MASTER

Consulting housing corporations using the cost optimality method

the design and development of a method for informed decisions tailored to Grontmij

van der Sande, R.P.J.

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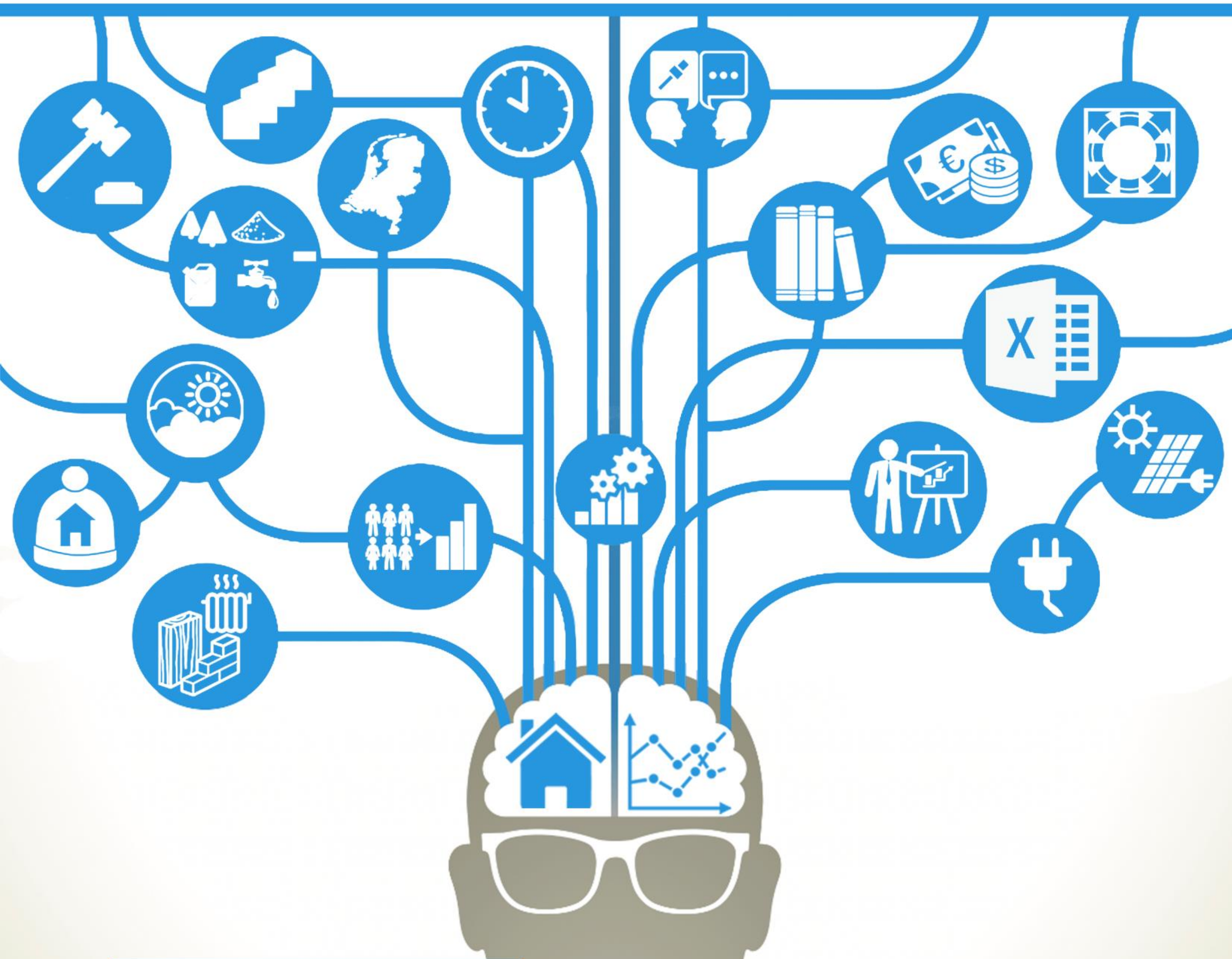

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Title	:	Consulting housing corporations using the Cost Optimality method.
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Abstract

Given the need for a transition towards a more sustainable housing portfolio [1], a growing interest calls for cost optimal housing concepts. By starting a partnership with the TU/e via a graduation project, Grontmij invested in a cost optimality method that enables their clients in the housing corporation sector to make informed decisions when developing the built environment.

A good understanding of the current developments in the housing sector is important, while decisions to upgrade are mainly financially driven, societal objectives play a part too. Consequently, over twenty experts from Grontmij, housing corporations, and research institutes were interviewed. The interviewees provided input for the SWOT confrontation which revealed the added value for the decision support method, that supports documented decision making.

The method is designed to analyze the performance of design variants and provide the cost optimal solution for a range of scenarios. This enables Grontmij to give well considered advice on probing questions from the market. Implementation for case specific details is embedded in the method, maximizing its applicability. Further enhancement is achieved by developing the method in the familiar Excel environment, shaping an intuitive user interface for a large user data base at Grontmij.

The performance of the decision support method is investigated and improved by a case study. It is assessed using a range of design variants and scenarios. The design variants are comprised of building envelope options, heating options and renewable energy generation options. The most influential scenarios that affect the performance of the design variants, are included in the method: user scenarios, climate scenarios and economic scenarios.

The decision support method revealed design variants in the case study that provide significant (110%) energy reduction for minor (11%) extra costs over the life cycle. The design variant equipped with an ASHP and 35m^2 PV panels showed the most promising result. Other findings revealed that there is not one absolute cost optimal solution for all the scenarios. The major influential actor proved to be the economic scenario. The housing corporation's business model for sustainable housing relies heavily on the feed-in tariff. The rate of the feed-in tariff is unmanageable by housing corporations, as it is subjected to political decision making. The decision support method adds value by assessing the financial sensitivity of the designs solutions in respect of changes in the feed-in tariff. Consequently, housing corporations are enabled to make well informed decisions given the insight in the financial robustness of each design variant.

Housing corporations are running out of time if they wish to have their building stock to meet the energy efficiency targets derived from the EPBD. The findings in the study enable Grontmij to advise housing corporations how to achieve their complex task for corporate social responsibility.

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Nomenclature

Symbols

The Buildings Performance Institute Europe (BPIE) definitions [2]:

Cost-optimal level	Cost-optimal level is the energy performance level which leads to the lowest cost during the estimated economic lifecycle.
Nearly zero-energy buildings (NZEB)	“Nearly zero-energy building” means a building that has very high energy performance, as determined in accordance with Annex I of the EPBD recast. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
Net present value	The net present value (NPV) is a standard method for the financial assessment of long-term projects. It measures the excess or shortfall of cash flows, calculated at their present value at the start of the project.
Reference buildings	Representative buildings that are characterized by their functionality and regional conditions, including indoor and outdoor climate conditions, geometries etc.

1 Introduction

1.1 Business opportunity

Grontmij is continuously seeking to improve their business opportunities towards the market segment of the housing corporations. By starting a partnership with the TU/e via a graduation project, Grontmij aims to further develop their business advisory on a multi-disciplinary field. A literature study and interviews conducted earlier revealed a desire for a decision support method based on the EBPD cost optimality method.

With natural resources depleting, the awareness for a more sustainable way of living is wide spread. Governments have set themselves targets to decrease the energy use and increase the share of renewable energy. The Netherlands has committed itself in 2020 to consume 14% of its energy from renewable sources. In 2013 it consumed 4.5% of its energy from renewable sources [1].

The built environment has a great potential to reduce the energy demand and increase renewable energy. Housing associations have large stock portfolios (26 million homes, meaning 11% of existing dwellings in the EU) [3]. Due to its size, they play an important role in the ambitious Dutch commitment.

In the Netherlands a significant part of the housing stock (30 to 40%) is owned by housing associations. These housing associations have inherited a complex social task to make their housing stock with limited funds future-proof in a pleasant living and working environment. Many housing corporations struggle with the preservation of their existing dwellings to many and very diverse reasons of technical, financial, social / governance nature (Figure 1).

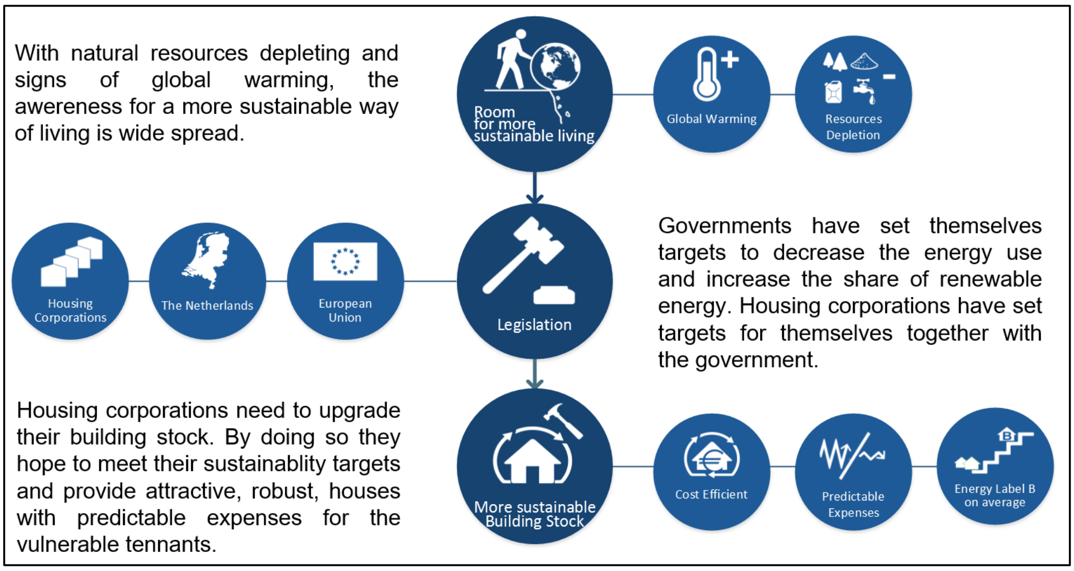

Figure 1: Challenges for the social housing corporations.

1.2 Context

Grontmij
Grontmij is part of Sweco. Sweco plans and designs the communities and cities of the future. Its work results in sustainable buildings, efficient infrastructure and access to electricity and clean water. With 14,500 employees in 15 countries, they offer their customers the right expertise for every situation. Sweco carries out projects in 70 countries annually throughout the world. Sweco is Europe's leading architecture and engineering consultancy, with sales of approximately SEK 15.2 billion (€ 1.7 billion) (pro forma 2014). The company is listed on NASDAQ OMX Stockholm AB.

Trends in the housing sector
The housing sector has changed significantly over the course of the last few years. A brief summary of the developments of the trends is given below. Its content derives from a DESTEP Analysis of which Figure 2 gives a schematic overview.

- Feasibility covenant " energiebesparing huursector " is challenged by corporations;
- Energy savings as a goal shifts to a way for saving on housing costs;
- Investments in new construction slow down, focus shifts to the existing stock;
- Planning for upgrading houses is preferably executed with natural moments;
- Since July 2015, there is the Authority Housing Associations, which holds financial supervision on the housing corporations and can impose penalties.
- Housing corporations have to make sure that in 2018 at least 95% of households - that have legal right to housing benefit - are assigned a house with a renting fee below the capping threshold.

Housing corporations are faced with new legislation and social responsibility that directly affects their business. A covenant stating high targets in terms of upgrading the building stock was signed by the umbrella organization of the housing corporations. At the same time there is political pressure to keep the houses affordable. How realistic the demands are is debatable. Corporations invest less in new buildings and more in the existing housing stock.

In the integral vision on the housing market [4][5], the following themes for the period 2016 -2019 are appointed with priority:

- Affordability and availability for the target audience;
- Creating an energy efficient social housing stock in accordance with the agreements in the National Energy Accord and the Covenant on Energy Rental Sector;
- Housing urgent target groups;
- Housing for tenants that require more care and elderly tenants, to live longer independently.

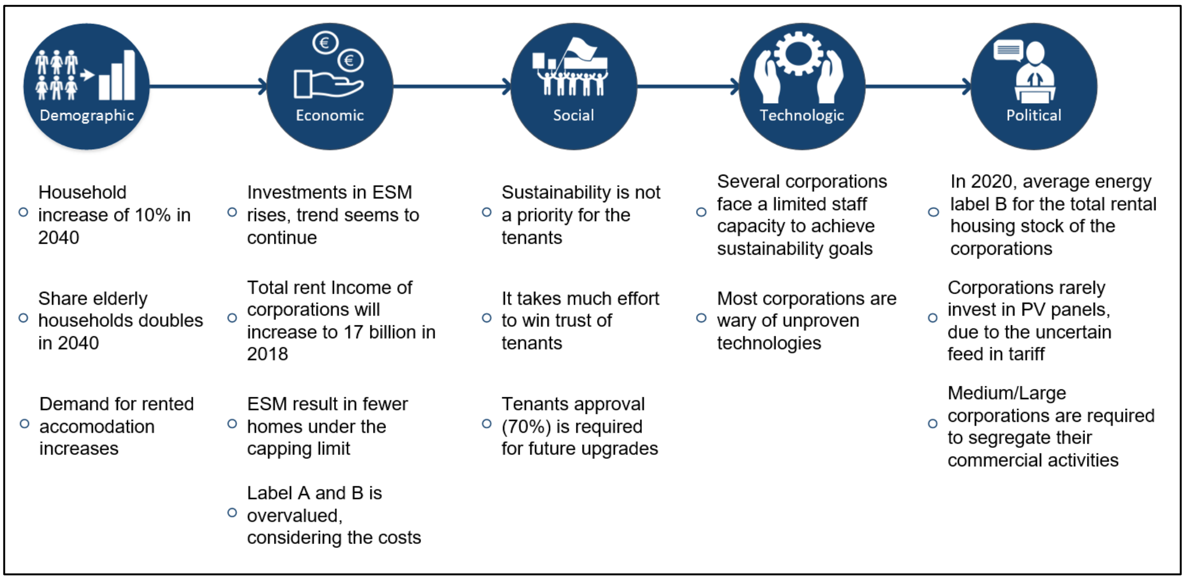

Figure 2: Schematic overview of the DESTEP Analysis.

Foundation of the decision support method

The decision support method is based on the cost optimality method, as stated in the introduction. Cost-optimality models are used by EU member states to define their building requirements. Hence, the EU has guidelines for cost-optimality models [6]. The complete process to assess and report on cost-optimal levels for buildings energy performance is extensively described in several studies [2], [7] [8].

Cost-optimality is a special case of cost-effectiveness. Literature describes cost-effectiveness as a measure or package of measures where the cost of implementation is lower than the value of the benefits that result, taken over the expected life of the measure [9]. Commercial stakeholders consider cost-effectiveness differently as their return on investment is leading. The “cost-optimal” result is that action or combination of actions that maximizes the net present value e.g. minimize the total life cycle cost.

Cost-optimality is an effective approach to highlight the performances between sets of energy saving measures (ESM). By evaluating ESM variants, it will be possible to identify three types of potential gaps. Figure 3 gives a graphical representation of cost optimality and the gaps it identifies.

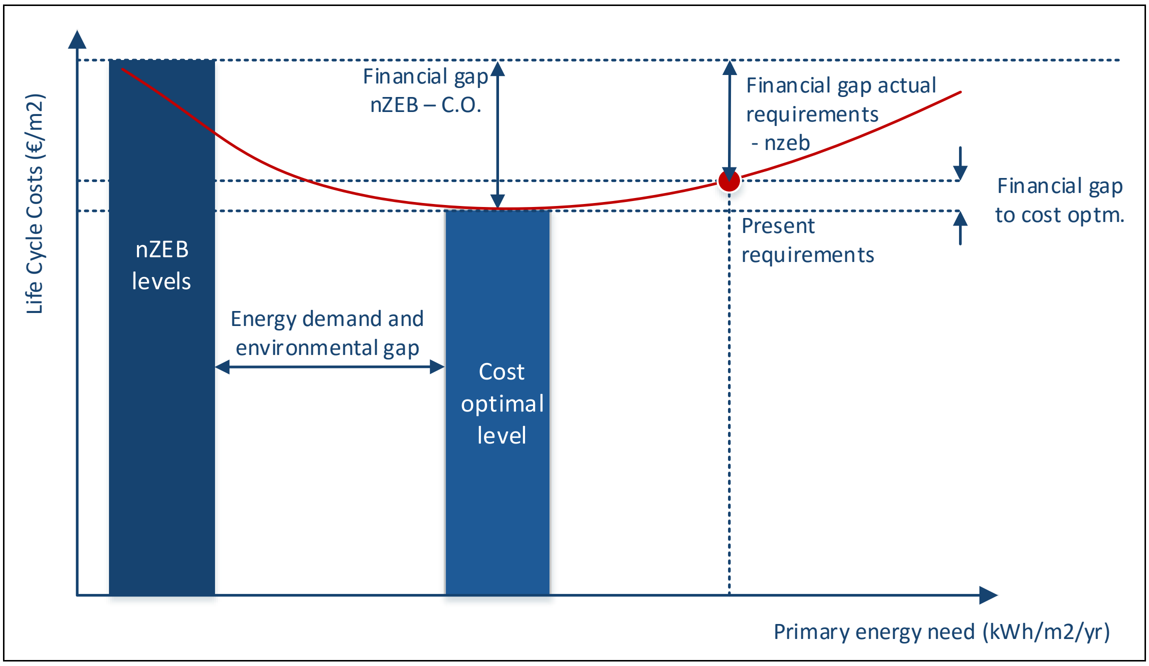

Figure 3: Graphical overview of cost optimality.

1.3 Objectives and research question

Many housing corporations struggle with both the preservation of their existing dwellings and deciding on new housing concepts. The struggles derive from many and very diverse reasons of technical, financial, social / governance nature. The survey conducted for this study revealed a desire to predict how a range of housing concepts perform over time under uncertainties.

Hence, study aims to contribute to making well considered decisions in terms of upgrading or building new sustainable housing concepts by providing Grontmij a user friendly method that supports the assessment of design variants under a range of scenarios.

The scenarios are split into three categories:

- User scenarios
- Climate scenarios
- Economic scenarios

This results in the following research question:

What is a cost optimal method that enables Grontmij to advise housing corporations in a range of design variants under a range of scenarios towards a more sustainable portfolio?

1.4 Thesis outline

A deep understanding of the study's findings is best achieved when there is a basic understanding of the underlying methodology (Chapter 2). This chapter addresses the foundation of the study: the methodology of the interviews and the decision support method. Assuring the method is fit for practice requires a case study. It acts as a coat rack for the development of the method. The case study's reference building, design variants and scenarios are represented in chapter 3.

Using the methodology as described in chapter 2, and the case study in chapter 3, we can investigate the outcome and put it into context in chapter 4. The process of developing the method and analyzing the result unveiled interesting and diverse aspects that are worthy for further investigation, which are summarized in chapter 6 which also concludes the research.

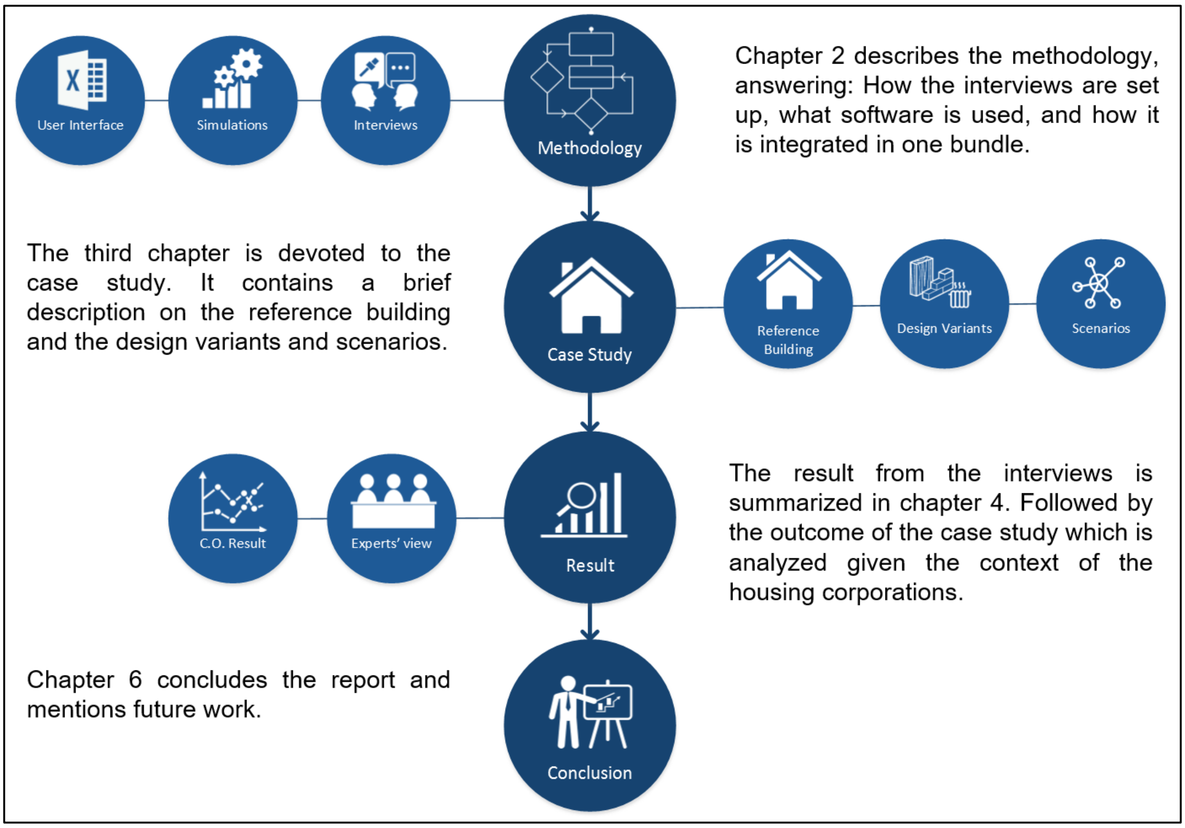

Figure 4: Schematic overview of the report structure.

2 Methodology

2.1 Field study

A good understanding of the current developments in the housing sector is important, as decisions to upgrade are not only financial driven. Grontmij values a verification on the studied literature. Over twenty experts from Grontmij, housing corporations, and research institutes are interviewed, giving practical insight and input for the decision support method.

Asking the proper interview questions is indispensable for gathering valuable information. There are many guidelines that provide support, in this case the guideline Kempen and Keizer [10]. Good preparation is key, which is why a pilot is performed to test the questionnaires and improve shortcomings. An iterative process ensures the interviews offer depth on specific topics. Key points are noted and the interviews have a semi-structured nature to encourage the interviewees to express his or her view freely. The questionnaires are available in Appendix I .

Findings from the literature study on the developments in the housing sector, opportunities and threats are assessed by the interviewees enabling them to verify and co-create the SWOT analysis. Grontmij values information that improves their market opportunities towards the market segment of the housing corporations. How Grontmij can strengthen their advisory is based on the SWOT analysis. The findings not directly related to the cost optimality method are documented in a separate report. Figure 5 gives the flowchart of the field study.

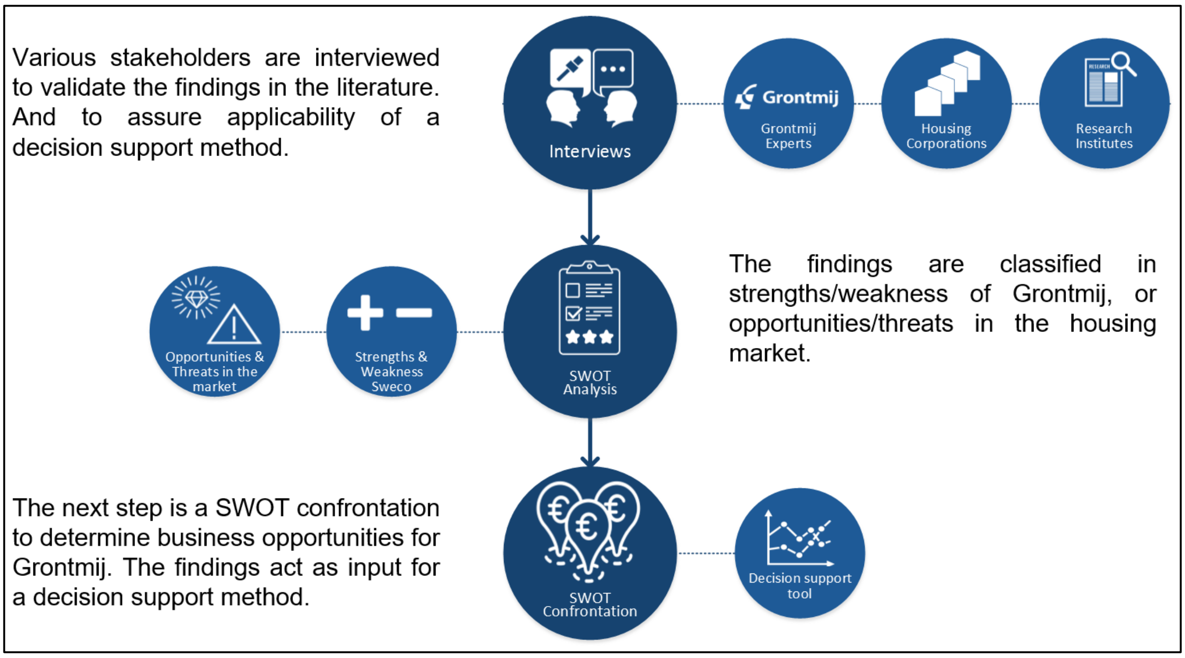

Figure 5: Flowchart field study.

2.2 Decision support method

Developing the decision support method begins when the challenges in the sector are known. The method includes housing concepts from a range of energy efficiency, costs, and scenarios. Figure 6 gives a schematic representation of the methodology.

Excel acts as the starting point, where data from other sources are stored in. Building performance simulation software predict the hourly heating demand for each combination of energy saving measures under different user & climate scenarios (electric consumption of appliances excluded).

The System Advisory Model predicts the energy production of renewable energy variants and their costs. This is again stored in Excel where variants of household appliances are added, and the heating demand is converted is converted using the corresponding SCOP values of the heating systems. Finally, the costs are calculated and economic scenarios applied.

Tableau extracts the result from excel and displays it in a user friendly environment. A custom user interface gives displays the result in a professional and attractive setting.

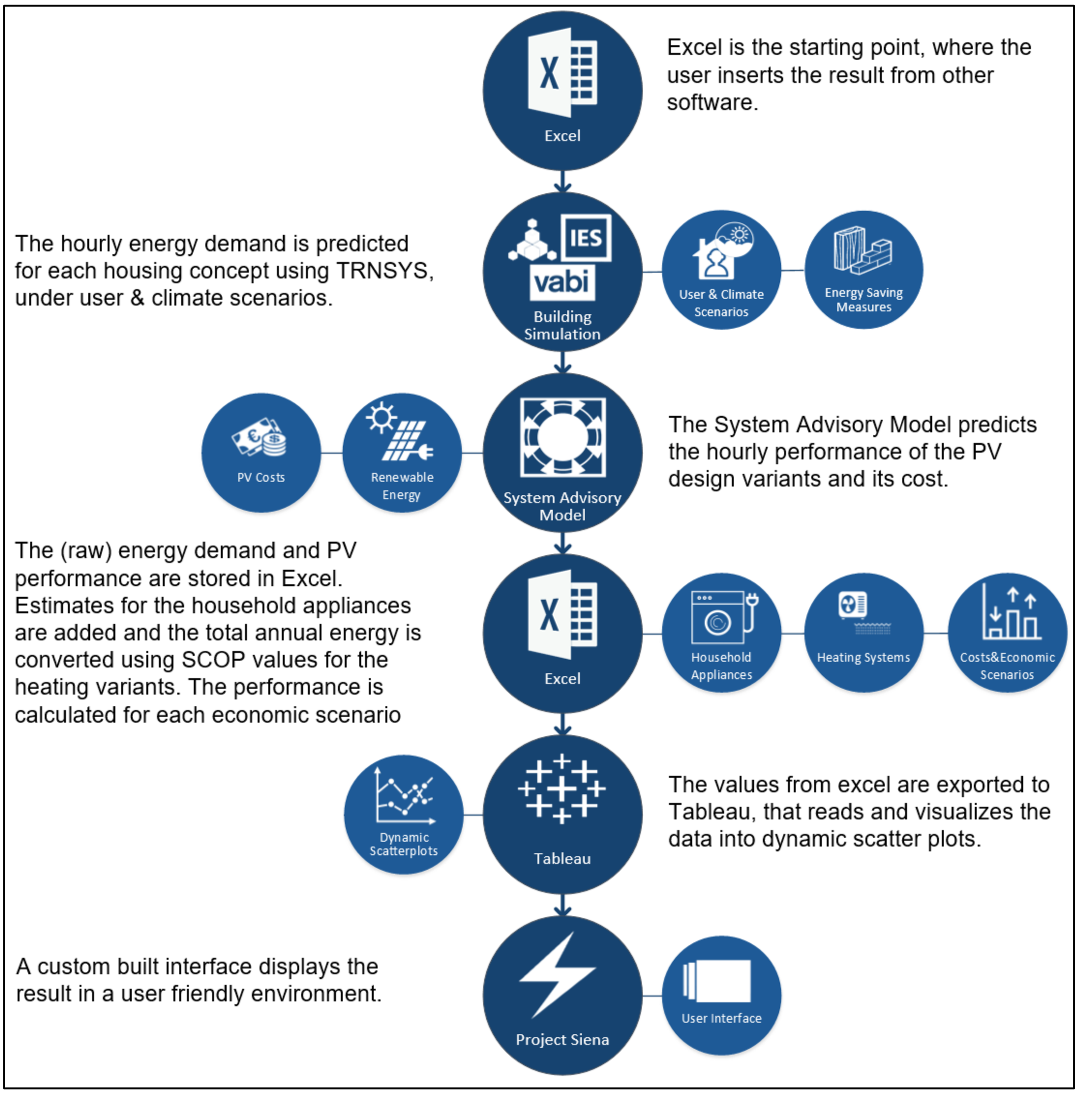

Figure 6: Schematic representation of the methodology.

3 Case Study

The performance of the decision support method is investigated by a case study. The reference building is given a brief introduction and subsequently the scenarios and design variants. It ends with an estimation of the building costs and the energy demand. Figure 7 gives a schematic overview.

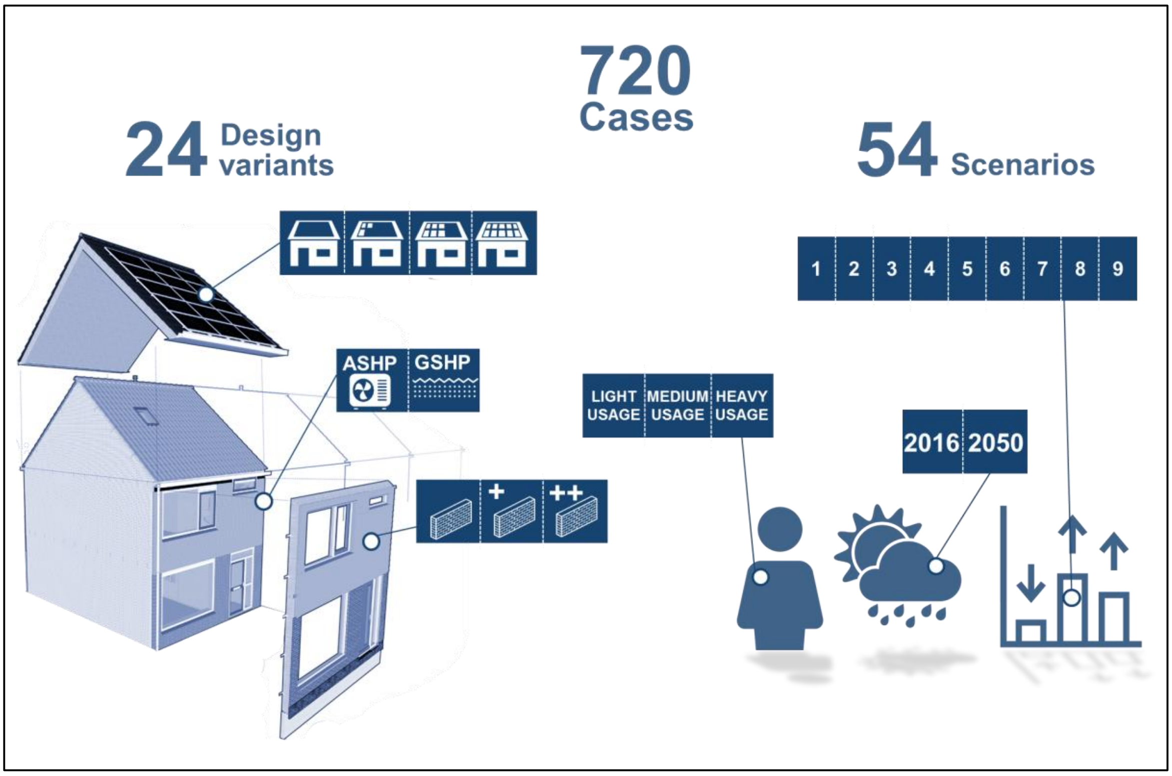

Figure 7: Overview case study.

3.1 Reference building

The reference building is chosen with care to represent a large part of the building stock. Nevertheless, the performance of the design variants rely on case specific details and the outcome should be weighed accordingly[11] . The reference building used in this project is developed by the Dutch state organization RVO. Its purpose is, among others, to help assessing the impact of building concepts and scenarios. The building of choice is the terraced house , as it is the most common building type in the Netherlands [12]. The number of terraced houses in the Netherlands is compared with other building types in figure 8, whereas figure 9 gives a graphical representation of the house.

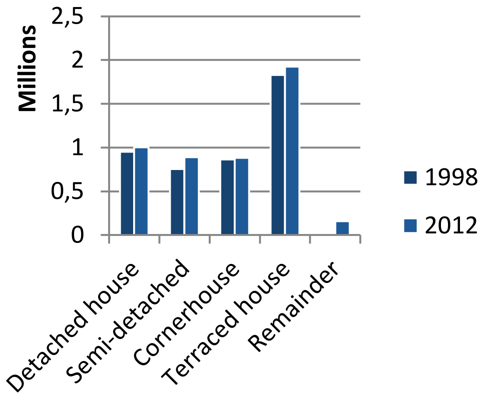

Figure 8: Dutch building types. [12]

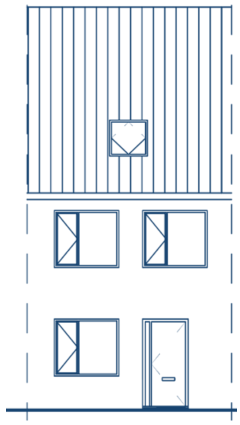

Figure 9: Reference building terraced house. [13]

3.2 Design variants

Building Envelope Options

The building envelope measures represent packages of technical measures intended to minimize the energy demand and global costs. The study conducted by R. Kotireddy [14] comprises a significant number of design variants. Three packages of building envelope measures are assembled with help of Grontmij. Table 1 gives a summary of the technical variants analyzed. Appendix 3 provides more information.

Table 1: Overview building envelope options

Parameters	Low	Medium	Strong
Walls, floor Rc (m^2k/W)	3	5	10
Roof Rc (m^2k/W)	4	6	10
Windows U value (W/m^2K	2.54	1.01	0.4

Heating System options

The houses are heated by all electric systems: either an air source heat pump (ASHP) or a ground source heat pump (GSHP). Despite Gas' popularity in the Netherlands as primary heat source (93%) [15]), gas is excluded in the housing concepts. Gas is a finite natural resource with long term predicted cost escalation [15]. The all-electric systems are considered a sustainable and robust choice. Table 2 gives an overview of the heating systems.

Table 2: Overview heating system options

Parameter	Air Source Heat Pump	Ground Source Heat Pump
Seasonable coefficient of performance	2,8	5,2

Renewable Energy Systems options

Housing corporations are cautious with investing in renewable energy systems, in contrast with private home owners. The uncertainty with Net-metering is one of the main causes for the lack of investments in renewable energy systems [16]. Predicting the performance of PV panels can contribute to decision making. Therefore the impact of renewable energy systems are assessed on four levels (Table 3).

Table 3: Overview renewable energy system options

Parameters	RES: None	RES: Small	RES: Medium	RES: Large
Total module area in m^2	0	10	25	35

3.3 Scenarios

Social housing corporations, Grontmij's clients, strive for steady expenses for their tenants. The target group of social housing corporations exists primarily of more economic vulnerable tenants. Their financial reserves are often insufficient to absorb fluctuating energy costs. If the energy prices are included in the rent, the risk falls down to the housing corporations. Assessing the design variants on user & climate scenarios provides an estimation of the risk.

User Scenarios

Research conducted earlier have made cost-optimization calculations based on standard assumptions on climate conditions and user behavior [11] [17]. Various studies have underlined the importance of occupant behavior in building performance simulations [18][19]. In current building performance simulation tools user behavior generally is represented in a very static way [20]. This study investigates 3 user scenarios.

The occupancy behavior's prevailing feature is the choice of indoor temperature [19]. The most common heating patterns will therefor provide an estimation of the occupants' influence along with other parameters as given in Table 4.

Table 4: User scenarios.

Parameters	Light	Medium	Heavy
Indoor temperature, Occupied °C	18	20	22
Indoor temperature, Unoccupied °C	14	16	18
Internal heat gains due to appliances and lighting, W/m^2	2	4	6
Electricity use for appliances and lighting, W/m2	2	4	6
DHW consumption, L/day	60	120	180
Occupancy profile	Evening	All day	All day

Climate Scenarios

There is growing consensus that the built environment is influenced by climate change. Hence, this study will include multiple climate files. By doing so, the impact of climate change on building concepts can be investigated. Note: The renewable energy systems use a fixed climate file, its performances are not affected by the climate scenarios.

Table 5: Climate scenarios.

Parameter	Description
Climate file	Regular: Standard weather file
	Future: Climate file 2050 G+

Economic Scenarios

Between 60 and 70% of the housing corporations do not invest in PV panels [16]. The uncertainty regarding future arrangements of net-metering is the primary cause of the reluctance to invest in PV. The small portion that does invest regards the future of net-metering as risk that results in smaller scale PV investments.

Table 6: Economic scenarios, prices are 30 year averages.

Name	Electricity costs	Feed-in tariff
Scenario 1: "Average, electricity costs = feed-in"	0.27 €/kWh	0.27 €/kWh
Scenario 2: "Average, electricity costs > feed-in"	0.27 €/kWh	0.20 €/kWh
Scenario 3: "Average, electricity costs >> feed-in"	0.27 €/kWh	0.10 €/kWh
Scenario 4: "Low, electricity costs = feed-in"	0.25 €/kWh	0.25 €/kWh
Scenario 5: "Low, electricity costs > feed-in"	0.25 €/kWh	0.16 €/kWh
Scenario 6: "Low, electricity costs >> feed-in"	0.25 €/kWh	0.07 €/kWh
Scenario 7: "High, electricity costs = feed-in"	0.29 €/kWh	0.29 €/kWh
Scenario 8: "High, electricity costs > feed-in"	0.29 €/kWh	0.23 €/kWh
Scenario 9: "High, electricity costs >> feed-in"	0.29 €/kWh	0.13 €/kWh

Energy price of the first three scenarios are based on the Energy Research Centre [21]. The feed-in tariff is equal to the energy price for scenario 1 as indicated in Table 6, whereas scenario 2 it is slightly lower, and scenario 3 even less.

Scenario 4, 5, 6 follow the same trend with exception of the energy price: which is lower than the first three scenarios. Scenario 7, 8, 9, have a higher energy price. The life cycle costs are influenced by the economic scenarios, as shown in Figure 13.

3.4 Cost calculation

This study aims to give an estimation of the costs. A more accurate representation of the construction and maintenance costs requires a higher level of details on the building elements. The cost estimations derive from a market-based analysis extracted from Grontmij and other sources. Costs that are equal for all variants, such as the purchase of the land plot, are excluded.

This study differentiates 3 types of cost estimations that derive from an earlier extensive study on cost optimality [22]:

- Investment costs
- Global costs
- Life cycle costs

The investment costs for this study consists of the building envelope costs, heating system investment cost & maintenance costs, and –if applicable – costs for renewable systems. The global costs include the investment costs, maintenance and energy costs (building and user-related).

The main focus lies on the life cycle costs (LCC). The most common simplified life cycle costs exclude energy costs. As in most cases, this is a private agreement between the tenant and energy supplier.

New legislation has recently been adopted by the Dutch parliament: the energy performance fee (EPF) [23]. The EPF paves the way for new business models for housing corporations. It is a monthly fee that may be charged by the landlord to the tenant if the property is equipped as such that the building-related and user-related energy is annually balanced out by on-site renewable energy.

This results in two simplified ways of calculating the life cycle costs from a housing corporation perspective:

$$LCC_{(\text{for "normal housing"})} = \text{Investment costs} + \text{maintenance costs}$$

$$LCC_{(\text{for energy efficient housing})} = \text{Investment costs} + \text{maintenance costs} + \text{energy costs} - \text{energy performance fee}$$

Both formulas are used for the case study, as the low insulated envelope does not meet the EPF prescribed energy efficiency standard [24].

The costs for the building envelope derive from financial ratios, e.g. rough estimations. Table 7 gives the ratios for each building envelope option.

Table 7: Building costs: Building envelope

Parameters	Standard insulated	Extra insulated	Extreme insulated
Building costs	815 €/m² [25]	909 €/m² [25]	1100 €/m² [25]
Additional costs	15%	20%	20%

The costs of heat pumps rely on multiple factors. The prices given in Table 8 are considered average prices for residential heat pumps.

Table 8: Building costs: Heating system

Parameters	Air Source Heat Pump [26]	Ground Source Heat Pump [27]
Installation costs	€ 10940 [27]	€ 21000
Monthly Subscriptions costs		€ 200
Annual maintenance	€ 200	€ 90 [26]

The energy prices are indicative and rely on future developments, hence the implementation of economic scenarios (chapter 3.3). The standard scenario (economic scenario 1) derives from Table 9. The average price is taken for 30 years.

Table 9: Energy prices for households [21]

Electricity [eurocent / kWh]	2015	2020	2025	2030	2035	2040	2045*	2050*	30 year average
Marginal rate	23	25	25	26	28	29	29	29	26.75
Net metering	23	25	25	26	28	29	29	29	26.75

*Note: The energy prices for both 2045 and 2050 were excluded in the source file and are presumed identical with 2040.

The discount rate is used to index the energy payments from tenants, given the housing corporations might have to borrow money for the investment. Housing corporations can borrow money with a low interest rate (Table 10), due to guarantees given by the Dutch Central Housing Fund.

Table 10: Discount rate housing corporations.

Parameter	
Discount rate	3,5% [21]

Housing corporations are allowed to charge tenants a financial compensation for measures that lead to energy efficient houses. The energy performance fee (in dutch: energieprestatievergoeding) is charged monthly and the size of the fee is equal to the average energy cost. In the case study it is fixed on €80,-.

4 Results

4.1 Field study analysis

The result of the interviews is presented here to give a brief overview of the current developments in the sector and the different perspectives. Experts are involved in the research from the beginning of the research till the end. The experts (Figure 10) are interviewed to verify the literature findings, filling in the SWOT analysis and improving the method.

Figure 10: Schematic overview of the interviewees

The interviewees are selected with care. To achieve a broad perspective known critics to cost optimality models are interviewed as well. An attempt is made to summarize the perspectives of Grontmij, the research institutes and the housing corporations.

Advice strategic approach

Housing corporations are facing turbulent times where business as usual does not apply. Providing affordable housing that will stand the test of time is a prominent theme. And time is changing, the target group will be more diverse with former refugees and an aging population[5].

Grontmij's broad variety of expertise can potentially solve the complex and diverse challenges of housing corporations. However, the competition is fierce and housing corporations have the tendency to work with trusted partners. In particular, large contractors have invested resource over the last couple of years. Their size makes it possible for chain integration, offering Design Build Finance and Maintain (DBFM) solutions.

However, the larger number and diversity of housing corporations creates opportunities for Grontmij. There is simply put no standard housing corporation [28]. Large housing corporations have ties with large contractors. Smaller sized corporations often prefer to work with local contractors, with strong ties to the local community. Partnering with local contractors seems most beneficial for Grontmij. Local contractors do not always have the expertise to solve the complex challenges.

The new Housing act states that corporations should reasonable contribute to the implementation of the municipal housing policy [29]. Grontmij has an established reputation in the municipality area, where it has successfully proven its added value. Fruitful opportunities may arise when combining the management expertise of Grontmij and local contractor's ties with the housing corporation. Housing corporations should be treated different from commercial clients. Successfully comprehending with their social background requires a set of consultancy skills that not solely focus on profit and efficiency. Serving their tenants and their employees are often placed before profit and efficiency.

Perspective Grontmij's experts

Several thousands of houses are currently managed by Grontmij Real Estate Management, on behalf of institutional investors. The housing corporation market, however, is left mostly untouched. The majority of the interviewees recognize the housing corporation sector as a potential market.

Housing corporations tend to work with familiar trusted partners and are cautious for unfamiliar faces. Gaining their trust requires long term investments and personal connections with the housing corporations. Some of the services Grontmij can provide, involve possible loss of jobs at housing corporations due to increased efficiency. Services in that area are unlikely accepted given the conservative nature of housing corporation as a social organization, according to several of Grontmij's experts. It is stressed that the housing corporations require a different approach than commercial clients. A set of consultancy skills tailored to social housing corporations can increase Grontmij's success.

Perspective research institute's experts

Both Platform31 and Energiesprong are strong advocates of nearly zero energy buildings (nzeb). Platform31, the premier knowledge and networking organization for urban and regional development [30] and its innovation program Energiesprong are well established research institutes in the housing market. They guide contractors and other parties towards affordable nzeb.

Some of the housing corporations are conservative organizations and tend to stick to what they are familiar with, according to Energiesprong's Target Group manager, who strongly believes housing corporations need to redefine their business model: "They have to get back to their core business, providing housing for their primary target group" (tenants with a yearly income below €34911) [29]. Activities apart from providing rental housing should be considered outsourcing to commercial parties. "Housing corporations are not achieving their profitability of 3,5% without strong changes.

The outgoing request for proposals in tenders to commercial parties should be non-rigid to encourage innovative solutions. Convinced of future cost reduction, they believe investing in anything less than nearly energy zero is inadequate. Outcomes of cost optimization studies receive little credit from both Platform31 and Energiesprong. Bringing parties together and creating innovative solutions along with optimizing the construction process have the most potential. No cost optimization study can put a price on that. Research institute ECN values cost optimizations studies more. ECN has its own cost optimization method to advise the Dutch government on their policies.

Perspective housing corporation's experts

It is a turbulent time for housing corporations, of which upgrading their building stock is one of the many challenges. The interviews confirmed the findings in literature, upgrading the housing stock remains a priority despite of other challenges. Money has never been the issue, stated the interviewed developer. "There are plenty of resources but we are not sure where to spend it on".

Not fully convinced of rigorous measures to upgrade dwellings straight to nearly energy zero, energy label B is perceived as more cost effective. The umbrella organization AEDES represents the housing corporations. However, in practice not all corporations feel committed to the covenants signed by AEDES. The corporations wish to achieve the sustainability target (label B) but it is not cast in concrete. Their primarily focus is providing affordable housing.

There is skepticism at housing corporations towards cost optimization study as it is often based on unrealistic assumptions. Reality is often more complex than cost optimization studies assume. One of the examples stated by a housing corporation developer: “A rent near the capping limit is often assumed for cost optimization studies. In reality it is often far from near maximum, due to a variety of reasons. The projected financial calculations then predict a too optimistic scenario”.

4.2 Decision support method

The case study in this paper served mainly to shape the decision support method. Nevertheless, the case study’s result can provide helpful insight in cost optimal solutions. A selection of result is showcased that enables Grontmij to advise housing corporations in new design variants. The performance of the design solutions can be measured in multiple ways. Measuring it by analyzing the global cost is common for cost optimality studies [22]. Investigating the global cost for this study point out the lesser insulated building envelope (“Low) as the most cost optimal design solution. As pointed out in Figure 11, the “Low” insulated envelope financially outperforms more insulated envelopes.

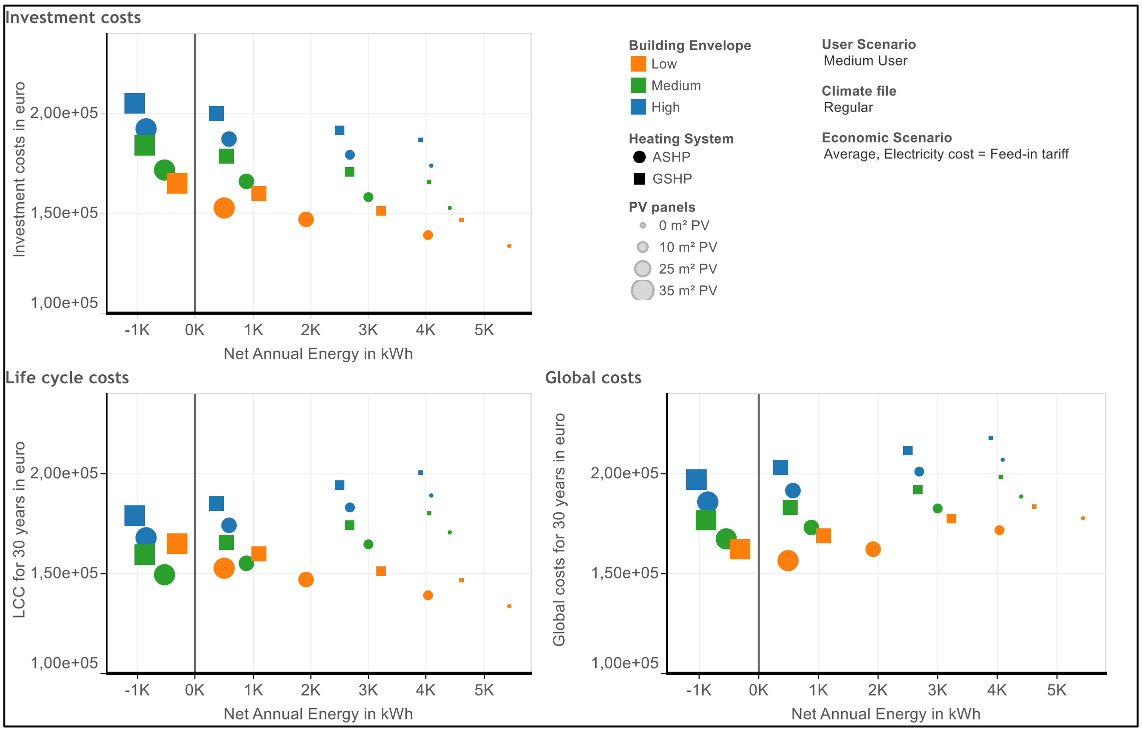

Figure 11: Investment costs, life cycle costs, and global costs for the 24 design variants. There is noticeable difference between the life cycle costs (housing corporation’s perspective) and the global costs.

The life cycle costs are of most interest, as they determine the costs from a housing corporation’s perspective. It is worth noting that the energy costs and the energy performance fee is included in the more insulated building envelops (“Medium” & “High”), whereas the lesser insulated building envelope (“Low”), excludes energy costs. Chapter 3.4. explains more about the costs calculation method.

The “Low” insulated building envelope is cost optimal from a housing corporation perspective as indicated in Figure 11. Given the need for a more sustainable housing portfolio, it is worth considering to invest a modest amount more to achieve considerable energy savings. From that perspective it is advisable to consider investing in a more insulated envelope (“Medium”), and equipping it with an air source heat pump. If housing corporations chose to invest in energy efficient building envelopes, they should consider the scenarios that affect the energy costs. Part of the decision support method is the assessment of these scenarios on the design solutions. The impact of all the scenarios on the design variants equipped with the air source heat pump is given in Figure 12. The design variants with a ground source heat pump are excluded in the figure as it is outperformed by the air source heat pump in every scenario.

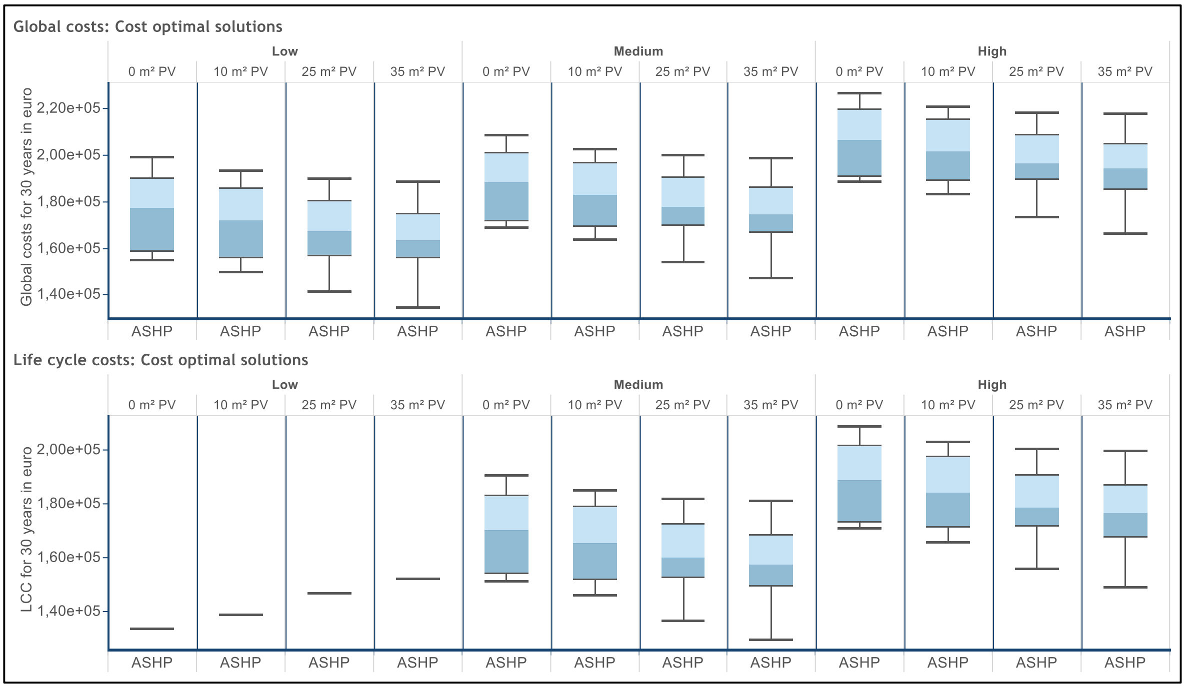

Figure 12: Financial performance of the design variants equipped with an air source heat pump. Cost optimal solutions for the global and life cycle costs point out the “low” building envelope as cost-optimal for the majority of the scenarios. The “low” building envelope show only one line for the boxplots, as the energy prices influenced by the scenarios are not included in its life cycle costs.

Impact of economic scenarios on the life cycle costs

The economic scenarios affect the financial performance the most. The design variants are assed for a total of 9 economic scenarios as discussed in chapter 3.3. An economic scenario where the energy prices rise result in energy efficient cost optimal solutions. If the energy prices drop, the less energy efficient design variants are cost optimal. Figure 13 shows the financial impact of the economic scenarios on the design variants with energy efficient building envelopes (“Medium” & “High”), which include energy costs.

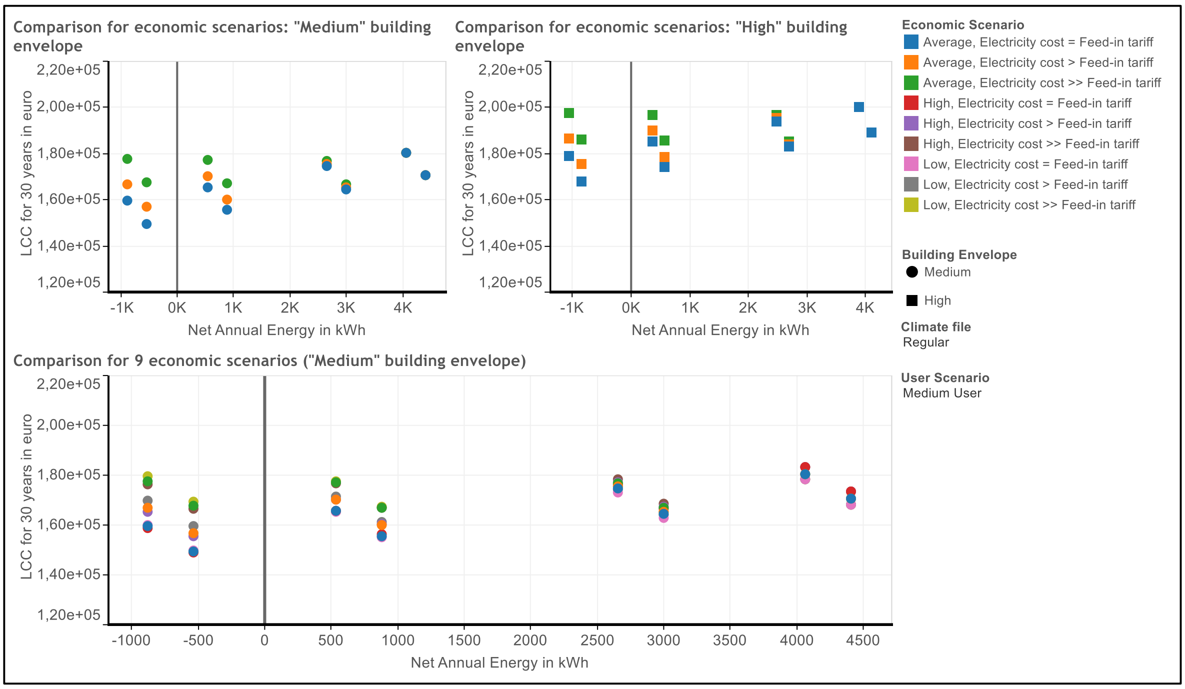

Figure 13: Impact of economic scenarios on the life cycle costs of the building envelopes "medium" and "high". Economic scenarios are most influential on the cost optimal solutions. An economic climate where the energy prices rise, favor the energy efficient designs, while dropping prices favor the less energy efficient designs.

Impact of user scenarios on the life cycle costs

While the economic scenarios have the most influence on the cost optimal level, the impact of user scenarios should not be neglected: it has a significant influence on the energy demand. The life cycle costs fluctuate accordingly, as shown in Figure 14. Insight in robustness of design variants regarding user scenarios can enable housing corporations to define their energy performance fee. Percentage-wise, the user related energy demand is most dominant in the design variants with a highly insulated building envelope. There are examples where newly renovated buildings are equipped with energy efficient appliances to reduce the energy demand further.

Impact of climate scenarios on the life cycle costs

In comparison with the economic and user scenarios, the climate scenarios have the least impact on the performance. The lesser insulated design variants are influenced the most by the outdoor conditions, however, its effect is not strong enough to influence the cost optimal solutions. An overview of the result is given in Figure 15.

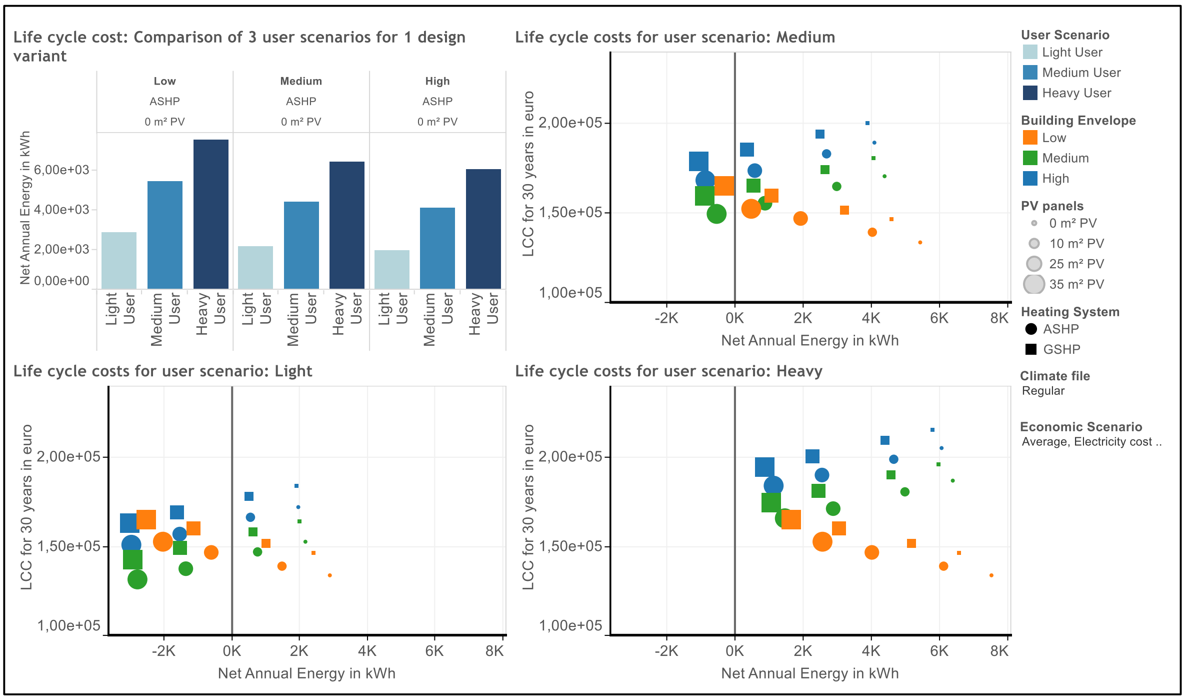

Figure 14: The three user scenarios cause significant differences in total life cycle costs. The "low" building envelope is not affected by the user scenarios, as its life cycle costs is calculated differently.

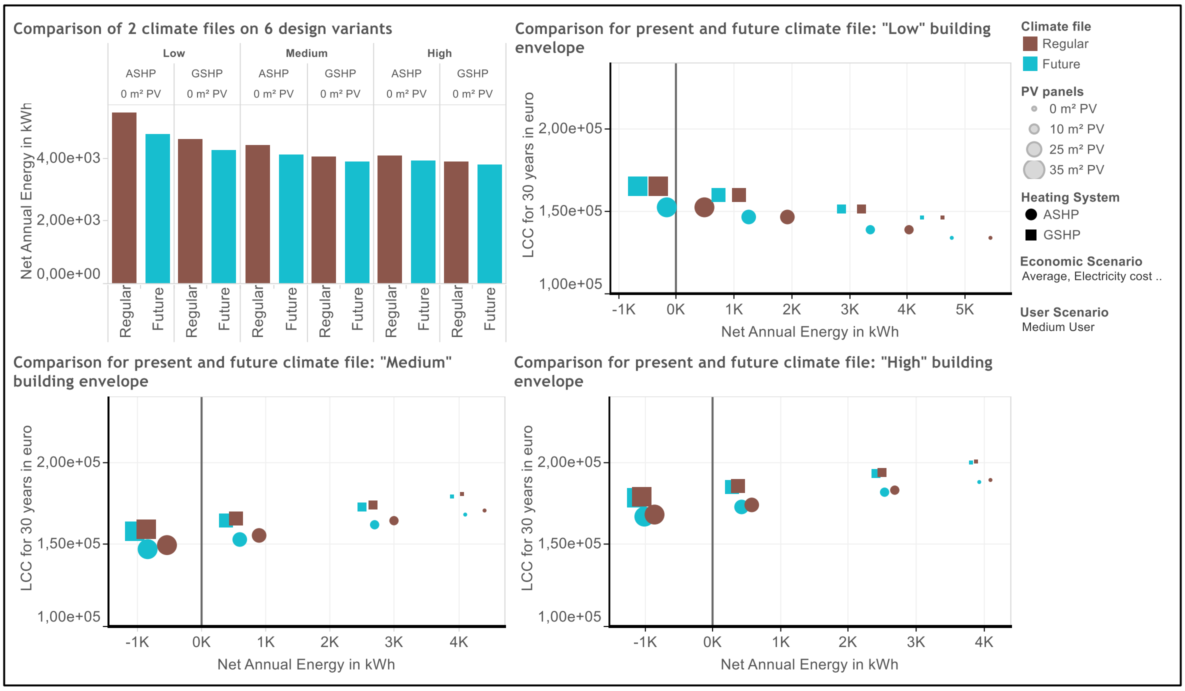

Figure 15: The current climate and future climate scenario affect the design options differently. The "low" building envelope experiences larger differences in comparison with the "medium" and "high" building envelope.

5 Conclusion

5.1 Conclusion

Making the housing stock more energy efficient is one of the many challenges housing corporations face. The sense of urgency to meet the sustainability targets derived from the EBPD, does not enforce immediate action. Lack of financial funds is not always the case, investing in energy efficient housing is considered risky due to its new technology and business case.

Housing corporations struggle with mapping a strategy towards a future proof building stock. The cost optimization study can strengthen Grontmij's advisory. The methodology can help to answer questions that the majority of the housing corporations face: How will net-metering affect my building stock and which housing concepts should be investigated. There is not one particular housing concept fit for all housing corporations. The decision support method is designed to give a performance indication of housing concepts in a conceptual stage. By providing information in an early stage, decision makers can decide what is worth further investigating for their particular case.

For most scenarios, the energy efficient design variants have slightly higher life cycle costs. Whether it outweighs the considerable energy efficiency is for the housing corporation to decide. The performance of energy efficient housing concepts relies heavily on the energy subscription (EPF), which on its turn relies on net-metering. The method includes multiple scenarios to determine the effect of a change in the feed-in tariff. The economic scenarios affect the business model, in particular the variants that affect the EPF. The combination of high usage scenarios and a low energy price with even lower feed in tariff has a significant impact on the financial performance of energy efficient design variants.

Neighboring countries have lesser attractive net-metering arrangements. The current Dutch arrangement is accused of preventing innovation towards energy storage. Arguably this could mean in 2020 the Dutch government might follow the neighboring's footsteps and reduce the feed-in tariff. The impact of the feed in tariff should also be set against the Dutch struggles in meeting the climate goals. By doing so a strong shift in the feed-in tariff is less likely. Housing corporations currently investing nearly zero energy buildings rely on a good transition period and future breakthroughs in energy storage.

Overall, the life cycle costs from a housing corporation's perspective tend to be lower for design variants with lower investment costs. However, great leap forward on energy efficiency can be achieved by accepting minor additional life cycle costs. Additional advantages beyond energy saving have not been taken into account but should not be neglected.

5.2 Recommendation future work

The mismatch in energy supply and demand results in grid dependency, accompanied by the net metering regulation. Including energy storage as a design variant can further enrich the feasibility of in particular design variants with a large PV capacity. Further improvement of the decision support method is achieved by including added property value. The economic disinvestment after the life cycle can positively influence the business case for more energy efficient design variants. The performance of the heat pumps can be more accurate by calculating temperature dependent convergent factors.

The user related energy consumption is of increasing importance with more energy efficient building envelopes. Investigating the cost optimal appliances can add value for housing corporations where the energy performance fee applies.

An increasing portion of the social housing corporations are elderly tenants [4]. Providing comfortable housing for tenants that require more care and elderly tenants, to live longer independently is appointed by the Dutch minister as priority. Design variants optimized for that particular group can aid housing corporations.

The decision support method is designed to minimize the user effort. It is possible to further automate the process. The System Advisory Model - which predicts the performance of renewable systems - can be further automated with a script. During this study the applicability of such a script has been tested on a small scale prototype. The script is available in appendix II and can serve as a foundation for future automation.

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Appendix 1

Interview questions

Interne vragenlijst

Kennismaking

1. Kan je in een paar zinnen vertellen welke werkzaamheden je verricht voor Grontmij?
2. Idem voor je betrokkenheid bij woningcorporaties?

Introductie

3. Korte introductie van de afstudeerder en het afstudeerproject.

SWOT

4. Wat zie je als sterkten van Grontmij binnen het marktsegment woningcorporaties?
   a) In welke zaken zit de unieke concurrentiepositie van Grontmij?

•

5. Wat zie je als zwakten van Grontmij binnen het marktsegment woningcorporaties?
   a) In welke zaken is er achterstand op concurrentie binnen Grontmij?

•

6. Wat zie je als kansen voor Grontmij binnen het marktsegment woningcorporaties?
   a) Wat moeten we veranderen, verminderen of juist verbeteren om deze kansen te kunnen oppakken?

   •

7. Wat zie je als bedreigingen voor Grontmij binnen het marktsegment woningcorporaties?
   a) Wat moeten we veranderen, verminderen of juist verbeteren om deze bedreigingen te kunnen pareren?

   •

8. Zou je in de SWOT kwadranten willen aanvullen op basis van het genoemde? Implicaties van sterkten en zwakten op basis van kansen en bedreigingen.

•

9. Wat zijn volgens jou de belangrijkste concurrenten van Grontmij binnen deze context?

Afsluitende vragen.

10. Zijn er nog aspecten die je als belangrijk ziet maar die we nog niet genoemd hebben?

•

11. Wie denk je dat wellicht nog interessant en leerzaam is om te spreken binnen Grontmij?

•

12. Dankwoord en uitnodigen voor eindpresentatie in februari/maart.

Externe vragenlijst

Introductie

1. Introductie van de student en de onderzoekscontext:

"Vanuit de Technische Universiteit Eindhoven doe ik onderzoek naar de ontwikkelingen binnen de sterk veranderende woningcorporatiesector. Onderzoeksvragen hierbij betreffen de implicaties bij het verduurzamen van de gebouwenvoorraad. U bent benaderd aangezien u (binnen deze studie) als sectorexpert wordt beschouwd, om deze reden wil ik u een aantal vragen stellen betreffende de ontwikkelingen binnen het marktsegment woningcorporaties.

Kennismaking

1. Wat is uw beroep in het dagelijks leven?
   a) Hoe zou u uw ervaring binnen de huursector en specifiek binnen de woningcorporatiesector willen kenschetsen?

Inhoudelijk

2. Wat zijn volgens u ontwikkelingen binnen huurmarkt die (in)direct invloed (kunnen) hebben op de woningcorporaties?
   a) Welke ontwikkelingen ziet u voor woningcorporaties als het meest kansrijk/verontrustend? Waarom?
   b) Hoe beïnvloedt iedere ontwikkeling uw organisatie?
   c) In hoeverre kan de ontwikkeling verschillend uitwerken per woningcorporatie?
   d) Wat is hiervan de oorzaak?

•

3. Welke lokale en regionale ontwikkelingen hebben invloed op de lokale woningcorporatie?
   a) Wat zijn de gevolgen van de zojuist genoemde ontwikkelingen voor de bedrijfsstrategie?
   b) Wat zijn de gevolgen van de zojuist genoemde ontwikkelingen voor personeel?
   c) Wat zijn de gevolgen van de zojuist genoemde ontwikkelingen voor logistiek en huisvesting?

   •

4. Corporaties moeten hun DAEB en niet-DAEB gaan scheiden. In hoeverre zal dat invloed hebben op de bedrijfsvoering?
   a) Verwacht u dat dit gevolgen heeft voor de duurzaamheids ambities?

   •

5. Elke corporatie moet 95 procent van de huurtoeslaggerechtigde huishoudens een woning met een huurprijs onder de aftoppingsgrens toewijzen vanaf 2017.
   a) Kunt u aangeven wat de gevolgen zouden zijn van deze maatregel voor uw organisatie?
   b) Verwacht u dat dit gevolgen heeft voor de duurzaamheids ambities?

   •

6. Hoe ziet u het toekomstbeeld voor woningcorporaties?
   a) Wat ziet u als kansen voor woningcorporaties?
   b) Wat ziet u als bedreigingen voor woningcorporaties?
   c) Op welke ontwikkelingen ziet u woningcorporaties hier nu en binnen 5 jaar hoofdzakelijk op inspelen?

Afsluitende vragen

7. Zijn er nog aspecten die u als belangrijk ziet maar die nog niet genoemd zijn?
8. Wie denkt u dat wellicht nog interessant en leerzaam is om te spreken binnen dit kader?
9. Dankwoord.

Appendix 2

Script System Advisory Model

```
/*
        CONFIGURATION OPTIONS
                                                                */

//file names for in- and output
path = path_only( project_file() );
input_file = path + '/sam-excel-exchange-example.xlsx';        //input    uses    the    excel
fileyear1_hourly_e_tofromgrid
output_file = path + '/sam-output.csv';                               //output is in a csv file

//define the name of excel input
input_name = 'hourlyload_';

//amount of input rows from excel
input_amount = 2;

print_to_log = true; //prints simulation status to log

//set the current SAM case
active_case('Residential PV System');
/*
        END OF CONFIGURATION OPTIONS
        DO NOT EDIT BELOW THIS LINE              */

//create an Excel object and open the Excel file
xl = xl_create();
xl_open(xl, input_file);

//Step 1: read input values from SAM and write them to Excel.
//Do this first because the costs in Step 2 are calculated
//using Excel formulas based on the number of modules and inverters.
n_modules = get('total_modules');
n_inverters = get('inverter_count');

xl_set(xl,n_modules,'number_of_modules');
xl_set(xl,n_inverters,'number_of_inverters');

//Step 2: read values from Excel
//These values will be calculated using the values from Step 1.
//values are read from the XL object as strings, so need to be
//converted to numbers xl_get() can read either cell references (D34)
// or cell names (module_cost) from Excel.
module = to_real( xl_get(xl,'module_cost') );
inverter = to_real( xl_get(xl,'D34') );
bos = to_real( xl_get(xl,'bos_cost') );
labor = to_real( xl_get(xl,'labor_cost') );
overhead = to_real( xl_get(xl, 'margin_cost') );
inflationSAM = to_real(xl_get( xl,'inflation') );

//allocate input and output arrays
input_data = alloc(input_amount);
output_data = alloc(input_amount);

for(i=1;i< input_amount+1 ;i++) {
        row = to_string(input_name + i);
        input_data[i] = real_array( xl_get(xl, row) );
}
```

```
//close the Excel file and free the Excel object
xl_close(xl);
xl_free(xl);

//Step 3: Set values of SAM inputs
set('module_costunits',0); //set module cost units to $/Wdc
set('per_module',module);
set('inverter_costunits',1); //set inverter cost units to $/Wdc
set('per_inverter',inverter);
set('bos_equip_perwatt',bos);
set('install_labor_perwatt',labor);
set('install_margin_perwatt',overhead);
set('inflation_rate',inflationSAM);
//set('load_user_data',hourlyload);


//initialize table to store output data
csvoutput = {};
//simulate active case
for(i=0;i<input_amount;i++) {
        y=to_real(i)+1;

set('load_user_data',
input_data[y]);

        msg="";
        ok = simulate(msg,1);
        if (ok==true && print_to_log==true) outln("Wrote column output" + y + " in output file: "+ output_file + " -- case:
" + active_case());
        elseif (print_to_log==true) outln("Simulation failed with the following messages:\n",msg);

        //start from one instead of zero for readable output


        //write results to table
        csvoutput{"output " + y} = real_array(get('year1_hourly_e_tofromgrid'));

}

//write csv file to disk
csvwrite(output_file, csvoutput
```

Appendix 3

TRNSYS simulation input

	Building Envelope Package (3)		
	Low	Medium	Heavy
Walls, floor (Rc)	3	5	10
Roof (Rc)	4	6	10
Window (U-value)	2.54	1.01	0.4

	User Scenarios (3)		
	Low	Medium	High
Temperature Occupied, °C	18	20	22
Temperature Unoccupied, °C	14	16	18
Internal heat gains due to appliances and lighting, W/m^2	2	4	6
Electricity use for appliances and lighting, W/m^2	2	4	6
DHW consumption, L/day	60	120	180
Occupancy profile	Evening	All day	All day

Climate Scenarios (2)	
Reference	2050-G+

Appendix 4

System Advisory Model simulation input

SAM version 2015.6.30			
Location	Netherlands NLD Amsterdam (INTL)		
Inverter	Apparent Inc,: MGI220-MC4 120V [CEC 2011)		
System Design			
System sizing	Desired array size: 6.2 kWdc / 4.5 kWdc / 1.8 kWdc		
	DC to AC ratio: 1.10		
Configuration at Reference Conditions			
Module: Nameplate capacity	6.027	4.305	1.722
Module: Number of modules	28	20	8
Module: Modules per string	1	1	1
Module: Strings in parallel	28	20	8
Module: Total module area	34.8 m2	24.9 m2	10 m2
Module: String Voc	47.7 V	47.7 V	47.7 V
Module: String Vmp	41.0 V	41.0 V	41.0 V
Inverters: Total capacity	5.4 kWac	3.96 kWac	1.62 kWac
Inverters: Total capacity	5.9 kWdc	4.34 kWdc	1.78 kWdc
Inverters: Number of inverters	30	22	22
Inverters: Max DC voltage	42.0	42	42
Inverters: Min MPPT voltage	16.0	16	16
Inverters: Max MPPT voltage	42.0	42	42
Tracking & Orientation	Tilt: 33 degrees		
	Azimuth 180 degrees		
Lifetime	Degradation rate 0.5 % per year		