in volume in this case results in a higher score and vice versa.

Table 24: Normalised scores for the grid dependency and sustainability criteria.

Reference			**Costs**			**Dependency**			**Capacity**		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0.34	0.34	0.34	0.09	0.51	0.34	0.34	1	0.51	0	0.69	0.37

6.4.3. Stakeholder utility scores

In this section the scoring of the qualitative and quantitative criteria is combined into a multi criteria analysis for each stakeholder. Like mentioned in the method, this gives an answer to the main research question. It allows to examine the marginal gain or loss in utility for each stakeholder in comparison to the reference scenario and between optimisation scenarios. Below, the multi criteria analysis for each influential stakeholder is discussed.

DSO

Both Enexis and Liander indicated in their interview that the most important criteria is the availability of connection capacity (Enexis & Liander, Appendix A). These criteria are important because they are concerned with their core business of providing grid connections to consumers. Nowadays, congestion is one of the additional worries and closely relates to the availability of connection capacity. When asked for a ranking both DSOs gave first place to the connection capacity and a shared second place to the solution of grid congestion and the scalability thereof (Enexis & Liander, Appendix A). Table 25 shows an overview of the criteria of the DSO and the corresponding scores. Figure 29 is a visual representation of Table 25. The resulting total utility score of the DSO is in all scenarios higher than that of the reference scenario. There is one exception to this, which is the least performing version of the cost optimisation scenario. This is mainly due to the low score and relatively heavy weighting for the free connection capacity criterion. On average the DSO benefits from the implementation of a smart grid, no matter the optimization objective. However, on average the cost and capacity optimization should be most preferred, with a slightly higher utility score for the capacity optimisation scenario.

Table 25: Total utility score calculations for the DSO.

Scenario		***Reference***	***Costs***			***Dependency***			***Capacity***		
Criteria	*weight*	-	min	max	avg	min	max	avg	min	max	avg
Free connection capacity	0.50	0.30	0.00	0.93	0.50	0.30	0.66	0.34	0.30	1.00	0.61
Timing of solution grid congestion	0.25	0.50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Scalability	0.25	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total utility	-	**0.40**	**0.25**	**0.72**	**0.50**	**0.40**	**0.58**	**0.42**	**0.40**	**0.75**	**0.56**

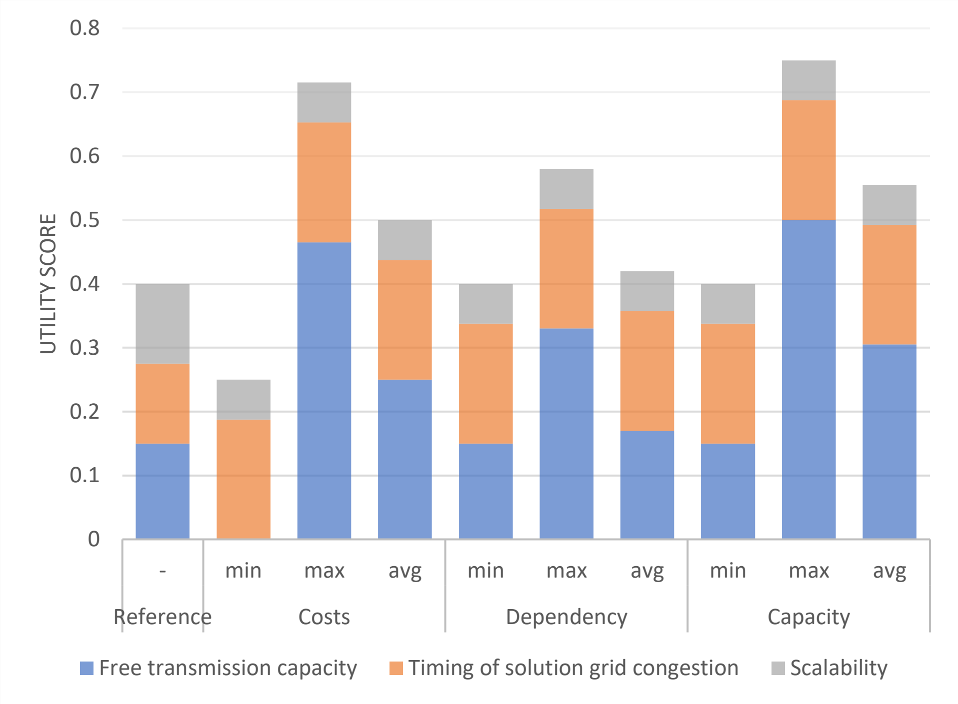

Figure 29: Overview of the utility scores for the DSO.

NPRES

In Table 26 the criteria scoring and weights of the NPRES are provided. A visual representation is given in Figure 30. This stakeholder indicated that all criteria are equally important, hence the equal weights (NPRES, Appendix A). All optimization scenarios on average outperform the reference scenario. Furthermore, all maximum utility scores of each scenario are almost equal. Only the grid dependency optimisation scores 0.01 lower on total utility. Despite this minor difference, the minimum utility of this scenario is the only one achieving a higher utility score than the reference scenario. Nonetheless, the minimum utility scores of the cost and capacity optimisation scenarios are 0.01 and 0.02 lower, respectively.

Table 26: Total utility score calculations for the NPRES.

Scenario		***Reference***	***Costs***			***Dependency***			***Capacity***		
Criteria	*weight*	-	min	max	avg	min	max	avg	min	max	avg
Free connection capacity	0.25	0.30	0.00	0.93	0.50	0.30	0.66	0.34	0.30	1.00	0.61
Grid dependency	0.25	0.34	0.09	0.51	0.34	0.34	1.00	0.51	0.00	0.69	0.37
Timing of solution grid congestion	0.25	0.50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Electricity price developments	0.25	0.50	0.75	0.75	0.75	0.50	0.50	0.50	0.50	0.50	0.50
Total utility	-	**0.41**	**0.40**	**0.74**	**0.59**	**0.47**	**0.73**	**0.53**	**0.39**	**0.74**	**0.56**

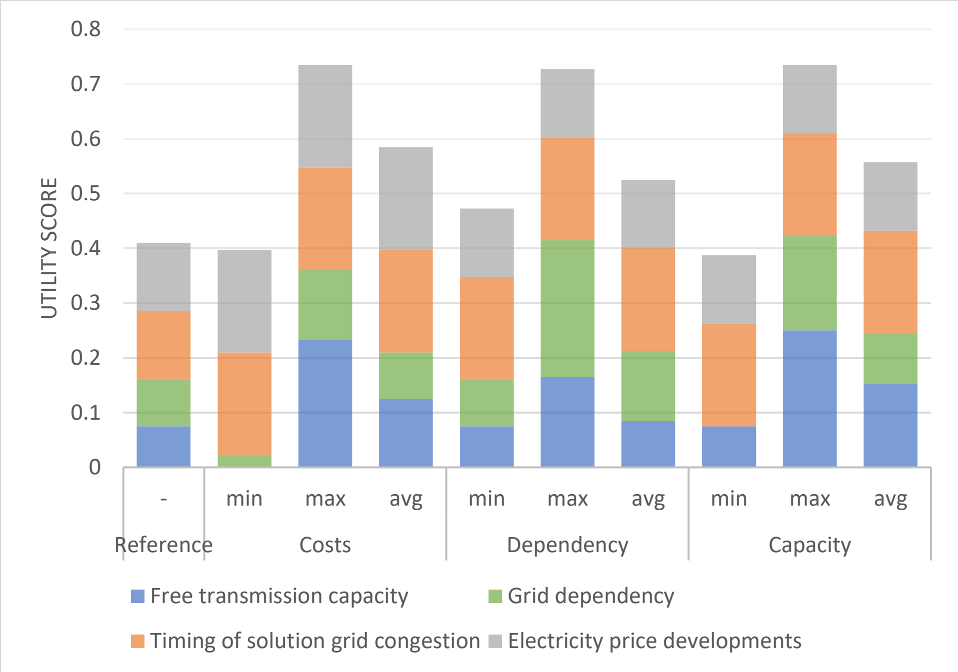

Figure 30: Overview of the utility scores for the NPRES.

Regulator

The interests of this stakeholder only concert qualitatively scored criteria. Therefore, there is no difference in minimum, maximum and average utility scores within each optimisation scenario. The criteria and corresponding scores of the regulator are provided in Table 27 and visually shown in Figure 31. The reference scenario has a lower utility score than all scenarios. This indicates that the regulator gains utility of implementing a smart grid, no matter the optimisation. This is predominantly the effect of the improved ease of use for the consumer and the improved service that can be provided by the DSO. The mutual difference between the non-reference scenarios arises from the trade promotion criterion. Although the capacity optimisation has no effect on trade stimulation the cost optimisation promotes trade, whereas the dependency optimisation does not.

Table 27: Total utility score calculations for the regulator.

Scenario		***Reference***	***Costs***			***Dependency***			***Capacity***		
Criteria	*weight*	-	min	max	avg	min	max	avg	min	max	avg
Robustness	0.20	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Promote trade	0.20	0.50	0.75	0.75	0.75	0.00	0.00	0.00	0.50	0.50	0.50
Ease of use	0.20	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DSO service quality	0.20	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fairness of operation	0.20	0.50	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total utility	-	**0.50**	**0.80**	**0.80**	**0.80**	**0.65**	**0.65**	**0.65**	**0.75**	**0.75**	**0.75**

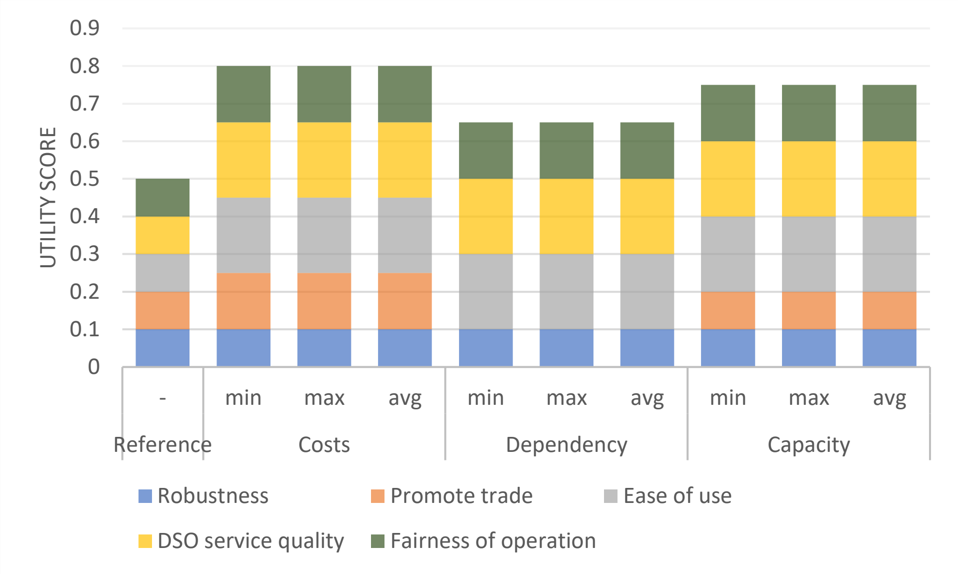

Figure 31: Overview of the utility scores for the regulator.

Business owners

In Table 28 the criteria, weights and scores for business owners are combined. Figure 32 gives a visual representation. An overview of the calculation of the weights is given in section 4.2. Only the minimum total utility scores of the cost and capacity optimisation are lower than the reference utility score. These are, however, outliers as on average these optimisations achieve higher utility scores. Moreover, the maximum utility score of the cost optimisation is the highest of all utility scores. The grid dependency optimisation always outperforms the reference situation. However, the maximum and average score of this scenario is lower than the maximum and average utility score of the two other optimisations. The main difference is found within the scores of the cost criteria, which after robustness has the highest weighting. Whether there should be a preference for either the cost or capacity optimisation scenario is dependent on the configuration of the business park. Although the maximum score of the cost optimisation is the highest, the utility score of the capacity optimisation is higher on average.

Table 28: Total utility score calculations for the business owners.

Scenario		***Reference***	***Costs***			***Dependency***			***Capacity***		
Criteria	*weight*	-	min	max	avg	min	max	avg	min	max	avg
Costs	0.23	0.22	0.23	1.00	0.5	0	0.2	0.15	0.03	0.61	0.54
Sustainability	0.19	0.34	0.09	0.51	0.34	0.34	1.00	0.51	0.00	0.69	0.37
Free transport capacity	0.14	0.3	0	0.93	0.5	0.3	0.66	0.34	0.3	1.00	0.61
Time consumption	0.13	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Robustness	0.31	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total utility	-	**0.38**	**0.36**	**0.74**	**0.53**	**0.39**	**0.61**	**0.46**	**0.33**	**0.70**	**0.56**

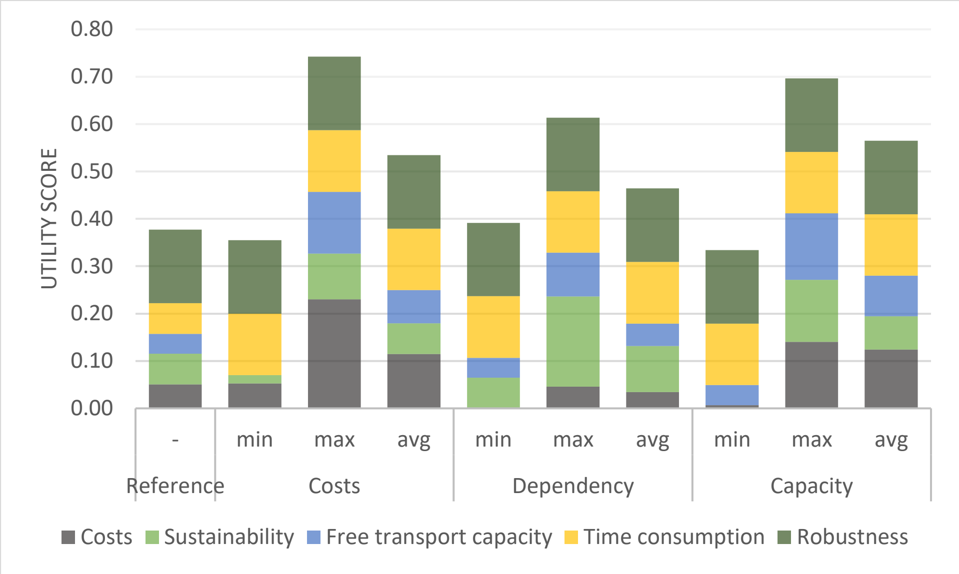

Figure 32: Overview of the utility scores for the business owners.

7. Discussion

This chapter discusses the limitations of this research. Furthermore, it addresses the possibilities for future research and provides an overview of the theoretical implications of this research.

7.1. Limitations and uncertainties

Several input data of the model have limitations. The main objective of the model is to effectively forecast the benefits of a smart grid over a year. Especially the time series inputs, but also the connection costs and average annual electricity consumption, are a good example. These inputs are based on present or historical data, however, that does not give any guarantee that they remain the same in the future. The most striking example is the recent electricity price developments due to geopolitical tensions (Nieuws, 2022). Such developments have impact on the benefits that can be achieved by smart grids. However, providing accurate predictions of future developments is difficult, especially in a high development sector. Nonetheless, the model used in this research can still be applied when input data changes.

Another limitation of the model is the simplifications and assumptions to display the effects of implementing a smart grid for a broad range of business park configurations. These simplifications and assumptions include the simplified version of modelling the flexible load and the assumption on the size of the flexible load and batteries. This research assumes that all flexible load is balanced over a time span of 24 hours. However, the assets capable of providing flexible load have more specific availability hours. For example, an electric vehicle is not likely to provide flexible load outside of working hours. Albeit the 24-hour period is a well-educated assumption for the aggregated flexible load, a more detailed model would provide more accurate results. A more detailed model should simulate each flexible load providing asset separately. However, the aim of this study was to provide an overview of the system benefits. A detailed method of modelling would have required too much computing power in the model of this research. It is a concept that can be explored in future research, which is described in section 7.3.

Lastly, in this research it is assumed that the consumption profiles of individuals of a business park can be aggregated. In reality, not all entities on a business park are directly connected to each other. There are two possible workarounds to this. The first one is to physically adapt the grid infrastructure, for which a closed distribution system exemption should be obtained from the regulator. The second workaround is to virtually bring all parties together by means of a virtual net, under the assumption that the grid infrastructure of the DSO already aggregates consumption at a sub-station. Unfortunately, private usage of a publicly regulated grids – to which other parties might also be connected – is within current legal boundaries not allowed. However, here too applies that an exemption can be made by the regulator. Moreover, the virtual net approach is supported by both aggregators and DSOs and thus likely to be standardised in the future.

7.2. Theoretical and practical implications

This research adds to the theoretical body of smart grids assessment by taking a stakeholder-based approach. By using a mixed method approach to construct a utility score for each stakeholder their quantitative and qualitative considerations can be expressed in a combined score. In contrast to previous research, this gives a more complete and holistic approach to the assessment of smart grid implementations at business parks. This approach is not only valid for smart grid assessment but could also be applied to the assessment of other technologies where there is a multitude of stakeholders with differing interests.

Furthermore, this research evaluates the effects of implementing a smart grid for a broad range of business park configurations. Furthermore, it analyses the differences between three optimisation objectives that can be given to the energy management system. This provides most of the business parks in the Netherlands an estimate of the benefits and disadvantages that the implementation of a smart grid would have. Moreover, it gives insights in the additional benefits that can be gained by adapting the configuration of the business park. Similarly, if development plans for the configuration are already established, it provides a preliminary insight. Lastly, this research provides the relevant stakeholders with an assessment framework that could be used to fuel the discussion between stakeholders. Likewise, it can be used for setting up contracts and agreements when implementing a smart grid.

7.3. Future research

In scoping this research, it was decided to only focus on electricity as an energy carrier. However, despite the electrification trends, other energy carriers could also play a role in smart grids operations. Therefore, future research could build upon this research by adding other energy carriers, such as renewable gas and hydrogen.

Besides, this research focussed on three optimisation scenarios. However, based on the results it could be interesting to have combined optimisation objectives. For example, in the connection capacity minimisation it is seen that assets are only utilised during peak periods. Outside these periods it could be interesting to give another optimisation objective to the system, so that additional benefits can be achieved. Future research could provide more elaborate insights into what extent optimisations can be combined and quantify the additional benefits thereof.

As mentioned in the first section of the discussion several assumptions and generalisations are done to assess the impact of implementing a smart grid for a wide variety of business park configurations. This shows general trends between different configurations for the different optimisations. However, when considering implementation for a specific business park, a detailed case study might be of value. Future research could then provide more accurate insights by modelling the park at issue on a more detailed level. This primarily entails modelling all flexible load providing assets separately and using consumption profiles of the respective park. Furthermore, it includes a more qualitative analysis of consumer aggregator contracts, so that it is optimised for the specific business park.

Lastly, some model inputs are based on present or historical data, however, that does not give any guarantee that they remain the same in the future. Albeit hard to predict how these inputs will develop, a scenario study could provide additional insight in the results of the scenarios that are likely to happen.

8. Conclusion

This research aimed to provide insights in the effects on the utility of the relevant stakeholders is for implementing a smart grid at a business park. In the Netherlands 5 types of business parks are distinguished, each with a typical combination of commercial activities that take place at the park. Furthermore, business parks can vary in their technical composition in the amount of solar production, flexible load and battery capacity that is available. Moreover, the optimisation objective that is given to the energy management system determines the operational management. In this research a cost minimisation scenario, grid dependency minimisation scenario, and connection capacity minimisation scenario are examined.

Besides the multitude in configurations there are multiple relevant stakeholders when it comes to implementing a smart grid. The most influential stakeholders are the business owners located at the park, the DSO, local and national authorities, and the regulator. Their utilities are expressed in a multi criteria analysis, consisting of both qualitative and quantitative criteria. In the qualitative results it is seen that the implementation of a smart grid is in all scenarios beneficial in combating grid congestion, easy to use due to aggregator services, and improves the quality of service a DSO can offer. Furthermore, the additional insights that result from the advanced metering infrastructure allow for an increased fairness of operation in comparison to the reference situation. In the cost optimisation scenario, it also promotes trade, whereas in the grid dependency minimisation it does not. In the capacity minimisation there is no change. The only criterion that does not benefit from the implementation of a smart grid is the scalability. This is due to the interface incompatibility of system components but is a matter of time before they are compatible.

The quantitative criteria are examined in the model. In the cost optimisation it is seen that in comparison to the reference scenario the cost decrease on average by 16%. This is mainly due to savings on connection costs in combination with price arbitrage that is captured by the flexible load and batteries. In configurations with large batteries the grid dependency increases as extra electricity is traded to capitalise on the price arbitrage. Due to more than half of the costs savings being the result of a reduction in connection costs it is seen that typically the required grid connection capacity also declines.

In the grid dependency scenario, it is seen that the total volume that is exchanged with the grid decreases up to 23% for configurations with large solar production. In the configurations where solar production does not often exceed demand, little savings are achieved on either cost, total volume exchanged with the grid or the required connection capacity. The configurations with lots of solar generation display a reduction in solar electricity that is injected into the grid, increasing self-sufficiency. This also results in less grid connection capacity that is required. The costs for these configurations increase by up to 13% due to extensive use of the batteries and a negative price arbitrage for the time over which electricity is redistributed.

In the connection capacity minimisation scenario, it is seen that the required connection capacity can be decreased by 31% at most and 14% on average. In the configurations where solar production often exceeds demand a cost increase is common and vice versa. A reduction in costs is the result of reduced connection costs. An increase is the result of round trip-efficiency losses and the same negative price arbitrage as in the grid dependency scenario. On average this results in no change in costs over all configurations. The total volume exchanged with the grid increases in the configurations with little solar production due to round trip efficiency losses of the battery. In configurations with large solar production there is less dependency on the grid due to an increase in self-consumption.

After combining the scores and weights of the criteria for each stakeholder it is seen that almost all utility scores of each optimisation scenario for all influential stakeholders is higher than the utility score of the reference scenario. There are some minimum scores which are lower, but on average the implementation of a smart results in an increase in utility score. This indicates that on average each stakeholder benefits from the implementation of a smart grid. When making a comparison between scenarios the cost and capacity optimisation scenarios outperform the grid dependency optimisation. The DSOs then prefer the capacity optimisation the most, whereas the NPRES and regulator prefer the cost optimisation. For the business owners it depends on the configuration of the business park whether they prefer the cost or capacity optimisation.

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Appendix A (Interview summaries)

Summary Enexis (1 & 2)

- A smart grid is a demarcated area where the grid is smartly controlled by means of measurement and control technology in combination with ICT. Furthermore, it can be the binding factor to facilitate local cooperation.
- The current procedure for Enexis when congestion occurs is first to apply congestion management. In congestion management the DSO engages in active steering of individual parties' demand, for which a compensation is given (bilateral agreement).
- It is also possible to set up a non-firm ATO. This is a more advanced bilateral agreement in which parties are allowed to lay claim at more connection capacity, however only in certain timeslots during the day. This corresponds to a dynamic capacity contract, which is possible to offer after the implementation of a smart grid. However, currently it is legally not allowed. Nonetheless, in congested area's exemptions can be made.
- Another option is the appointment of an aggregator that on a substation detailed level manages and balances energy flows.
- The last option is to privatize the local distribution grid and have one large connection with the regulated grid. These kinds of systems are better known as closed distribution systems.
- Closed distribution systems are unpreferred by DSO's. This is because permissions for these systems are granted for 10 years. After that they can be prolonged, but also be terminated. When they are terminated, the grid is reassigned to be once again managed by the DSO. Often the cabling and technique is not according to DSO standards, making it difficult to reintegrate the closed distribution system.
- Currently the DSO's have mathematical models running to estimate the load on each substation, but this can be way more accurately done by managing in real time, which is the case in a smart grid.
- Appointing an aggregator seems the most promising option. The aggregator can then make agreements with the DSO on grid usage at aggregated level and agreements with individual parties on a more detailed level. However, this is legally not (yet) possible.
- The innovation department of the DSO is trying to develop products or services that better facilitate the usage of free connection capacity. Currently the free connection capacity is determined based on the peak in consumption. However, the consumption profiles are dynamic, and peaks often only occur once. We can then either lower the peak to have a larger bandwidth of free capacity or offer a dynamic connection capacity (that varies over time).
- So, in the end there is all kinds of flavors to solve congestion and the best option might vary for each case. That does not necessarily form a problem; however, it is important that the solutions are scalable. In other words, a mechanism that solves congestion can be favorable to only a single case, but in theory it should be applicable to any scenario.
- The primary objective of the DSO is to connect as much parties as possible, which can be done by efficiently using the grid. This is not always in control of the DSO, but she aims to have the right incentives in place to do so. Some incentives turn out to be more beneficial than others and now we're trying what and which works best.

The main difficulty resides in the fact that the incentives might need to vary over time.

Summary Liander

- The definition "Smart grids" has become an umbrella term.
- Smart is threefold. 1st is being able to monitor what happens on the grid. 2nd is interpreting and acting based on the data. 3rd is a feedback loop over 1st and 2nd.
- Technologically speaking all these things are already possible.
- Toughest challenge is the organizational aspect. Both the financial organization and the agreements that need to be set up.
- Questions like who is making the initial investment and how are benefits divided over the partaking companies seem unable to answer.
- Furthermore, are governments and DSO allowed to co-finance?
- The best approach to solution seems to be to appoint an energy service company (ESCO) or aggregator. This is to unify interests and enable business parks to act as an individual entity.
- Another challenge is the absence of regulation on applying smart ICT technologies. Regulation seems to be outdated and currently only dictates DSO's to be non-discriminatory. Regulation for more effective use of the grid must be developed.
- DSOs are actively participating in testing grounds with the objective to make transport capacity more flexible. All with the main objective to create opportunities to connect more parties to the grid. Examples are dynamic pricing and discounts on contracts with less security of supply (might be that the desired capacity is not always available)
- However, the main challenge with these solutions is their scalability. Each testing ground is different, how do we develop a single solution that can be applied to all cases?
- In essence, the main aim of the DSO is to create as much free capacity as possible to connect as much parties as possible. Currently DSO do not have a detailed enough insight in the consumption of individual parties, which is why they make an estimate for each substation. By having more information this can be done way more accurate.
- Nonetheless, having the information does not enable the DSO to also steer demand. For this purpose, the designation of a ESCO or aggregator is convenient. They can invest in smart technologies behind the meter, whereas the DSO cannot due to regulations.
- Under current regulation the dynamic pricing is also not allowed. However, if an area experiences grid congestion exemptions can be made.

Summary NPRES

- First, let me start by mentioning that lately smart grids have become an umbrella definition. An upcoming definition is the term energy hubs (which basically entails the same, as it entails the same umbrella terminology).
- For me it entails a geographical location in which there is exchange of energy and organizing that in an "optimal" manner.
- Also, from a governmental perspective there is increasing attention for promoting development of the system, instead of only renewable sources. This of course

became evident after the huge spurge in decentralized renewable production, which led to grid congestion.

- The TKI-programme for system integration is now considering subsidies and policies for promoting system integration.
- The challenge we face in the RESsen is how advanced metering- and control technology should be applied to fasten the energy transition.
- What we see as most important from a (NP)RES perspective for smart grids is that it enables the potential of renewable generation in an area to be used for consumption in the same area. Renewable production is not a goal on itself, it is to satisfy the demand by means of renewable production. By placing solar and wind energy near consumption we can achieve this. However, to optimally manage the increasing flows of electricity smart infrastructure could be the solution.
- By organizing the energy balance locally, we create local markets as a replacement for the national market we know now. These “micro markets” are then easy to manage by means of smart grids. However, this requires some change:
    - Socially: how to organize such a concept?
    - Financially: The worth of the system shifts from volume based to power based, as this is more important for locally balancing the energy.
    - Institutional: Who manages these systems? How are these systems regulated?

  When the answers to these questions are found, an area can be extremely enriched by implementing a smart grid. The overall objective of this system formation is to have the national backbone in place but create local pockets that minimize their grid dependency. This goes both ways as they should rely on importing from the grid as little as possible, but also rely as little as possible for exporting to the grid.
- The optimal combination is a holarchic structure in which local ‘pockets’ become as little dependent on the centralised grid as possible.
- The three criteria that are equally important in this challenge are:
    - Current congestion should be solved as fast as possible because it is hampering the developments.
    - Regions should become less dependent on the grid, so that local communities are created.
    - Having more constant prices for energy. Current prices are killing for consumers, and we can’t have that.
- The Netherlands is split up into 30 regions, each being responsible for its of energy strategy towards zero emissions. Above these individual regions there is a national consortium (national program regional energy strategies). The functioning of this national program is mainly facilitating and somewhat framing. We focus on collective knowledge for fixing communal challenges within the energy infrastructure. Furthermore, we try to support all regions in achieving their renewable production goals. A more and more dominant criteria is regional system efficiency. So not to deploy solar and wind energy to produce as much renewable electricity as possible, but because it has a regional function (red; there is also consumption of this energy).
- In the end it is each region individually that determines their own strategy, but we do provide basic guidelines and knowledge. I notice that this communal approach is appreciated.

Summary ACM (regulator)

- The regulator is mainly concerned with smart grids due to regulation of private grids. A smart grid can be applied in both a closed distribution grid (private) and the regular distribution grid (public). Private grids are only allowed with an exemption from the regulator. There are some prerequisites that should be fulfilled to be eligible for an exemption. The main prerequisites are:
    - No residential parties within the grid
    - No more than 500 connected parties
    - The production process of all parties must be coherent
        - Often chemical sites (like Chemelot)
- Based on the last criteria almost all business parks are excluded of being eligible for an exemption.
- The regulator confirms the search of the DSOs for mechanisms that unlock demand side flexibility. One of these mechanisms are adaptations in tariff structures. As of right now the tariff structure is not aimed at efficiently using the already installed connection capacity.
- The main legal body that provides regulation for all that concerns electricity is the Electricity Law. Within this law several codes are drafted, of which one is the tariff code. In the tariff code all regulations regarding the tariff structures are written down. Changing these codes and/or electricity law is a long and tedious process in which all alternatives should be considered properly. A lot of testing and research is done, but all in all its an enormous effort that takes time.
- When a code needs changes, it is up to the DSOs to propose an alternative, for which they must interact with the relevant stakeholders. The proposal is then taken into consideration by the regulator and weighed on the criteria in article 36 of the Electricity law. This is an iterative process of which the final product is a new code. This process is fastened due to the regulator already actively taking place in the working groups where a new proposal is being drafted. By doing so, possible shortcomings can be identified in an early stage.
- Each criteria in article 36 is equally important because these are regulations that all should be fulfilled.
- The main regulatory barrier for implementing smart grids at business parks are the required changes in the codes to optimally make use of the grid. The proposed new code should be carefully weighed on all criteria of article 36, which is a long and precise process. All criteria are equally important.

Summary Spectral (aggregator)

- When implementing a smart grid each party is equipped with an advanced meters and a central industrial computer is installed to direct these meters.
- Currently it is legally not allowed to implement a smart grid that at a business park that is connected to the distribution grid. However, now that grid congestion is occurring more and more frequently exceptions are made within congested areas. Nonetheless this is only for a trial period, so that the results can be used for constructing new regulations.
- Besides this legal barrier Spectral also foresees a possible technical hiccup. Beforehand all assets within an energy system were managed individually. By implementing a smart grid all assets should cooperate, which requires all assets to

have complementary interfaces. This is not yet always the case and thus API’s sometimes need updating to be compatible within smart grids. However, this should only be a matter of time.

- When implementing a smart grid at a business park it is most common to assign an aggregator that set ups a contract with each entity. This process is complex and takes time. It roughly takes 1-2 years to complete the full process of implementing a smart grid and agree on all contracts.
- Due to the current application of smart grids only being allowed in congested areas the focus is to decongest the grid. However, a smart grid could also be used to minimize costs or maximize self-sufficiency.
- If choosing to combat congestion, it is worthwhile to analyze the loads of a substation instead of only the business park. The business park is only part of the load that is handled by the substation and the substation typically is the point of congestion.
- When analyzing the costs of a smart grid implementation it is important to look at the contracts of each individual party. There are two possible contract configurations within a smart grid. The first one is an aggregated contract, where all individual parties have a contract with the aggregator and the aggregator has a contract with the supplier. The second form consists of all parties having an individual contract. In this form it is financially beneficial to utilize the contract with the lowest costs as much as possible. This can be managed by an aggregator. The most elegant and simple form is the first one. Having simple contracts makes it easier to quickly set up all the required agreements to implement a smart grid.
- It is also possible to aggregate assets and use them to trade at the imbalance and day-ahead markets. It makes most sense to do this on an aggregated level so that large capacities/volumes can be traded. The imbalance markets have strict regulations and trading on these markets is hard to combine with volume-based trading.
- There are multiple assets that can provide flexible load. The most important one is batteries, which are basically fully dedicated to providing flex power. Furthermore, there is charging stations, heating, cooling and sometimes ATES. If this is already managed by a building energy management system, it is often possible to connect to the energy management system of a smart grid. Otherwise, some additional measurement and control technology might be required.
- Implementing a smart grid at business parks where there is park management is easier than where there is no park management. This is mainly due to the cohesion between all companies, which is already present when there is park management.

Summary Firan (smart system developer)

- Smart grid developers are mostly approached by individual parties or initiatives, but also by municipalities. The latter one is somewhat odd, as they are not a typical client for implementing a smart grid. This is mainly due to the municipality having a facilitating role for companies that are established in their area. Now that companies can have a hard time settling in certain area’s due to grid congestion, they approach the municipality to find solutions. The municipality wants a strong business climate and thus forwards these challenges to the market.

- Technically, the implementation of smart grids is already fully feasible. All individual components are familiarized nowadays and at most there might be some challenge in putting them all together. This should not be more than configurating API's/protocols of different systems to be compatible. Nonetheless, there are already some known use cases.
- For example, in our smart grid control platform it is all about balance and each asset within a system can be equipped with the necessary metering and control infrastructure to virtually balance a grid.
- If this approach is applied to business parks each company is equipped with smart meters, and as they are all connected to the same grid, we then balance the grid. Currently each company has its own connection and its own contract, but in the future, we could manage this in a collective manner. This is done by means of a 'virtual connection' which is the collective connection for a whole business park. This concept is physically applied in a closed distribution system, there they have a physical collective connection instead of a virtual one. The advantage of having a virtual one is that it can be realized in a much shorter timeframe, as there is no need to adapt the physical energy infrastructure.
- By implementing the smart grid, each company can have a more dynamic profile for the connection capacity that is reserved for them. Currently this is a static range that is reserved for any point in time. Having a smart grid gives more certainty that the system is in balance and that the capacity boundaries of cables and substations are not exceeded.
- From a financial perspective smart grid are also ready for implementation. However, challenges remain in the agreements and decision that should be made by a multitude of entities. This often results in organizational challenges as all partaking companies should agree on the configuration. In practice there can be numerous of reasons why parties don't want to collaborate. In the end each party has its own interests and considerations.

Summary Semper Power (service provider)

- The main benefits Semper Power sees in the application of a smart grid is the alternative it provides for a grid connection. Especially now that connection capacity is becoming rare this is a worthy alternative. Furthermore, it could provide financial benefits in the future, however, that is somewhat speculative. This is based on the opportunities and incentives that arise for individuals that can be self-sufficient.
- Now the incentives are too much focused on purely having renewable generation. For example, the SDE++ is providing a steady source of income for renewables as it closes the financial gap between investments and market prices.
- Nonetheless, policies could shift these incentives and therefore fasten the process towards local management. Currently we are used to being able to ask the DSO for a larger grid connection, making the installation of solar panels always renumerating within a reasonable timeframe. However, by shifting these incentives, it could become only beneficial if the generated electricity is also used locally.
- Let us assume a business park without a grid connection, but only with a battery so that loads are managed locally. The financial outcome is unfavorable, mainly due to the battery being underused for most of the time. The revenues can then be enlarged by trading in other energy markets with the free battery capacity. However,

the operational management of this concept is extremely complex and sometimes not even compatible with the restrictions that come with trading in the imbalance markets.

- Furthermore, the markets are currently quite volatile and can quickly change. This makes it difficult to predict which markets are most profitable over time. It is possible to switch strategies and markets over time, however, that requires a heavy time investment to monitor all relevant markets. This is a service that could be provided by market parties such as Semper Power. By remotely accessing the EMS of an energy system this battery operation strategy service is part of a local energy management service that could be provided by aggregators.
- A battery can be used to operate in multiple markets, but the principle is to split the capacity into multiple "virtual" batteries. There are two main services a battery can provide:
  1. Support the frequency of the grid
  2. Charge and discharge electricity

  The first relates to trading within the imbalance markets and comes with very strict regulations. Capacity that is reserved for frequency regulations should be always available and can therefore not be combined with buying and selling electricity.

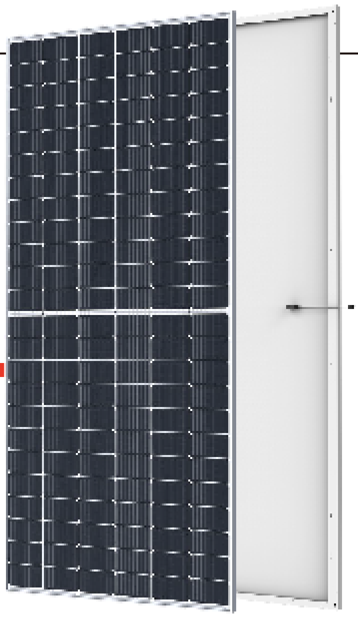
Appendix B (Datasheet solar panels)

Mono Multi Solutions

THE

TALLMAX[M]

FRAMED 144 LAYOUT MODULE



PRODUCTS	POWER RANGE
TSM-DE17M(II)	440-465W

144 LAYOUT
MONOCRYSTALLINE MODULE

440-465W
POWER OUTPUT RANGE

21.3%
MAXIMUM EFFICIENCY

0~+5W
POSITIVE POWER TOLERANCE

Founded in 1997, Trina Solar is the world's leading total solution provider for solar energy. With local presence around the globe, Trina Solar is able to provide exceptional service to each customer in each market and deliver our innovative, reliable products with the backing of Trina as a strong, bankable brand. Trina Solar now distributes its PV products to over 100 countries all over the world. We are committed to building strategic, mutually beneficial collaborations with installers, developers, distributors and other partners in driving smart energy together.

Comprehensive Products and System Certificates

IEC61215/IEC61730/IEC61701/IEC62716
ISO 9001: Quality Management System
ISO 14001: Environmental Management System
ISO14064: Greenhouse Gases Emissions Verification
ISO45001: Occupational Health and Safety Management System

Trinasolar

High power

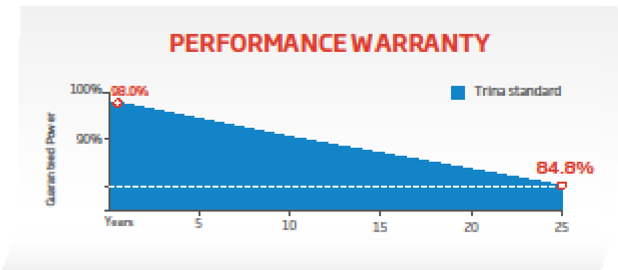
- Up to 465W front power and 21.3% module efficiency with half-cut and MBB (Multi Busbar) technology bringing more BOS savings
- Lower resistance of half-cut and good reflection effect of MBB ensure high power

High reliability

- Ensured PID resistance through cell process and module material control
- Resistant to salt, acid and ammonia
- Mechanical performance: Up to 5400 Pa positive load and 2400 Pa negative load

High energy generation

- Excellent IAM and low light performance validated by 3rd party with cell process and module material optimization
- Better anti-shading performance and lower operating temperature



Appendix C (Datasheet inverter)

SG110CX Premium

SUNGROW
Clean power for all

Multi-MPPT String Inverter for 1000 Vdc System

HIGH YIELD

- 9 MPPTs with max. efficiency 98.7%
- Compatible with bifacial module
- Built-in PID recovery function

SMART O&M

- Touch free commissioning and remote firmware upgrade
- Smart IV Curve diagnosis*
- Fuse free design with smart string current monitoring

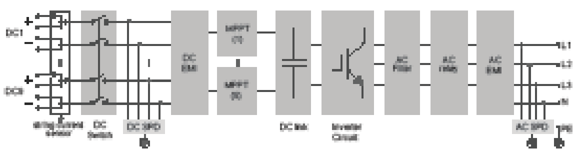
SAVED INVESTMENT

- Compatible with Al and Cu AC cables
- DC 2 in 1 connection enabled
- Q at night function

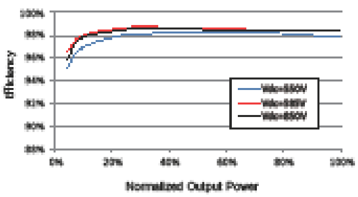
PROVEN SAFETY

- IP66 and C5 anti-corrosion
- DC Type I+II SPD, AC Type II SPD
- AFCI function protects system safety

CIRCUIT DIAGRAM



EFFICIENCY CURVE



Appendix D (Optimisation results)

park	solar	battery	flex	reference				cost optimization				self consumption optimization				minimize peak optimization			
criteria				costs	volume	min	max	costs	volume	min	max	costs	volume	min	max	costs	volume	min	max
unit				€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW
High Quality	0%	0%	5%	711,816	16,623,234	913	3,628	698,762	16,623,234	904	3,447	711,816	16,623,234	913	3,628	708,860	16,623,234	867	3,447
			10%	711,816	16,623,234	913	3,628	686,416	16,623,234	856	3,265	711,816	16,623,234	913	3,628	701,718	16,623,234	822	3,265
			15%	711,816	16,623,234	913	3,628	674,755	16,623,234	809	3,084	711,816	16,623,234	913	3,628	690,291	16,623,234	776	3,084
		10%	5%	711,816	16,623,234	913	3,628	677,019	16,702,613	541	3,182	711,816	16,623,234	913	3,628	701,356	16,718,043	511	3,182
			10%	711,816	16,623,234	913	3,628	666,096	16,696,511	493	3,005	711,816	16,623,234	913	3,628	693,795	16,733,904	458	3,005
			15%	711,816	16,623,234	913	3,628	658,007	16,693,024	446	2,892	711,816	16,623,234	913	3,628	688,053	16,732,756	414	2,892
		30%	5%	711,816	16,623,234	913	3,628	648,590	16,842,386	-185	2,896	711,816	16,623,234	913	3,628	684,616	16,684,123	0	2,896
			10%	711,816	16,623,234	913	3,628	641,495	16,844,362	-232	2,793	711,816	16,623,234	913	3,628	682,996	16,650,495	187	2,793
			15%	711,816	16,623,234	913	3,628	635,112	16,854,451	-280	2,711	711,816	16,623,234	913	3,628	677,232	16,674,761	542	2,711
	25%	0%	5%	564,841	12,330,030	-1,316	3,393	551,879	12,323,758	-1,237	3,224	571,568	12,259,532	-1,237	3,393	562,639	12,339,870	-1,395	3,224
			10%	564,841	12,330,030	-1,316	3,393	538,963	12,332,507	-1,261	3,054	576,175	12,197,761	-1,158	3,393	559,529	12,379,945	-1,264	3,054
			15%	564,841	12,330,030	-1,316	3,393	527,196	12,356,607	-1,316	2,884	579,028	12,144,416	-1,079	3,393	551,511	12,433,538	-1,330	2,884
		10%	5%	564,841	12,330,030	-1,316	3,393	525,153	12,481,810	-1,569	2,884	571,237	12,103,934	-1,008	3,393	548,231	12,264,389	-1,389	2,884
			10%	564,841	12,330,030	-1,316	3,393	513,825	12,521,485	-1,624	2,736	574,926	12,060,621	-1,111	3,393	541,004	12,336,340	-1,438	2,736
			15%	564,841	12,330,030	-1,316	3,393	504,342	12,573,852	-1,679	2,652	577,787	12,022,061	-930	3,393	534,472	12,480,626	-1,528	2,652
		30%	5%	564,841	12,330,030	-1,316	3,393	491,752	13,082,977	-2,295	2,635	571,752	11,944,216	-1,097	3,393	541,198	13,069,445	-2,281	2,635
			10%	564,841	12,330,030	-1,316	3,393	484,050	13,097,887	-2,228	2,549	575,285	11,927,510	-904	3,393	540,433	13,603,578	-2,234	2,549
			15%	564,841	12,330,030	-1,316	3,393	478,352	13,113,502	-2,262	2,488	579,851	11,917,870	-987	3,393	535,443	13,763,156	-2,347	2,488
	50%	0%	5%	433,326	13,193,822	-4,210	3,393	420,368	13,089,825	-4,131	3,224	436,408	12,757,536	-4,131	3,563	437,972	13,001,597	-4,131	3,563
			10%	433,326	13,193,822	-4,210	3,393	407,358	12,999,002	-4,052	3,054	438,887	12,336,856	-4,052	3,628	446,424	12,789,809	-4,052	3,628
			15%	433,326	13,193,822	-4,210	3,393	394,959	12,927,518	-3,973	2,884	440,365	11,934,028	-3,973	3,628	450,487	12,566,145	-3,973	3,628
		10%	5%	433,326	13,193,822	-4,210	3,393	392,053	13,050,573	-3,869	2,861	437,140	12,085,031	-4,131	3,563	434,609	12,895,788	-3,768	3,339
			10%	433,326	13,193,822	-4,210	3,393	379,965	12,985,005	-3,952	2,696	434,473	11,680,174	-4,052	3,481	437,709	12,674,222	-3,690	3,399
			15%	433,326	13,193,822	-4,210	3,393	370,617	12,930,453	-4,036	2,616	439,907	11,294,379	-3,973	3,616	441,769	12,445,452	-3,611	3,535
		30%	5%	433,326	13,193,822	-4,210	3,393	355,547	13,115,694	-4,595	2,595	440,861	10,876,058	-4,131	3,563	422,795	13,120,580	-3,043	3,043
			10%	433,326	13,193,822	-4,210	3,393	347,435	12,955,230	-4,678	2,512	439,328	10,506,826	-4,052	3,481	424,685	12,408,787	-2,964	2,964
			15%	433,326	13,193,822	-4,210	3,393	341,053	12,759,432	-4,762	2,456	437,802	10,161,757	-3,561	3,535	416,079	11,883,833	-2,885	2,885
	75%	0%	5%	301,937	16,620,664	-7,104	3,393	288,977	16,502,849	-7,026	3,224	303,418	16,106,599	-7,026	3,563	301,030	16,377,864	-7,026	3,339
			10%	301,937	16,620,664	-7,104	3,393	275,958	16,392,180	-6,947	3,054	304,148	15,602,170	-6,947	3,628	314,006	16,066,030	-6,947	3,628
			15%	301,937	16,620,664	-7,104	3,393	263,523	16,288,709	-6,868	2,884	304,934	15,108,212	-6,868	3,628	317,743	15,781,324	-6,868	3,628
		10%	5%	301,937	16,620,664	-7,104	3,393	260,502	16,431,923	-6,663	2,861	305,676	15,350,450	-6,663	3,563	308,652	16,282,686	-6,663	3,563
			10%	301,937	16,620,664	-7,104	3,393	247,743	16,329,142	-6,584	2,691	302,567	14,855,885	-6,584	3,481	310,644	16,000,625	-6,584	3,498
			15%	301,937	16,620,664	-7,104	3,393	237,705	16,213,060	-6,582	2,581	305,088	14,370,807	-6,868	3,616	316,008	15,717,896	-6,505	3,616
		30%	5%	301,937	16,620,664	-7,104	3,393	221,862	16,216,317	-7,140	2,555	312,613	13,911,446	-6,399	3,563	307,885	16,315,582	-5,937	3,563
			10%	301,937	16,620,664	-7,104	3,393	213,979	15,929,363	-7,224	2,477	303,964	13,428,155	-6,320	3,481	306,773	16,367,106	-5,858	3,498
			15%	301,937	16,620,664	-7,104	3,393	207,654	15,603,919	-7,307	2,423	303,800	12,954,819	-6,868	3,538	310,955	16,647,505	-5,779	3,600

park	solar	battery	flex	reference				cost optimization				self consumption optimization				minimize peak optimization			
criteria				costs	volume	min	max	costs	volume	min	max	costs	volume	min	max	costs	volume	min	max
unit				€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW
Industrial	0%	0%	5%	886,372	19,701,455	764	5,173	869,118	19,701,455	728	4,914	886,372	19,701,455	764	5,173	878,226	19,701,455	729	4,914
			10%	886,372	19,701,455	764	5,173	852,247	19,701,455	690	4,655	886,372	19,701,455	764	5,173	863,946	19,701,455	687	4,655
			15%	886,372	19,701,455	764	5,173	837,239	19,701,455	652	4,397	886,372	19,701,455	764	5,173	851,629	19,701,455	649	4,397
		10%	5%	886,372	19,701,455	764	5,173	835,262	19,817,763	211	4,461	886,372	19,701,455	764	5,173	859,962	19,829,968	225	4,461
			10%	886,372	19,701,455	764	5,173	822,215	19,811,559	173	4,226	886,372	19,701,455	764	5,173	849,292	19,840,013	187	4,226
			15%	886,372	19,701,455	764	5,173	813,267	19,808,481	135	4,083	886,372	19,701,455	764	5,173	843,111	19,851,156	146	4,083
		30%	5%	886,372	19,701,455	764	5,173	794,536	20,852,632	-823	4,056	886,372	19,701,455	764	5,173	841,961	19,937,943	-629	4,056
			10%	886,372	19,701,455	764	5,173	786,015	20,921,456	-862	3,914	886,372	19,701,455	764	5,173	828,548	19,791,098	-809	3,914
			15%	886,372	19,701,455	764	5,173	778,544	20,993,566	-900	3,801	886,372	19,701,455	764	5,173	823,380	19,788,028	-850	3,801
	25%	0%	5%	764,009	16,488,433	-1,258	5,003	747,139	16,480,551	-1,208	4,747	773,136	16,433,832	-1,208	5,003	761,915	16,471,618	-1,308	4,747
			10%	764,009	16,488,433	-1,258	5,003	729,847	16,476,565	-1,177	4,491	778,071	16,382,853	-1,158	5,003	753,031	16,452,720	-1,358	4,491
			15%	764,009	16,488,433	-1,258	5,003	714,498	16,476,058	-1,221	4,235	781,934	16,336,071	-1,108	5,003	741,007	16,342,944	-1,169	4,235
		10%	5%	764,009	16,488,433	-1,258	5,003	711,481	16,611,896	-1,485	4,322	772,869	16,202,149	-1,044	5,003	740,455	16,465,203	-1,559	4,322
			10%	764,009	16,488,433	-1,258	5,003	698,452	16,618,588	-1,526	4,104	778,043	16,169,578	-1,158	5,003	731,492	16,449,525	-1,471	4,104
			15%	764,009	16,488,433	-1,258	5,003	689,339	16,631,004	-1,568	3,968	781,356	16,141,543	-930	5,003	727,934	16,456,608	-1,654	3,968
		30%	5%	764,009	16,488,433	-1,258	5,003	669,818	17,842,746	-2,520	3,928	772,870	16,048,222	-627	5,003	735,469	16,370,166	-2,367	3,928
			10%	764,009	16,488,433	-1,258	5,003	661,377	17,916,146	-2,561	3,792	777,042	16,042,349	-147	5,003	722,341	16,403,763	-2,331	3,792
			15%	764,009	16,488,433	-1,258	5,003	653,191	17,997,294	-2,602	3,667	794,234	16,038,303	0	5,003	715,902	16,474,333	-2,025	3,667
	50%	0%	5%	655,064	14,810,837	-3,514	4,973	638,162	14,799,525	-3,464	4,724	664,761	14,704,244	-3,464	4,973	651,749	14,779,598	-3,464	4,724
			10%	655,064	14,810,837	-3,514	4,973	621,125	14,796,116	-3,414	4,474	669,959	14,604,301	-3,414	4,973	646,243	14,730,889	-3,614	4,474
			15%	655,064	14,810,837	-3,514	4,973	604,353	14,804,179	-3,364	4,224	675,024	14,509,671	-3,364	4,973	636,468	14,713,374	-3,664	4,224
		10%	5%	655,064	14,810,837	-3,514	4,973	599,202	14,881,320	-3,402	4,241	665,572	14,328,745	-3,464	4,973	632,947	14,868,487	-3,496	4,241
			10%	655,064	14,810,837	-3,514	4,973	584,559	14,896,330	-3,459	4,049	670,527	14,238,455	-3,254	4,973	624,349	14,921,760	-3,414	4,049
			15%	655,064	14,810,837	-3,514	4,973	573,549	14,923,942	-3,516	3,913	674,468	14,151,167	-3,364	4,973	620,908	15,104,158	-3,364	3,913
		30%	5%	655,064	14,810,837	-3,514	4,973	554,503	15,905,235	-4,437	3,873	667,166	13,673,843	-3,464	4,973	624,010	15,695,063	-3,564	3,873
			10%	655,064	14,810,837	-3,514	4,973	545,987	15,986,440	-4,494	3,737	674,047	13,596,406	-3,414	4,973	614,632	14,780,636	-3,614	3,737
			15%	655,064	14,810,837	-3,514	4,973	537,750	16,075,741	-4,551	3,617	676,396	13,521,385	-3,364	4,973	606,896	14,746,560	-3,617	3,617
	75%	0%	5%	548,518	14,763,625	-5,770	4,964	531,927	14,658,947	-5,720	4,714	557,256	14,348,235	-5,720	5,173	558,492	14,488,325	-5,720	5,173
			10%	548,518	14,763,625	-5,770	4,964	514,869	14,593,257	-5,670	4,464	561,357	13,972,995	-5,670	5,173	563,497	14,199,674	-5,670	5,173
			15%	548,518	14,763,625	-5,770	4,964	498,117	14,566,227	-5,620	4,215	564,904	13,645,103	-5,620	5,173	567,729	14,077,493	-5,620	5,173
		10%	5%	548,518	14,763,625	-5,770	4,964	491,678	14,619,107	-5,386	4,197	556,926	13,543,030	-5,213	5,117	559,415	14,597,014	-5,203	5,203
			10%	548,518	14,763,625	-5,770	4,964	476,540	14,614,868	-5,444	3,994	558,884	13,231,478	-5,242	5,105	561,816	14,415,804	-5,153	5,129
			15%	548,518	14,763,625	-5,770	4,964	465,255	14,639,389	-5,501	3,858	563,330	12,980,678	-5,620	5,170	560,276	14,245,950	-5,103	5,032
		30%	5%	548,518	14,763,625	-5,770	4,964	444,424	15,407,241	-6,421	3,818	559,163	12,365,015	-5,720	5,117	530,883	13,491,757	-4,168	4,168
			10%	548,518	14,763,625	-5,770	4,964	435,336	15,408,282	-6,478	3,682	558,131	12,193,942	-5,670	5,105	531,993	13,149,805	-4,118	4,118
			15%	548,518	14,763,625	-5,770	4,964	426,966	15,455,647	-6,535	3,567	566,359	12,045,338	-5,620	5,204	522,343	13,729,040	-4,068	4,068

park	solar	battery	flex	reference				cost optimization				self consumption optimization				minimize peak optimization			
criteria				costs	volume	min	max	costs	volume	min	max	costs	volume	min	max	costs	volume	min	max
unit				€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW
Logistics	0%	0%	5%	502,646	11,669,637	560	2,619	493,463	11,669,637	532	2,488	502,646	11,669,637	560	2,619	499,026	11,669,637	588	2,488
			10%	502,646	11,669,637	560	2,619	485,089	11,669,637	504	2,357	502,646	11,669,637	560	2,619	494,901	11,669,637	577	2,357
			15%	502,646	11,669,637	560	2,619	477,556	11,669,637	476	2,227	502,646	11,669,637	560	2,619	487,022	11,669,637	476	2,227
		10%	5%	502,646	11,669,637	560	2,619	478,545	11,722,390	270	2,278	502,646	11,669,637	560	2,619	491,947	11,730,985	275	2,278
			10%	502,646	11,669,637	560	2,619	471,687	11,719,833	242	2,150	502,646	11,669,637	560	2,619	486,689	11,732,912	262	2,150
			15%	502,646	11,669,637	560	2,619	465,422	11,718,865	214	2,026	502,646	11,669,637	560	2,619	480,754	11,738,788	242	2,026
		30%	5%	502,646	11,669,637	560	2,619	458,856	11,893,161	-254	2,044	502,646	11,669,637	560	2,619	479,714	11,763,686	0	2,044
			10%	502,646	11,669,637	560	2,619	453,403	11,920,918	-282	1,950	502,646	11,669,637	560	2,619	479,601	11,781,197	0	1,950
			15%	502,646	11,669,637	560	2,619	448,947	11,955,184	-310	1,883	502,646	11,669,637	560	2,619	472,585	11,715,326	103	1,883
	25%	0%	5%	279,298	9,749,797	-3,937	2,484	270,008	9,686,928	-3,902	2,360	282,354	9,435,445	-3,902	2,609	283,445	9,728,469	-3,902	2,609
			10%	279,298	9,749,797	-3,937	2,484	260,704	9,633,848	-3,866	2,236	283,223	9,132,258	-3,866	2,619	283,725	9,281,126	-3,866	2,619
			15%	279,298	9,749,797	-3,937	2,484	251,850	9,593,366	-3,830	2,112	283,394	8,842,490	-3,830	2,619	289,156	9,338,652	-3,830	2,619
		10%	5%	279,298	9,749,797	-3,937	2,484	249,657	9,655,200	-3,640	2,098	283,233	8,939,188	-3,640	2,609	284,034	9,588,374	-3,640	2,609
			10%	279,298	9,749,797	-3,937	2,484	240,626	9,619,979	-3,676	1,974	283,787	8,646,170	-3,866	2,612	286,847	9,418,487	-3,604	2,612
			15%	279,298	9,749,797	-3,937	2,484	232,653	9,594,888	-3,713	1,888	284,078	8,367,653	-3,568	2,616	288,165	9,266,676	-3,568	2,625
		30%	5%	279,298	9,749,797	-3,937	2,484	222,455	9,631,565	-4,162	1,878	285,840	8,031,389	-3,296	2,609	283,352	9,742,117	-3,116	2,651
			10%	279,298	9,749,797	-3,937	2,484	216,831	9,521,971	-4,199	1,809	284,778	7,762,084	-3,866	2,612	296,455	9,942,126	-3,080	3,080
			15%	279,298	9,749,797	-3,937	2,484	211,882	9,425,107	-4,237	1,747	284,580	7,505,781	-3,373	2,615	299,351	9,663,587	-3,044	3,038
	50%	0%	5%	67,179	15,894,555	-8,590	2,484	57,958	15,830,888	-8,554	2,360	69,126	15,516,327	-8,554	2,609	70,735	15,871,091	-8,554	2,609
			10%	67,179	15,894,555	-8,590	2,484	48,695	15,768,530	-8,518	2,236	68,843	15,143,864	-8,518	2,619	67,963	15,315,479	-8,518	2,619
			15%	67,179	15,894,555	-8,590	2,484	39,463	15,705,573	-8,483	2,112	68,117	14,776,333	-8,483	2,619	75,703	15,272,046	-8,483	2,619
		10%	5%	67,179	15,894,555	-8,590	2,484	37,418	15,776,653	-8,292	2,098	71,120	14,925,764	-8,554	2,609	71,091	15,674,820	-8,292	2,609
			10%	67,179	15,894,555	-8,590	2,484	28,259	15,713,029	-8,256	1,974	70,290	14,558,608	-8,518	2,609	72,386	15,461,476	-8,256	2,609
			15%	67,179	15,894,555	-8,590	2,484	19,643	15,641,014	-8,221	1,850	69,684	14,195,995	-8,221	2,615	73,438	15,238,839	-8,221	2,615
		30%	5%	67,179	15,894,555	-8,590	2,484	7,581	15,500,736	-8,254	1,808	75,791	13,794,702	-8,554	2,609	72,202	15,655,918	-7,768	2,619
			10%	67,179	15,894,555	-8,590	2,484	1,978	15,274,161	-8,291	1,743	75,880	13,434,698	-7,733	2,609	75,478	15,600,438	-7,733	2,739
			15%	67,179	15,894,555	-8,590	2,484	-3,015	15,048,506	-8,329	1,687	74,408	13,078,304	-7,786	2,694	70,689	15,639,151	-7,697	2,616
	75%	0%	5%	-144,225	22,917,294	-13,242	2,484	-153,414	22,859,804	-13,207	2,360	-142,307	22,520,222	-13,207	2,609	-139,604	22,892,993	-13,207	2,609
			10%	-144,225	22,917,294	-13,242	2,484	-162,641	22,800,867	-13,171	2,236	-142,936	22,126,930	-13,171	2,619	-144,904	22,299,373	-13,171	2,619
			15%	-144,225	22,917,294	-13,242	2,484	-171,578	22,745,710	-13,135	2,112	-144,230	21,738,503	-13,135	2,619	-138,434	22,204,133	-13,135	2,619
		10%	5%	-144,225	22,917,294	-13,242	2,484	-173,976	22,801,793	-12,945	2,098	-139,609	21,888,056	-13,207	2,609	-141,050	22,689,604	-12,945	2,609
			10%	-144,225	22,917,294	-13,242	2,484	-183,162	22,739,110	-12,909	1,974	-140,470	21,498,830	-13,171	2,609	-140,415	22,457,140	-12,909	2,609
			15%	-144,225	22,917,294	-13,242	2,484	-192,093	22,666,757	-12,873	1,850	-141,710	21,113,980	-12,920	2,615	-139,553	22,225,436	-12,873	2,616
		30%	5%	-144,225	22,917,294	-13,242	2,484	-205,875	22,440,423	-12,421	1,741	-133,579	20,658,162	-13,207	2,609	-139,673	22,704,839	-12,421	2,651
			10%	-144,225	22,917,294	-13,242	2,484	-211,546	22,181,387	-12,385	1,678	-134,426	20,276,340	-12,987	2,609	-137,729	22,623,098	-12,385	2,739
			15%	-144,225	22,917,294	-13,242	2,484	-216,125	21,941,619	-12,421	1,631	-136,245	19,898,624	-12,349	2,615	-143,092	22,603,523	-12,349	2,616

park	solar	battery	flex	reference				cost optimization				self consumption optimization				minimize peak optimization			
criteria				costs	volume	min	max	costs	volume	min	max	costs	volume	min	max	costs	volume	min	max
unit				€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW
Maritime	0%	0%	5%	752,140	16,945,757	729	4,232	737,757	16,945,757	692	4,020	752,140	16,945,757	729	4,232	745,654	16,945,757	692	4,020
			10%	752,140	16,945,757	729	4,232	723,942	16,945,757	656	3,809	752,140	16,945,757	729	4,232	733,964	16,945,757	656	3,809
			15%	752,140	16,945,757	729	4,232	711,745	16,945,757	619	3,597	752,140	16,945,757	729	4,232	723,904	16,945,757	619	3,597
		10%	5%	752,140	16,945,757	729	4,232	711,122	17,038,451	269	3,665	752,140	16,945,757	729	4,232	731,690	17,049,654	271	3,665
			10%	752,140	16,945,757	729	4,232	700,313	17,034,105	233	3,462	752,140	16,945,757	729	4,232	722,083	17,057,199	234	3,462
			15%	752,140	16,945,757	729	4,232	692,888	17,031,354	196	3,352	752,140	16,945,757	729	4,232	716,183	17,065,625	196	3,352
		30%	5%	752,140	16,945,757	729	4,232	678,425	17,709,538	-577	3,331	752,140	16,945,757	729	4,232	715,546	17,162,152	0	3,331
			10%	752,140	16,945,757	729	4,232	671,460	17,770,661	-614	3,220	752,140	16,945,757	729	4,232	706,129	17,021,018	0	3,220
			15%	752,140	16,945,757	729	4,232	664,838	17,836,734	-650	3,120	752,140	16,945,757	729	4,232	701,191	17,016,063	0	3,120
	25%	0%	5%	644,215	14,088,815	-1,115	4,083	629,596	14,081,474	-1,071	3,874	651,806	14,040,128	-1,071	4,083	641,949	14,073,871	-1,159	3,874
			10%	644,215	14,088,815	-1,115	4,083	615,659	14,077,276	-1,038	3,665	655,672	13,994,550	-1,026	4,083	635,447	14,061,753	-1,203	3,665
			15%	644,215	14,088,815	-1,115	4,083	603,123	14,076,678	-1,078	3,456	658,839	13,952,759	-982	4,083	625,431	13,984,741	-1,078	3,456
		10%	5%	644,215	14,088,815	-1,115	4,083	601,129	14,180,893	-1,272	3,532	650,130	13,847,302	-1,071	4,083	625,082	14,014,937	-1,252	3,532
			10%	644,215	14,088,815	-1,115	4,083	591,016	14,185,973	-1,309	3,364	655,587	13,815,853	-868	4,083	618,214	14,030,983	-1,283	3,364
			15%	644,215	14,088,815	-1,115	4,083	583,261	14,195,439	-1,346	3,247	658,175	13,788,657	-982	4,083	614,044	14,016,876	-1,331	3,247
		30%	5%	644,215	14,088,815	-1,115	4,083	568,551	15,035,659	-2,118	3,230	650,042	13,707,345	-774	4,083	614,917	14,081,472	-1,159	3,230
			10%	644,215	14,088,815	-1,115	4,083	561,036	15,100,649	-2,155	3,112	654,494	13,701,319	-394	4,083	609,792	13,962,249	-1,886	3,112
			15%	644,215	14,088,815	-1,115	4,083	554,251	15,171,452	-2,192	3,016	667,619	13,697,081	-112	4,083	602,937	14,840,390	-2,517	3,016
	50%	0%	5%	547,642	12,599,816	-3,116	4,036	533,719	12,587,837	-3,071	3,833	556,356	12,499,239	-3,071	4,036	544,927	12,573,834	-3,160	3,833
			10%	547,642	12,599,816	-3,116	4,036	519,342	12,588,994	-3,027	3,630	560,604	12,407,369	-3,027	4,036	539,838	12,551,807	-3,204	3,630
			15%	547,642	12,599,816	-3,116	4,036	505,483	12,607,793	-2,983	3,428	564,796	12,322,259	-2,983	4,036	532,171	12,548,435	-3,248	3,428
		10%	5%	547,642	12,599,816	-3,116	4,036	502,449	12,656,212	-3,000	3,459	556,885	12,186,888	-3,071	4,036	529,766	12,566,198	-3,071	3,459
			10%	547,642	12,599,816	-3,116	4,036	490,676	12,679,738	-3,050	3,315	560,881	12,105,746	-3,027	4,036	523,102	12,641,095	-3,027	3,315
			15%	547,642	12,599,816	-3,116	4,036	481,268	12,721,852	-3,099	3,203	563,857	12,027,884	-2,676	4,036	520,808	12,862,005	-2,983	3,203
		30%	5%	547,642	12,599,816	-3,116	4,036	466,569	13,389,764	-3,847	3,181	557,521	11,645,519	-2,766	4,036	522,195	13,376,752	-2,993	3,181
			10%	547,642	12,599,816	-3,116	4,036	459,102	13,460,391	-3,896	3,068	561,981	11,576,184	-3,027	4,036	518,162	13,446,161	-3,068	3,068
			15%	547,642	12,599,816	-3,116	4,036	452,107	13,549,791	-3,946	2,971	574,817	11,508,885	-2,983	4,036	513,237	13,622,232	-2,971	2,971
	75%	0%	5%	453,746	12,915,384	-5,116	4,027	439,799	12,829,038	-5,072	3,824	461,596	12,530,502	-5,072	4,230	457,587	12,621,960	-5,072	4,092
			10%	453,746	12,915,384	-5,116	4,027	425,773	12,770,997	-5,028	3,622	465,121	12,172,259	-5,028	4,232	466,508	12,378,608	-5,028	4,232
			15%	453,746	12,915,384	-5,116	4,027	411,861	12,738,404	-4,983	3,419	465,962	11,843,059	-4,983	4,232	470,318	12,153,858	-4,983	4,232
		10%	5%	453,746	12,915,384	-5,116	4,027	407,205	12,784,044	-4,760	3,401	461,972	11,828,360	-4,649	4,230	465,321	12,791,349	-4,649	4,269
			10%	453,746	12,915,384	-5,116	4,027	395,583	12,761,259	-4,810	3,267	464,929	11,497,704	-4,605	4,229	473,154	12,316,385	-4,605	4,561
			15%	453,746	12,915,384	-5,116	4,027	386,106	12,755,630	-4,859	3,158	467,149	11,211,032	-4,983	4,225	476,262	12,601,764	-4,560	4,495
		30%	5%	453,746	12,915,384	-5,116	4,027	369,844	13,188,547	-5,606	3,132	462,896	10,680,060	-4,620	4,230	450,423	11,843,677	-3,802	3,802
			10%	453,746	12,915,384	-5,116	4,027	361,923	13,166,321	-5,656	3,023	464,967	10,461,490	-5,028	4,229	456,670	11,656,446	-3,758	3,758
			15%	453,746	12,915,384	-5,116	4,027	354,761	13,195,828	-5,706	2,927	467,266	10,285,380	-4,983	4,216	456,595	11,340,539	-3,714	3,714

park	solar	battery	flex	reference				cost optimization				self consumption optimization				minimize peak optimization			
criteria				costs	volume	min	max	costs	volume	min	max	costs	volume	min	max	costs	volume	min	max
unit				€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW	€	kWh	kW	kW
Mixed	0%	0%	5%	241,885	5,678,710	382	1,239	237,293	5,678,710	366	1,177	241,885	5,678,710	382	1,239	240,960	5,678,710	363	1,177
			10%	241,885	5,678,710	382	1,239	233,024	5,678,710	347	1,115	241,885	5,678,710	382	1,239	238,684	5,678,710	344	1,115
			15%	241,885	5,678,710	382	1,239	228,850	5,678,710	328	1,053	241,885	5,678,710	382	1,239	235,613	5,678,710	326	1,053
		10%	5%	241,885	5,678,710	382	1,239	229,951	5,707,377	242	1,086	241,885	5,678,710	382	1,239	238,484	5,709,242	240	1,086
			10%	241,885	5,678,710	382	1,239	225,974	5,704,857	223	1,026	241,885	5,678,710	382	1,239	235,301	5,708,064	221	1,026
			15%	241,885	5,678,710	382	1,239	223,002	5,703,218	204	983	241,885	5,678,710	382	1,239	233,749	5,708,309	201	983
		30%	5%	241,885	5,678,710	382	1,239	220,176	5,749,927	-6	989	241,885	5,678,710	382	1,239	233,018	5,689,528	0	989
			10%	241,885	5,678,710	382	1,239	217,486	5,747,729	-25	948	241,885	5,678,710	382	1,239	231,564	5,684,496	300	948
			15%	241,885	5,678,710	382	1,239	215,321	5,746,872	-44	919	241,885	5,678,710	382	1,239	230,380	5,740,774	-47	919
	25%	0%	5%	171,950	4,219,198	-846	1,154	167,435	4,199,939	-816	1,096	173,711	4,111,909	-816	1,154	170,889	4,221,614	-876	1,096
			10%	171,950	4,219,198	-846	1,154	162,928	4,188,749	-787	1,038	175,117	4,012,756	-787	1,154	169,094	4,219,109	-800	1,038
			15%	171,950	4,219,198	-846	1,154	158,546	4,182,834	-781	980	175,439	3,921,237	-757	1,154	166,555	4,151,392	-795	980
		10%	5%	171,950	4,219,198	-846	1,154	158,095	4,235,980	-841	983	173,613	3,922,122	-693	1,154	165,950	4,212,696	-816	983
			10%	171,950	4,219,198	-846	1,154	153,768	4,234,796	-862	928	174,515	3,831,937	-663	1,154	162,744	4,234,269	-787	928
			15%	171,950	4,219,198	-846	1,154	150,831	4,237,260	-883	897	175,385	3,750,653	-633	1,154	161,045	4,209,966	-760	897
		30%	5%	171,950	4,219,198	-846	1,154	145,597	4,404,797	-1,060	892	174,141	3,627,507	-674	1,154	163,483	3,821,275	-816	892
			10%	171,950	4,219,198	-846	1,154	143,166	4,380,630	-1,096	861	174,976	3,564,882	-787	1,154	162,283	3,770,527	-861	861
			15%	171,950	4,219,198	-846	1,154	140,768	4,343,569	-1,131	837	174,812	3,513,566	-629	1,154	161,881	3,727,725	-837	837
	50%	0%	5%	106,485	5,759,958	-2,288	1,154	101,970	5,720,504	-2,259	1,096	107,544	5,583,533	-2,259	1,211	108,508	5,764,322	-2,259	1,211
			10%	106,485	5,759,958	-2,288	1,154	97,462	5,685,151	-2,229	1,038	108,147	5,409,740	-2,229	1,239	110,071	5,771,678	-2,229	1,239
			15%	106,485	5,759,958	-2,288	1,154	92,984	5,648,186	-2,199	980	108,825	5,238,980	-2,199	1,239	109,899	5,587,054	-2,199	1,239
		10%	5%	106,485	5,759,958	-2,288	1,154	92,229	5,702,737	-2,177	972	108,292	5,323,772	-2,259	1,211	108,715	5,703,877	-2,135	1,211
			10%	106,485	5,759,958	-2,288	1,154	87,905	5,661,925	-2,213	914	108,262	5,152,834	-2,229	1,227	109,883	5,725,445	-2,105	1,229
			15%	106,485	5,759,958	-2,288	1,154	84,291	5,610,911	-2,248	880	107,788	4,984,722	-2,199	1,221	110,845	5,633,332	-2,075	1,227
		30%	5%	106,485	5,759,958	-2,288	1,154	79,206	5,631,597	-2,425	875	110,034	4,828,888	-2,259	1,211	113,326	5,795,593	-1,887	1,367
			10%	106,485	5,759,958	-2,288	1,154	76,458	5,520,572	-2,460	843	109,604	4,661,403	-2,229	1,227	112,655	5,564,119	-1,857	1,394
			15%	106,485	5,759,958	-2,288	1,154	74,369	5,414,040	-2,496	820	107,178	4,497,481	-2,199	1,221	114,860	5,665,607	-1,827	1,441
	75%	0%	5%	41,035	7,795,234	-3,730	1,154	36,522	7,757,812	-3,701	1,096	41,769	7,600,147	-3,701	1,211	42,701	7,802,601	-3,701	1,211
			10%	41,035	7,795,234	-3,730	1,154	32,010	7,723,230	-3,671	1,038	41,919	7,407,516	-3,671	1,239	44,431	7,813,407	-3,671	1,239
			15%	41,035	7,795,234	-3,730	1,154	27,526	7,685,209	-3,641	980	41,915	7,217,142	-3,641	1,239	44,561	7,596,805	-3,641	1,239
		10%	5%	41,035	7,795,234	-3,730	1,154	26,775	7,734,947	-3,577	972	42,772	7,319,536	-3,577	1,211	43,374	7,720,186	-3,577	1,211
			10%	41,035	7,795,234	-3,730	1,154	22,459	7,692,879	-3,578	914	42,078	7,128,716	-3,671	1,227	44,759	7,663,152	-3,547	1,229
			15%	41,035	7,795,234	-3,730	1,154	18,471	7,636,191	-3,613	864	41,917	6,940,151	-3,554	1,224	45,443	7,607,838	-3,517	1,233
		30%	5%	41,035	7,795,234	-3,730	1,154	13,278	7,625,924	-3,790	858	44,682	6,780,668	-3,701	1,211	44,352	7,805,941	-3,329	1,264
			10%	41,035	7,795,234	-3,730	1,154	10,504	7,502,912	-3,825	828	44,206	6,594,095	-3,353	1,227	46,788	7,596,350	-3,299	1,362
			15%	41,035	7,795,234	-3,730	1,154	8,235	7,374,460	-3,861	804	43,167	6,409,596	-3,641	1,221	49,144	7,582,773	-3,269	1,441

Appendix E (Relative change to reference)

park	solar	battery	flex	Costs optimisation			Dependency optimisation			Capacity optimisation		
Criteria				Costs	Volume	Peak	Costs	Volume	Peak	Costs	Volume	Peak
High Quality	0%	0%	5%	-2%	0%	-5%	0%	0%	0%	0%	0%	-5%
			10%	-4%	0%	-10%	0%	0%	0%	-1%	0%	-10%
			15%	-5%	0%	-15%	0%	0%	0%	-3%	0%	-15%
		10%	5%	-5%	0%	-12%	0%	0%	0%	-1%	1%	-12%
			10%	-6%	0%	-17%	0%	0%	0%	-3%	1%	-17%
			15%	-8%	0%	-20%	0%	0%	0%	-3%	1%	-20%
		30%	5%	-9%	1%	-20%	0%	0%	0%	-4%	0%	-20%
			10%	-10%	1%	-23%	0%	0%	0%	-4%	0%	-23%
			15%	-11%	1%	-25%	0%	0%	0%	-5%	0%	-25%
	25%	0%	5%	-2%	0%	-5%	1%	-1%	0%	0%	0%	-5%
			10%	-5%	0%	-10%	2%	-1%	0%	-1%	0%	-10%
			15%	-7%	0%	-15%	3%	-2%	0%	-2%	1%	-15%
		10%	5%	-7%	1%	-15%	1%	-2%	0%	-3%	-1%	-15%
			10%	-9%	2%	-19%	2%	-2%	0%	-4%	0%	-19%
			15%	-11%	2%	-22%	2%	-2%	0%	-5%	1%	-22%
		30%	5%	-13%	6%	-22%	1%	-3%	0%	-4%	6%	-22%
			10%	-14%	6%	-25%	2%	-3%	0%	-4%	10%	-25%
			15%	-15%	6%	-27%	3%	-3%	0%	-5%	12%	-27%
	50%	0%	5%	-3%	-1%	-2%	1%	-3%	-2%	1%	-1%	-2%
			10%	-6%	-1%	-4%	1%	-6%	-4%	3%	-3%	-4%
			15%	-9%	-2%	-6%	2%	-10%	-6%	4%	-5%	-6%
		10%	5%	-10%	-1%	-8%	1%	-8%	-2%	0%	-2%	-10%
			10%	-12%	-2%	-6%	0%	-11%	-4%	1%	-4%	-12%
			15%	-14%	-2%	-4%	2%	-14%	-6%	2%	-6%	-14%
		30%	5%	-18%	-1%	9%	2%	-18%	-2%	-2%	-1%	-28%
			10%	-20%	-2%	11%	1%	-20%	-4%	-2%	-6%	-30%
			15%	-21%	-3%	13%	1%	-23%	-15%	-4%	-10%	-31%
	75%	0%	5%	-4%	-1%	-1%	0%	-3%	-1%	0%	-1%	-1%
			10%	-9%	-1%	-2%	1%	-6%	-2%	4%	-3%	-2%
			15%	-13%	-2%	-3%	1%	-9%	-3%	5%	-5%	-3%
		10%	5%	-14%	-1%	-6%	1%	-8%	-6%	2%	-2%	-6%
			10%	-18%	-2%	-7%	0%	-11%	-7%	3%	-4%	-7%
			15%	-21%	-2%	-7%	1%	-14%	-3%	5%	-5%	-8%

		30%	5%	-27%	-2%	1%	4%	-16%	-10%	2%	-2%	-16%
			10%	-29%	-4%	2%	1%	-19%	-11%	2%	-2%	-18%
			15%	-31%	-6%	3%	1%	-22%	-3%	3%	0%	-19%
Industrial	0%	0%	5%	-2%	0%	-5%	0%	0%	0%	-1%	0%	-5%
			10%	-4%	0%	-10%	0%	0%	0%	-3%	0%	-10%
			15%	-6%	0%	-15%	0%	0%	0%	-4%	0%	-15%
		10%	5%	-6%	1%	-14%	0%	0%	0%	-3%	1%	-14%
			10%	-7%	1%	-18%	0%	0%	0%	-4%	1%	-18%
			15%	-8%	1%	-21%	0%	0%	0%	-5%	1%	-21%
		30%	5%	-10%	6%	-22%	0%	0%	0%	-5%	1%	-22%
			10%	-11%	6%	-24%	0%	0%	0%	-7%	0%	-24%
			15%	-12%	7%	-27%	0%	0%	0%	-7%	0%	-27%
	25%	0%	5%	-2%	0%	-5%	1%	0%	0%	0%	0%	-5%
			10%	-4%	0%	-10%	2%	-1%	0%	-1%	0%	-10%
			15%	-6%	0%	-15%	2%	-1%	0%	-3%	-1%	-15%
		10%	5%	-7%	1%	-14%	1%	-2%	0%	-3%	0%	-14%
			10%	-9%	1%	-18%	2%	-2%	0%	-4%	0%	-18%
			15%	-10%	1%	-21%	2%	-2%	0%	-5%	0%	-21%
		30%	5%	-12%	8%	-21%	1%	-3%	0%	-4%	-1%	-21%
			10%	-13%	9%	-24%	2%	-3%	0%	-5%	-1%	-24%
			15%	-15%	9%	-27%	4%	-3%	0%	-6%	0%	-27%
	50%	0%	5%	-3%	0%	-5%	1%	-1%	0%	-1%	0%	-5%
			10%	-5%	0%	-10%	2%	-1%	0%	-1%	-1%	-10%
			15%	-8%	0%	-15%	3%	-2%	0%	-3%	-1%	-15%
		10%	5%	-9%	0%	-15%	2%	-3%	0%	-3%	0%	-15%
			10%	-11%	1%	-19%	2%	-4%	0%	-5%	1%	-19%
			15%	-12%	1%	-21%	3%	-4%	0%	-5%	2%	-21%
		30%	5%	-15%	7%	-11%	2%	-8%	0%	-5%	6%	-22%
			10%	-17%	8%	-10%	3%	-8%	0%	-6%	0%	-25%
			15%	-18%	9%	-8%	3%	-9%	0%	-7%	0%	-27%
	75%	0%	5%	-3%	-1%	-1%	2%	-3%	-1%	2%	-2%	-1%
			10%	-6%	-1%	-2%	2%	-5%	-2%	3%	-4%	-2%
			15%	-9%	-1%	-3%	3%	-8%	-3%	4%	-5%	-3%
		10%	5%	-10%	-1%	-7%	2%	-8%	-10%	2%	-1%	-10%
			10%	-13%	-1%	-6%	2%	-10%	-9%	2%	-2%	-11%
			15%	-15%	-1%	-5%	3%	-12%	-3%	2%	-4%	-12%
		30%	5%	-19%	4%	11%	2%	-16%	-1%	-3%	-9%	-28%
			10%	-21%	4%	12%	2%	-17%	-2%	-3%	-11%	-29%
			15%	-22%	5%	13%	3%	-18%	-3%	-5%	-7%	-29%
Logisti	0%	0%	5%	-2%	0%	-5%	0%	0%	0%	-1%	0%	-5%
			10%	-3%	0%	-10%	0%	0%	0%	-2%	0%	-10%

			15%	-5%	0%	-15%	0%	0%	0%	-3%	0%	-15%
		10%	5%	-5%	0%	-13%	0%	0%	0%	-2%	1%	-13%
			10%	-6%	0%	-18%	0%	0%	0%	-3%	1%	-18%
			15%	-7%	0%	-23%	0%	0%	0%	-4%	1%	-23%
		30%	5%	-9%	2%	-22%	0%	0%	0%	-5%	1%	-22%
			10%	-10%	2%	-26%	0%	0%	0%	-5%	1%	-26%
			15%	-11%	2%	-28%	0%	0%	0%	-6%	0%	-28%
	25%	0%	5%	-3%	-1%	-1%	1%	-3%	-1%	1%	0%	-1%
			10%	-7%	-1%	-2%	1%	-6%	-2%	2%	-5%	-2%
			15%	-10%	-2%	-3%	1%	-9%	-3%	4%	-4%	-3%
		10%	5%	-11%	-1%	-8%	1%	-8%	-8%	2%	-2%	-8%
			10%	-14%	-1%	-7%	2%	-11%	-2%	3%	-3%	-8%
			15%	-17%	-2%	-6%	2%	-14%	-9%	3%	-5%	-9%
		30%	5%	-20%	-1%	6%	2%	-18%	-16%	1%	0%	-21%
			10%	-22%	-2%	7%	2%	-20%	-2%	6%	2%	-22%
			15%	-24%	-3%	8%	2%	-23%	-14%	7%	-1%	-23%
	50%	0%	5%	-14%	0%	0%	3%	-2%	0%	5%	0%	0%
			10%	-28%	-1%	-1%	2%	-5%	-1%	1%	-4%	-1%
			15%	-41%	-1%	-1%	1%	-7%	-1%	13%	-4%	-1%
		10%	5%	-44%	-1%	-3%	6%	-6%	0%	6%	-1%	-3%
			10%	-58%	-1%	-4%	5%	-8%	-1%	8%	-3%	-4%
			15%	-71%	-2%	-4%	4%	-11%	-4%	9%	-4%	-4%
		30%	5%	-89%	-2%	-4%	13%	-13%	0%	7%	-2%	-10%
			10%	-97%	-4%	-3%	13%	-15%	-10%	12%	-2%	-10%
			15%	-104%	-5%	-3%	11%	-18%	-9%	5%	-2%	-10%
	75%	0%	5%	-6%	0%	0%	1%	-2%	0%	3%	0%	0%
			10%	-13%	-1%	-1%	1%	-3%	-1%	0%	-3%	-1%
			15%	-19%	-1%	-1%	0%	-5%	-1%	4%	-3%	-1%
		10%	5%	-21%	-1%	-2%	3%	-4%	0%	2%	-1%	-2%
			10%	-27%	-1%	-3%	3%	-6%	-1%	3%	-2%	-3%
			15%	-33%	-1%	-3%	2%	-8%	-2%	3%	-3%	-3%
		30%	5%	-43%	-2%	-6%	7%	-10%	0%	3%	-1%	-6%
			10%	-47%	-3%	-6%	7%	-12%	-2%	5%	-1%	-6%
			15%	-50%	-4%	-6%	6%	-13%	-7%	1%	-1%	-7%
Maritime	0%	0%	5%	-2%	0%	-5%	0%	0%	0%	-1%	0%	-5%
			10%	-4%	0%	-10%	0%	0%	0%	-2%	0%	-10%
			15%	-5%	0%	-15%	0%	0%	0%	-4%	0%	-15%
		10%	5%	-5%	1%	-13%	0%	0%	0%	-3%	1%	-13%
			10%	-7%	1%	-18%	0%	0%	0%	-4%	1%	-18%
			15%	-8%	1%	-21%	0%	0%	0%	-5%	1%	-21%
		30	5%	-10%	5%	-21%	0%	0%	0%	-5%	1%	-21%

			10%	-11%	5%	-24%	0%	0%	0%	-6%	0%	-24%
			15%	-12%	5%	-26%	0%	0%	0%	-7%	0%	-26%
	25%	0%	5%	-2%	0%	-5%	1%	0%	0%	0%	0%	-5%
			10%	-4%	0%	-10%	2%	-1%	0%	-1%	0%	-10%
			15%	-6%	0%	-15%	2%	-1%	0%	-3%	-1%	-15%
		10%	5%	-7%	1%	-14%	1%	-2%	0%	-3%	-1%	-14%
			10%	-8%	1%	-18%	2%	-2%	0%	-4%	0%	-18%
			15%	-9%	1%	-20%	2%	-2%	0%	-5%	-1%	-20%
		30%	5%	-12%	7%	-21%	1%	-3%	0%	-5%	0%	-21%
			10%	-13%	7%	-24%	2%	-3%	0%	-5%	-1%	-24%
			15%	-14%	8%	-26%	4%	-3%	0%	-6%	5%	-26%
	50%	0%	5%	-3%	0%	-5%	2%	-1%	0%	0%	0%	-5%
			10%	-5%	0%	-10%	2%	-2%	0%	-1%	0%	-10%
			15%	-8%	0%	-15%	3%	-2%	0%	-3%	0%	-15%
		10%	5%	-8%	0%	-14%	2%	-3%	0%	-3%	0%	-14%
			10%	-10%	1%	-18%	2%	-4%	0%	-4%	0%	-18%
			15%	-12%	1%	-21%	3%	-5%	0%	-5%	2%	-21%
		30%	5%	-15%	6%	-5%	2%	-8%	0%	-5%	6%	-21%
			10%	-16%	7%	-3%	3%	-8%	0%	-5%	7%	-24%
			15%	-17%	8%	-2%	5%	-9%	0%	-6%	8%	-26%
	75%	0%	5%	-3%	-1%	-1%	2%	-3%	-1%	1%	-2%	-1%
			10%	-6%	-1%	-2%	3%	-6%	-2%	3%	-4%	-2%
			15%	-9%	-1%	-3%	3%	-8%	-3%	4%	-6%	-3%
		10%	5%	-10%	-1%	-7%	2%	-8%	-9%	3%	-1%	-9%
			10%	-13%	-1%	-6%	2%	-11%	-10%	4%	-5%	-10%
			15%	-15%	-1%	-5%	3%	-13%	-3%	5%	-2%	-11%
		30%	5%	-18%	2%	10%	2%	-17%	-10%	-1%	-8%	-26%
			10%	-20%	2%	11%	2%	-19%	-2%	1%	-10%	-27%
			15%	-22%	2%	12%	3%	-20%	-3%	1%	-12%	-27%
Mixed	0%	0%	5%	-2%	0%	-5%	0%	0%	0%	0%	0%	-5%
			10%	-4%	0%	-10%	0%	0%	0%	-1%	0%	-10%
			15%	-5%	0%	-15%	0%	0%	0%	-3%	0%	-15%
		10%	5%	-5%	1%	-12%	0%	0%	0%	-1%	1%	-12%
			10%	-7%	0%	-17%	0%	0%	0%	-3%	1%	-17%
			15%	-8%	0%	-21%	0%	0%	0%	-3%	1%	-21%
		30%	5%	-9%	1%	-20%	0%	0%	0%	-4%	0%	-20%
			10%	-10%	1%	-23%	0%	0%	0%	-4%	0%	-23%
			15%	-11%	1%	-26%	0%	0%	0%	-5%	1%	-26%
	25%	0%	5%	-3%	0%	-5%	1%	-3%	0%	-1%	0%	-5%
			10%	-5%	-1%	-10%	2%	-5%	0%	-2%	0%	-10%
			15%	-8%	-1%	-15%	2%	-7%	0%	-3%	-2%	-15%

	10%	5%	-8%	0%	-15%	1%	-7%	0%	-3%	0%	-15%
		10%	-11%	0%	-20%	1%	-9%	0%	-5%	0%	-20%
		15%	-12%	0%	-22%	2%	-11%	0%	-6%	0%	-22%
	30%	5%	-15%	4%	-8%	1%	-14%	0%	-5%	-9%	-23%
		10%	-17%	4%	-5%	2%	-16%	0%	-6%	-11%	-25%
		15%	-18%	3%	-2%	2%	-17%	0%	-6%	-12%	-27%
50%	0%	5%	-4%	-1%	-1%	1%	-3%	-1%	2%	0%	-1%
		10%	-8%	-1%	-3%	2%	-6%	-3%	3%	0%	-3%
		15%	-13%	-2%	-4%	2%	-9%	-4%	3%	-3%	-4%
	10%	5%	-13%	-1%	-5%	2%	-8%	-1%	2%	-1%	-7%
		10%	-17%	-2%	-3%	2%	-11%	-3%	3%	-1%	-8%
		15%	-21%	-3%	-2%	1%	-13%	-4%	4%	-2%	-9%
	30%	5%	-26%	-2%	6%	3%	-16%	-1%	6%	1%	-18%
		10%	-28%	-4%	8%	3%	-19%	-3%	6%	-3%	-19%
		15%	-30%	-6%	9%	1%	-22%	-4%	8%	-2%	-20%
75%	0%	5%	-11%	0%	-1%	2%	-3%	-1%	4%	0%	-1%
		10%	-22%	-1%	-2%	2%	-5%	-2%	8%	0%	-2%
		15%	-33%	-1%	-2%	2%	-7%	-2%	9%	-3%	-2%
	10%	5%	-35%	-1%	-4%	4%	-6%	-4%	6%	-1%	-4%
		10%	-45%	-1%	-4%	3%	-9%	-2%	9%	-2%	-5%
		15%	-55%	-2%	-3%	2%	-11%	-5%	11%	-2%	-6%
	30%	5%	-68%	-2%	2%	9%	-13%	-1%	8%	0%	-11%
		10%	-74%	-4%	3%	8%	-15%	-10%	14%	-3%	-12%
		15%	-80%	-5%	3%	5%	-18%	-2%	20%	-3%	-12%

Appendix F (NPV's)

park	**solar**	**battery**	**flex**	cost optimization			dependency optimization			capacity optimization		
criteria				I	(B-C)	NPV	I	(B-C)	NPV	I	(B-C)	NPV
High Quality	0%	0%	5%	26,364	13,055	**65,327**	26,364	0	**-26,364**	26,364	2,957	**-5,598**
			10%	26,364	25,400	**152,035**	26,364	0	**-26,364**	26,364	10,098	**44,562**
			15%	26,364	37,061	**233,938**	26,364	0	**-26,364**	26,364	21,525	**124,819**
		10%	5%	26,364	34,797	**218,036**	26,364	0	**-26,364**	26,364	10,461	**47,107**
			10%	26,364	45,720	**294,757**	26,364	0	**-26,364**	26,364	18,022	**100,213**
			15%	26,364	53,809	**351,571**	26,364	0	**-26,364**	26,364	23,763	**140,537**
		30%	5%	26,364	63,226	**417,712**	26,364	0	**-26,364**	26,364	27,200	**164,678**
			10%	26,364	70,321	**467,544**	26,364	0	**-26,364**	26,364	28,821	**176,059**
			15%	26,364	76,704	**512,376**	26,364	0	**-26,364**	26,364	34,584	**216,542**
	25%	0%	5%	26,364	12,962	**64,678**	26,364	-6,727	**-73,608**	26,364	2,203	**-10,894**
			10%	26,364	25,879	**155,397**	26,364	-11,334	**-105,967**	26,364	5,312	**10,946**
			15%	26,364	37,646	**238,045**	26,364	-14,186	**-126,002**	26,364	13,330	**67,262**
		10%	5%	26,364	39,689	**252,392**	26,364	-6,396	**-71,284**	26,364	16,611	**90,302**
			10%	26,364	51,016	**331,952**	26,364	-10,085	**-97,193**	26,364	23,838	**141,061**
			15%	26,364	60,500	**398,560**	26,364	-12,946	**-117,289**	26,364	30,370	**186,940**
		30%	5%	26,364	73,089	**486,986**	26,364	-6,911	**-74,902**	26,364	23,643	**139,697**
			10%	26,364	80,792	**541,082**	26,364	-10,443	**-99,712**	26,364	24,408	**145,071**
			15%	26,364	86,490	**581,106**	26,364	-15,010	**-131,786**	26,364	29,399	**180,120**
	50%	0%	5%	26,364	12,958	**64,645**	26,364	-3,082	**-48,011**	26,364	-4,646	**-58,994**
			10%	26,364	25,968	**156,022**	26,364	-5,562	**-65,426**	26,364	-13,098	**-118,360**
			15%	26,364	38,367	**243,111**	26,364	-7,039	**-75,802**	26,364	-17,161	**-146,894**
		10%	5%	26,364	41,273	**263,520**	26,364	-3,814	**-53,154**	26,364	-1,283	**-35,376**
			10%	26,364	53,361	**348,422**	26,364	-1,147	**-34,423**	26,364	-4,383	**-57,146**
			15%	26,364	62,709	**414,077**	26,364	-6,581	**-72,585**	26,364	-8,443	**-85,667**
		30%	5%	26,364	77,779	**519,925**	26,364	-7,535	**-79,289**	26,364	10,531	**47,600**
			10%	26,364	85,891	**576,899**	26,364	-6,003	**-68,524**	26,364	8,641	**34,324**
			15%	26,364	92,273	**621,722**	26,364	-4,476	**-57,802**	26,364	17,247	**94,774**
	75%	0%	5%	26,364	12,960	**64,660**	26,364	-1,482	**-36,770**	26,364	907	**-19,994**

			10%	26,364	25,979	**156,104**	26,364	-2,211	**-41,891**	26,364	-12,069	**-111,132**
			15%	26,364	38,414	**243,439**	26,364	-2,997	**-47,417**	26,364	-15,806	**-137,379**
		10%	5%	26,364	41,435	**264,660**	26,364	-3,739	**-52,626**	26,364	-6,715	**-73,529**
			10%	26,364	54,194	**354,273**	26,364	-630	**-30,790**	26,364	-8,707	**-87,519**
			15%	26,364	64,232	**424,774**	26,364	-3,151	**-48,494**	26,364	-14,071	**-125,192**
		30%	5%	26,364	80,075	**536,051**	26,364	-10,676	**-101,350**	26,364	-5,948	**-68,140**
			10%	26,364	87,958	**591,414**	26,364	-2,027	**-40,603**	26,364	-4,836	**-60,329**
			15%	26,364	94,283	**635,838**	26,364	-1,863	**-39,452**	26,364	-9,018	**-89,703**
Industrial	0%	0%	5%	21,091	17,254	**100,093**	21,091	0	**-21,091**	21,091	8,145	**36,119**
			10%	21,091	34,125	**218,588**	21,091	0	**-21,091**	21,091	22,426	**136,419**
			15%	21,091	49,133	**324,001**	21,091	0	**-21,091**	21,091	34,743	**222,928**
		10%	5%	21,091	51,110	**337,882**	21,091	0	**-21,091**	21,091	26,410	**164,400**
			10%	21,091	64,157	**429,518**	21,091	0	**-21,091**	21,091	37,080	**239,344**
			15%	21,091	73,105	**492,369**	21,091	0	**-21,091**	21,091	43,261	**282,759**
		30%	5%	21,091	91,836	**623,929**	21,091	0	**-21,091**	21,091	44,411	**290,834**
			10%	21,091	100,357	**683,776**	21,091	0	**-21,091**	21,091	57,824	**385,042**
			15%	21,091	107,828	**736,248**	21,091	0	**-21,091**	21,091	62,992	**421,338**
	25%	0%	5%	21,091	16,870	**97,394**	21,091	-9,127	**-85,198**	21,091	2,093	**-6,388**
			10%	21,091	34,161	**218,845**	21,091	-14,062	**-119,855**	21,091	10,978	**56,016**
			15%	21,091	49,511	**326,650**	21,091	-17,925	**-146,987**	21,091	23,002	**140,467**
		10%	5%	21,091	52,528	**347,841**	21,091	-8,860	**-83,321**	21,091	23,553	**144,338**
			10%	21,091	65,557	**439,354**	21,091	-14,035	**-119,664**	21,091	32,516	**207,291**
			15%	21,091	74,670	**503,359**	21,091	-17,347	**-142,930**	21,091	36,075	**232,286**
		30%	5%	21,091	94,191	**640,469**	21,091	-8,862	**-83,331**	21,091	28,540	**179,360**
			10%	21,091	102,632	**699,753**	21,091	-13,033	**-112,630**	21,091	41,668	**271,566**
			15%	21,091	110,817	**757,244**	21,091	-30,225	**-233,381**	21,091	48,107	**316,793**
	50%	0%	5%	21,091	16,902	**97,622**	21,091	-9,697	**-89,200**	21,091	3,315	**2,189**
			10%	21,091	33,938	**217,278**	21,091	-14,896	**-125,711**	21,091	8,820	**40,860**
			15%	21,091	50,711	**335,080**	21,091	-19,960	**-161,282**	21,091	18,596	**109,517**
		10%	5%	21,091	55,862	**371,262**	21,091	-10,508	**-94,897**	21,091	22,117	**134,251**
			10%	21,091	70,505	**474,109**	21,091	-15,464	**-129,701**	21,091	30,714	**194,634**
			15%	21,091	81,515	**551,438**	21,091	-19,404	**-157,377**	21,091	34,155	**218,802**

		30%	5%	21,091	100,561	**685,205**	21,091	-12,102	**-106,090**	21,091	31,054	**197,021**
			10%	21,091	109,077	**745,018**	21,091	-18,983	**-154,417**	21,091	40,432	**262,884**
			15%	21,091	117,314	**802,874**	21,091	-21,332	**-170,917**	21,091	48,168	**317,220**
	75%	0%	5%	21,091	16,591	**95,437**	21,091	-8,738	**-82,462**	21,091	-9,974	**-91,143**
			10%	21,091	33,649	**215,247**	21,091	-12,839	**-111,266**	21,091	-14,979	**-126,295**
			15%	21,091	50,401	**332,901**	21,091	-16,386	**-136,178**	21,091	-19,211	**-156,021**
		10%	5%	21,091	56,840	**378,130**	21,091	-8,409	**-80,149**	21,091	-10,897	**-97,625**
			10%	21,091	71,978	**484,455**	21,091	-10,366	**-93,900**	21,091	-13,298	**-114,489**
			15%	21,091	83,263	**563,715**	21,091	-14,812	**-125,123**	21,091	-11,758	**-103,676**
		30%	5%	21,091	104,094	**710,022**	21,091	-10,645	**-95,858**	21,091	17,635	**102,773**
			10%	21,091	113,181	**773,848**	21,091	-9,613	**-88,608**	21,091	16,525	**94,974**
			15%	21,091	121,552	**832,636**	21,091	-17,841	**-146,399**	21,091	26,175	**162,754**
Logistics	0%	0%	5%	44,818	9,183	**19,681**	44,818	0	**-44,818**	44,818	3,620	**-19,392**
			10%	44,818	17,557	**78,494**	44,818	0	**-44,818**	44,818	7,745	**9,577**
			15%	44,818	25,090	**131,401**	44,818	0	**-44,818**	44,818	15,624	**64,921**
		10%	5%	44,818	24,101	**124,456**	44,818	0	**-44,818**	44,818	10,699	**30,326**
			10%	44,818	30,959	**172,628**	44,818	0	**-44,818**	44,818	15,957	**67,258**
			15%	44,818	37,224	**216,627**	44,818	0	**-44,818**	44,818	21,892	**108,942**
		30%	5%	44,818	43,790	**262,746**	44,818	0	**-44,818**	44,818	22,932	**116,248**
			10%	44,818	49,243	**301,042**	44,818	0	**-44,818**	44,818	23,045	**117,040**
			15%	44,818	53,699	**332,339**	44,818	0	**-44,818**	44,818	30,061	**166,316**
	25%	0%	5%	44,818	9,290	**20,429**	44,818	-3,056	**-66,283**	44,818	-4,148	**-73,952**
			10%	44,818	18,594	**85,778**	44,818	-3,925	**-72,388**	44,818	-4,427	**-75,914**
			15%	44,818	27,448	**147,963**	44,818	-4,096	**-73,589**	44,818	-9,859	**-114,061**
		10%	5%	44,818	29,640	**163,362**	44,818	-3,935	**-72,457**	44,818	-4,737	**-78,088**
			10%	44,818	38,671	**226,791**	44,818	-4,490	**-76,351**	44,818	-7,550	**-97,845**
			15%	44,818	46,645	**282,793**	44,818	-4,781	**-78,397**	44,818	-8,867	**-107,099**
		30%	5%	44,818	56,842	**354,417**	44,818	-6,543	**-90,772**	44,818	-4,054	**-73,293**
			10%	44,818	62,466	**393,919**	44,818	-5,481	**-83,312**	44,818	-17,157	**-165,324**
			15%	44,818	67,416	**428,683**	44,818	-5,283	**-81,921**	44,818	-20,053	**-185,665**
	50%	0%	5%	44,818	9,221	**19,949**	44,818	-1,946	**-58,490**	44,818	-3,556	**-69,793**
			10%	44,818	18,485	**85,010**	44,818	-1,664	**-56,503**	44,818	-784	**-50,323**
			15%	44,818	27,716	**149,849**	44,818	-938	**-51,407**	44,818	-8,524	**-104,688**
		10%	5%	44,818	29,762	**164,214**	44,818	-3,941	**-72,499**	44,818	-3,912	**-72,295**
			10%	44,818	38,920	**228,540**	44,818	-3,111	**-66,670**	44,818	-5,206	**-81,386**

			15%	44,818	47,536	**289,055**	44,818	-2,505	**-62,410**	44,818	-6,259	**-88,777**
		30%	5%	44,818	59,599	**373,777**	44,818	-8,612	**-105,304**	44,818	-5,023	**-80,096**
			10%	44,818	65,202	**413,130**	44,818	-8,701	**-105,929**	44,818	-8,299	**-103,106**
			15%	44,818	70,194	**448,194**	44,818	-7,229	**-95,589**	44,818	-3,510	**-69,473**
	75%	0%	5%	44,818	9,189	**19,722**	44,818	-1,918	**-58,290**	44,818	-4,622	**-77,278**
			10%	44,818	18,416	**84,530**	44,818	-1,289	**-53,872**	44,818	679	**-40,048**
			15%	44,818	27,353	**147,299**	44,818	4	**-44,787**	44,818	-5,791	**-85,493**
		10%	5%	44,818	29,751	**164,138**	44,818	-4,616	**-77,237**	44,818	-3,175	**-67,118**
			10%	44,818	38,936	**228,655**	44,818	-3,755	**-71,190**	44,818	-3,810	**-71,579**
			15%	44,818	47,868	**291,386**	44,818	-2,515	**-62,482**	44,818	-4,672	**-77,636**
		30%	5%	44,818	61,650	**388,184**	44,818	-10,646	**-119,591**	44,818	-4,552	**-76,793**
			10%	44,818	67,321	**428,018**	44,818	-9,799	**-113,642**	44,818	-6,496	**-90,443**
			15%	44,818	71,900	**460,179**	44,818	-7,981	**-100,870**	44,818	-1,133	**-52,780**
Marine	0%	0%	5%	44,818	14,384	**56,207**	44,818	0	**-44,818**	44,818	6,487	**742**
			10%	44,818	28,199	**153,236**	44,818	0	**-44,818**	44,818	18,176	**82,844**
			15%	44,818	40,396	**238,903**	44,818	0	**-44,818**	44,818	28,236	**153,501**
		10%	5%	44,818	41,019	**243,279**	44,818	0	**-44,818**	44,818	20,451	**98,820**
			10%	44,818	51,828	**319,198**	44,818	0	**-44,818**	44,818	30,057	**166,291**
			15%	44,818	59,252	**371,343**	44,818	0	**-44,818**	44,818	35,957	**207,731**
		30%	5%	44,818	73,716	**472,929**	44,818	0	**-44,818**	44,818	36,594	**212,205**
			10%	44,818	80,680	**521,844**	44,818	0	**-44,818**	44,818	46,012	**278,349**
			15%	44,818	87,303	**568,360**	44,818	0	**-44,818**	44,818	50,949	**313,028**
	25%	0%	5%	44,818	14,619	**57,861**	44,818	-7,591	**-98,136**	44,818	2,267	**-28,899**
			10%	44,818	28,556	**155,745**	44,818	-11,457	**-125,287**	44,818	8,769	**16,768**
			15%	44,818	41,093	**243,799**	44,818	-14,624	**-147,528**	44,818	18,784	**87,112**
		10%	5%	44,818	43,086	**257,803**	44,818	-5,915	**-86,361**	44,818	19,133	**89,563**
			10%	44,818	53,200	**328,834**	44,818	-11,372	**-124,691**	44,818	26,001	**137,802**
			15%	44,818	60,954	**383,298**	44,818	-13,960	**-142,867**	44,818	30,172	**167,095**
		30%	5%	44,818	75,664	**486,614**	44,818	-5,827	**-85,746**	44,818	29,299	**160,963**
			10%	44,818	83,179	**539,396**	44,818	-10,279	**-117,013**	44,818	34,424	**196,958**
			15%	44,818	89,964	**587,050**	44,818	-23,404	**-209,196**	44,818	41,278	**245,103**
	50%	0%	5%	44,818	13,923	**52,971**	44,818	-8,713	**-106,017**	44,818	2,716	**-25,744**
			10%	44,818	28,300	**153,952**	44,818	-12,962	**-135,856**	44,818	7,805	**9,997**
			15%	44,818	42,160	**251,294**	44,818	-17,153	**-165,297**	44,818	15,472	**63,848**
		10%	5%	44,818	45,193	**272,602**	44,818	-9,242	**-109,732**	44,818	17,877	**80,740**
			10%	44,818	56,966	**355,290**	44,818	-13,238	**-137,798**	44,818	24,541	**127,546**

			15%	44,818	66,374	**421,366**	44,818	-16,215	**-158,705**	44,818	26,835	**143,658**
		30%	5%	44,818	81,074	**524,610**	44,818	-9,879	**-114,205**	44,818	25,448	**133,915**
			10%	44,818	88,541	**577,056**	44,818	-14,338	**-145,523**	44,818	29,481	**162,242**
			15%	44,818	95,536	**626,186**	44,818	-27,174	**-235,678**	44,818	34,405	**196,829**
	75%	0%	5%	44,818	13,947	**53,140**	44,818	-7,849	**-99,948**	44,818	-3,841	**-71,793**
			10%	44,818	27,974	**151,656**	44,818	-11,375	**-124,713**	44,818	-12,762	**-134,451**
			15%	44,818	41,885	**249,367**	44,818	-12,216	**-130,616**	44,818	-16,572	**-161,212**
		10%	5%	44,818	46,541	**282,065**	44,818	-8,226	**-102,595**	44,818	-11,575	**-126,113**
			10%	44,818	58,164	**363,699**	44,818	-11,182	**-123,360**	44,818	-19,407	**-181,128**
			15%	44,818	67,640	**430,259**	44,818	-13,403	**-138,952**	44,818	-22,516	**-202,963**
		30%	5%	44,818	83,902	**544,476**	44,818	-9,150	**-109,084**	44,818	3,324	**-21,474**
			10%	44,818	91,823	**600,107**	44,818	-11,221	**-123,628**	44,818	-2,924	**-65,352**
			15%	44,818	98,985	**650,413**	44,818	-13,520	**-139,775**	44,818	-2,849	**-64,828**
Mixed	0%	0%	5%	18,455	4,592	**13,801**	18,455	0	**-18,455**	18,455	925	**-11,957**
			10%	18,455	8,861	**43,784**	18,455	0	**-18,455**	18,455	3,201	**4,026**
			15%	18,455	13,035	**73,100**	18,455	0	**-18,455**	18,455	6,272	**25,596**
		10%	5%	18,455	11,934	**65,364**	18,455	0	**-18,455**	18,455	3,401	**5,435**
			10%	18,455	15,911	**93,300**	18,455	0	**-18,455**	18,455	6,584	**27,788**
			15%	18,455	18,883	**114,173**	18,455	0	**-18,455**	18,455	8,136	**38,692**
		30%	5%	18,455	21,709	**134,021**	18,455	0	**-18,455**	18,455	8,867	**43,823**
			10%	18,455	24,399	**152,915**	18,455	0	**-18,455**	18,455	10,321	**54,038**
			15%	18,455	26,564	**168,116**	18,455	0	**-18,455**	18,455	11,505	**62,354**
	25%	0%	5%	18,455	4,515	**13,255**	18,455	-1,761	**-30,826**	18,455	1,061	**-11,005**
			10%	18,455	9,022	**44,915**	18,455	-3,167	**-40,698**	18,455	2,856	**1,603**
			15%	18,455	13,405	**75,693**	18,455	-3,489	**-42,962**	18,455	5,395	**19,438**
		10%	5%	18,455	13,855	**78,855**	18,455	-1,663	**-30,137**	18,455	6,000	**23,685**
			10%	18,455	18,182	**109,249**	18,455	-2,565	**-36,467**	18,455	9,206	**46,207**
			15%	18,455	21,119	**129,876**	18,455	-3,435	**-42,580**	18,455	10,906	**58,142**
		30%	5%	18,455	26,353	**166,637**	18,455	-2,190	**-33,840**	18,455	8,467	**41,013**
			10%	18,455	28,784	**183,712**	18,455	-3,026	**-39,709**	18,455	9,668	**49,446**
			15%	18,455	31,182	**200,556**	18,455	-2,862	**-38,557**	18,455	10,069	**52,264**
	50%	0%	5%	18,455	4,515	**13,259**	18,455	-1,058	**-25,886**	18,455	-2,023	**-32,663**
			10%	18,455	9,023	**44,921**	18,455	-1,662	**-30,128**	18,455	-3,586	**-43,640**
			15%	18,455	13,501	**76,374**	18,455	-2,340	**-34,888**	18,455	-3,414	**-42,433**
		10%	5%	18,455	14,256	**81,676**	18,455	-1,807	**-31,145**	18,455	-2,230	**-34,115**
			10%	18,455	18,580	**112,043**	18,455	-1,776	**-30,930**	18,455	-3,397	**-42,316**
			15%	18,455	22,194	**137,426**	18,455	-1,303	**-27,606**	18,455	-4,360	**-49,077**

	30%	5%	18,455	27,280	**173,147**	18,455	-3,549	**-43,378**	18,455	-6,840	**-66,497**
		10%	18,455	30,027	**192,446**	18,455	-3,118	**-40,356**	18,455	-6,170	**-61,790**
		15%	18,455	32,116	**207,116**	18,455	-693	**-23,322**	18,455	-8,375	**-77,275**
75%	0%	5%	18,455	4,514	**13,247**	18,455	-734	**-23,608**	18,455	-1,666	**-30,155**
		10%	18,455	9,025	**44,936**	18,455	-883	**-24,658**	18,455	-3,396	**-42,306**
		15%	18,455	13,509	**76,429**	18,455	-880	**-24,633**	18,455	-3,526	**-43,217**
	10%	5%	18,455	14,261	**81,705**	18,455	-1,737	**-30,654**	18,455	-2,339	**-34,880**
		10%	18,455	18,576	**112,014**	18,455	-1,042	**-25,776**	18,455	-3,724	**-44,611**
		15%	18,455	22,564	**140,027**	18,455	-882	**-24,650**	18,455	-4,408	**-49,414**
	30%	5%	18,455	27,758	**176,504**	18,455	-3,647	**-44,069**	18,455	-3,317	**-41,752**
		10%	18,455	30,531	**195,984**	18,455	-3,171	**-40,726**	18,455	-5,752	**-58,857**
		15%	18,455	32,800	**211,918**	18,455	-2,132	**-33,427**	18,455	-8,109	**-75,407**