Energy control in the dwelling market

A case-study on energy consumption and generation in the dwelling market of Eindhoven

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Chapter 1: Introduction

The current issue about the future energy supply is one of the most important issues. The current dependency of fossil fuels and the absence of good alternatives put the whole current Western prosperity and even existence at risks. All the basic products like, food, clothing and shelter, that protect human beings from nature, and the corresponding logistic processes that are necessary to transport these goods depend on fossil fuels. The current world population has achieved its current size because fossil fuels made it possible to produce and transport, among others, the basic products faster and in bigger volumes.

In order to keep the current world population at its current level the world is in desperate need of available and affordable energy. The dependency on fossil fuels leads to a couple of non solvable problems and therefore they drive today's energy discussion (Mackay 2009). First, the nature of the source; fossil fuels are a finite resource. This means that its existence in its cheap form may run out in the coming 100 years. Currently the resource is used for all kind of manners, from simply heating the dwellings we live in to manufacture all kind of plastics and cosmetic stuff. Second, the dependency of the fossil fuels; fossil fuels can only be distracted at certain regions of the world. Most of these regions have political uncertain and unstable regimes. Since the world economy depends on fossil fuels, the rest of the world depends, indirectly, as it comes to the availability of the resource, on these regions as well. Third, the effect of fossil fuels on the climate; the biggest contributor to climate change is the increase in greenhouse gasses like carbon dioxide (CO_2). Greenhouse gasses are the result of the consumption of fossil fuels and increases, among other, the average global temperature.

At the moment the problems are still solvable, and there are multiple different solutions. In order to get to these solutions, different types of strategies can be applied. One of the most used strategies in the Netherlands is the Trias Energetica. This strategy applies three steps:

1. Minimize the total demand of energy as much as possible.
2. Use, for the remaining energy demand, as much as possible sustainable energy sources
3. Use for the remaining energy demand, fossil fuels.

The three different steps provide certain guidelines of using energy, but it does not provide any solutions. In practice there are two types of solutions. On the one hand the minimization of the energy consumption can be achieved by changing the behavior of users. For example, energy can be saved by switching the light off in empty rooms or by turning the thermostat one degree Celsius lower. On the other hand the minimization of energy consumption and the generation of energy through sustainable sources can be achieved by technical solutions.

Reduction of the energy consumption can be achieved in many different fields. This study is executed as part of the KENWIB project (Kennisclusser Energie Neutraal Wonen In Brainport) and studies aspects of the long-term ambition of the city of Eindhoven. The city has pronounced the ambition be energy neutral somewhere between

2035 and 2045. This means that on annual base the city wants to fulfill its own energy consumption in a sustainable way. The ambition includes all building and device bounded energy and excludes all energy consumed by traffic. As a consequence the total gas and electricity consumption of the city must be reduced as much as possible and all remaining gas and electricity demand must be provided in sustainable way.

Within the city of Eindhoven there are basically three different energy consuming parties that can be distinguished: Citizens, companies and public organizations. As it comes to minimizing the total energy consumption of the city each of three parties must be investigated and provided with standardized solutions. This study only focuses on one of the three parties, namely the citizens. Citizens consume energy through their dwellings. They consume gas by heating their dwellings and their demanded water and they consume electricity by the usage of all kind of devices.

The reason for the study on this party is twofold. On the one hand the monitoring of the current energy consumption of dwellings is easy to measure and it is available through different sources (e.g. CBS, ENDINET, etc.), on the other hand, on dwelling level, multiple different standardized tools consists to analyze and improve the energy performance of different types of dwellings (e.g. verbeteruwhuis.nl, energiebesparingsverkenner, energielastenverlager, energiebespaarwijzer). However the extrapolation of these tools on a macro level, for example, on a city level, does not exist and is extremely interesting in the case of Eindhoven.

1.1 Problem definition

The municipality of Eindhoven has announced the ambition to be energy neutral in the period between 2035 and 2045. At the moment the city investigates the right strategy to achieve the ambition and it investigates the available tools the market offers. The city has three different energy consuming parties. One of the parties is the citizen party which consumes energy through its dwellings. The market offers different analyzing tools to investigate the energy performance of different types of dwellings, and it offers tools that investigate the effects of different improvements. However the energy performance of all dwellings within a city on macro level is missing. The municipality has no idea what the energetic and financial effects of different dwelling improvement packages are on a city level.

Despite all the currently and historically taken efforts (FiT programs on different techniques, and information campaigns), the energy consuming rate is still far from the neutral target. In addition, there is no clarity on the effects of proven techniques on a macro scale. The municipality has no idea of the price quality ration of the different techniques and therefore she has no idea which technique to focus on. In short, this leads to the following problem definition:

There is no clarity of the financial and energetic effects of energetic improvement packages for the dwelling market on a city level.

1.2 Problem questions

As a solution to the problem the study performs two different case-studies on the existing dwelling market. Both case-studies represent stand-alone researches that try to find an answer on the above presented problem.

The first case-study investigates the financial and energetic effects of a maximal improvement of all dwelling bounded energy labels in Eindhoven. Therefore the study seeks an answer on the following three research questions:

RQ1: What are, theoretical, the potential annual energetic savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?

RQ2: What are, theoretical, the potential annual financial savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?

RQ3: Is the investment financial feasible, and if so, under what conditions?

The second case-study investigates the potential of dwelling bounded PV systems. It develops a method to calculate the total potential roof area of all the dwellings in Eindhoven that is suitable for the implementation of PV systems, and it calculates the financial and energetic effects of different implementation scenarios during a certain simulation period. The case-study seeks an answer on the following research questions:

RQ1: What are the most important energetic and financial variables as it comes to a large- scale implementation of PV systems in Eindhoven?

RQ2: Which scenarios can be distinguished and what are the effects of the scenarios?

RQ3: What will be the total financial and energetic effects in case the technology will be large-scale implemented in the city?

1.3 Research Boundaries

Since time is as always the most important restrictive variable it is important the study has a certain focus, which as result leads to certain boundaries. The first boundary is that the research focuses on the energy neutral target of the municipality of Eindhoven. Therefore, both case-studies will use as target study the city of Eindhoven and all calculations will be performed on the current dwelling stock of the city. However, since the different dwellings in one city are in general not completely different from another city, the results of this city can be used as a starting point for other municipalities.

Furthermore, the study only investigates energy saving measures applied on the existing dwellings stock of Eindhoven. Newly built dwellings are constructed according to current construction laws and legislations meaning that the energy performance of these dwellings is, in most cases, optimal. However, especially the older dwellings leave energetically spoken, much room for improvements, and therefore the newly built dwellings are excluded from the study.

As mentioned before, there are two types of solutions of the energy problem, namely technical solutions and behavioral solutions. Both case-studies focus on the technical solutions, meaning that the behavioral solutions fall outside the scope both case-studies.

Finally the study only focuses on energetic and financial effects of improvement measures. This means that organizational forms are excluded. Nonetheless the study provides certain preconditions of the organization of the different improvement measures; however the main focus will be on the large-scale effects of the measures.

1.4 Expected results

Both case-studies will be simulated with the simulation tool MS excel and try to give more insight in the financial and energetic effects of technical interventions on the existing dwelling stock of Eindhoven. The study expects the following results:

- Insight in the total gas and electricity savings of intervention strategies in the existing dwelling market. Different intervention strategies lead to different energy savings. One of the expected results is to get more insight on the energetic effects of these different strategies on a city level.
- Insight in the necessary investment costs of the different intervention strategies. Different investment costs lead to different finance strategies. One of the expected results is to get more insight on the necessary investments of the different energetic improvements on a city level.
- Insight in the conditions and feasibility to compete with conventional energy sources. Different intervention strategies lead to different energy savings and different investment costs, and since these intervention strategies compete with conventional energy sources, it is necessary to know the financial and energetic effects of the different intervention strategies and to know the conditions these effects are achieved, in order to get more insight in the competiveness of the technical interventions.

Chapter 2: Research Design

This research consists of two different case-studies. The first case-study investigates the effects of a maximal improvement of the dwelling bounded energy label, and the second case-study investigates the effects of the implementation of PV systems on the complete suitable roof area of the dwelling stock of Eindhoven. Both case-studies are stand-alone investigations, with the similarity that both studies explore the improvements of dwellings.

2.1 Conceptual model

Both case-studies can be put together in one conceptual model (Figure 1). The conceptual model consists of four different phases:

- The target area phase: This phase is for both case-studies the same and represents the starting point of the case-studies. The complete housing stock of Eindhoven is converted into standardized dwellings. The standardization process is performed for each individual dwelling and is based on the construction period of the dwelling and the type of dwelling. Consequently average numbers of the standardized dwelling are used in the next phase (e.g. gas and electricity consumption, roof area, etc.)
- The contextual orientation phase: This phase is unique for each case-study and it calculates the total energetic savings and investment costs of the different interventions. The two improvement packages together represent the dwelling bounded energy label improvements and are calculated by the first case-study, the PV system implementation intervention is calculated by the second case-study. The phase ends with the potential energetic savings and corresponding investment costs on a city level.
- Simulation phase: This phase of for both case-studies the same. The simulation phase simulates two situations and compares both situations with each other. The first situation consists of different scenarios of intervention strategies, and the second situation consists of a benchmark, which represents an unchanging current situation. Both situations are simulated during a simulation period of 34 year, starting in 2011 and ending in 2045.
- Conclusion phase: The conclusion phase discusses the different findings of the case-studies and tries to find answers on the different research questions.

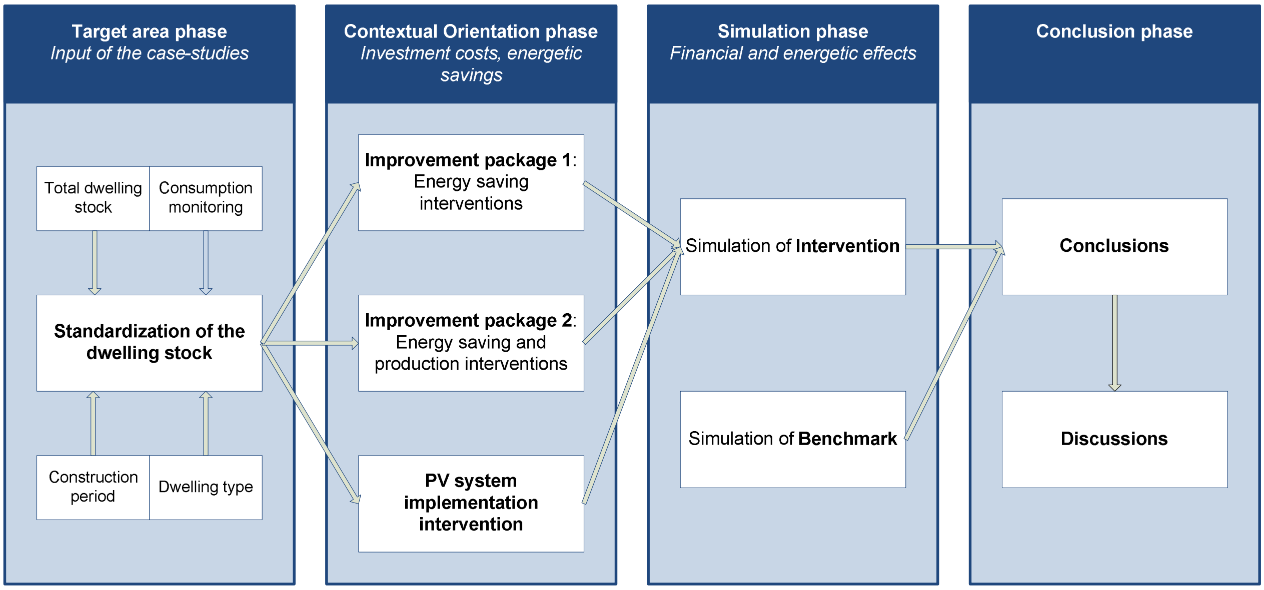

Figure 1: Conceptual model of the study

2.1 Reading guide

After this introduction chapter, the study directly starts with the description and implementation of the case-studies.

Chapter three described the first case-study on dwelling bounded energy labels. The chapter starts with a brief introduction which is based on literature research. Then the framework of the calculation tool of the contextual orientation phase will be elaborated. Subsequently the target area is applied on the calculation tool and the results of these calculations will be used as input for the simulation phase. Finally the results of the simulations will be discussed in the final parts of chapter three.

Chapter four describes the second case-study on PV systems. The chapter starts with a brief introduction on PV systems and its different components and the current Dutch legal frame according to PV systems which are both based on literature research. After the introduction the chapter continues with the elaboration of the target area and the different variables which are necessary in order to calculate the effects of the implementation of PV systems. Subsequently the chapter describes the development of these variables in order to calculate the effects during the simulation period. Finally the different scenario will be described and simulated and the results will be discussed at the end of chapter four.

Chapter 3: Case-study on dwelling bounded energy labels

This chapter elaborates the results of the case study on energy labels in the dwelling market of Eindhoven. The chapter starts with a brief introduction of dwelling bounded energy labels in general and it elaborates any possible legal issues of the Dutch market according to these energy labels.

After the introduction the focus will be on the simulation method of the case-study. The case-study consists of two parts. The first part calculates the energetic effects of two improvement packages on the current dwellings stock and it calculates the corresponding investment costs of these improvements. The second part simulates the effects of the first part during a simulation period, starting in 2011 and ending in 2045, and compares the result with a benchmark. Both parts will be calculated using the simulation tool MS Excel. All calculations of the first part will be executed according to the calculation tool of AgentschapNL.

The goal of the case-study on dwelling bounded energy labels is to study the energetic and financial effects of a maximal improvement of all the dwelling bounded energy labels within the city boundaries of Eindhoven. The case-study therefore seeks an answer to the next research questions:

RQ1: **What are, theoretical, the potential annual energetic savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?**

RQ2: **What are, theoretical, the potential annual financial savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?**

RQ3: **Is the investment financial feasible, and if so, under what conditions?**

3.1 Introduction on energy labels

The energy label for dwellings is a measure that shows how energy efficient a dwelling is, in comparison with other dwellings of the same type. In 2002 the European parliament introduced the EPBD directive. The directive is aimed at reducing the greenhouse emissions and the dependency on fossil fuels. The label presents the measure in classes and colors. The classes have a range from a dark green A++ class, indicating a very energy efficient dwelling, to a dark red G class, indicating a very energy inefficient dwelling. All comparisons are made between similar dwellings. The measure is one of technical nature, meaning that the behavior component is excluded in its determination. Instead it calculates the necessary calculations with an average behavior component.

Optimization of a dwellings energy label is interesting for four reasons:

- *Reduction of the monthly electricity and gas costs*: Monthly fixed costs consist for an important part of gas and electricity costs. Since the average gas and electricity prices and the average electricity consumption have only increased the last couple of decades, due to the exhaustibility of fossil fuels, it is obvious that this tendency continuous in the near future. A greener energy label has a reduction of the energy consumption as effect and therefore a reduction of the monthly fixed costs.

- *Better selling position of the dwelling*: Due to the reduction of the monthly fixed costs, the selling position of dwelling with an energy label is better than the selling position of dwellings without an energy label. Studies confirm that dwellings with an energy label have a shorter selling period than dwellings without an energy label. Dwellings with a label have an average selling period which is about a month shorter than those of corresponding dwellings without a label. Furthermore studies also confirm that dwellings with a green energy label (A++ to C) have a better selling price than dwellings with a red energy label (D to G). Dwellings with a green label yield approximately 3% more income than corresponding dwellings with a red label (Brounen et al 2011). This increase of the selling position is especially currently desirable since the dwelling market finds itself at the moment in a though position.
- *Independency of resources*: The reduction of the consumption of fossil fuels and the ability to generate, at least for a part, one's own energy demand, leads to a more independent situation. At the moment most of the fossil energy sources are located in political instable locations, which have strong fluctuations in energy prices and, perhaps in the future, fluctuations in energy supply, as a result.
- *Reduction of the CO_2 emissions:* A reduction of the fossil energy consumption, leads to a reduction of the CO_2 and other greenhouse gas emissions which leads to less environmental damage.

The energy label is presented in a report and is based on different installation and isolation properties of the dwelling. The label can only be determined by a certified energy advisor, and is assigned by a standardized method. This method calculates the energy-index, which in turn determines the energy label class and color. The standardized method must be approved by the so-called assessment guideline 9501 (or in short BRL 9501), which ensures the quality of the labels.

The energy index (energie index) or EI is an indicator of the energy performance of a dwelling or another building. How lower the energy index is, the better the energy performance is. The EI is determined using an Energy Performance Advice (Energie Prestatie Advies) or EPA. The energy performance of a dwelling is determined by analyzing the construction, energetic, and installation characteristics of a dwelling or another building. In total dozens of properties of a building are determined and used in the standardized method, the result of this standardizes method is the EI. The table below shows the label classes in combination with the Energy Index.

Table 1: Energy label classes and corresponding Energy Index

Label class	Energy Index	Label class	Energy Index	Label class	Energy Index
A++	≤ 0,5	B	1,06 – 1,30	E	2,01 – 2,40
A+	0,51 – 0,70	C	1,31 – 1,60	F	2,41 – 2,90
A	0,71 – 1,05	D	1,61 – 2,00	G	> 2,90

Since 2010 the rules for granting an energy label are greatly simplified due to the high costs of determining an energy label. From then on the calculation method estimates the total energy consumption of a dwelling for space heating, water heating and lightning, per square meters per year in giga joule. This amount is then subtracted by the total estimated heat recovery from sewage water, ventilation, and estimated energy production methods like for example PV systems or solar boilers. The total calculations are based on average occupancy, average outdoor climate, and average heating behavior. The total energy consumption of a dwelling is expressed in gas, electricity and heath consumption and is determined under average circumstances, irrespective of the behavior of residents. The energy label also contains a list of possible measures which have an energy-saving effect.

The possible measures to improve the energy performance of a dwelling can be categorized in the following manner:

- *Isolation improvement of the dwelling*: This is a measure that improves the energy performance by decreasing the total energy demand of a dwelling. An improvement of a dwellings isolation value has as result that less heat leaks out of the dwelling and that in turn has as result that the dwelling needs less heated. Since in the Netherlands almost all the dwellings use gas as fuel for their heating systems, an improvement of a dwelling's isolation value leads to a decrease of the gas consumption.
  There are basically seven different standardized areas suitable to improve the isolation of a dwelling. It is possible to isolate the façade, the roof, the floor, the windows, cracks and crevices, CH pipes in unheated spaces, and the ventilation system. Theoretically it's of course possible to isolate all the potential areas a dwelling leaks heat. However in practice, isolation improvement of the standardized areas leads to the best energy performance improvements.
  The quality of the isolation depends on the used material and on the thickness of the isolation and this in turn depends on the terminal resistance (warmteweerstand) or Rd. The terminal resistance is defined as the degree a material reflects heat. The higher the Rd value, the better the isolation value. The total terminal resistance of the different standardized areas and the dwelling itself can be expressed with the Rc value, which is a combination of the different individual Rd values.
- Installation improvement of the dwelling: This is a measure that improves the energy performance by decreasing the total energy demand of a dwelling. A dwelling has two types of installations, namely heating systems that heat the different spaces of dwellings and hot-water heating systems that heat the required hot water of a dwelling. Both installations run, in most cases, on natural gas. The installations burn gas and use the resulted heat to warm the different spaces of a dwelling or the requested hot water. Modern installations have a higher efficiency meaning that more heat can be generated with less gas. This means that the type of installations have an important effect on the energy performance of a dwelling.
- Energy generation measures: This is a type of measure that improves the energy performance of a dwelling by supplying a part of the total energy demand in a sustainable way. The energy generation

methods of a dwelling either supply electricity or heat. With current techniques, electricity can be generated with photovoltaic systems (or PV systems) and heat can be generated with either a solar boiler or a terminal storage system underground (WKO). The terminal storage system is only an option in case of newly built houses.

The next chapter elaborated the legal restrictions and/or possibilities of the dwelling bounded energy label and the three different energy performances measures.

3.2 Dutch legal frame

This chapter elaborates in short the different legal stipulations of the Dutch dwelling market according to the energy label.

As stated before the European parliament introduced the dwelling bounded energy label in 2002. It took a couple of years to prepare the Dutch dwelling market for an introduction. Per the first of January 2008 the energy label was mandated by any transaction of a dwelling (or other commercial or industrial building), in case the building was constructed at least ten years ago. Housing corporations were given an extra year to comply with this requirement, with the restriction that after the period their entire building stock had to be provided with an energy label.

At the beginning of 2010 the energy label was improved in many ways. The requirements for calculating the energy label were accentuated. Furthermore, the check on the certified energy advisors become stricter as are the penalty costs in case advisors do not work according the requirements. Striking fact is that the check on the applicability of the energy labels leaves a lot to be desired. Especially, in most cases of a conveyance of the dwelling, the energy label is not included.

Not all the dwellings are compelled to have an energy label in case of a conveyance of the dwelling. The following exceptions can be determined, in these cases an energy label is not compelled in case of a transaction (VROM 2011):

- Dwellings younger than ten years. In these cases the energy performance coefficients (EPC) were calculated during the construction period.
- In case a certified energy advisor has formulate an energy performance advise (EPA, nowadays known under the name ‘Maatwerkadvies energiebesparing’), between the period of the first of July 2002 and the first of January 2008.
- In case of the transaction of a recognized monument, houseboat, house-trailer, unheated accommodation buildings, buildings with an industrial function, temporary buildings, religious buildings and detached buildings with a usable area less than 50 m^2.

The legal stipulations according to the renovation of dwellings are beyond the scope of this case-study. The study assumes that all the energy improvements, the calculation tool of AgenschapNL suggests, can be achieved without difficult or long term legal stipulations.

3.3 Execution of the case-study on energy labels

The first case-study investigates the total possible energetic improvements of the dwelling stock of Eindhoven as a result of a maximal improvement of the dwelling bounded energy labels. It uses a calculation model of AgentschapNL which is based on example dwellings and it uses a simulation tool which is designed in MS Excel. The AgentschapNL method is called 'voorbeeldwoningen 2011, bestaande bouw'. The ins and outs of the methods will be elaborated during this chapter.

The case-study consists of two parts. Both parts only focus on the existing dwelling stock of Eindhoven and all calculations are calculated with the simulation tool MS Excel. The first part applies the target area on the calculation tool and calculates the total energetic improvements and required investment costs in case two improvement packages were applied on all dwellings in Eindhoven. The second part uses the results of the first part and applies these results in a simulation tool. The tool calculates the total and annual financial and energetic effects, until the year 2045, in case both implementation packages were implemented.

The chapter starts with an explanation of the framework of the calculation tool. Subsequently the different parts of the calculation tool will be elaborated together with a description of the target area Eindhoven. Next the first step of the case-study will be performed and the acquired results will be briefly discussed.

The results of the first step of the case-study will be used as input for the simulation tool. First the framework of the simulation tool will be elaborated together with the different parts of it. Next the results of the first step will be implemented in the simulation tool and the acquired results will be discussed briefly. Finally the case-study will be used to find an answer on the research questions.

3.3.1 Framework and elaboration of the calculation tool

In short the calculation tool of AgentschapNL (voorbeeldwoningen 2011, bestaande bouw) calculates the energetic and financial effects of improvement packages of existing dwellings. The energetic effects can be expressed in gas consumption reduction, electricity consumption reduction and as an energy label improvement. Both the improvement packages as the dwellings are standardized in order to calculate the effects on a macro-scale. Since the calculation tool performs it calculations with standardized example dwellings and standardized improvement measures, the tool is not appropriate for analyses on a micro-scale.

The dwellings are standardized in so-called example dwellings. An example dwelling is selected on both the type of dwelling and the construction period of the dwelling. The method is based on WoON 2006 (Kern publicatie WoON

Energie 2006) study, which is a research of the Dutch ministry of VROM into the energetic quality of the existing Dutch dwelling stock. In total the energy module of WoON 2006 contains 5.000 existing dwellings with a construction period till 2005. All the dwellings of the module are classified in 36 different dwelling types and subtypes and four or five different construction periods. This leads eventually to 154 different example dwellings, which together represent the total dwelling stock of the Netherlands. The different example dwellings represent, in main lines, dwellings with the same dwelling characteristics like: Energetic consumption levels, average dwelling surface areas of different construction parts, the most common isolation values, and the most common installations. Table 2 shows all the possible example dwellings included in the tool.

Table 2: Establishment of the example dwellings

Dwelling type	Dwelling subtype	Construction period
Detached dwelling (vrijstaande woning)	-	<1965, 1965 – 1974, 1975 – 1991, 1992 - 2005
Two-family dwelling (2-onder-1-kap woning)	-	<1965, 1965 – 1974, 1975 – 1991, 1992 - 2005
Terraced dwelling (rijtjes woning)	Corner dwelling, Middle dwelling	<1945, 1946 – 1964, 1965 – 1974, 1975 – 1991, 1992 - 2005
Duplex property (maisonnettewoning)	Corner dwelling top floor, Middle dwelling top floor, Corner dwelling middle floor, Middle dwelling middle floor, Corner dwelling ground floor, Middle dwelling ground floor, Middle dwelling, top and ground floor, Corner dwelling, top and ground floor,	<1965, 1965 – 1974, 1975 – 1991, 1992 – 2005
Gallery dwelling (galerijwoning)	Corner dwelling top floor, Middle dwelling top floor, Corner dwelling middle floor, Middle dwelling middle floor, Corner dwelling ground floor, Middle dwelling ground floor, Middle dwelling, top and ground floor, Corner dwelling, top and ground floor,	<1965, 1965 – 1974, 1975 – 1991, 1992 – 2005
Portico dwelling (portiekwoning)	Corner dwelling top floor, Middle dwelling top floor, Corner dwelling middle floor, Middle dwelling middle floor, Corner dwelling ground floor, Middle dwelling ground floor, Middle dwelling, top and ground floor, Corner dwelling, top and ground floor,	<1945, 1946 – 1964, 1965 – 1974, 1975 – 1991, 1992 - 2005
Other flat dwelling (overige flatwoning)	Corner dwelling top floor, Middle dwelling top floor, Corner dwelling middle floor, Middle dwelling middle floor, Corner dwelling ground floor, Middle dwelling ground floor, Middle dwelling, top and ground floor, Corner dwelling, top and ground floor,	<1945, 1946 – 1964, 1965 – 1974, 1975 – 1991, 1992 – 2005

The calculation tool presents, for each example dwelling, four different energy levels. Two of these energy levels, namely, improvement package 1 and improvement package 2, represent the energetic results of the implementation both standardized improvement packages:

- **Original state**: Represents the energy level of the example dwellings in their original state, constructed according to the at that moment applicable construction rules.

- **Current state**: Represents the energy level of the example dwellings in their current state. Especially the somewhat older dwellings are, over time, much improved by all kinds of energy saving measures. The current state of the dwellings represents the current state of the example dwellings according to the WoON study 2006. The current state is used as the starting point for the calculation of the first step of the case-study.
- **Improvement package 1**: Represents the energy level of the example dwellings in case improvement package 1 was applied. The first improvement package exists of isolation and installation improvements. As it comes to isolation improvements, the façade, roof and floor isolation is upgraded to and Rc value of 2,53m^{2}K/W) and HR++ windows are placed. As it comes to installation improvements, a HR 107 combination boiler is installed.
- **Improvement package 2**: Represents the energy level of the example dwellings in case improvement package 2 was applied. The second improvement package is an extension of the first improvement package and consists, on top of the isolation and installation improvements, also of a solar boiler (2,7m^2 in case of single-family dwellings and 2,0m^2 in case of multi-family dwellings) and a PV-system (15m^2 in case of single-family dwellings and 10 m^2 in case of multi-family dwellings).

In order to standardize the example dwellings original and the current state energy level, actual average energy results were used. The data of the studied dwellings of the WoON 2006 study, together with the DGMR study (DGMR study on EI, 2008) on energy-Index (EI) values were used to determine the EI values and all the other properties of the example dwellings original and current state energy level. The example dwellings were chosen in a way that average dwelling properties, and with that, average energy consumptions per dwelling were, as much as possible, equal. The improvement packages were selected in a practical way, meaning that they were selected by inventorying currently the possible technical most likely achievable improvements. The calculations of these improvement packages were based on theoretical improvements in a way that is currently adapted in practice. Also the financial consequences, in the form of investment costs, were studied. The study method of these financial consequences is elaborated in the next part of this chapter.

So in short, the first step of the case-study applies a calculation took of AgentschapNL. The calculation tool calculates, for each example dwelling, the total energetic savings of two improvement packages and it calculates the corresponding investment costs. Both improvement packages apply as starting point the current state energy level of the example dwellings. Figure 2 presents the design of the first step.

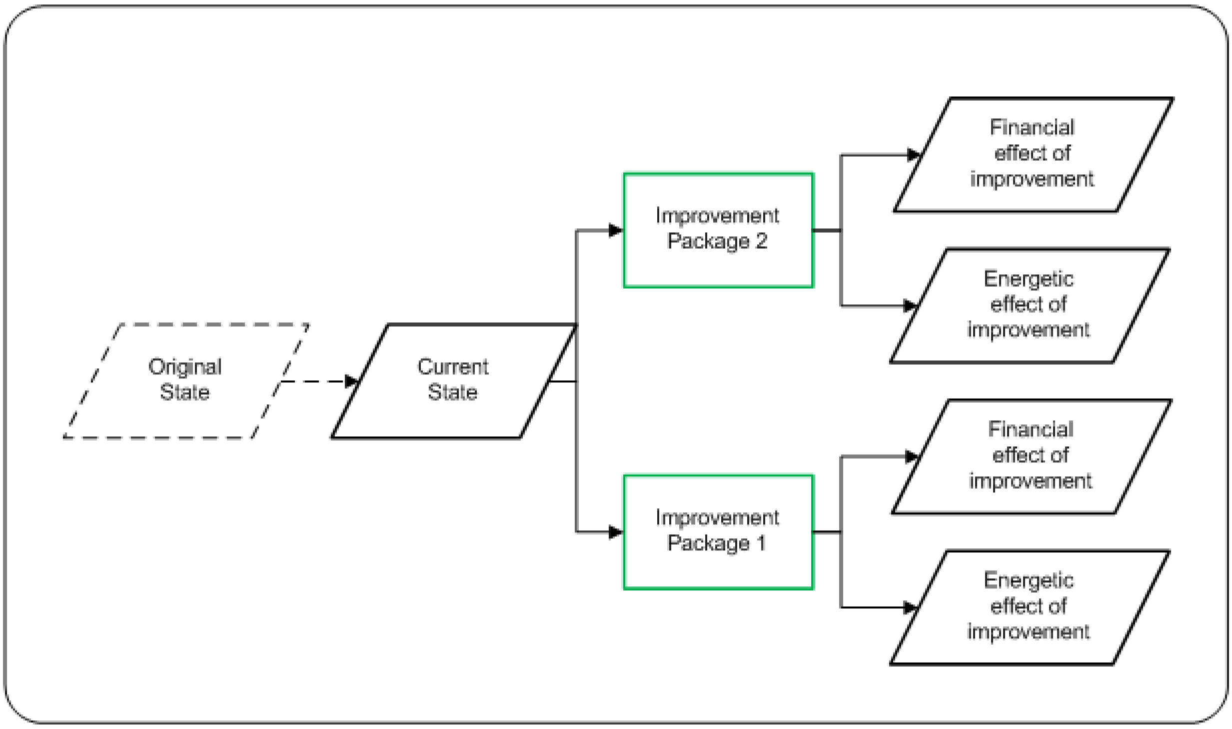

Figure 2 Design on the first step of the case-study

The calculation tool of AgentschapNL only presents the total and most important energetic results of each of the four energy levels. This means that no further insight is given in the exact calculation. For each energy level and example dwelling the following results are presented:

- The total annual average primary gas demand per example dwelling (in m^3).
- The total annual average dwelling-related electricity demand (in kWh).
- The energy-index (EI) per dwelling;
- The energy label of the dwelling;
- The total primary energy demand of the dwelling (in MJ);

The results were presented per example dwelling and per energy level in Appendix F. The results of the original state energy level are presented in Table 69, the results of the current state energy level are presented in Table 70, the results of improvement package 1 energy level are presented in Table 71, and finally the results of improvement package 2 are presented in Table 72.

Furthermore, Appendix F also presents the technical values of three of the four energy levels (current state, improvement package 1 and improvement package 2). As stated before, the first improvement package calculates the isolation and installation improvement, the second improvement package calculates the same improvements as the first improvement package and on top of that it calculates the effect of the installation of a PV systems and a solar boiler.

Table 73 presents technical information of each of the example dwellings about the average surface area and roof type of the dwelling and whether or not crack sealing is applied on the dwelling. Table 74 presents technical information about the average floor area and corresponding isolation value of each example dwelling. Table 75 presents technical information about roof sizes and corresponding isolation value of each example dwelling. Table 76 and Table 77 present technical information about the closed façade area and corresponding isolation value of each example dwelling. Table 78 and Table 79 present technical information about the open façade (windows) area and the corresponding different types of windows for each example dwelling. Table 80 presents technical information about the type of door and corresponding isolation value and type of ventilation system for all example dwellings. Table 81 presents technical information about the heating systems and the isolation of its corresponding pipes. Table 82 presents technical information about the water heating systems and the isolation of its corresponding pipes, and finally Table 83 presents technical information about the energy generation part of improvement package 2.

In calculation the total investment costs of both improvement packages, the tool makes a distinction between two types of investments and three types of dwelling ownerships. The dwelling is either a private property or a rental dwelling, and in case of a rental dwelling, it can either be a rental dwelling in the private sector or a rental dwelling in the social sector. An investment can either be on individual basis, meaning that an improvement package is implemented individually, or on project basis, meaning that an improvement package is implemented on project basis for more dwellings at the same time. Logically the investment costs on project basis are lower than the investment costs on individually basis, because in the first case economies of scale on labor and materials can be achieved. The case-study assumes that all private dwelling owners implement the improvement packages on individual basis. Furthermore the case-study assumes that the rental dwellings (in both private and social sector) implement the improvement packages on project basis.

The investment costs per technical improvement are also presented in Appendix F. All investment costs are based on the price level of March 2010, are excluding VAT, and concerning the average investment costs per improvement for both individual and project based approach. Table 84 to Table 95, all present the different investment costs per improvement. The isolation costs are presented per square meters and per total improvement for each example dwelling. The installation costs are presented per installation improvement. The PV system costs are presented per square meter PV module, per PV system and per example dwelling, and finally the solar boiler costs are presented per system. All the costs are presented for both the categories project basis investment costs and individual investment costs. Table 96 presents an overview of the total investment costs per investment category and per example dwelling.

The total investment costs per category as is presented in Table 96 and the energetic results as are presented from Table 69 to Table 72 were applied during the first stage of the case-study in order to calculate the total investment costs of the different investment packages and to calculate the corresponding energetic improvements of the improvement packages for the target area.

3.3.2 The target area

The case-study was performed on the target area Eindhoven. The target area includes of all the dwellings within the city borders of Eindhoven. In order to apply the calculation tool on all these dwellings, the total dwelling stock was translated to the different example dwellings, and therefore, two different datasets were used.

The first dataset was provided by the ENDINET, which is the network administrator of Eindhoven. The dataset consists of all kinds of information of 23.236 dwellings in Eindhoven (which is approximately ¼ of the total amount of dwellings in Eindhoven). The dataset represents actual data of 2008 and includes, among other things, information of the type of dwelling, the construction period and the total electricity and gas consumption.

Another dataset was acquired from the municipality of Eindhoven. This dataset consists of information of all the different types of dwellings in Eindhoven. The dataset was far more comprehensive according to the type of dwellings than the example dwellings of AgentschapNL. Nonetheless the categorization of AgentschapNL was used and applied on the comprehensive dataset (Appendix C, Table 32) and as a result the total amount of dwellings in Eindhoven in the 'type' categorization of AgentschapNL was known (Appendix C Table 32). Finally the dataset of ENDINET was used to complete the categorization of AgentschapNL by using the construction period of the different dwellings. As a result the total amount of dwellings in Eindhoven was fitted in the calculation tool of AgentschapNL.

It was unfortunately not possible to use all the different example dwellings of the tool, on the one hand because not all the information was available, and on the other hand because not all the example dwellings are present in dwelling stock of the city. Compared with the rest of the Netherlands, Eindhoven has a relative small amount of multi-family houses (e.g. flats or apartments), and because of this, comparatively little information about these type of dwellings is available. Of all the multi-family houses only the distinction between duplex dwellings, portico dwellings and other flat dwellings were known. The distinction of the gallery dwelling and all the subtypes of the multi-family dwellings were missing or not present in the city. Fortunately the calculation tool also provides average information on type level, on top of information on subtype level. This means that the tool also presents example dwellings of the multi-family dwellings on type level. The case-study applied these possibilities and eventually only the 31 most important example dwellings of the total 154 example dwellings were used for the calculation tool. Appendix C Table 32 presents the translation process of the total dwellings stock of Eindhoven to the example dwellings of the calculation tool (based on the dataset of the municipality). Appendix C Table 33 presents a summarization of this translation and finally Appendix C Table 29 presents the application of the dwelling stock of Eindhoven and the corresponding average gas and electricity consumption (based on the sample of ENDINET).

The dataset of ENDINET also provided information about the dwelling ownerships. As stated before the calculation tool support three types of dwelling ownerships. The dwelling is either a private property or a rental dwelling in the private sector or a rental dwelling in the social sector. The dataset of ENDINET provides the same classification as the tool. The (financial) calculations of the first step of the case-study are therefore performed with the actual information of ENDINET.

3.3.3 First step of the case-study: Application of target area on the calculation tool

This chapter describes the application of the target area on the calculation tool. Previous chapters described the financial savings and the total investment costs of the application of the two improvement packages on current state energy level example dwellings. Also the application of the target area on the different example dwellings was elaborated. This chapter combines these two steps and eventually presents, for the complete target area, the total investment costs, the total energetic savings and the energy label improvements in case both improvement packages were applied.

This chapter starts however by checking how well the calculation tool represents the total dwelling stock of Eindhoven. In other words, the check tests how well the calculations of the tool fit the target area. Therefore a comparison is made between the average gas consumption of the calculation tool (which in turn is based on average consumption of all the dwelling in the Netherlands) and actual average gas consumption of Eindhoven (which in turn is based on the dataset of ENDINET), in order to investigate the similarity of both figures and by that in order to investigate how well the example dwellings represent the housing stock of Eindhoven as a whole. In an ideal case both numbers match perfectly. Appendix F Table 97 presents the results of the comparison. Two types of comparisons have been made:

- Comparison between the actual numbers of ENDINET, per example dwelling, and the original state number of the calculation tool, per example dwelling. Both, the absolute difference and the deviation between both numbers are compared.
- Comparison between the actual numbers of ENDINET, per example dwelling, and the current state number of the calculation tool, per example dwelling. In this case the same comparison is made as with the original state numbers. Obliviously the deviation between the actual numbers and the current state numbers are smaller than the deviation between the actual numbers and the original state number.

The results of the comparison show that, even in current state, the differences are quite large. This means that the calculation tool does not represent the current housing stock in a perfect way. Especially the deviation of the older example dwellings is large. This leads to the following conclusions: The current state gas consumption numbers have a smaller deviation with the actual gas consumption numbers than the original state consumption numbers, but still the deviation is quite large.

For this reason two different scenarios will be simulated during the second part of the case-study. The first scenario simulates a situation in which the calculations of the first step of the case-study are performed with the absolute values of average energy consumption. In other words, the simulation calculations are performed using the values of the energy levels: current state, improvement package 1, and improvement package 2, which in turn are not based on average actual energy numbers of Eindhoven, but are based on average actual numbers of the Netherlands. The second scenario uses the relative energetic improvements. The relative improvement is determined from the calculations of the first scenario, as a percentage of the improvements, between the energy levels. This improvement percentage is used to calculate the energy consumption improvements of actual average consumption numbers of Eindhoven. Precise calculations will be elaborated during the second part of the case-study. Both scenarios are calculated using actual example dwelling numbers of the target area.
This means that in order to calculate the relative improvement, first the absolute improvement must be calculated. Appendix F, Table 98 presents the energetic effects of implementing both improvement scenarios. The improvements of the first improvement package are calculated by subtracting the average annual primary gas demand of the current state energy level by the average annual primary gas demand of the improvement package 1 level, and by subtracting the average annual dwelling-related electricity demand of the current state energy level by the total average annual dwelling-related electricity demand of the improvement package 1 level. The improvements of the second improvement package are calculated in a similar way.

As expected, most energetic improvements, as it comes to gas consumption, can be made by improving the older dwellings. As an effect of stricter construction legislation and the application of better isolation materials, the newer dwellings have better isolation values and therefore less gas is necessary to heat the different spaces of the dwelling. The results of Table 98 also show, in certain cases, an increase of the electricity demand after the implementation of improvement package 1. This can be explained by the fact that newer heating systems often use more electricity than the older owns.

Table 99 presents the total energetic improvements of both improvement packages. The improvements are calculated by multiplying, per example dwelling, the total amount of example dwellings of the target area with the average improvements of Table 98.

The total investment costs, in case of implementing both improvement packages, are calculated in a similar way.
The total investment cost per improvement package is calculated by multiplying the investment costs per example dwelling (Table 96) by the total amount of example dwellings of the target area (Table 29). The portion private properties are multiplied by the individual base investment costs and both private rentals and social rental dwellings are multiplied by the project base investment costs. Finally when both the individually and the project based investment are added with each other, the total investment costs for the complete target area can be calculated.

Table 3: Total investment costs improvement package 1 and 2

Example dwelling	*Energy label*	*Energy label*	*Total investment costs improvement package 1*	*Energy label*	*Energy label*	*Total investment costs improvement package 2*
	Current state	*Impr. Pack. 1*	*(€)*	*Current state*	*Impr. Pack. 2*	*(€)*
Detached	G	B	€ 13.803.995,-	G	A	€ 23.012.507,-
Detached	F	A	€ 7.073.284,-	F	A	€ 11.352.074,-
Detached	D	B	€ 25.478.364,-	D	A	€ 41.248.268,-
Detached	B	B	€ 5.013.170,-	B	A	€ 23.078.692,-
Two-family	F	B	€ 23.814.015,-	F	A	€ 42.410.266,-
Two-family	E	B	€ 8.451.873,-	E	A	€ 14.658.087,-
Two-family	C	B	€ 26.944.710,-	C	A	€ 46.582.172,-
Two-family	B	B	€ 8.346.209,-	B	A	€ 29.870.166,-
Terraced (corner)	G	B	€ 40.024.769,-	G	A	€ 73.505.404,-
Terraced (corner)	F	B	€ 41.484.317,-	F	A	€ 89.082.180,-
Terraced (corner)	E	B	€ 30.094.652,-	E	A	€ 60.301.272,-
Terraced (corner)	C	B	€ 31.581.512,-	C	A	€ 65.340.984,-
Terraced (corner)	B	B	€ 1.162.876,-	B	A	€ 12.434.499,-
Terraced (Middle)	G	B	€ 121.935.551,-	G	A	€ 235.447.385,-
Terraced (Middle)	F	B	€ 101.783.388,-	F	A	€ 239.230.976,-
Terraced (Middle)	E	B	€ 77.861.057,-	E	A	€ 168.793.180,-
Terraced (Middle)	D	B	€ 75.164.259,-	D	A	€ 169.833.589,-
Terraced (Middle)	C	B	€ 4.901.801,-	C	A	€ 51.758.974,-
Duplex property	G	A	€ 2.306.617,-	G	A	€ 3.771.670,-
Duplex property	E	A	€ 35.857.416,-	E	A	€ 65.079.864,-
Duplex property	D	A	€ 7.895.450,-	D	A	€ 15.776.378,-
Duplex property	C	A	€ 3.003.820,-	C	A	€ 6.565.475,-
Portico	B	B	€ 683.503,-	B	A	€ 2.976.312,-
Portico	G	B	€ 2.136.322,-	G	A	€ 4.668.566,-
Portico	D	A	€ 2.048.231,-	D	A	€ 4.589.113,-
Portico	C	B	€ 1.788.850,-	C	A	€ 4.226.800,-
Portico	B	B	€ 9.894,-	B	A	€ 192.003,-
Other + Gallery	E	A	€ 53.446.803,-	E	A	€ 104.195.965,-
Other + Gallery	E	C	€ 31.307.525,-	E	A	€ 64.965.495,-
Other + Gallery	C	A	€ 92.073.688,-	C	A	€ 166.506.378,-
Other + Gallery	B	B	€ 296.403,-	B	A	€ 50.800.428,-
Total investment costs			***€ 877.774.326,-***			***€1.892.255.123,-***

Table 3 presents the total necessary investment costs to implement both improvement packages. It shows among other things, that it is (theoretical) possible to improve every (example) dwelling in Eindhoven to a maximum energy label and furthermore it shows that an implementation of improvement package 1 (improvement of isolation and installation), requires a total investment of €877.774.326,- (or approximately €8.952,- per dwelling) and finally is shows that an implementation of improvement package 2 (installation of a small PV system and a solar boiler) requires a total investment of €1.892.255.123,- (or approximately €19.297,- per dwelling).

Table 4 presents the energetic effects of improvement package 1. Per example dwelling the total annual energy consumption is calculated. Each column of the table will briefly be elaborated:

1. *Example dwellings*: represents the example dwellings as were presented by the calculation tool of AgentschapNL
2. *Total gas consumption (actual data)*: Represents the total average annual gas consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding actual gas consumption. The average gas consumption per example dwelling is obtained from the dataset of ENDINET and represents average consumption data of Eindhoven.
3. *Total gas consumption (current state)*: Represents the total average annual gas consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding gas consumption. The average gas consumption per example dwelling is obtained from the calculation tool and represents the average consumption (per example dwelling) of the Netherlands.
4. *Total electricity consumption (actual data)*: Represents the total average annual electricity consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding actual electricity consumption. The average electricity consumption per example dwelling is obtained from the dataset of ENDINET and represents average consumption data of Eindhoven
5. *Total gas consumption (improvement package 1)*: represents the total annual gas consumption after the implementation of the first improvement package and is calculated by subtracting the annual average total gas consumption (current state) by the total energetic effects of the first improvement package (Table 99).
6. *Total electricity consumption (improvement package 1)*: represents the total annual electricity consumption after the implementation of the first improvement package and is calculated by subtracting the annual average total gas consumption (actual data) by the total energetic effects of the first improvement package (Table 99).
7. *Gas reduction (percentage)*: Represents the total gas consumption reduction in case the first improvement package is implemented. The reduction is calculated by dividing the ‘Total gas consumption (improvement package 1)’ by the ‘Total gas consumption (current state)’.
8. *Electricity reduction (percentage)*: Represents the total electricity consumption reduction in case the first improvement package is implemented. The reduction is calculated by dividing the ‘Total electricity consumption (improvement package 1)’ by the ‘Total electricity consumption (actual data)’.

Table 4: Energetic effects of improvement package 1

Example dwelling	Total gas consump.	Total gas consump.	Total elect. consump.	Total gas consump.	Total electr. consump.	Gas reduc.	Electr. reduc.
	Actual data	*Current data*	*Actual data*	*Improv. Pack. 1*	*Improv. Pack. 1*	*Perc.*	*Perc.*
	(m^3/year)	*(m^3/year)*	*(kWh/year)*	*(m^3/year)*	*(kWh/year)*		
Detached	3.108.345	3.811.029	5.666.128	1.205.094	5.666.128	68,38%	0,00%
Detached	1.338.741	1.530.794	2.490.207	596.674	2.490.207	61,02%	0,00%
Detached	4.354.541	3.591.479	9.742.890	2.170.539	9.742.890	39,56%	0,00%
Detached	4.169.953	2.958.712	10.445.304	2.675.732	10.445.304	9,56%	0,00%
Two-family	4.123.897	5.632.971	6.847.813	1.947.804	6.847.813	65,42%	0,00%
Two-family	1.425.598	1.644.995	2.601.000	665.883	2.601.000	59,52%	0,00%
Two-family	3.782.145	3.416.419	8.340.245	2.201.494	8.340.245	35,56%	0,00%
Two-family	3.114.037	2.821.234	8.663.461	2.442.431	8.663.461	13,43%	0,00%
Terraced (corner)	6.105.535	12.697.077	10.402.257	3.395.592	10.402.257	73,26%	0,00%
Terraced (corner)	7.825.642	12.506.535	13.604.026	4.289.046	13.604.026	65,71%	0,00%
Terraced (corner)	5.093.534	7.253.655	9.898.063	2.963.628	9.898.063	59,14%	0,00%
Terraced (corner)	5.314.057	5.169.142	11.739.746	3.247.053	11.739.746	37,18%	0,00%
Terraced (corner)	1.370.684	1.175.902	3.849.854	1.117.404	3.849.854	4,97%	0,00%
Terraced (Middle)	16.785.808	33.625.021	31.552.654	11.144.523	31.552.654	66,86%	0,00%
Terraced (Middle)	19.359.967	27.565.940	37.164.238	11.696.501	37.164.238	57,57%	0,00%
Terraced (Middle)	13.267.142	16.381.599	27.071.601	8.473.241	27.071.601	48,28%	0,00%
Terraced (Middle)	13.092.415	12.847.643	31.684.896	8.640.082	31.684.896	32,75%	0,00%
Terraced (Middle)	5.818.004	4.661.072	16.836.245	4.422.885	16.836.245	5,11%	0,00%
Duplex property	134.102	320.758	322.698	95.939	360.224	70,09%	-11,63%
Duplex property	3.043.130	5.379.904	7.662.145	2.083.862	7.788.130	61,27%	-1,64%
Duplex property	725.710	1.183.779	1.944.381	593.731	1.944.381	49,84%	0,00%
Duplex property	293.809	356.560	892.647	263.472	892.647	26,11%	0,00%
Portico	227.459	205.104	573.812	177.757	573.812	13,33%	0,00%
Portico	251.900	745.032	611.155	235.038	611.155	68,45%	0,00%
Portico	265.792	435.520	699.108	220.739	699.108	49,32%	0,00%
Portico	261.506	298.569	621.936	212.297	621.936	28,90%	0,00%
Portico	8.670	15.980	34.656	15.256	34.656	4,53%	0,00%
Other + Gallery	5.638.704	8.963.215	14.274.483	3.562.759	14.493.821	60,25%	-1,54%
Other + Gallery	3.605.014	7.497.339	9.813.291	4.216.656	9.813.291	43,76%	0,00%
Other + Gallery	6.348.935	8.707.211	17.441.436	5.411.653	17.788.337	37,85%	-1,99%
Other + Gallery	5.491.570	4.291.910	13.982.141	4.155.564	13.982.141	3,18%	0,00%
Total consump. (calculation tool)	***197.692.101***	***317.474.517***	***94.540.329***	***318.204.267***	***52,18%***	***-0,23%***	
Total consump. (actual data)	***145.746.347***	***317.474.517***	***69.698.827***	***318.204.267***	***52,18%***	***-0,23%***	

Table 5 presents the energetic effects of improvement package 2. Per example dwelling the total annual energy consumption is calculated. Each column of the table will briefly be elaborated:

1. *Example dwellings*: represents the example dwellings as were presented by the calculation tool of AgentschapNL
2. *Total gas consumption (actual data)*: Represents the total average annual gas consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding actual gas consumption. The average gas consumption per example dwelling is obtained from the dataset of ENDINET and represents average consumption data of Eindhoven.
3. *Total gas consumption (current state)*: Represents the total average annual gas consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding gas consumption. The average gas consumption per example dwelling is obtained from the calculation tool and represents the average consumption (per example dwelling) of the Netherlands.
4. *Total electricity consumption (actual data)*: Represents the total average annual electricity consumption and is calculated by multiplying the total actual amount of example dwellings of Eindhoven with its corresponding actual electricity consumption. The average electricity consumption per example dwelling is obtained from the dataset of ENDINET and represents average consumption data of Eindhoven
5. *Total gas consumption (improvement package 2)*: represents the total annual gas consumption after the implementation of the second improvement package and is calculated by subtracting the annual average total gas consumption (current state) by the total energetic effects of the second improvement package (Table 99).
6. *Total electricity consumption (improvement package 2)*: represents the total annual electricity consumption after the implementation of the first improvement package and is calculated by subtracting the annual average total gas consumption (actual data) by the total energetic effects of the second improvement package (Table 99).
7. *Gas reduction (percentage)*: Represents the total gas consumption reduction in case the second improvement package is implemented. The reduction is calculated by dividing the 'Total gas consumption (improvement package 1)' by the 'Total gas consumption (current state)'.
8. *Electricity reduction (percentage)*: Represents the total electricity consumption reduction in case the second improvement package is implemented. The reduction is calculated by dividing the 'Total electricity consumption (improvement package 2)' by the 'Total electricity consumption (actual data)'.

Table 5: Energetic effects of improvement package 2

Example dwelling	Total gas consump.	Total gas consump.	Total elect. consump.	Total gas consump.	Total electr. consump.	Gas reduc.	Electr. reduc.
	Actual data	*Current data*	*Actual data*	*Improv. Pack. 2*	*Improv. Pack. 2*	*Perc.*	*Perc.*
	(m³/year)	*(m³/year)*	*(kWh/year)*	*(m³/year)*	*(kWh/year)*		
Detached	3.108.345	3.811.029	5.666.128	1.062.513	4.568.977	72,12%	19,36%
Detached	1.338.741	1.530.794	2.490.207	531.122	1.982.922	65,30%	20,37%
Detached	4.354.541	3.591.479	9.742.890	1.923.418	7.873.014	46,44%	19,19%
Detached	4.169.953	2.958.712	10.445.304	2.391.180	8.304.089	19,18%	20,50%
Two-family	4.123.897	5.632.971	6.847.813	1.659.059	4.625.946	70,55%	32,45%
Two-family	1.425.598	1.644.995	2.601.000	570.834	1.865.451	65,30%	28,28%
Two-family	3.782.145	3.416.419	8.340.245	1.885.720	5.910.395	44,80%	29,13%
Two-family	3.114.037	2.821.234	8.663.461	2.108.858	6.096.647	25,25%	29,63%
Terraced (corner)	6.105.535	12.697.077	10.402.257	2.869.765	6.356.067	77,40%	38,90%
Terraced (corner)	7.825.642	12.506.535	13.604.026	3.597.538	7.825.905	71,23%	42,47%
Terraced (corner)	5.093.534	7.253.655	9.898.063	2.513.457	6.248.459	65,35%	36,87%
Terraced (corner)	5.314.057	5.169.142	11.739.746	2.747.964	7.693.555	46,84%	34,47%
Terraced (corner)	1.370.684	1.175.902	3.849.854	941.911	2.499.450	19,90%	35,08%
Terraced (Middle)	16.785.808	33.625.021	31.552.654	9.360.996	17.828.567	72,16%	43,50%
Terraced (Middle)	19.359.967	27.565.940	37.164.238	9.683.672	20.447.938	64,87%	44,98%
Terraced (Middle)	13.267.142	16.381.599	27.071.601	7.117.522	16.080.597	56,55%	40,60%
Terraced (Middle)	13.092.415	12.847.643	31.684.896	7.240.338	20.336.977	43,64%	35,81%
Terraced (Middle)	5.818.004	4.661.072	16.836.245	3.696.004	11.242.958	20,70%	33,22%
Duplex property	134.102	320.758	322.698	71.487	206.043	77,71%	36,15%
Duplex property	3.043.130	5.379.904	7.662.145	1.590.136	4.696.387	70,44%	38,71%
Duplex property	725.710	1.183.779	1.944.381	460.256	1.108.556	61,12%	42,99%
Duplex property	293.809	356.560	892.647	203.630	515.308	42,89%	42,27%
Portico	227.459	205.104	573.812	139.149	330.368	32,16%	42,43%
Portico	251.900	745.032	611.155	186.183	340.668	75,01%	44,26%
Portico	265.792	435.520	699.108	171.885	428.621	60,53%	38,69%
Portico	261.506	298.569	621.936	166.342	365.939	44,29%	41,16%
Portico	8.670	15.980	34.656	11.767	15.336	26,36%	55,75%
Other + Gallery	5.638.704	8.963.215	14.274.483	2.709.120	9.111.149	69,78%	36,17%
Other + Gallery	3.605.014	7.497.339	9.813.291	3.782.097	5.491.577	49,55%	44,04%
Other + Gallery	6.348.935	8.707.211	17.441.436	4.154.137	9.913.688	52,29%	43,16%
Other + Gallery	5.491.570	4.291.910	13.982.141	3.183.364	8.599.469	25,83%	38,50%
Total consump. (calculation tool)		***197.692.101***	***317.474.517***	***78.731.427***	***198.911.026***	***60,17%***	***37,49%***
Total consump. (actual data)		***145.746.347***	***317.474.517***	***58.043.886***	***198.454.855***	***60,17%***	***37,49%***

3.3.4 Results and conclusions of the first step of the case-study

The first step of the case-study investigated the total effects of two improvement packages on the total dwellings stock of Eindhoven. The first package describes an implementation of isolation and installation improvement, the second package describes an implementation of all improvements of the first improvement package and above that the implementation of a small roof-mounted PV system and a small solar boiler. The isolation of all dwellings was optimized to an Rc value of 2,53m^2K/W and all installations were optimized by replacing heating systems and water heating systems by a HR 107 combination boiler. The small roof-mounted PV system consists, for single-family dwellings, of a 15 square meter module system and for multi-family dwellings of a 10 square meter module system. The solar boiler consists, for single-family dwellings, of a 2,7 square meter system and for multi-family dwellings of a 2,0 square meter system.

All calculations were done with example dwellings. The calculation tool and the creation of the example dwellings were designed by AgentschapNL. All the example dwellings were selected on type and construction period and were assessed on equality of physical and energetic consumption properties. The tool presents average gas consumption of all example dwellings and electricity consumption of the installations of all example dwellings. A dataset by ENDINET and by the municipality of Eindhoven made it possible to implement Eindhoven as target area. All dwellings were fitted on the calculation tool of AgentschapNL which in turn made it possible to calculate the effects of both improvement packages on the total dwellings stock on Eindhoven.

Since the average gas consumption per example dwelling presented by the tool (in case of its current state) did not perfectly match the average actual gas consumption per example dwelling presented by ENDINET. The first step of the case-study described two possible applications of the tool. The first application applied the total housing stock of Eindhoven and calculated all energetic improvements of both improvement packages with the average gas consumption (per example dwelling) of the tool. The second application applied the total housing stock of Eindhoven and calculated all energetic improvements of both improvement packages with the actual gas consumption (of ENDINET) and calculated the improvements in terms of percentage of the first improvement.

Table 4 and Table 5 both present the total energetic effects of the implementation of both improvement packages and they present both applications of the tool. Table 3 presents the total necessary investment cost of both improvement packages per example dwelling. The tables shows that the implementation of the first improvement package on the target area results in a reduction of the total gas consumption of 52,18% and an increase of the total electricity consumption of 0,23%. Furthermore they show that, the implementation of the first improvement package requires a total investment of €877.774.326,-, which is about €8.952,- per dwelling. In case the second improvement package was implemented on the target area the total gas consumption could even be further reduced to total reduction of 60,17% and the electricity consumption could be reduced by a total reduction of

7,49%. The second improvement package requires a total investment of €1.892.255.123,-, which is about €19.297,- per dwelling.

In case of an application of the tool with absolute numbers (which is based on current state consumption numbers presented by the tool) the gas consumption could be reduced from a total consumption of 197.692.101 m^3 to a total consumption of 94.540.329 m^3 as an effect of the first improvement package, and it could be reduced to a total consumption of 78.731.427 m^3 as an effect of the second improvement package. In case of an application of the tool with relative numbers (which is based on the actual gas consumption presented by ENDINET and calculates with the relative effects of the application with absolute numbers) the gas consumption could be reduced from a total consumption of 145.746.347 m^3 to a total consumption of 69.698.827 m^3 as an effect of the first improvement package, and it could be reduced to a total consumption of 58.043.886 m^3 as an effect of the second improvement package. These figures will be used as an input of the second step of the case-study.

3.3.5 Framework and elaboration of the second step of the case-study

The second step of the case-study consists of an application of the results of the first step of the case-study in a simulation tool. The simulation tool simulates the financial and energetic results of the first step of the case-study in a timeline of 34 year. Basically the tool simulates, in time, the effects of two different situations. On the one hand it simulates the effects of an intervention measure, in this case, the implementation of improvement package 1 or improvement package 2, and on the other hand it compares the effects with a simulation of a benchmark. The benchmark represents a situation in which no intervention is implemented. In other words it represents a situation in which no improvement measure is implemented during the simulation period and therefore it simulates future effects of an unchanging current situation.

The simulation tool consists of three different parts:

- *General energy development part*: The first part simulates the development of the total electricity and gas demand of all the dwellings within the city of Eindhoven, starting from 2011 and ending by 2045. Besides the demand it also simulates the electricity and gas price development during the same period.
- *Energy costs of the benchmark*: The second part simulates the total annual electricity and gas costs of the benchmark during the period between 2011 and 2045, in case the energy demand and price develops according to calculates of the first step.
- *Energy costs of the intervention*; the last part simulates the total annual electricity and gas costs during the period between 2011 and 2045, in case improvement package 1 or improvement package 2 was implemented and according to the energy demand and price development as was calculated in the first step.

The total annual electricity demand is simulated during the period between 2011 and 2045. The annual demand is calculated with the help of historical (from 1995 to 2010) electricity demand (in PJ) of all the dwellings in the Netherlands. The historical data was obtained from the CBS Database StatLine (CBS, Den Haag/Heerlen July 2011). The total demand during the starting point (2008) was determined using, once more, the ENDINET dataset of Eindhoven. The sample of almost ¼ of all the dwellings was extrapolated to the total amount of dwellings (using the actual amount of different dwellings) of the city (Appendix C Table 29). Subsequently the actual electricity demand of all the dwellings of Eindhoven of the year 2008 was used, together with the historical data of the CBS, to create the historical total demand of Eindhoven (by multiplying each year the deviation of the total demand of the Netherlands by the electricity demand of Eindhoven). This resulted in the historical electricity demand of Eindhoven and in turn this demand was used to create a linear function of the electricity demand development of Eindhoven (Appendix C

Table 66 and Figure 31). The linear function was used to simulate the future electricity demand of the target area. The case-study assumes that the future demand rate is linear and behaves as it did in the past. The applied linear function for the future electricity demand behaves like the following linear function: y= -8.373.598.393 + 4.323.226x.

The total annual gas demand of a dwelling depends, contrary to the total annual electricity demand, on the physical properties of a dwelling. The last 15 years annual gas consumption of dwellings has slowly reduced, due to improvements on isolation and installation. Since the case-study attempts to measure the effects of these improvements, the study assumes that, in case of the benchmark, the annual gas demands does not increase of decrease, but instead stays at the same level during the simulation period. Doing this makes it possible to compare the benchmark with the intervention. Otherwise the benchmark would, undesirable, also calculate energetic effects of interventions, and since these interventions are also implemented by the improvement packages, it is no longer possible to compare the intervention strategy with the benchmark.

The total future electricity and gas price development was predicted with the help of the average deviation of the annual historical electricity prices of CBS (CBS, Den Haag / Heerlen, July, 2011), (Appendix C, Table 67 and Figure 32). Since the historical electricity and gas price developed, more or less, linearly, the study assumes that the price develops in the future at the same linear rate. Therefore the historical data of the CBS were used to create the linear function for future price development of both energy sources.

The information of the CBS makes a distinction between small users (electricity users with a yearly demand smaller than 2500 kWh or gas consumers with a yearly demand smaller than 1250 m^3) and normal user (electricity users with a yearly demand larger than 2500 kWh or gas consumers with a yearly demand larger than 1250 m^3). The small users have a higher electricity and gas tariff per unit than the normal users. The energy rates in the model consists of all the relevant costs aspects like network costs, supplier costs and logistics costs. Furthermore the rate is inclusive VAT and energy tax, but exclusive income energy tax refund. The rates represent the average rates of the different energy companies for the dwelling market and the small business market. The applied linear function for the development of the small electricity tariff looks like this: -25,42 + 0,0128x, and the function for the normal electricity tariff looks like this: -21,72 + 0,0109x. The applied linear function for the development of the small gas tariff looks like this: -70,16 + 0,0353x, and the linear function for the normal gas tariff looks like this: -31,34 + 0,0159x. In short, the study adapts linear growth rates for both electricity and gas demand development and electricity and gas price development, because the historical development also behaved according to this linear growth pattern.

The second part of the second step of the case-study simulates the total electricity and gas costs of all the example dwellings in Eindhoven of the benchmark. It simulates the electricity and gas costs of the annual future electricity demand (according to the first step) starting in 2011 and ending in 2045. This means that during this period neither any energy saving measures was implemented nor any other energy-generating measures were implemented. The purpose is to measure a clear effect of a large scale implementation of the improvement packages and this can only be done if it is compared with an unchanging situation.

The total annual electricity and gas costs are calculated by multiplying the annual corresponding demand by its corresponding tariffs. The corresponding tariffs are determined by counting the total amount of dwellings per tariff group, by checking the average energy demand per example dwelling. Appendix C, Table 30 and Table 31 show that from all the 98.058 dwellings, 32% are small electricity and users and 68% are normal electricity and gas users. The total costs of the benchmark are calculated per year (divided in electricity costs and gas costs) and are calculated by a cumulative cash flow of the annual costs.

The last part simulates the effects of the intervention. It is in this part that the different scenarios become visible. The simulation exists of a couple of different calculations, including the energetic calculations, financial calculations and the calculations concerning the overall effects of the different scenarios. The effects are afterwards calculated using some KPI's (Key Performance Indicators).

The energetic calculations concern the implementation of the intervention (in this case either improvement package 1 or 2). The case-study assumes a 100% implementation of the intervention at the end of 2010, because only current energetic effects and investment costs of the intervention are known. This means that the first energetic effects of the intervention are obtained a year after its implementation. The energetic effects depend on the intervention and are the results of the first step of the case-study. Furthermore during the simulation period the annual energy demand and prices develops as was elaborated in the first step.

The financial calculations calculate the investment costs of the intervention, it calculates the remaining annual electricity and gas costs, it calculates interest costs of the investment and it calculates a certain repayment of the investment. The total profit or loss is expressed in three different items, namely: a Long-term loan entry, an annual cost entry, and a cumulative costs entry.

The long-term loan represents the investment costs that were made for the implementation of the intervention. The model does not allocate the costs over other years. Instead the costs are, like in practice, completely allocated to the year they were actually made. The model assumes that all money necessary to implement the intervention, is borrowed through a long-term loan instead of paid with own funds. The long-term loan exists of a couple of different items:

- *Interest Rates;* In order to make the model somewhat more realistic, an interest rate was included. The interest rate calculates an extra debit item for the annual financial losses which in turn is expressed by the long-term loan. This means that at the end of the year, in case the year ends with a loss instead of a profit, an interest rate has to be paid over this loss. The model employs an interest rate of 3,34 percent, which is the interest rate the government has to pay this year over its national debt (which more precisely is the interest rate of government bonds). It is also interesting to investigate the financial effect of a higher or lower interest rate on the total cash flow. Therefore for both improvement packages also the effects of a situation without an interest rate will be elaborated and a situation with a high interest rate of 8% is elaborated. The situation without an interest rate could occur in case no debt needs to be made and equity is invested. This is, however, not a realistic scenario since investing equity also costs money since future interest income of the equity is no longer possible. Nonetheless it is interesting to see the effects. The situation with a high interest rate of 8% could occur in case dwelling owners themselves are charged for their own investment of the intervention. In case the large scale implementation is not centrally organized this could occur and it maximizes the interest costs. For this reason this is also not a desired scenario, but yet at the moment it seems to be the path we've chosen.

- *Repayment investment costs;* Since all investment costs are funded by a long-term loan, and this long-term loan only increase because of the interest costs, it is necessary to repay the investment costs. Otherwise the costs will only increase in time and with this another problem will be created. The repayment of the long-term loan is done on an annual basis. Each year the total annual cost of the benchmark is compared with the corresponding total annual cost of its corresponding intervention. The difference between both costs is used as a repayment of the long-term loan. In case the difference between both costs is negative, meaning that the annual cost in case of the implementation of the intervention is higher than the costs in case of the benchmark, no repayment is paid. If this is the case it is better not to implement the intervention since the new situation leads to annual higher costs than an unchanging situation. The situation could be caused by high interest rates. Besides the 'basic' repayment the model also supports an extra repayment per month and per dwelling. An extra payment can be used to reduce the costs even further. The sooner the long-term-loan is repaid, the lower the interest costs will be (which is especially interesting in case of a high interest rate). However this extra repayment is one of the options of the model, but initially it will not be used in the calculations.

The annual cost entry consists of all the yearly costs in case of implementing the intervention. It consists of the remaining annual electricity and gas costs, the annual interest costs of the investment and an annual repayment fee of the investment. The cumulative cost entry consists of the yearly cumulative costs of the intervention. In case the cumulative costs of the intervention are compared with the cumulative costs of the benchmark it is possible to see, each year, which strategy (intervention or benchmark) performs financially better.

The financial and energetic results of the different case-study scenarios are presented in two different ways. The financial results are presented in a plot. The plot shows the cash flow statement of the benchmark, it shows the total cumulative profit or loss of the intervention strategy, it shows the annual differences between both case flow statements, and it shows the development of the long-term loan. All four financial graphs are plotted against the time starting in 2011 and ending in 2045. The purpose of the plot is to compare the financial effects of the intervention and the benchmark. The results show if it is financial interesting to implement the intervention strategy. The final results are also presented in KPI's. The model presents in total eleven different KPI's (total electricity demand (kWh) ('Benchmark'), total electricity demand (kWh) ('Improvement package'), electricity Savings ('Benchmark - Improvement package'), total gas demand (m^3) ('Benchmark'), total gas demand (m^3) ('Improvement package'), gas savings ('Benchmark - Improvement package'), average energy payment; per month, per dwelling ('Benchmark'), average energy payment; per month, per dwelling ('Improvement package'), total cumulative costs ('Benchmark'), total cumulative costs ('Improvement package'), and the cumulative difference 2040 ('Benchmark - Improvement package'). The KPI's are presented for three different periods (Starting year (2011), ending year (2045), and total (2011 – 2045)). The KPI's are like the plots discussed during the next section.

3.3.6 Second step of the case-study: Application of simulation tool

The second step of the case-study consists of the application of the simulation tool, with as input, the output of the first step. The first step calculated on the one hand the total energetic effects of the two improvement packages and on the other hand the corresponding investment costs of those two improvement packages. The calculations were performed in an absolute way, using average annual energy numbers of all example dwellings of the Netherlands applied on the dwellings stock of Eindhoven, and the calculations were performed in a relative way using the relative energetic effects of the calculations which were performed in an absolute way on annual energy numbers of all example dwellings of Eindhoven and applied on the dwelling stock of Eindhoven.

This means the in total three different variables are important as it comes to the simulations of the scenarios of the second part of the case-study (Table 6):

- *Time of implementation*: The energetic effects and the total investment costs of the improvement packages are calculated using current dwelling properties and current price levels of the improvements, meaning that only short term implementation is possible. Therefore only one installation moment of the improvement package is simulated, namely: A 100% implementation at the end of 2010.
- *Improvement package dwellings*: The first step of the case-study calculated the implementation of two improvement packages. The first improvement package consists of isolation and installation improvements for each of the example dwellings. The second improvement package consists of the improvements of the first improvement package and on top of that it consists of implementation of a small PV-system and a solar boiler for each of the example dwellings.
- *Calculation method of the improvements*: Like stated in the previous paragraph simulations area either based on absolute calculations or relative calculations.

Table 6: Scenarios case-study 1

Time of implementation	Improvement package dwellings	Calculation method improvements
❖ S1: 100% implementation 2010	❖ S1: Improvement package 1	❖ S1: Absolute way
	❖ S2: Improvement package 2	❖ S2: Relative way

The combination of the three variables leads to four different case-study scenario, which will all be simulated during the second step of the case-study (Table 7).

Table 7: Structure of case-study scenarios

Case-study scenario	Time of implementation	Improvement package dwellings	Calculation method improvements
Scenario 1	100% implementation 2010	Improvement package 1	Absolute way
Scenario 2	100% implementation 2010	Improvement package 2	Absolute way
Scenario 3	100% implementation 2010	Improvement package 1	Relative way
Scenario 4	100% implementation 2010	Improvement package 2	Relative way

3.3.7 Results of the second step of the case-study

In total four different scenarios are simulated with the MS Excel simulation tool and the results of the simulations will be presented in this chapter.

3.3.7.1 Case-study scenario 1

The first scenario assumes a situation in which the first improvement package is implemented in 2011 according to the numbers of the tool and dwelling stock numbers of Eindhoven. In other words an improvement from the current state energy level to the energy level of improvement package 1 applied on all the example dwellings. This means that at the beginning of 2011 all dwellings in Eindhoven have a maximum improvement their isolation and installations.

The results are presented by Table 8 and Figure 3. Figure 3 presents the financial effects of the first scenario during the simulation period in case of an interest rate of 3.34%. The red line represent the total cumulative costs of the first improvement package, the blue line represent the total cumulative costs of the benchmark. The green line represents the difference between both cost curves. In case the green line is positive, the cumulative costs of the intervention are lower than the cumulative costs of the benchmark meaning that the implementation of the first improvement package leads to lower total energy costs. Of course in case the green line is negative, the opposite is true. The purple line represents the total long-term loan. A positive value of the purple line means that the loan still has some unpaid value. In case the value of the purple line equals zero the investment is completely repaid.

In case of an interest rate of 3,34 the total investment of the first improvement package is repaid in 2030. Until (and after) that time the monthly energy costs of the intervention are lower than the monthly energy costs of the benchmark. However, because of the urge to repay the long-term loan, the difference between the monthly energy expenses between the benchmark and the intervention, is employed to repay the investment costs. This explains the fact that the red and blue lines are, till 2030, exactly the same. After 2030 the loan is completely repaid meaning that the monthly expenses are reduced with the repayment rate and as a result the monthly costs of the intervention are lower than the monthly costs of the benchmark. This explains the fact that after 2030 the purple line equals zero and the green line increases.

Appendix G Figure 50 and Figure 51 present the financial graphs of the first scenarios in case of the application of an interest rate of 0% and 8%. In case, an interest rate of 0% would be applied, the financial results would be even better then in case an interest rate of 3,34% would be applied, and the investment costs would be repaid by 2021. In case of an interest rate of 8% the annual costs of the intervention would be higher than the annual costs of the benchmark, due to the high interest rate, and as an effect no repayment of the long-term loan is possible, which eventually leads to an exponential growth of the investment costs due to the exponential increasing interest rate.

Table 8 presents the KPI's of the first scenario. The first improvement package leads to a minor increase of the electricity demand of 0,23%, due to increasing electricity consumption of the improved installations of the dwelling, and it leads to a major decrease of the gas demand of 52,18%, due to better isolation of the dwelling. The first improvement package leads to a total average monthly energy costs during the simulation period of €281,- per dwelling. The benchmark leads to a total average monthly energy costs during the simulation period of €328,- per dwelling. This means that the implementation of the intervention leads to a decrease of the monthly energy costs of €47,-. In case the total costs are compared, the intervention leads to a total costs reduction of 1.9 billion euro during the simulation period.

All in all, the implementation of the first improvement package, under absolute conditions, only leads to major advantages. This means that in case energy demand and energy price develops according to historical data and an interest rate of 3,34 percent is used, no additional monthly payments are required on top of the benchmark situation. The implementation of the first improvement package leads to a reduction of 52,14% of the total gas demand and a minor increase of the electricity demand of 0,23%, furthermore the implementation leads to an average cost reduction of €47,- per month during the simulation period.

Table 8: Key Performance Indicators of case-study scenario 1

Key Performance Indicators	Starting year (2011)	Ending year (2045)	Overall (2011 - 2045)
Total electricity demand (kWh) 'Benchmark'	320.408.903	467.398.584	13.786.631.027
Total electricity demand (kWh) 'Improvement package 1'	321.138.654	468.128.334	13.812.172.290
Electricity Savings ('Benchmark - Improvement package 1')	-0,23%	-0,16%	-0,19%
Total gas demand (m^3) 'Benchmark'	197.692.101	197.692.101	6.919.223.519
Total gas demand (m^3) 'Improvement package 1'	94.540.329	94.540.329	3.308.911.524
Gas savings ('Benchmark - Improvement package 1')	52,18%	52,18%	52,18%
Average energy payment; per month, per dwelling	€ 178	€ 493	€ 328

('Benchmark')			
Average energy payment; per month, per dwelling ('Improvement package 1')	€ 178	€ 373	€ 281
Total cumulative costs ('Benchmark')	N.A.	N.A.	€ 13.499.880.996
Total cumulative costs ('Improvement package 1')	N.A.	N.A.	€ 11.579.677.222
Cumulative difference 2040 ('Benchmark - Improvement package 1')	N.A.	N.A.	€ 1.920.203.774

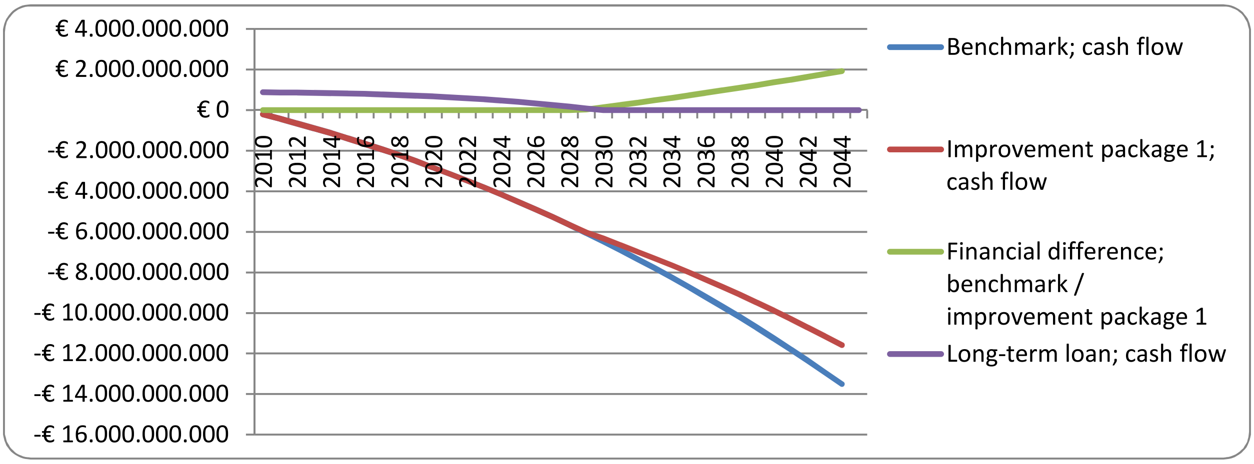

Figure 3: Financial effects of case-study scenario 1

3.3.7.2 Case-study scenario 2

The second scenario assumes a situation in which the second improvement package is implemented in 2011 according to the current state numbers of the tool and the actual dwelling stock of Eindhoven. This means that at the beginning of 2011 all dwellings in Eindhoven have, on top of the implemented maximal improved isolation values and installations, an implemented solar boiler and an installed PV system.

The results are presented by Table 9 and Figure 4. Both table as figure present the same variables as they do in case of scenario 1, only this time applied for scenario 2. The results of the second scenario are broadly the same as the results of the first scenario. However there are also some differences, mainly due to the higher investment cost and the lower monthly energy costs.

In case of an interest rate of 3,34 percent the total investment of the first improvement package is repaid in 2040. During the complete simulation time the monthly energy costs of the intervention situation are lower than the monthly energy costs of the benchmark. However, because of the urge to repay the long-term loan, the difference between the monthly energy expenses between the benchmark and the intervention, is employed to pay back the investment costs. This explains the fact that the red and blue lines are, until 2040, exactly the same. After 2040 the loan is completely repaid meaning that the monthly expenses are reduced with the repayment rate and as a result the monthly costs of the intervention are lower than the monthly costs of the benchmark. This explains the fact that after 2040 the purple line equals zero and the green line increases.

Appendix G Figure 52 and Figure 53 present the financial graphs of the second scenarios in case of the application of an interest rate of 0% and 8%. In case, an interest rate of 0% would be applied, investment costs would be repaid by 2024. In case of an interest rate of 8%, similar results are obtained as in the first case-study scenario under corresponding conditions.

Figure 19 presents the KPI's of the first scenario. The second improvement package leads to a major decrease of the electricity demand of 37%, due to the installation of roof mounted PV systems, and it leads to a major decrease of the gas demand of 60,17%, due to better isolation and installations of the dwelling and due to the installation of a solar boiler on each dwelling. The average electricity savings decrease in time as the total electricity demand increases. The second improvement package leads to a total average monthly energy costs during the simulation period of €303,- per dwelling. The benchmark leads to a total average monthly energy costs during the simulation period of €328,- per dwelling. This means that the implementation of the intervention leads to a decrease of the monthly energy costs of €25,-. In case the total costs are compared, the intervention leads to a total costs reduction of 1.0 billion euro during the simulation period.

All in all, the implementation of the second improvement package, under absolute conditions, also leads to major advantages. Energetically spoken the results exceed the results of the first case-scenario, since gas consumption is reduced with an extra 10% and electricity consumption is reduced with almost 40%. However financially spoken the extra savings come with a price. Although the second scenario shows that during the simulation period the intervention shows a better financial result than the benchmark, the second scenario achieves only half of the monthly savings the first scenario achieved. But still this means that in case energy demand and energy price develops according to historical data, and an interest rate of 3,34% is used, no additional monthly payments are required on top of the benchmark situation. Furthermore the total investments are repaid during the simulation period, which makes the second scenario also financially healthy.

Table 9: Key Performance Indicators of case-study scenario 2

Key Performance Indicators	Starting year (2011)	Ending year (2045)	Overall (2011 - 2045)
Total electricity demand (kWh) 'Benchmark'	320.408.903	467.398.584	13.786.631.027
Total electricity demand (kWh) 'Improvement package 2'	201.845.412	348.835.093	9.636.908.824
Electricity Savings ('Benchmark - Improvement package 2')	37,00%	25,37%	30,10%
Total gas demand (m^3) 'Benchmark'	197.692.101	197.692.101	6.919.223.519
Total gas demand (m^3) 'Improvement package 2'	78.731.427	78.731.427	2.755.599.929
Gas savings ('Benchmark - Improvement package 2')	60,17%	60,17%	60,17%
Average energy payment; per month, per dwelling ('Benchmark')	€ 178	€ 493	€ 328
Average energy payment; per month, per dwelling ('Improvement package 2')	€ 178	€ 287	€ 303
Total cumulative costs ('Benchmark')	N.A.	N.A.	€ 13.499.880.996
Total cumulative costs ('Improvement package 2')	N.A.	N.A.	€ 12.472.041.787
Cumulative difference 2040 ('Benchmark - Improvement package 2')	N.A.	N.A.	€ 1.027.839.209

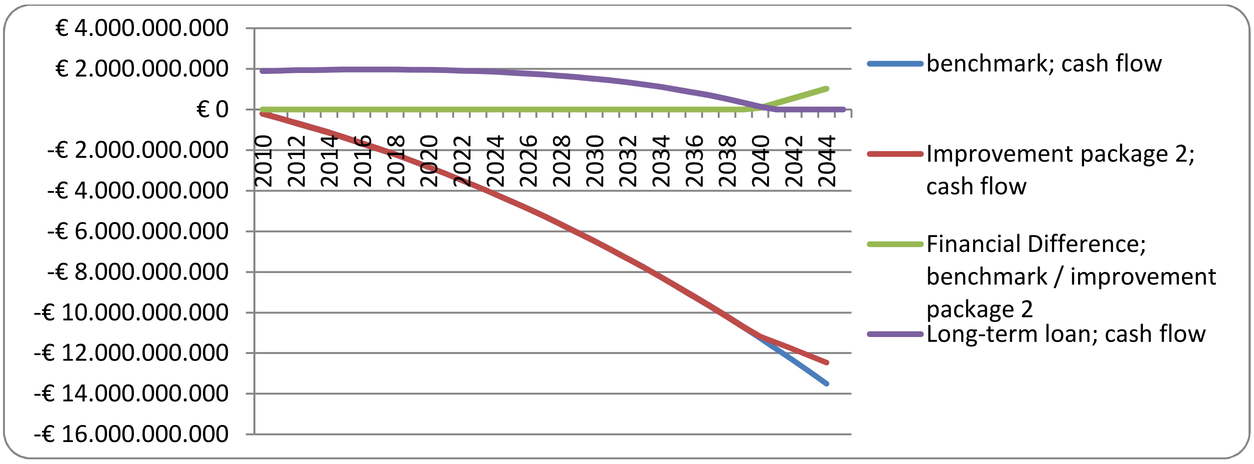

Figure 4: Financial effects of case-study scenario 2

3.3.7.3 Case-study scenario 3

The third scenario assumes a situation in which the first improvement package is implemented in 2011 according to relative energetic improvements and based on actual average energy consumption and actual dwelling stock numbers of Eindhoven. This means that at the beginning of 2011 all dwellings in Eindhoven have a maximum improvement of their isolation and installations.

The results are presented by Table 10 and Figure 5. Figure 5 presents the financial effects of the scenario during the simulation period in case of an interest rate of 3.34%. The colored lines represent the same variables as they do in Figure 3 and in Figure 4. Because the scenario performs it calculations with the average energetic improvements of scenario 1, the results are relatively the same, but absolutely they differ, because the actual annual average electricity and gas consumption for Eindhoven is lower than it is for the Netherlands (and therefore the current state energy level). This means the absolute improvement is less big and therefore the costs are relatively higher, since the costs of both scenarios are in absolute sense the same.

In case of an interest rate of 3,34% the total investment of the first improvement package is repaid in 2044. During the simulation period the monthly energy costs of the intervention are lower than the monthly energy costs of the benchmark. However, because of the urge to repay the long-term loan, the difference between the monthly energy expenses between the benchmark and the intervention, is employed to pay back the investment costs. This explains the fact that the red and blue lines are, till 2044, exactly the same, and the difference is hardly visible in the graph. After 2044 the loan is completely repaid meaning that the monthly expenses are reduced with the repayment rate and as a result the monthly costs of the intervention are lower than the monthly costs of the benchmark. This explains the fact that after 2044 the purple line equals zero and the green line increases.

Appendix H Figure 54 and Figure 55 the financial graphs of the first scenarios in case of the application of an interest rate of 0% and 8%. The results are similar of the results of the first scenario. It still shows the huge influence of the interest rate on the total cash flow.

Table 10 presents the KPI's of the third scenario. The first improvement package leads to relatively the same minor electricity increase and the same major gas decrease as was the case in the first scenario. However the absolute decrease is less large since the starting numbers are also less large. The first improvement package leads to a total average monthly energy costs during the simulation period of €282,- per dwelling. The benchmark leads to a total average monthly energy costs, during the simulation period, of €283,- per dwelling. This means that the implementation of the intervention leads to a decrease of the monthly energy costs of €1,-. In case the total costs are compared, the intervention leads to a total costs reduction of 60 million euro during the simulation period, which is seen the period and the total amount of dwelling almost negligible. The relative small result is the effect of the fact that the investment costs are not repaid until 2044.

The implementation of the first improvement package, under relative conditions, also leads to a financial healthy situation. This means that in case energy demand and energy price develops according to historical date and an interest rate of 3,34% is used, no additional monthly payments are required on top of the benchmark situation. The implementation of the first improvement package leads, relatively, to the same reduction of the total gas demand (52,14%) and the same minor increase of the electricity demand (0,23%). However because scenario 3 has to deal with similar investment costs as scenario 1, but with less absolute energetic results, the implementation leads to an average cost reduction of only €1,- per month during the simulation period. Because of this small reduction, the conclusion can be made that in this case, financially spoken the benchmark has the same performance as the intervention. However energetically spoken the intervention performs better than the benchmark.

Table 10: Key Performance Indicators of case-study scenario 3

Key Performance Indicators	Starting year (2011)	Ending year (2045)	Overall (2011 - 2045)
Total electricity demand (kWh) 'Benchmark'	320.408.903	467.398.584	13.786.631.027
Total electricity demand (kWh) 'Improvement package 1'	321.138.654	468.128.334	13.812.172.290
Electricity Savings ('Benchmark - Improvement package 1')	-0,23%	-0,16%	-0,19%
Total gas demand (m^3) 'Benchmark'	145.746.347	145.746.347	5.101.122.133
Total gas demand (m^3) 'Improvement package 1'	69.698.827	69.698.827	2.439.458.960
Gas savings ('Benchmark - Improvement package 1')	52,18%	52,18%	52,18%
Average energy payment; per month, per dwelling ('Benchmark')	€ 150	€ 432	€ 283
Average energy payment; per month, per dwelling ('Improvement package 1')	€ 150	€ 381	€ 282
Total cumulative costs ('Benchmark')	N.A.	N.A.	€ 11.672.766.409
Total cumulative costs ('Improvement package 1')	N.A.	N.A.	€ 11.612.463.257
Cumulative difference 2040 ('Benchmark - Improvement package 1')	N.A.	N.A.	€ 60.303.151

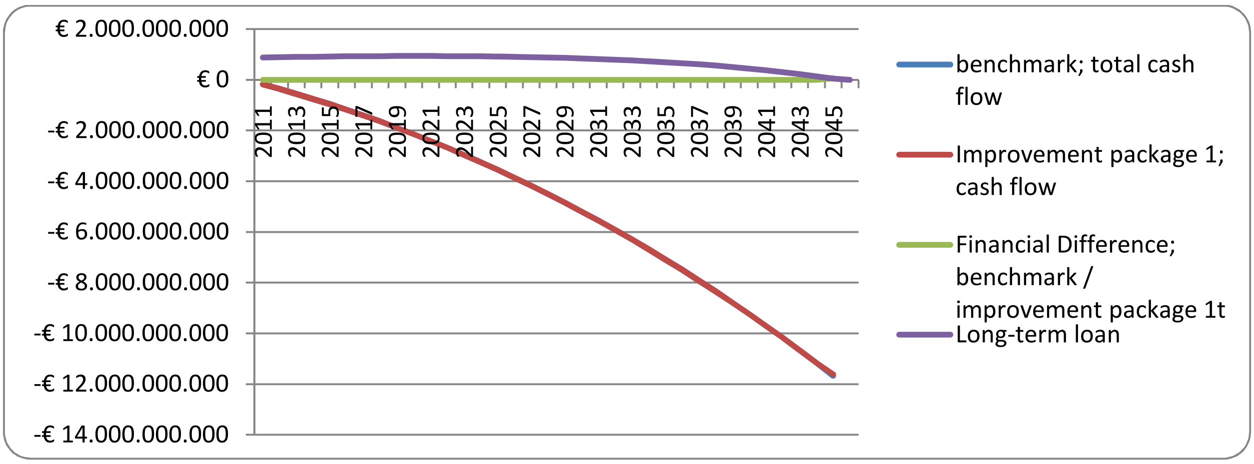

Figure 5: Financial effects of case-study scenario 3

3.3.7.4 Case-study scenario 4

The fourth scenario assumes a situation in which the second improvement package is, like the previous scenarios, implemented in 2011 according to relative energetic improvements and based on actual average energy consumption and actual dwelling stock numbers of Eindhoven. This means that at the beginning of 2011 all dwellings in Eindhoven have, on top of the implementation of a maximum improvement of the dwellings isolation and installations, an implementation of a solar boiler and a PV system.

The results are presented by Table 11 and Figure 6. Figure 6 presents the financial effects of the scenario during the simulation period in case an interest rate of 3.34% is applied. The colored lines represent the same financial variables as they do in the previous scenarios. Because the scenario calculates it calculations with average energetic improvements of scenario 2, the results are relatively the same, but absolutely they differ, because the actual annual average electricity and gas consumption for Eindhoven is lower than it is for the Netherlands. This means the absolute improvement is less big and therefore the costs are relatively higher, since the costs of both scenarios are in absolute sense the same.

Despite the fact that the long-term loan reaches its max during 2036 and decreases after that year, it is not possible to repay the investment costs during the simulation period, in case of an interest rate of 3,34%. The fact that the total long-time long behaves according to a parabolic function instead of an exponential funtion can be explained by the fact that gas consumption does not increase in time which makes the financial gap between the benchmark and the intervention during the simulation period slowly bigger, which in turn makes it possible to increase the repayment rate. Despite the inability to repay the long-term loan there is no financial different between the benchmark and the intervention. This explains the fact that the green lines stays zero.

Appendix H Figure 56 and Figure 57 presents the financial graphs of the fourth scenarios in case of the application of an interest rate of respectively 0% and 8%. An interest rate of 0% makes it possible to repay the total investment costs by 2036. In case of an interest rate of 8% the long-term loan grows, as was the case in the previous three scenarios, exponentially.

Table 11 presents the KPI's of the fourth scenario. The second improvement package leads, relatively, to the same major decrease of the electricity demand and the same major decrease of the gas demand as the second scenario. However the absolute decrease is, like the third scenario, less large since the starting numbers are also less large. The second improvement package does not lead to lower annual costs than the benchmark does. In both cases the average monthly costs will be €283,- per dwelling. Therefore the total costs of the intervention are the same as the total costs of the benchmark. Despite the decrease of the gas and electricity consumption, the fourth scenario leads to a financial unhealthy situation and is therefore not recommended, because at the end of the simulation period the long term-loan is larger than at the start.

Table 11: Key Performance Indicators of case-study scenario 4

Key Performance Indicators	Starting year (2011)	Ending year (2045)	Overall (2011 - 2045)
Total electricity demand (kWh) 'Benchmark'	320.408.903	467.398.584	13.786.631.027
Total electricity demand (kWh) 'Improvement package 1'	201.845.412	348.835.093	9.636.908.824
Electricity Savings ('Benchmark - Improvement package 1')	37,00%	25,37%	30,10%
Total gas demand (m^3) 'Benchmark'	145.746.347	145.746.347	5.101.122.133
Total gas demand (m^3) 'Improvement package 1'	58.043.886	58.043.886	2.031.536.017
Gas savings ('Benchmark - Improvement package 1')	60,17%	60,17%	60,17%
Average energy payment; per month, per dwelling ('Benchmark')	€ 150	€ 432	€ 283
Average energy payment; per month, per dwelling ('Improvement package 1')	€ 150	€ 432	€ 283
Total cumulative costs ('Benchmark')	N.A.	N.A.	€ 11.672.766.409
Total cumulative costs ('Improvement package 1')	N.A.	N.A.	€ 11.672.766.409
Cumulative difference 2040 ('Benchmark - Improvement package 1')	N.A.	N.A.	€ -

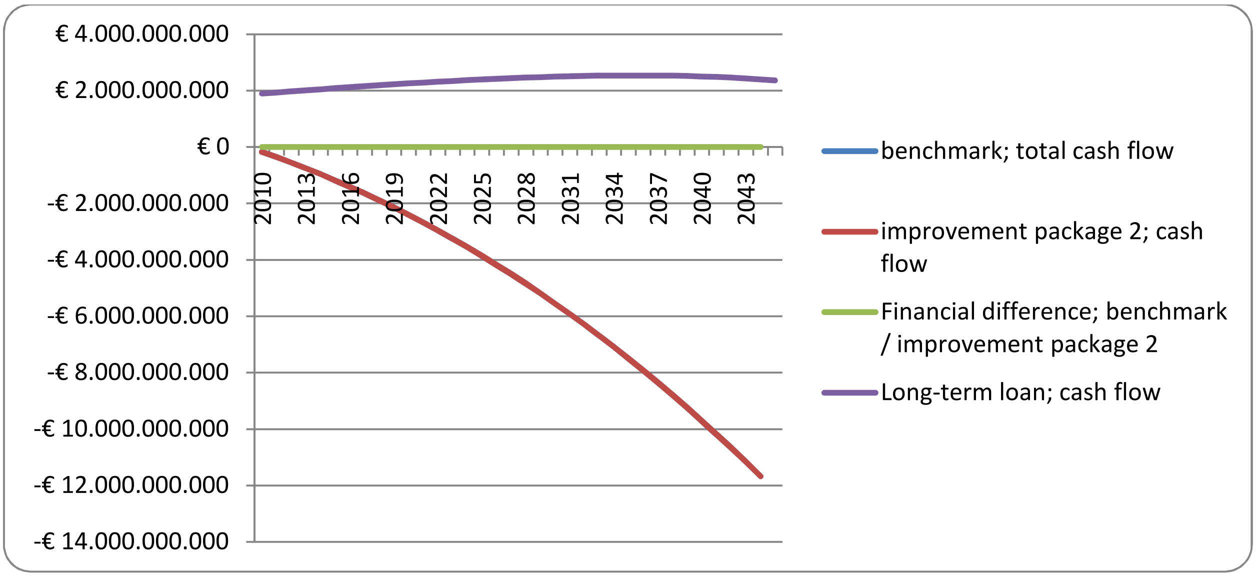

Figure 6: Financial effects of case-study scenario 4

3.3.8 Conclusions & Discussion

This section briefly discusses the complete results of the first case-study, formulates its most important conclusions and answers the research questions as were formulated at the beginning of the chapter.

The case-study described an application of the calculation tool of AgentschapNL, on dwelling bounded energy labels, on the target area Eindhoven, and was divided into two different parts. The first part calculated the total investment costs and the total energetic effects of two intervention measures. The second part calculated the financial effects of the intervention measures during a simulation period of 34 year and compared the results with a benchmark. All calculations were performed with the simulation tool MS Excel and were performed on example dwellings. Example dwellings are dwellings with similar energetic consumption and similar dwelling characteristics and their selections are based on the type of the dwelling and the construction period of the dwelling.

The first intervention measure described the implementation of improvement package 1. The first improvement package described an improvement of a dwellings isolation values (upgrade of the façade, roof and floor isolation to a Rc value of 2,53m^2K/W and upgrade of the windows to HR++ windows) and the improvement of a dwellings installations (implementation of a HR 107 combination boiler). The second intervention measure described the implementation of improvement package 2. The second improvement package described an extension of the first improvement package and described, on top of the isolation and installation improvement, also the implementation of a small roof mounted PV system and the implementation of a solar boiler.

Unfortunately the tool did not fit perfectly on the target area Eindhoven. All energetic improvement calculations were calculated from a certain starting point. The tool of AgentschapNL called this starting point, 'the current state' of all the dwellings. 'The current state' was expressed in current average gas consumption and the current average dwelling-related electricity demand. Both numbers were calculated by the WoON study 2006 and were based on average consumption numbers for all the dwellings in the Netherlands. In order to check the applicability of the tool, the actual average gas consumption per example dwelling, which is based on data of ENDINET, was compared with 'the current state' gas consumption per example dwelling of the tool. Unfortunately the tool did not fit perfectly on the target area, and therefore the tool calculated, for each improvement package, two different scenarios. The first scenario executed its calculations with, 'the current state' of the tool as the starting point, the second scenario executed its calculation with the relative effects of the first scenario and used as starting point the actual average gas consumption of ENDINET. Combining the two different starting points with the two different improvement packages leads to 4 scenarios.

The first two scenarios calculated the effects of the improvement packages on energetic consumption numbers of the tool, which were based on average numbers of the Netherlands. The advantage of using these numbers is that the financial and energetic calculations are correct, meaning that the investment costs correspond with the energetic improvements. The disadvantage of using these numbers is that the numbers do not (completely) fit the application of the target area, because the actual average consumption of the target area is much lower than the average consumption of the tool. In case the (absolute) savings of the improvement packages were applied on the actual average consumption (based on ENDINET), in certain cases, the new consumption (in case the improvement packages were installed) would turn up to be negative, which of course is not possible. A possible solution to fix the problem is to work with relative savings. In this case the energetic savings, in terms of percentage, of the calculations based on numbers of the calculation tool were applied on actual energy consumption of the target area. The advantage of using these relative improvements is that they fit better on the target area, meaning that the energetic effects can be measures more precisely. The disadvantage is that the relative costs are higher, because both methods use the same investment costs, except the energetic savings, in case the relative improvements were applied on actual numbers, are smaller.

Applying all four scenarios in the two different parts of the case-study leads to the following results:

Scenario 1: This scenario describes a 100% percent implementation of the first improvement package in 2010, with as starting point of the calculations the 'current state' average energy consumption of the tool, and with absolute improvement calculations. Implementation of the first scenario leads to major advantages. This means that in case energy demand and energy price develops according to historical date and an interest rate of 3,34% is used, no additional monthly payments are required on top of the benchmark situation and the total investments are repaid during the simulation period. The implementation of the first improvement package leads to a reduction of 52,14% of the total gas demand and a minor increase of the electricity demand of 0,23%, furthermore the implementation leads to an average cost reduction of €48,- per month during the simulation period. The implementation of the first scenario leads, compared with the benchmark, during the simulation period to a total profit of about 1.9 billion euro.

Scenario 2: This scenario describes a 100% implementation of the second improvement package in 2010, with as starting point of the calculations, the 'current state' average energy consumption of the tool, and with absolute improvement calculations. Implementation of the second scenario leads, as the first scenario, to advantages, only on a different level. Energetically spoken the results exceed the results of the first case-scenario, since gas consumption is reduced with an extra 10% and electricity consumption is reduced with almost 40%. However financially spoken the extra savings come with a price. Although the second scenario shows that during the simulation period the intervention shows a better financial result than the benchmark, the second scenario achieves only half of the monthly savings the first scenario achieved. But still this means that in case energy demand and energy price develops according to historical data, and an interest rate of 3,34% is used, no additional monthly payments are required on top of the benchmark situation. Furthermore the total investments are repaid during the simulation period, which makes the second scenario also financially healthy.

Scenario 3: This scenario describes a 100% implementation of the first improvement package in 2010, with as starting point of the calculations, the actual average energy consumption of ENDINET, and with relative improvement calculations. The implementation of the first improvement package, under these conditions, also leads to a financial healthy situation. This means that in case energy demand and energy price develops according to historical data and an interest rate of 3,34% is used, no additional monthly payments are required on top of the benchmark situation and the investment costs are repaid during the simulation period. The implementation of the third scenario leads, relatively, to the same reduction of the total gas demand (52,14%) and the same minor increase of the electricity demand (0,23%) as scenario 1. However because scenario 3 has to deal with similar investment costs as scenario 1, but with less absolute energetic improvements, the implementation leads to a negligible average cost reduction of only €1,- per month during the simulation period. Therefore, financially spoken, the benchmark has the same performance as the intervention. However, energetically spoken, the intervention performs better than the benchmark.

Scenario 4: This scenario describes a 100% implementation of the second improvement package in 2010, with as starting point of the calculations, the actual average energy consumption of ENDINET, and with relative improvement calculations. The implementation of the second improvement package, under these conditions, leads to a financial unhealthy situation. This means that in case energy demand and energy price develops according to historical data and an interest rate of 3,34% is used, additional monthly payments are required on top of the benchmark situation, otherwise it is not possible to repay the investment costs during the simulation period. Only an extra monthly repayment of €22,50 per dwelling leads to financial healthy situation, meaning that at the end of the simulation period the investment costs are repaid and financially the intervention has equally total costs as the benchmark. The implementation of the fourth scenario leads, relatively, to the same reduction of the total gas demand (60,17%) and the same reduction of the total electricity demand (37%) as scenario 2. However because scenario 4 has to deal with similar investment costs as scenario 2, but with less absolute energetic improvements, the intervention leads, during the simulation period, in case of no extra repayments to equally average cost per month as the benchmark and to a total long-term loan which is bigger than the initially investment costs. In case of an extra monthly repayment of €22,50 per dwelling , during the simulation period, the average monthly costs of the intervention is equal to the average monthly costs of the benchmark. The extra monthly repayment leads eventually, at the end of the simulation period, to equally total costs between the intervention and the benchmark and it leads to a fully repayment of the investment costs.

As was discussed before, the total monthly costs depend, for the main part, on the applied interest rate. The starting point of the study was to investigate the macro-economic effects of improving the current dwellings stock of Eindhoven. In case this improvement would be handled centrally, for instance by the city, province or government, the total investment would be much higher and as a consequence the applied interest rate would be lower. In that case an interest rate comparable of an interest rate the government has to pay over national depth could be applied, which is, at the moment, about 3,34%. However, in case a centrally policy turns out to be infeasible, the only alternative is a decentralized policy. In this case the total investment per improvement would be much lower, since all dwelling owners are responsible for their own improvements, and as a consequence the interest rate would be much higher. In that case probably an interest rate of about 8 percent would be applied, which results in higher monthly costs of the benchmark than of the intervention, which makes it impossible to repay the investment costs. And as a consequence the long-term loan will grow exponentially because of the interest rate.

This means that the interest rate determines for an important part the successfulness of the investment. In case it's too high the costs will grow exponentially, in case it's too low, the costs will be repaid easily. It is therefore also possible to determine the breakpoint of the interest rate. The breakpoint can be defined as the interest rate that results, at the end of the simulation period, in equally costs between the benchmark and the intervention and is calculated with no additional monthly repayment fee. In case of scenario 1, the breakpoint interest rate is 4,65%, in case of scenario 2, it is 3,55%, in case of scenario 3, it is 3,35%, and, finally, in case of scenario 4, it is 2,8%.

This leads to the following answers on the research questions.

RQ1: What are, theoretical, the potential the energetic savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?

The answer is provided by the simulation of the four different scenarios. In all cases, the intervention leads to major energetic savings. The total gas consumption of all the dwellings in Eindhoven could be reduced with 52,17% in case of isolation and installation improvements and with 60,17% in case of isolation and installation improvements and on top of that the installation of a solar boiler. The total electricity consumption of all the dwellings in Eindhoven could be reduced with 37% in case of the installation of a small roof-mounted PV system.

RQ2: What are, theoretical, the potential monthly financial savings in case all the dwelling within the city boundaries of Eindhoven were improved to a maximal energy label?

The financial savings depend on used scenario. Since the target area does not perfectly fit in the tool, two different calculation methods are applied with both advantages and disadvantages. The actual costs would probably lie somewhere between both methods. In case the installations and isolation values of all dwellings of the target area would be improved, and an interest rate of 3,34% would be applied, the monthly average costs could be reduced with €0,- to €49,- per month. In case, on top of the installations and isolation values improvement, also a small roof-mounted PV system and solar boiler would be installed, and also an interest rate of 3,34% would be applied, the monthly average costs could be reduced with €25,-, but is could also be increased with 22,5 euro. This really depends on the calculation method.

RQ3: Is the investment financial feasible, and if so, under what conditions?

Three of the four scenarios lead to a financial feasible situation. Scenario 1 is, by far, most financial feasible, the second scenario leads to more energetic improvements than the first scenario but with only half of the average monthly financial savings and the third scenario is also feasible but leads only to energetic improvements and no financial improvements (or losses). The fourth scenario is not financial feasible. Only in case of an extra repayment of €22,50 the scenario would be feasible, otherwise the scenario leads to a situation in which the long-term loan at the end of the simulation period is bigger than at the beginning. Furthermore, and this applies to all the scenarios, the feasibility depends, for its main part, on the applied interest rate.

Chapter 4: Case-study on Photovoltaic systems

This chapter elaborates the results of the case study on photovoltaic (PV) systems in the dwelling market. The chapter starts with a brief introduction of PV. During the introduction the different technical applicability's and the different kind of technologies will be elaborated. Subsequently the legal issues of the Dutch market according to PV systems will be elaborated, next the present performances and prices of the dominant technology together with their short and long term development will be discussed and finally the calculations of different scenarios in case of implementing the technique in the city of Eindhoven will be discussed.

In total eight different scenarios will be simulated. The scenarios will differ from each other in penetration time of the market, efficiency development of the PV system and price development of the PV system. The simulation will be executed in MS Excel with a time interval of one year starting in the year 2011 and ending in the year 2045.

The case study will only discuss on-grid systems and will thus exclude stand-alone systems. A PV system which is connected to the local electricity network is referred to as being 'on-grid'. Any excess power that is generated can be fed back into the electricity grid. Under a FiT regime, the owner of the PV system is paid according the law for the power generated by the local electricity provider. The FiT regime in the Netherlands will be discussed in the legal part of this chapter.

The case study will ignore the effects and investments necessary for high penetration of PV in the grids. A recent case-study (European Distributed Energy Partnership, 2011) has evaluated how much PV can be integrated into the distribution network without causing network failures. The study found that Germany, which by end of 2010 had more than 16000 MW of PV electricity integrated into its network, is still a long way from exceeding grid limitations. The study recommends that PV could account for up to 20% of supply without affecting the grid, under some technical developments.

Different technologies have different appearances and therefore different aesthetic values. Since taste is very personal and the differences between the systems are only small, the aesthetic values of different systems will be excluded in this study

The goal of the PV case-study is to study the opportunities of PV systems for the existing dwelling market in Eindhoven. The study attempts to find an answer on the following research questions:

RQ1: What are the most important energetic and financial variables as it comes to a large- scale implementation of PV systems in Eindhoven?

RQ2: Which scenarios can be distinguished and what are the effects of the scenarios?

RQ3: What will be the total financial and energetic effects in case the technology will be large-scale implemented in the city?

4.1 Introduction on photovoltaic systems

Photovoltaic systems contain cells that convert sunlight into electricity. Inside each cell there are layers of a semi-conducting material. Light falling on the cell creates an electric field across the layers, causing electricity to flow. The intensity of the light determines the amount of electrical power each cell generates. A photovoltaic system does not need bright sunlight in order to operate. It can also generate electricity on cloudy and rainy days from reflected sunlight, although the intensity and therefore the amount of electrical power a cell generates is higher in bright sunlight.

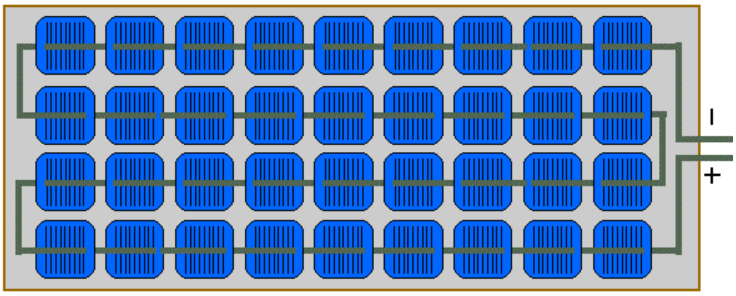

Figure 7: A module consist of in series connected solar cells

A grid-connected PV system can be divided into different parts (Figure 8), namely: A Photovoltaic modules to collect sunlight, an inverter to transform the direct current (DC) to alternate current (AC), a solar meter to measure the total amount of energy that is fed into the grid, a support structures to orient the PV modules toward the sun and some cables and other materials to connect the system. All the materials of a PV system besides the PV modules and the Inverter are also known as 'Balance of System' (BOS) elements. A PV module consists of in series connected solar cells of photovoltaic materials (Figure 7).

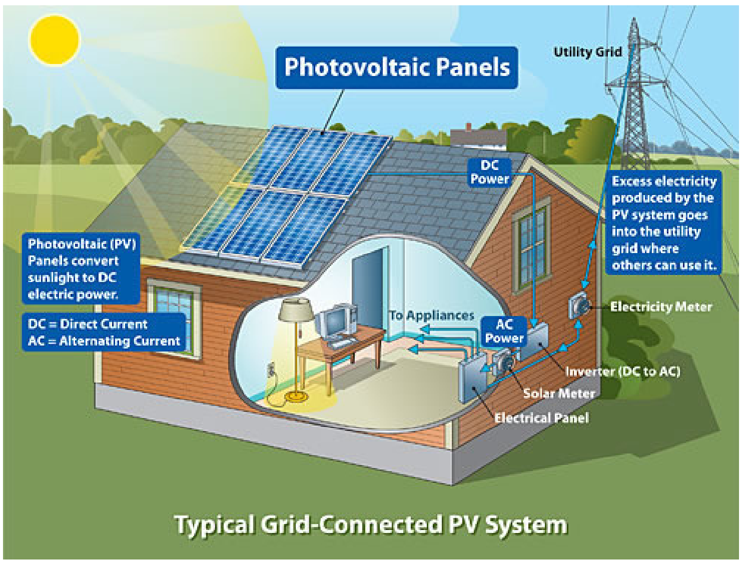

Figure 8: Grid-connected PV system and its parts (Mass Audubon, 2011)

The solar cell is the basic element of a PV system and is in most cases either made from: crystalline silicon, grown ribbons, or from alternative semiconductor materials deposited in thin layers on a low-cost backing (thin film). The systems nominal power is measured in Watt-peak (Wp). Wp is a standardized global measure executed in laboratory standardized test conditions (also known as STC) (M. Topic et. al 2006). STC is created to be able to compare different types of PV panels in an equal way. The power under STC means that the power of a panel is measured with a radiation of 1000W/m^2 and a panel temperature of 25 degrees Celsius.

The power generated by a single PV module varies from a few Wp (typically 20 to 60 Wp) up to 120 to 300 Wp depending on module size and the technology used. There are three types of technologies classified in first, second and third generation:

- First generation technology is the basic crystalline silicon (c-Si).
- Second generation includes Thin Film technologies.
- Third generation includes concentrator photovoltaics, organics and other technologies.

The thin silicon cells are made of wafers cut from a crystal or a block of silicon. The type of crystalline cells produced depends on how the wafers are made. There are three main types, namely: Mono crystalline (mc-Si), polycrystalline or multi-crystalline, (pc-Si) and Ribbon and sheet-defined film growth (ribbon/sheet c-Si). The mono crystalline provides the highest cell efficiency of the first generation technologies and therefore the highest power generation. Crystalline silicon is the most mature and adopted technology in the market. The technology represents about 80% of the market today.

The first generation cells have an efficiency of 14% to 22%, meaning they turn these percentages of sunlight reaching them into electricity. A standard c-Si module is made up of about 60 to 72 solar cells and has a nominal power ranging from 120 to 300 Wp depending on size and efficiency. The average module size lays between 1,4 m^2 and 1,7 m^2. Module producers usually guarantee a power output of 80% of the Wp, even after 20 to 25 years. Module lifetime is typically considered of 25 years, although it can easily reach over 30 years. The raw material of the first generation technology is silicon. This material is the second most abundant element in the Earth's crust after oxygen, it is found in Quarts or sand.

Thin film modules are constructed by depositing extremely thin layers of photosensitive material on to a low cost backing such as glass, stainless steel or plastic. Once the deposited material is attached to the backing, it is laser-cut into multiple thin cells. Contrary to first generation technology, the thin film modules are flexible and can therefore be better integrated in objects. Nowadays there are four types of Thin Film modules commercially available, namely: Amorphous silicon (a-Si), multi junction thin silicon film (a-Si/μc-Si), cadmium telluride (CdTe), and copper, indium, gallium, (di)selenide/(di)sulphide(CIGS) and copper, indium, (di)selenide/(di)sulphide (CIS).

Thin film modules have an efficiency of 7 to 12%, meaning they turn these percentages of sunlight reaching them into electricity. Typical module power ranges from 60 Wp to 350 Wp (although the 350 Wp has only been achieved in laboratory conditions). The thin film modules have no common industry agreement on optimal module size. As a result they vary from 0,6 to 1,0 m^2 for CIGS and CdTe to 1,4 to 5,7 m^2 for silicon based Thin Films.

The third generation technologies are PV technologies that are beginning to reach the market and are therefore called 'emerging'. They can be classified as: Advanced inorganic Thin Films such as spherical CIS and Thin-Film polycrystalline silicon solar cells, organic solar cells which include both fully organic and hybrid dye-sensitized solar cells, and thermo-photovoltaic (TPV) low band-gap cells which can be used in combined heat and power (CHP) systems. Third generation PV systems are in development and are not yet commercial available, nonetheless the technology is very promising and interesting for future scenarios. Since the third generation technology is not yet commercial ready for implementation in the present market it will not be included in the calculations for the case study.

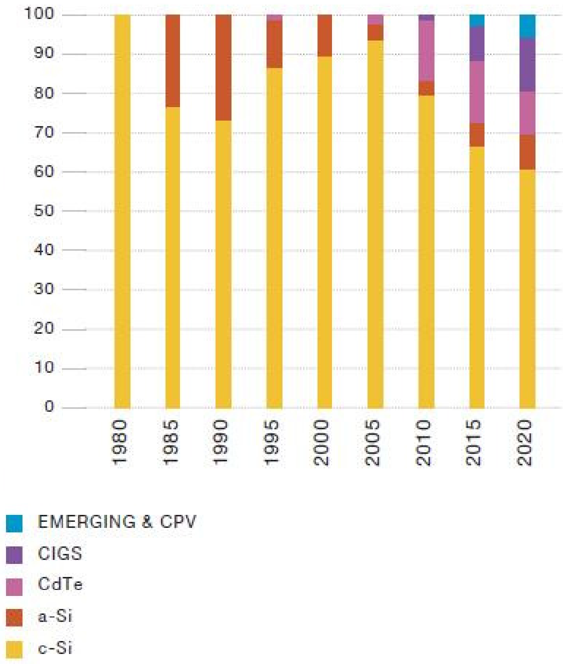

Figure 9: Market penetration PV technologies

Crystalline silicon technologies have dominated the market for the last 30 years. Within the first generation technologies mono- and multi-crystalline cells have both an equal market proportion. However, multi-crystalline cells are gaining market share. Ribbon c-Si represents less than 5% of the market. Within the second generation technologies amorphous silicon (a-Si) was the dominant technology for the last three decades, however the last decade its market share has decreased significantly compare to CdTe and CIGS. Third generation technologies will enter the market real soon. They are expected to achieve a 5% market share by 2020. The European Photovoltaic Industry Association (EPIA) expects that by 2020 the first generation technologies will have a market share of 61%, the second generation technologies will have a market share of 33% and the third generation technologies will have a market share of about 6% (Figure 7).

At the moment the first and second generation technologies are most suitable to compete with conventional energy supply gain from fossil materials. There are some important differences between the first and second generation technologies which affects the suitability for a large-scale implementation. Both technologies differ mainly in three variables greatly with each other, namely in efficiency, construction costs and lifespan.

The Crystalline Silicon modules generate more electricity than the thin film modules. Per square meter the power differs from 140 Wp/m^2 for the first generation technologies against 80 Wp/m^2 for the second generation technologies. Although the Thin Film modules are less efficient than the Crystalline Silicon modules (7 – 12%

against 14% - 22%), they perform better under diffuse light conditions (as a result of cloudiness and/or sunset/sunrises) and have less trouble of power loss as a result of high temperatures. Thin Film technologies are a lot cheaper to produce. At the moment the Thin Film modules are about 25% cheaper than the Crystalline Silicon modules. However to generate the same amount of energy with both systems, more Thin Films modules are necessary which, as a result, makes the initial costs of both systems about the same. Finally, currently the most important advantage of the Crystalline Silicon technology is its lifespan. The first generation modules have a lifespan of about 25 to 30 years and the second generation technologies only have a lifespan of 5 to 15 years. This makes, at the moment, the first generation cells more profitable to invest than the second generation cells. In the near future however, the second generation modules will have a better chance to compete with the first generation technologies due to future developments in system costs and life expectancy.

Because of the differences in efficiency, system costs, lifespan, and market maturity, the case study will mainly focus on the first and second generation cells in the city of Eindhoven. The third generation cells will only be used as inspiration for the development of future scenarios. Table 12 presents a summary of the different generation cells and their current module efficiency.

Table 12: PV technologies and current module efficiency (EPIA, 2010)

Technology	Thin Film					Crystalline Silicon		CPV
	(a-Si)	(CdTe)	CI(G)S	a-Si/µc-Si	Dye s. cells	Mono	Multi	III-V Multi-junction
Cell efficiency	4-8%	10-11%	7-12%	7-9%	2-4%	16-22%	14-18%	30-38%
Module Efficiency						13-19%	11-15%	~25%
Area needed per kWp (for modules)	~15m^2	~10m^2	~10m^2	~12m^2		~7m^2	~8m^2	

Besides the different types of technology, it is also possible to make a distinction in applicability of the technique. Different applications will in turn lead to different system costs and different energetic generation values. Basically two different systems can be distinguished:

- Residential and commercial systems. This is the most common application of solar PV systems. In this case PV systems are installed on dwellings and on businesses in developed areas. A connection with the local electricity network makes it possible to sell an excess of power generated by the solar cells back to the grid. When solar energy is not available, electricity can be drawn from the grid.
- Industrial and utility-scale power plants. Large industrial PV systems can produce enormous quantities of electricity. The solar panels for industrial systems are usually mounted on frames on the ground, but can also be installed on large industrial buildings such as warehouses, airport terminals or railway stations. This way the urban space has a double-use and, this makes it possible to put electricity into the grid where energy-intensive users are located (Table 13).

The case-study will only focus on the dwelling market. Therefore only the residential and commercial system type will be used for the calculations.

Table 13: Type and size of applications (source: EPIA report 2011)

Type of application	Market segment			
	Residential	Commercial	Industrial	Utility scale
	<10 kWp	10kWp – 100kWp	100 – kWp – 1MWp	>1MWp
Ground-mounted			X	X
Roof-top	X	X	X	
Integrated to façade/roof	X	X		

4.2 Dutch legal frame

The Netherlands has as many other countries in the world its own rules and legislation according to sustainable energy techniques. The Netherlands applies two sorts of rules and legislation as it comes to photovoltaic systems, one focuses on the building permits of the systems, the other focuses on the Feed-in Tariffs of the possible electricity fed back into the grid. Currently in the Netherlands it is not necessary to have a construction permit (bouwvergunning) for the placing of PV systems. The department of VROM has formulated a list of rules which the system must meet. Municipalities are not allowed to formulate extra rules, as long as the system complies with these rules:

- The PV system must be placed on the roof of a building
- The PV system must have an energy generation or heat supply purpose for the building it is placed on. It is also allowed to place a PV system on a building that serves another building on the same parcel (e.g. a PV system on a garage).
- The panels must be integrated with the system for generating electricity.
- In case the PV system is placed on a sloping roof, the following set of rules will come into force:
    - The solar panels are not allowed to stick out and must therefore remain within the plane of the roof.
    - The solar panels must be placed in the same angle as the pitch they are placed on.
    - The solar panels must be placed directly on the roof.
- In case the PV system is placed on a flat roof, then the system must be placed at least as far from the edge of the roof as the height of the system (e.g. if the highest point of the panel is 50 cm, than the distance between the system and the edge of the roof must also be at least 50 cm).
- The PV system must be used for private use. The electricity law (elektriciteitswet) guarantees a compensation for small users for electricity that is fed back into the net (in the Netherlands this is called 'salderen'). The Netherlands defines a small user as a user with at most a connection capacity of 3x80 ampere. This compensation is limited and means that the energy supplier is compelled to deduct the private consumption with the energy delivered to the grid, to a limit of 3000 kWh per year (although most energy suppliers apply a limit of 5000 kWh per year). In the near future this limited will be increased by law to 5000 kWh. In case more

energy than the limit is generated and fed back into the grid, the user is entitled to have a certain fee (terugleververgoeding). This fee is not quantified, but must be a reasonable.

- It is prohibited to place a PV system on a monument or to place it in a by government designated city- or townscape.

Basically this means that by law and regulation it is currently only attractive for small users to place small PV systems (with a maximum electricity generation of 5000 kWh per year). Bigger users need a construction permit which can cause long delays and get for every kWh (more than 5000 kWh per year) fed back in the grid only a small compensation. This information is used in the different scenarios presented later in this chapter. Financial support schemes will be discussed later.

4.4 Current system costs and revenues

Currently the PV market is booming. A lot of information is available about system properties and system costs. Unfortunately the information is not always directly useful and most of the time not straightforward. The PV market is very nontransparent, because system suppliers are in most cases unclear about the selling conditions of agreements, the commercial market is not yet mature and suppliers benefit from this situation (Icon Publishers 2009). Also the amount of energy a PV system can generate is very district and time dependent. The northern regions of Europe have less radiation per square meter than the southern regions of Europe and the cell efficiency and system costs has also changed over time. For this reason the case-study uses a market study of PV system price and PV system performances in the surroundings of Eindhoven.

The chapter first starts with the relation between the power, efficiency and area of a panel. These three properties of a panel can easily be transformed into each other using the following formulas:

P = A*N*1000

A = P/(1000*N)

N = P/(1000*N)

P = The STC power of a panel expressed in watt

A = Area of a panel in m^2

N = the efficiency of a panel

1000 = the radiation in watt per m^2 in which the peak power (or STC power) of the panel is determined.

In order to calculate the total amount of energy a system can generate per year certain information is necessary. Basically three things are important:

1. The total amount of solar radiation.
2. The total power of the panels
3. Losses in the system (which in turn depends on the Performance ratio)

The annual radiation in the PV plane is expressed in kWh/m^2. Siderea, a small energy consultancy company for private households in the Netherlands, has measured the radiation in Eindhoven the last seven years (Appendix A, Table 25). Eindhoven measures an annual radiation of 1039 kWh/m^2, measured on a horizontal surface. However most solar systems are not built on a flat surface but they are built on a sloping surface. The radiation on sloping surfaces depends on the orientation of the surface and on the angle of the pitch. Table 14 present the correction factors to transforms the horizontal radiation to a sloping one. The table contains an annual average radiation coefficient for the Netherlands.

Table 14: Orientation and angle correction factor PV

Orientation compared to South orientation			
Angle of the pitch	0	45	90
20 degree	1,08	1,01	0,94
30 degree	1,09	1,00	0,91
40 degree	1,08	0,98	0,87

The total power of the panels depends on the efficiency of the panels. Apendix A, Table 26, Table 27 and Table 28present the results of three market samples. The market samples are collected from three sources. The most recent information (of 2010 and 2011) is collected from tenders of the 'Brabant bepaart' program. This program functions as helpdesk for the subsidy program of the province Noord-Brabant. The information of 2008 and 2009 is collected from an independent market study executed by the company 'Icon Publishers' (Icon Publishers, 2008).

Table 15 shows a summarization of the average values of the market samples. The table shows a decrease of the average costs per Wp in the last three years, and an small increase of the average Wp per m^2. That's logical since recent years the cell efficiency has increased and production capacity and therefore production costs has decreased (EPIA 2011). The average costs per Wp and the average Wp per m^2 are based on complete PV solar system (including the costs of modules, inverter, BOS elements, installation costs and VAT) with a power ranging from 119 Wp to 4200 Wp. Red colored numbers represent the estimated installation costs per Wp. Estimated costs were included in case the information was missing. The study estimated installation costs of 10% of the total costs.

Table 15: Conclusions PV market samples

Year	Sample size	Average Costs/Wp (€)	Sample size	Average Wp/m^2	Efficiency
2008	8	6,59	8	131,63	13,16%
2009	14	5,97	0	N/A	N/A
2010	8	3,51	7	139.73	13,97%
2011	6	3,41	1	139,44	13,94%

Estimations were based on a study conducted by EPIA of PV systems price development. According to that study the price of PV modules has decreased substantially over the past 30 years. The price of inverters has followed a similar price learning curve to that of PV modules. Prices of the BOS elements have not decreased with the same speed. This is mainly because of the price of the raw materials used in these elements (Steel, copper and stainless steel). Installation costs have decreased at different rates depending on the type of application and on the maturity of the market. Reduction in prices for materials (such as mounting structures), cables, land use and installation account for much of the decrease in BOS costs. Another contributor of the decrease in BOS costs and installation costs is the increase of the cell efficiency. Higher efficiency cells results in lower material and space usage which results in lower BOS and installation costs.

The study divided the different parts of a PV system and estimated the price of these parts as a percentage of the total system. The studied systems are small PV systems for small rooftop (3 kWp) installations in mature markets. Because of the importance of the maturity of the market only first and second generation PV systems are investigated. The results are presented in Figure 10.

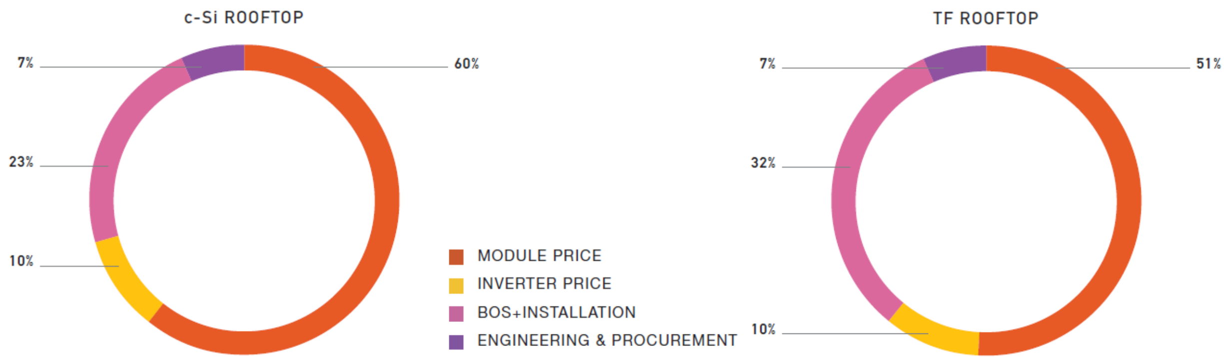

Figure 10: Costs of PV system elements; first generation (left) and second generation system (right)

Finally the capacity of a PV system depends on losses in the system, which in turn is expressed in the so-called Performance ratio (PR). These losses are reflected in the term (1-PR). The PR is a criterion that expresses the quality of the PV system and is defined as the yield in kWh/kWp divided by the radiation in kWh/m^2. The PR is determined by the following factors: Temperature of the PV modules (losses from 1% to 3%), radiation and power dissipation (losses from 3% to 7%), and inverter and cable losses (losses from 3% to 10%). The study of Siderea (Appendix A

Table 25) shows an average PR of 0,83 for PV systems in Eindhoven.

The yield of a PV system (in kWh) can be calculated with the following formula (Siderea 2011):

Yield (kWh) = Radiation on the panels (kWh/m^2) x PV power (kWp) x Performance Ratio

The formula can partially be filled using the data of Eindhoven from the study of Siderea and from the market sample:

Yield (kWh/m^2) = 1039 x (orientation, angle and obstruction correction) x 139,74 x 0,83

4.5 System costs and revenues development

There are three main factors that influence the costs and revenues of PV systems, namely: the system price development, the cell efficiency development, and the financial support of governments.

4.5.1 Financial support

Until recently, the Dutch government applied a Feed-in Tariff (FiT) scheme that guaranteed a price for all renewable electricity that was fed into the grid and a subsidy scheme for the purchase of PV systems. These financial support arrangements were collected in the so-called SDE standard and were intended, among others, for private small users. Due to its popularity the standard is recently updated. The new arrangement, also known as the SDE(+) standard, is only intended for companies, institutions and nonprofit organizations, this is expressed by the fact that only PV installations with a minimal of 15 kWp are supported. That excludes the most important party for the city of Eindhoven, namely private users, since these parties own most of the roof areas of Eindhoven. For this reason the study excludes the usage of the financial support program of the government.

A striking fact is that conventional electricity prices do not reflect actual production costs. The European Union invests more in nuclear energy research (€540 million yearly in average over five years through the EURATOM treaty) than in research for all renewable energy sources, smart grids and energy efficiency measures combined (€335 million yearly in average of seven years through the Seventh framework program). Actually today in Europe fossil fuels and nuclear power are still receiving four times the level of subsidies that all types of renewable energies do (IEA, World Energy Outlook, 2011).

4.5.2 System price development

The cost of PV systems has been constantly decreasing over time. Over the last 30 years the price of PV modules has reduced by 22% each time the cumulative installed capacity (in MW) has doubled (see the right picture of Figure 11 of the Navigant consulting of EPIA). The following factors affect the costs of a PV system and with that the competitiveness of PV with conventional energy sources:

- *Production optimization*; as companies scale up production, they use more automation and larger line capacities. Improved production process can also reduce wafer breakage and line downtime.
- *Economies of scale;* As for all manufacturing industries, producing more products lowers the cost per unit. Economies of scale can be achieved at the following supply and production stages: Bulk buying of materials, obtaining more favorable interest rates for financing and efficient marketing. Capacity increases, combined with technological innovation and manufacturing optimization, have radically reduced the cost per unit.
- *Extended lifetime of PV systems;* Extending the lifetime of a PV system increases overall electrical output and improves the cost per kWh. Most producers give module performance warranties for 25 years. The

component that affects product lifetime the most is the encapsulating material. Intense research is being carried out in this field. However, the industry is cautious about introducing substitute materials because they need to be tested over the long-term. The target is to reach lifetimes of 40 years by 2020.

- *Development of standards and specifications;* the development of standards and consistent technological specifications helps manufacturers to work towards common goals. Widely accepted goals contribute to reduce costs in design, production, and deployment. Standards also foster fair and transparent competitions as all actors in the market must play by the same rules.
- *Technological innovation*; these innovations lead to more efficient cells (which will be discussed later) and more environmentally friendly materials and fewer materials within PV systems. The PV sector has a primary goal to introduce more environmentally friendly materials to replace scarce resources such as silver, indium and tellurium, and materials such as lead and cadmium. Lead-free solar cells are already available in the market. However, a number of manufactures claim that by 2012 the cells are expected to be lead-free, without performance losses (c-Si roadmap, ITPV, 2011). Alternatives to silver will be on the market in 2015. Another research area aims to reduce the material usage and energy requirements. This is done by using thinner wafers, more efficient wafers, and poly-silicon substitutes.

4.5.3 Cell efficiency development

Besides the factors that affect the price of PV systems, there are also factors affect the performance of PV systems. The most important factor is the cell efficiency. When PV modules perform better, they use less material (such as active layers, aluminum frames, glass and other substrates) and they require less surface area (this reduces the need for mounting structures, cables and other components).

The PV system efficiency and costs for residential systems can be expressed in a price (expressed in euro) per kWh and can be plotted in time for the last twenty years and for the upcoming thirty years. Figure 11 (left picture) shows this historical development and these future trends and compares them with retail electricity prices. The upper and the lower parts of the PV curve represents northern Europe and southern Europe respectively. The utility prices for electricity are split into peak power prices (usually during day) and bulk power prices. Central Europe will become (according to these predictions) cost-competitive with peak power before 2020.

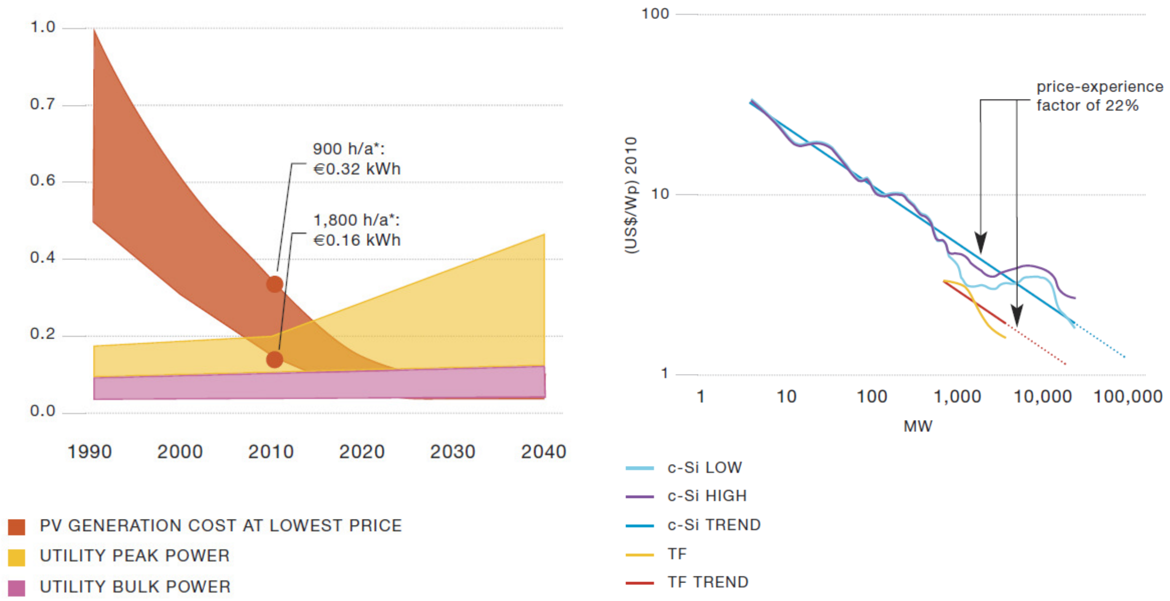

Figure 11: PV price development; Compared with retail prices (left) and the installed base (right)

*h/a = hours of sun per annum. 900 h/a corresponds to northern countries 1800 h/a corresponds to southern countries of Europe. Eindhoven finds itself somewhere between those extremes.

The European Photovoltaic Industry Association (EPIA) applied the qualitative underpinnings of the development of the increasing cell efficiency and the decreasing system price and translated them into quantitative underpinnings for the upcoming ten to twenty years. The underpinnings are presented in Table 16 and Figure 12. These quantitative underpinnings will be used as input for the different future scenarios of the case study.

Table 16: PV technology; Objectives for the upcoming 10 years

		2007	2010	2015	2020
Turnkey price large systems (€/Wp)		5	2,5 – 3,5	2	1,5
Typical PV Module efficiency range (%)	Crystalline Silicon	13-18%	15-19%	16-21%	18-23%
	Thin Films	5-11%	6-12%	8-14%	10-16%
	Concentrators	20%	20-25%	25-30%	30-35%
Inverter lifetime (years)		10	15	20	>25
Module lifetime (years)		20-15	25-30	30-35	35-40

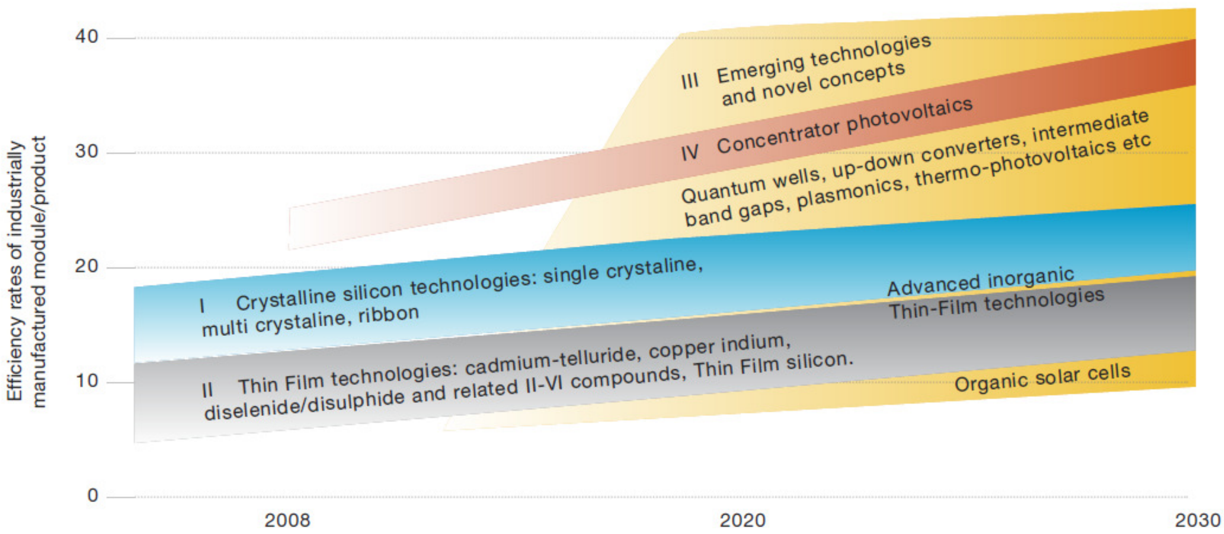

Figure 12: PV cell efficiency development

4.6 Execution of the case-study on photovoltaic systems

The case-study main goal will be to investigate the potential energy that can be generated using PV systems in the existing dwelling market of Eindhoven for the upcoming years until the year 2045. The study is a typical Bottom-up study, meaning that the total PV potential of the dwelling market in Eindhoven is calculated from extrapolation of different 'example dwellings'. What is meant by these example dwellings will elaborated during the upcoming chapter. The study only calculated the potential PV power of systems that were allowed without a building permit (see Chapter '4.2 Dutch legal frame'). This means that only small and roof-mounted systems are included in the calculations. Furthermore the study includes all the different roofs of the residential sector.

The case-study includes two different parts. The first part consists of a brief description of the studied dwelling sample and other important energetic and financial variables that affect the financial and energetic results of the case-study. The second part consists of a number of different scenarios. The first part delivers the information necessary to calculate the effects of the different scenarios of the second part.

4.6.1 Dwelling and roof data Eindhoven

The study makes a distinction between dwellings with a sloping roof and dwellings with a flat roof and in case of dwellings with a sloping roof the study also makes a distinction between the different orientations of the roofs. Both types have a different available area suitable for PV systems. The chapter starts with elaborating the different types of roof in order to examine the total roof area suitable for PV modules and subsequently the total suitable roof area will be applied on the city of Eindhoven.

4.6.1.1 Available area of a sloping roof

There are eight possible dwelling orientations and in case of dwellings with a sloping roof there are 16 different roof orientations (Figure 13). From these 16 different orientations, 10 orientations are suitable for PV modules.

Since the dwellings are randomly built and Eindhoven has, as most cities, a circular shape, the study assumes that the different dwelling orientations equally occur within the city. In other words the study assumes a randomly distributed dwelling position of the dwelling stock of Eindhoven. Therefore the study assumes that 2/16th of the sloping roofs have South orientation, 4/16th of the sloping roofs have a South-East or a South-West orientation and 4/16th of the sloping roofs have a West or East orientation. The remaining 6/16th have a North, North-East or North-West orientation and are therefore not suitable for PV modules.

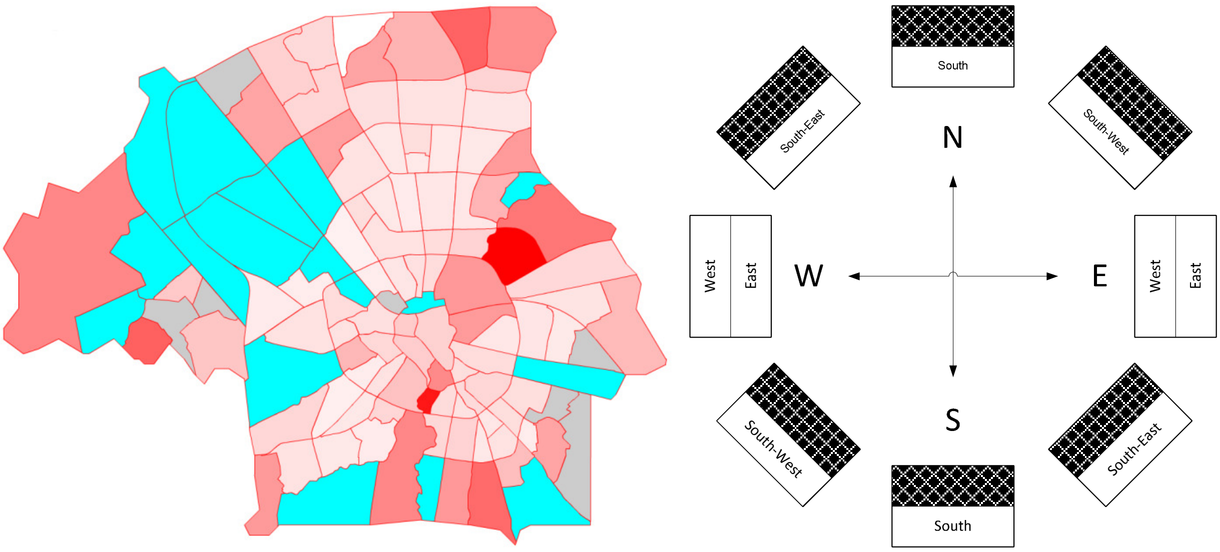

Figure 13: Structure of the city and suitable roof orientations

Furthermore the study assumes that, of all dwellings with a sloping roof, the roofs were built with an angle of 40 degree and all the roofs have a two sloping planes. According to Dutch regulation, the modules must be built directly on the roof, with the same angle as the roof and are not allowed to stick out, and must therefore remain within the plane of the roof. For this reason the calculations of the case-study, concerning sloping roofs are done with panels with an angle of 40 degree.

4.6.1.2 Available area of a flat roof

In theory the surface of a flat roof is entirely suitable for PV. It is, after all, possible to place the modules in every direction and in every angle, ensuring the modules receive the most radiation and therefore generate the most electricity. However, in case of a flat roof, other problems appear. On the one hand there are legal issues and on the other hand there are shadow inconveniences as a consequence of modules that are placed to close together. The greater the angle of the modules, the higher the panel will reach, the larger the distance must be between different rows of modules in order to prevent shadow inconveniences.

According to Dutch legislation modules on a flat roof must be placed at a certain distance from the edge of the roof. This distance is prescribed as follow: 'The system must be placed at least as far from the edge of the roof as the height of the system (e.g. if the highest point of the panel is 50 cm, than the distance between the system and the edge of the roof must also be at least 50 cm)'. This means that the higher the panels reach (as a consequence of the angle in which the module is placed), the further away from the edge of the roof the systems must be placed, and therefore the les modules can be placed on a roof. This provides a consideration between height and total number of modules.

The small consultancy company Sideara did an in optimization study for this problem. According to their findings the optimal angle the modules should be place is 20 degree. In case the modules are placed with an optimal angle of 36 degrees the distance between the modules must be at least four or five times the height of the module. If the modules are placed with an angle of 20 degree, this distance is reduces to only two times the height of the system. Therefore the calculations of the case-study are executed with an angle of 20 degree and with a South orientation. The calculations are based on a standard PV module of 99 cm by 165,5 cm (Figure 14 (A)). Placing a standard modules with an angle of 20 degree results in a systems height of 33,86 cm (Figure 14). Figure 15 presents an overview of the results of the necessary distance between the rows of panels and the distance between the modules and the edge of the roof (within the picture C represents the height of the module).

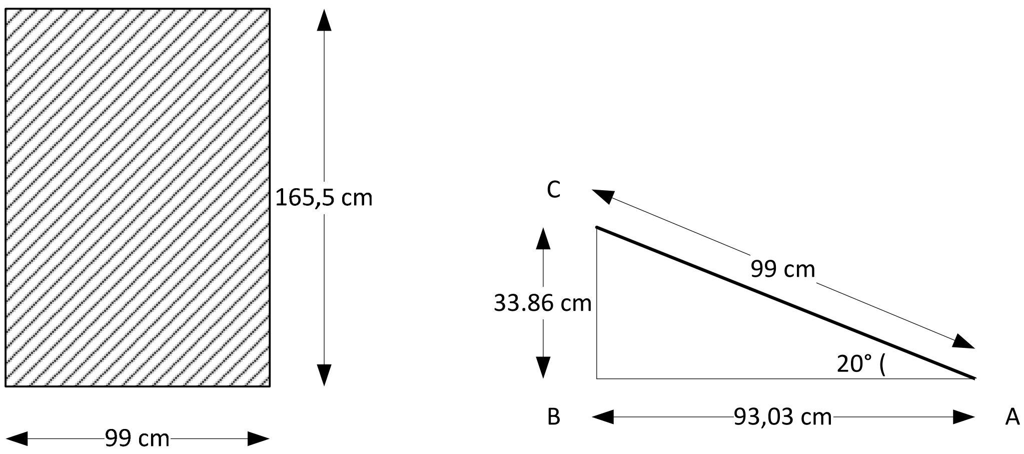

Figure 14: A); measures module B); measures module with angel of 20 degree

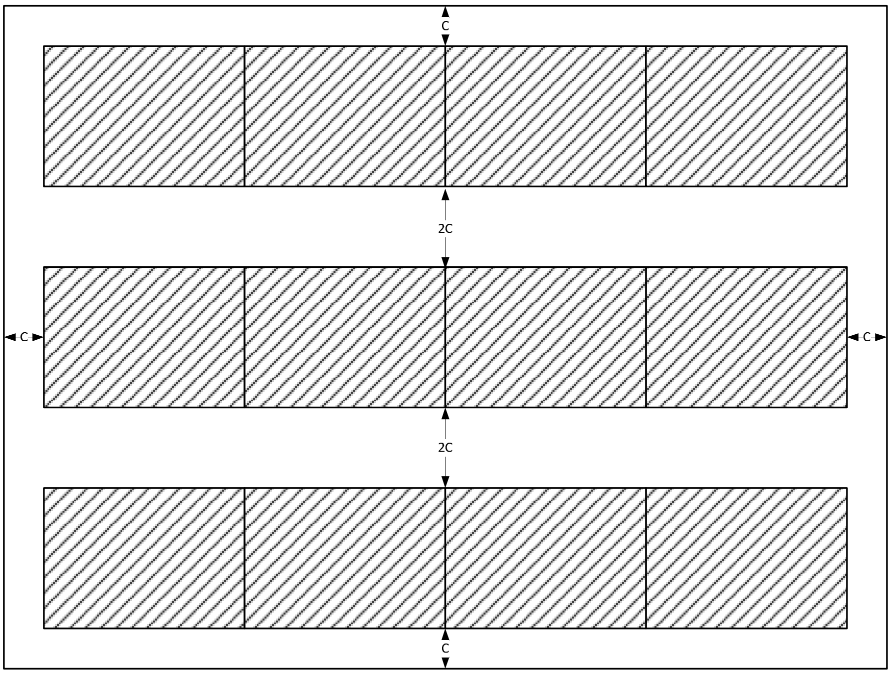

Figure 15: Installation of the modules on a flat roof

The positions of the modules (Figure 15) can be translated to the necessary extra space required per module (Figure 16). The calculation is not completely correct since the calculations assume every module is, like the module in Figure 16, a corner module (meaning it is placed at the end of a row) and logically a center module (meaning it is placed in the centre of a row) need less space than a corner module. The extra required distance (to the right or left as a consequence of the corner) per module depends on the length of the row of modules. But since the length of the rows depend on the size and shape of the roof and every roof is unique it is hard to standardize this information. Therefore the necessary extra space per module is calculated according to the assumption that every module is a corner module (Figure 15), in practice however probably a little bit less additional space per module is required. On the other hand however, modules are relative large and non-flexible and as a result empty areas may appear (in case a piece of area is too small to cover a module it is for PV nonetheless useless). So probably those figures cancel each other out.

The portion of the roof that is suitable for PV can be calculated by dividing the module size by the module size added with the extra required size ((0,99*1,665)/((0,99+0,3386+0,3386)*(1,665+0,3386))) = 0,4934. This means that only 49,34% of a flat roof is suitable for PV modules.

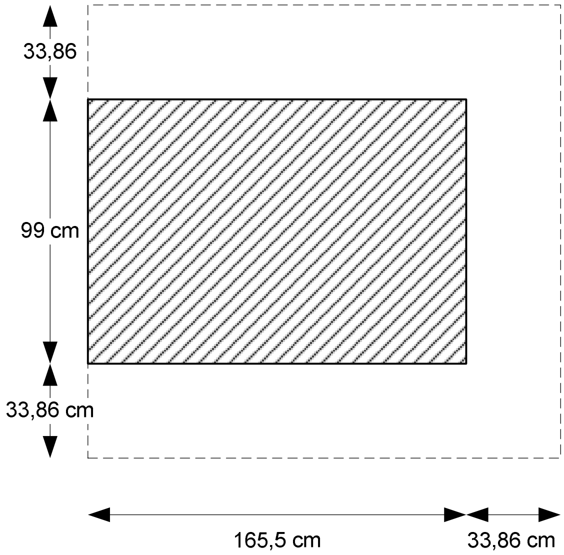

Figure 16: Addition required space of a module on a flat roof

4.6.1.3 Dwelling and roof sample Eindhoven

In order to calculate the total amount of flat and sloping roof areas of all the dwellings in Eindhoven the study used a calculation tool of AgentschapNL (voorbeeld woningen 2011, betaandebouw). The tool investigated the total amount of different types of dwellings of the Netherlands and categorized the total amount of dwellings in example dwellings. The example dwellings are dwellings with similar physical characteristics and therefore similar energetic consumption values. The categorization is based on the type of dwelling and the construction period of the dwelling. Combing the type of dwelling with the different construction periods leaves eventually 154 different example dwellings. Of each of the example dwellings, different statistics are calculated including the type of roof and the average size of the roof (Appendix C, Table 35 and Table 36).

In order to apply the categorization on the dwelling stock of Eindhoven, the total stock was translated to the different example dwellings, and therefore, two different datasets were used.

The first dataset was provided by the ENDINET, which is the network administrator of Eindhoven. The dataset consists of all kinds of information of 23.236 dwellings in Eindhoven (which is approximately ¼ of the total amount of dwellings in Eindhoven). The dataset represents actual data of 2008 and includes, among other things, information of the type of dwelling, the construction period and the total electricity and gas consumption.

Another dataset was acquired from the municipality of Eindhoven. This dataset consists of information of all the different types of dwellings in Eindhoven. The dataset was far more comprehensive according to the type of dwellings than the example dwellings of AgentschapNL. Nonetheless the categorization of AgentschapNL was used and applied on the comprehensive dataset (Appendix C, Table 32) and as a result the total amount of dwellings in Eindhoven in the 'type' categorization of AgentschapNL was known (Appendix C Table 32). Finally the dataset of ENDINET was used to complete the categorization of AgentschapNL by using the construction period of the different dwellings. As a result the total amount of dwellings in Eindhoven was fitted in the calculation tool of AgentschapNL.

It was unfortunately not possible to use all the different example dwellings of the tool, on the one hand because not all the information was available, and on the other hand because not all the example dwellings are present in dwelling stock of the city. Compared with the rest of the Netherlands, Eindhoven has a relative small amount of multi-family houses (e.g. flats or apartments), and because of this, comparatively little information about these type of dwellings is available. Of all the multi-family houses only the distinction between duplex dwellings, portico dwellings and other flat dwellings were known. The distinction of the gallery dwelling and all the subtypes of the multi-family dwellings were missing or not present in the city. Fortunately the calculation tool also provides average information on type level, on top of information on subtype level. This means that the tool also presents example dwellings of the multi-family dwellings on type level. The case-study applied these possibilities and eventually only the 31 most important example dwellings of the total 154 example dwellings were used for the calculation tool. Appendix C Table 32 presents the translation process of the total dwellings stock of Eindhoven to the example dwellings of the calculation tool (based on the dataset of the municipality). Appendix C Table 33 presents a summarization of this translation and finally Appendix C Table 29 presents the application of the dwelling stock of Eindhoven and the corresponding average gas and electricity consumption (based on the sample of ENDINET).

An application of the dwelling stock of Eindhoven in the categorization of AgentschapNL leads to a total available flat and sloping roof area. And this in turn could be combined with the previous chapters in order to calculate the theoretical total available roof area, suitable for PV (See Appendix C, Table 37). The summarization of this table is presented by Table 17 . This means that, in theory, 59,85% of the residential roof area of the target area is suitable for PV modules.

Table 17: Summarization of total, PV suitable, roof area of the dwelling stock of Eindhoven

Total dwelling roof area	Total dwelling roof area suitable for PV	Percentage of total
5.379.161 m^2	3.219.237 m^2	59,85%

4.6.2 Energetic variables

Besides the total roof area, the type of roof and the orientation of the roof of each dwelling, and a number of other variables are necessary to calculate the potential amount of energy that can be generated by PV systems. Most of the variables are already discussed other will be discussed during this section. As stated before the yield of a PV system (in kWh) can be calculated with the following formula:

Yield (kWh) = Radiation on the panels (kWh/m^2) x PV power (kWp) x Performance Ratio

The formula can partially be filled using the standard data of Eindhoven from the study of Siderea and from the market sample:

Yield (kWh/m^2) = 1039 x (orientation factor - obstruction loss) x roof area x PV power (kWp) x 0,83

The average horizontal radiation of Eindhoven, the average performance ration of PV systems in Eindhoven, and the different orientation factors are elaborated in the previous chapters and are therefore not elaborated again. The obstruction loss is an efficiency loss of the modules caused by obstacles that prevent direct radiation to reach the cell. Neighboring buildings, trees, chimneys, skylights, etc. are all examples of obstacles that provide a certain obstacle loss. Siderea assumes in her calculations an obstruction loss of several percent in case of little obstructions to 20% in case of much obstruction (Siderea 2011). This case study assumed in its calculation an average obstruction loss of 10%. Table 18 presents a short summarization of the most important variables and their corresponding references.

Table 18: Summarization of the most important variables and their corresponding references

Variable		Value	Reference
Horizontal Radiation Eindhoven(kWh/m2)		1039	Siderea, Appendix A, Table 25
Performance Ratio Eindhoven		0,83	Siderea, Appendix A, Table 25
Orientation factor Sloping Roof (40°)	*South*	1,08	Siderea, Table 14
	South-East & South-West	0,98	Siderea, Table 14
	West & East	0,87	Siderea, Table 14
Orientation factor Flat Roof (20°)	*South*	1,08	Siderea, Table 14
	South-East & South-West	1,01	Siderea, Table 14
	West & East	0,94	Siderea, Table 14
Obstruction Loss (average)		10,00%	Siderea, FAQ
Salderingsgrens (kWh)		5.000	Department of VROM

Finally the last necessary missing energetic variable is the system power per square meter. Earlier the current system power was determined by means of an executed market study (Table 26, Table 27, Table 28). This market study served as a starting point for this case-study. As it comes to the future development of the modules (more particular the development of the cell efficiency), the case study follows the objectives of EPIA for the upcoming years (EPIA 2011) (Table 16, Figure 12). Since the efficiency development is a very uncertain process the case-study used three different scenarios, namely: an expected scenario (using the average development of the EPIA study, starting from 140 Wp in 2011 to 250 Wp in 2040), a pessimistic development (using less than the average development of the EPIA study, starting from 140 Wp in 2011 to 200 Wp in 2040), and an optimistic development (using more than the average development of the EPIA study, starting from 140 Wp in 2011 to 400 Wp in 2040). Appendix C, Table 38,Table 39, and Table 40 present the precise details of the three development scenarios.

As a first step in the case study the three basic scenarios were applied on the available potential roofs of the example dwellings of AgentschapNL with the basic assumptions as discussed earlier. This results in a potential energy generation per year and per example dwelling for the upcoming thirty year. Per basic scenario, with a time interval of five years, the potential energy generation with the appliance of small roof mounted PV systems is calculated in case the total suitable and available roof area is used. The results are presented in Appendix C, from Table 41 to Table 61.

4.6.3 Financial variables

As it comes to financial variables the most important variable is the system costs development variable of a PV system and it components. The starting point for the case-study is again generated from the market-study. The future developments were as much as possible adopted from the EPIA study[1].

As it comes to the price development, EPIA has actual data on current and historical large mounted system prices and EPIA has future scenarios for large mounted system prices. Together with Greenpeace EPIA has developed two different future price development scenarios for large mounted systems, namely: The Paradigm Shift scenario and the Accelerated scenario (EPIA 2011). Both scenarios will be applied in the case study. The most important differences between the scenarios are the result of differences in political support. In the Accelerated scenario assumes a lower level of political commitment than the Paradigm Shift Scenario.

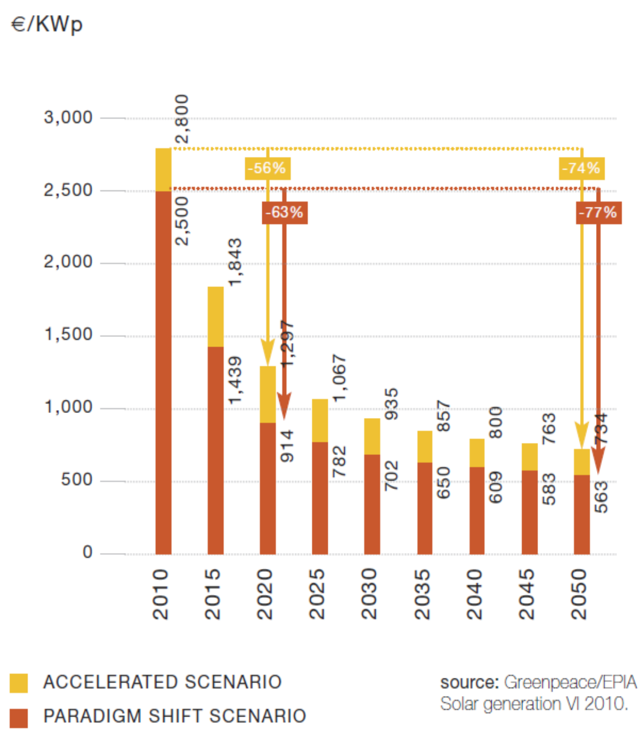

Figure 17: EPIA future system price development objectives

Political support is the key variable as it comes to the price development of PV systems. Fast market deployment is difficult with insufficient additional global political support. Without the potential for economies of scale, PV production costs and prices will fall at a slower rate than in the Paradigm Shift scenario. This will result in a lower level of PV deployment, which impacts the final target.

The market-study applied the actual system and component price data of EPIA (Figure 10) on current and historical small and roof mounted system prices of the different market studies. In order to make the information of EPIA useful, the large system future objectives (Figure 17) were transformed into small-roof mounted future objected using a correction factor. The difference of the current and historical system prices between the small and large systems were about 37% for the Paradigm Shift Scenario and 22% for the Accelerated Scenario. This number was also applied on the future scenarios. The module and inverter lifetime developments were also available by the EPIA study (unfortunately only until the year 2020) (EPIA 2011). Appendix C, Table 62 and Table 63 present the two different scenarios and their corresponding module and inverter lifetime and their corresponding system price per Wp.

Since the different parts of a PV system have different lifetimes, it is also necessary to make a distinction between the costs of the different parts of a PV system (EPIA 2011). The distinction was made using a study of EPIA, EuPD, Navigant Consulting and SolarBuzz. These parties together investigated the prices of the different parts in terms of percentage of the total. The studied systems were small (3kWp) rooftop mounted installations in mature markets. For the case-study these values were adopted and furthermore is assumed that the mutually relation of the different parts does not change over time.

4.6.4 Photovoltaic system scenarios

In total eight different scenarios will be elaborated and simulated. Each scenario will be assessed on financial and energetic results and will be compared with a benchmark. The benchmark is a situation in which no PV system would be installed (in other words with a continuing of the current situation). The scenarios are chosen by the manipulation of three variables, namely time of installation, PV system cost development and the efficiency development. In other words the basic scenarios as were presented earlier are combined with different market penetration of the PV system:

- *Time of installation*; the ultimate goal is a 100% market penetration of small roof-mounted PV systems in the dwelling market in the year 2040. This means that by 2040 all the available and suitable roof area will be used to generate electricity. There are, however, two different scenarios to pull this off. The first scenario simulates a 100% PV system installation in 2011 and the second scenario has a wider spread and simulates an equal distribution of the PV system installation, with an installation of 14.29% every five years. Although the first scenario might not seem achievable it is very interesting to compare it with the second scenario. The two different scenarios are selected in order to investigate the financial and energetic effects of a situation in which the market is penetrated in an early stadium versus a situation in which the total market it penetrated in a later stadium.

- *PV system cost development*; there are two different basic scenarios that will be simulated as it comes to the development of the PV system costs, namely: The Paradigm Shift Scenario and the Accelerated Scenario (Appendix C, Table 62 and Table 63).
- *PV system efficiency development*; three different scenarios will be presented as it comes to the future development of the efficiency of the PV systems, namely: The pessimistic scenario with a current efficiency of 140 Wp/m^2 and a future efficiency of 200 Wp/m^2 in 2040, an expected scenario with a current efficiency of 140 Wp/m^2 and a future efficiency of 250 Wp/m^2, and finally an optimistic Scenario with a current efficiency of 140 Wp/m^2 and a future efficiency of 400 Wp/m^2.

Table 19: The variables of the different PV scenarios

Time of Installation	PV system cost development	PV system efficiency development
❖ S1: 100% install. 2011 ❖ S2: 14,29% install. Every 5 year	❖ S1: Accelatered Scenerio ❖ S2: Paradigm Scenario	❖ S1: Pessimistic Scenario ❖ S2: Expected Scenario ❖ S3: Optimistic Scenario

Table 19 presents a shot summarization of the possible values of the variables of the different scenarios. In case the three basic variables are combined in a number of possible ways, eight most interesting scenarios occur. These scenarios are selected for the simulation of the case-study (Table 20). The '100% installation in 2011 variable' is only simulated with the expected scenario to reduce the total amount of different scenarios. The '14,29% installation every 5 year' is simulated with a combination of all the other variables, and as a result 6 scenarios can be selected.

Table 20: Scenarios for the case-study on PV systems

Case-study Scenario	Time of Installation	PV system cost development	PV system efficiency development
Scenario 1	100% install. 2011	Accelatered Scenerio	Expected Scenario
Scenario 2	14,29% install. Every 5 year	Accelatered Scenerio	Expected Scenario
Scenario 3	14,29% install. Every 5 year	Accelatered Scenerio	Pessimistic Scenario
Scenario 4	14,29% install. Every 5 year	Accelatered Scenerio	Optimistic Scenario
Scenario 5	100% install. 2011	Paradigm Scenario	Expected Scenario
Scenario 6	14,29% install. Every 5 year	Paradigm Scenario	Expected Scenario
Scenario 7	14,29% install. Every 5 year	Paradigm Scenario	Pessimistic Scenario
Scenario 8	14,29% install. Every 5 year	Paradigm Scenario	Optimistic Scenario

4.6.5 Simulation Method

The case-study is performed with the simulation tool MS Excel. The simulation model simulates the financial and energetic results of each scenario (or intervention measure) during a timeline of 34 year. Basically the tool simulates, in time, the effects of two different situations. On the one hand it simulates the effects of an intervention measure, in this case, the implementation of improvement package 1 or improvement package 2, and on the other hand it compares the effects with a simulation of a benchmark. The benchmark represents a situation in which no intervention is implemented. In other words it represents a situation in which no improvement measure is implemented during the simulation period and therefore it simulates future effects of an unchanging current situation.

The case-study is performed with the simulation Tool MS Excel. Basically the method exists of three different parts:

- *General energy development part*: The first part simulates the future development of the total electricity demand of all the dwellings within the city of Eindhoven, starting from 2011 and ending by 2045, and it simulates the electricity price development of the same period.
- *Total electricity costs of the benchmark*: The second part simulates the total annual electricity costs of all the dwellings in case of the benchmark. The benchmark represents a scenario in which no PV systems or other energy savings or generation measures were installed during the period between 2011 and 2045. During the simulation period, it calculates the total annual electricity costs in case electricity demand and price develops as was calculated in the first step.
- *Total electricity costs of the intervention*; the last part simulates the total annual electricity costs in case PV systems were installed according to the concerning scenario and according to the electricity demand and price development as was calculated in the first step.

The total annual electricity demand is simulated during the period between 2011 and 2045. The annual demand is calculated with the help of historical (from 1995 to 2010) electricity demand (in PJ) of all the dwellings in the Netherlands. The historical data was obtained from the CBS (CBS, Den Haag / Heerlen, 2011) Database StatLine. The total demand during the starting point (2008) was determined using the ENDINET dataset of Eindhoven. The sample of almost ¼ of all the dwellings was extrapolated to the total amount of dwellings (using the actual amount of different dwellings) of the city (Appendix C Table 29). Subsequently the actual electricity demand of all the dwellings of Eindhoven of the year 2008 was used, together with the historical data of the CBS, to create the historical total demand of Eindhoven (by multiplying each year the deviation of the total demand of the Netherlands by the electricity demand of Eindhoven). This resulted in the historical electricity demand of Eindhoven and in turn this demand was used to create a linear function of the electricity demand development of Eindhoven (Appendix C

Table 66 and Figure 31). The linear function was used to simulate the future electricity demand of the target area. The case-study assumes that the future demand rate is linear and behaves as it did in the past. The applied linear function for the future electricity demand behaves like the following linear function: y= -8.373.598.393 + 4.323.226x.

The annual electricity price development is determined using the average deviation of the annual historical electricity costs of CBS (CBS, Den Haag / Heerlen, 2011) (Appendix C, Table 67 and Figure 32). Like the linear future electricity demand rate the study also assumes that the future electricity price develops linearly. In this case also the historical data of the CBS was used to create the linear function.

The data of the CBS makes a distinction between small users (users with a yearly demand smaller than 2500 kWh) and normal user (users with a yearly demand larger than 2500 kWh). The small users have a higher electricity tariff per kWh than the normal users. The electricity rates in the model consists of all the relevant costs aspects like network costs, supplier costs and logistics costs. Furthermore the rate is inclusive VAT and energy tax, but exclusive income energy tax refund. The electricity rates represent the average rates of the different energy companies for the dwelling market and the small business market. The applied linear function for the small tariff looks like this: -25,42 + 0,0128x. The applied linear function for the normal tariff looks like this: -21,72 + 0,0109x.

So in short, the study adapts a linear growth rate for both the electricity demand as the electricity price developments, because the historical development also behaved according to a linear growth pattern.

The second part simulates the total electricity costs of the benchmark. It simulates the electricity costs of the annual future electricity demand (as to step 1) starting in 2011 and ending by 2045. This means that during this period neither any electricity saving measure was implemented nor any other electricity-generating measures were implemented. The purpose is to measure a clear effect of a large scale implementation of PV and this can only be done if it is compared with an unchanging situation.

The total annual electricity costs are calculated by multiplying the total annual electricity demand by the corresponding tariffs. The corresponding tariffs are determined by counting the total amount of dwellings per tariff group, by checking the average energy demand per example dwelling. Appendix C, Table 30 shows that from all the 98.058 dwellings, approximately 32% are small users and 68% are normal users. The total costs of the benchmark are calculated per year and are calculated by a cumulative cash flow of the annual costs.

The last part simulates the effect of the installation of PV systems. It is in this part that the different scenarios become visible. The simulation exists of a couple of different calculations, including the energetic calculations, financial calculations and the calculations concerning the overall effects of the different scenarios. The effects are afterwards calculated using some KPI's (Key Performance Indicators).

The energetic calculations concern the total amount of installed PV systems and its corresponding electricity generation. One of the changing variables for the scenarios is the installation moment of the PV systems. Different installation times provide different electricity generation rates and different system costs. Since the system costs decreases in time and the electricity rates increases in time the chosen installation times largely affect the financial and energetic effects. The total amount of generated electricity is calculated by multiplying for each of the example dwellings, the total amount of energy that can be generated (from Table 41 to Table 61), which in turn depends on the chosen system efficiency scenario, by the total amount of example dwellings in Eindhoven, by the total percentage that needs to be installed during that period, which in turn depends on the chosen scenario.

For example case-study scenario 1 dictates a 100% PV system installation in 2011 of the expected scenario and the accelerated scenario. Table 41 presents the potential amount of energy that can be generated in the expected scenario in the year 2011 for each of the example dwellings in case the complete roof was used for PV systems. The total potential energy that can be generated with PV systems can easily be calculated by multiplying the total amount of dwellings per example dwelling by the total amount of energy that can be generated in case the complete roof of the dwelling was used for PV. This leads to a total amount of energy that can be generated in 2011 in case the expected scenario and the accelerated scenario would be applied. Finally this amount needs to be multiplied by the desired amount of installations, in this case by 100%.

The model also takes into account the wear-out of the modules which result in a decreasing efficiency in time. Most of the module producers guarantee 80% of the nominal power after 25 years. Despite the fact that probably the systems have less power loss than the expected 20% after 25 years, the study adopts the power loss nonetheless. This means an average loss of 0,80% percent per year. The study does not account an improvement meaning that the annual power loss of a system built in 2010 is the same as a system built in 2040.

Furthermore the system takes into account the lifetime of the different components of a PV system. This means that after the lifetime ends, a system or a part of the system is replaced for a new one. The study makes a distinction between the two most important and most expensive parts of a PV system, namely the inverter and the modules. Both parts can be replaced without replacing the whole system. The other parts beside the inverter are automatically replaced in case the modules are replaced.

The financial calculations calculate the investment costs of the system or the replacements of parts of the system, it calculates the electricity costs in case the PV systems cannot fully meet the annual electricity demand and it calculated the revenues in case an excess of electricity is fed back into the grid. The PV systems or parts are always installed at the end of a year, meaning that the costs are made in year the system was installed and the first electricity gaining are obtained at the beginning of the year after the installation. The total profit or loss is expressed in three different items, namely: a Long-term loan entry, an annual cost entry, and a cumulative costs entry.

The long-term loan represents the investment costs that were made for the installation an acquisition of the PV systems or/and system parts. The model does not allocate the system costs or system part costs over its lifetime years. Instead the costs are, like in practice, completely allocated to the year they were actually made. The model assumes that all money necessary to acquire and install PV systems or parts of it, is borrowed through a long-term loan instead of paid with own funds. The long-term loan exists of a couple of different items:

- *Electricity costs or/and revenues*; at the end of each year the model compares the total annual electricity demand of the year with the total amount of PV generated electricity. An excess is sold back to the grid, a deficiency is sold from conventional sources. In case an excess has to be sold back to the grid, a distinction is again made between the sources of the generated electricity. Small users get less funding per kWh than normal users. Since normal users usually have more roof area available and as a result are therefore able to feed more electricity back to the grid they get more funding. The distinction is 12% in case of the small users and 88% in case of normal users. Meaning that in case electricity is fed back to the grid, 88% of the electricity comes from normal users and 12% comes from small users.
- *Interest Rates;* In order to make the model somewhat more realistic, an interest rate was included. The interest rate calculates an extra debit item for the annual losses which in turn is expressed by the long-term loan. This means that at the end of the year, in case the year ends with a positive balance of the long-term loan, an interest rate has to be paid over the loan. The model employs an interest rate of 3,34%, which is the interest rate the government has to pay this year over its national debt (which more precisely is the interest rate of government bonds). In case the organization, and with that, the total investment is executed centrally, for example by the national government, the total investment would be larger and as a result, the interest rate would be much lower, than in case the organization would be executed decentralized. It is also interesting to investigate the financial effect of a higher or lower interest rate on the total cash flow. Therefore for each scenario also the effects of a situation without an interest rate will be elaborated and a situation with a high interest rate of 8% will be elaborated. The situation without an interest rate could occur in case no debt needs to be made and equity is invested. This is not a realistic scenario since investing equity also costs money since future interest income of the equity is no longer possible. Nonetheless it is interesting to see the effects. The situation with a high interest rate of 8% could occur in case dwelling owners themselves are charged for their own PV systems. In case the large scale implementation is not centrally organized this could occur and it maximizes the interest costs. For this reason this is also not a desired scenario, but yet at the moment it seems to be the path we've chosen.
- *Repayment investment costs;* Since all investment costs are funded by a long-term loan, and this long-term loan only increase because of the interest costs, it is necessary to repay the investment costs. Otherwise the costs will only increase in time and with that another problem is created. The repayment of the long-term loan is done on an annual basis. Each year the total annual cost of the benchmark situation

is compared with the total annual cost of its corresponding year in case of an intervention. The difference between both costs is used as a repayment of the long-term loan. In case the difference between both costs is negative, meaning that the annual costs of the PV case-study scenario are higher than the costs in case of the benchmark, no repayment is paid. If this is the case it is better not to invest in PV since an intervention leads to annual higher costs than an unchanging situation. Besides the 'basic' repayment the model also supports an extra repayment per month and per dwelling. An extra payment can be used to reduce the costs even further. The sooner the long-term-loan is repaid, the lower the absolute interest costs will be (which is especially interesting in case of a high interest rate).

The financial and energetic results of the different case-study scenarios are presented in three different ways. The energetic results are presented in a plot. The plot shows the development of the electricity demand starting in 2011 and ending in 2045 and the plot shows the total amount of PV generated electricity. The purpose of the plot is to compare the supply and demand of electricity in the dwelling market. The financial results are also presented in a plot. The plot shows the cash flow statement of the benchmark, the plot shows the total cumulative profit or loss of the different intervention scenarios, and the plot shows the difference between both figures. All three financial graphs are plotted against the time starting in 2011 and ending in 2045. The purpose of the second plot is to compare the financial effects of the case-study. The results show if and when it is financial interesting to invest in PV technologies.

The final results are presented in KPI's. The model presents in total eight different KPI's (total electricity generated during simulation period (in kWh), total electricity demand during simulation period (in kWh), total electricity generated of demand during simulation period (in percentage), average electricity payment per month per dwelling (benchmark), average electricity payment per month per dwelling (PV scenario), total cumulative costs (benchmark), total cumulative costs (PV scenario) and the cumulative difference in 2040 (benchmark / PV scenario)). The KPI's are presented for three different periods (starting year (2011), ending year (2045), and overall (2011 – 2045)). The KPI's are not presented in the results section, but are discussed in the conclusion and discussion section.

4.6.6 Results

This section presents the results of the case-study on PV systems. In total eight different scenarios are simulated with the MS Excel simulation model and the results of the simulations will be presented in this chapter. The results of the different scenarios are elaborated in comparison with each other. The results of the first scenario are elaborated in combination with the results of the fifth scenario, because both scenarios simulate a situation of a 100% PV system installation in 2011. The Results of the second, third and fourth scenario are also elaborated in comparison with each other since these scenario simulate a gradually market penetration of PV systems with the accelerated costs development and finally the results of the sixth, seventh and eighth scenario are again elaborated in comparison with each other because they simulate a gradually market penetration of PV systems with the paradigm shift scenario. This section only presents the most important results. The next section discusses the results and tries to formulate the most important conclusions.

4.6.6.1 Case-study scenario 1 & 5

The first scenario assumes a situation in which the PV system costs develop according to the accelerated scenario, and the PV system efficiency develops according the expected scenario. Furthermore the scenario simulates an extreme situation in which 100% of all the suitable roof area (of all the dwellings in Eindhoven) is provided with PV systems at the end of 2010. As a consequence of this approach all the inverters of the systems are replaced in 2025 and the other components are replaced in 2040. Figure 18 and Figure 19 present the financial and energetic effects of the first scenario. Both graphs represent the situation in which an interest rate of 3,34% is applied and no additional repayments are included. Some interesting conclusions can be drawn.

Figure 18 presents the financial effects of scenario 1 during the period between 2011 and 2045. The red line describes the cumulative costs in case of the benchmark. It describes the current and future electricity demand. Future demand is based on historical data and follows a linear growth pattern which is based on the average growth of the last 15 years (Appendix C, Table 66). The purple line describes the cumulative total Profit or loss of the implementation of the PV systems according to scenario 1. The light blue line describes the differences between both lines. A positive value of the blue line represents the fact that the benchmark situation (the red line) has higher costs than the PV scenario situation (the purple line). In case of a negative value obviously the opposites is true. The dark blue line represents the long-term loan.

The red line starts in the year 2011 without any costs and finishes in 2045 with total electricity costs of € 6.546.320.980,-. The cost curve seems to develop exponential. This is correct since the distribution of the normal user electricity tariffs and small user electricity tariffs have more effect when electricity demand increases. The purple line starts in 2011 with a small total loss of € 85.242.500,-, which can be explained by the fact that from a users point of view the investment costs of the 100% implementation of PV systems during that year is not directly on their account. For a users view of point the investment costs are translated in repayment costs and in interest costs, all in order to make the investment costs manageable. This means that the total investment costs is slowly paid as the total long-term loan decreases. The dark blue line starts in 2010 with a total long-term loan of € 1.548.451.494, which can be explained by the 100% PV system implementation at the end of 2010. At the end of the year 2040 the total system is worn-out and replaced, this explains the twist in the dark blue line. As the figure show the second investment is much smaller than the first investment and the second investment is paid back much sooner than the first investment. This can be explained by the fact the due to the decrease of the PV system price and the increase of the PV system efficiency, more money is available to repay the long-term loan which is a lot smaller as a consequence of the decreased system price.

During the period the costs of the purple line and the red line increases with the same rate. This is logically since the red line represents the cumulative electricity costs of the benchmark and the purple line represents the cumulative electricity costs in case PV systems were installed according to the first scenario plus the repayment of the loan which is the difference between both lines. The dark blue line shows the loan is repaid in the year 2044. Since the annual repayment and interest costs represents quite a large part of the yearly costs, the annual costs decreases largely at the moment the loan is repaid and as a consequence after 2044 the scenario makes, in comparison with the benchmark, for the first time, a small profit. As a result of this profit the cumulative costs of the scenario (purple line) decreases and the light blue line crosses the zero cost line, meaning that from 2044 the cumulative costs of the benchmark are higher than the cumulative cost of the first scenario (including PV systems).

In total the situation in which PV is installed according the first scenario makes a small total profit during the simulation period of €387.044.126,-. This means that the scenario with PV (in case of implementation as to case-study scenario 1) is preferable over the scenario without PV (as it comes to the financial effects and in case a timeline is used of 35 years).

Figure 19 presents the annual energetic effects of scenario 1 during the simulation period. The blue line describes the annual, linear growing, electricity demand rate in time. The red line describes the total amount of electricity that is generated with the PV systems in case of implementation according to scenario 1.

Figure 19 shows that the first scenario generates, as a result of the 100% implementation of the PV systems, in 2011 more energy is than is requested. Due to the decrease of the system efficiency and the increase of the electricity demand in time, electricity demand exceeds the electricity generation (from 2014). In 2040 the system is replaced by a new one, and because of the increased efficiency of the new system the annual electricity generation largely covers the annual electricity demand.

The applicable interest rate has large effects on the total costs of the scenario. The massive impact of the interest costs on the total costs become clear when different interest rates are compared. Appendix D Figure 34 and Figure 35 shows the financial effects of the first scenario in case of an interest rate of respectively zero and eight percent. In case of zero percent interest the loan is repaid in 2023 and from that point on the light blue line crosses the zero cost line meaning that the situation with PV installed according to the first scenario is preferable over the benchmark situation. In case of eight percent interest the total annual costs of the benchmark are lower than the costs of the scenario with PV, even during the first three years, were more energy is generated than demanded. As a result it is in this situation not possible to repay the loan and as a consequence of the high interest rate of loan, and with that, the total annual costs grow exponential. This means that in case an interest rate of eight percent is applied on the first scenario, implementation it is not preferable.

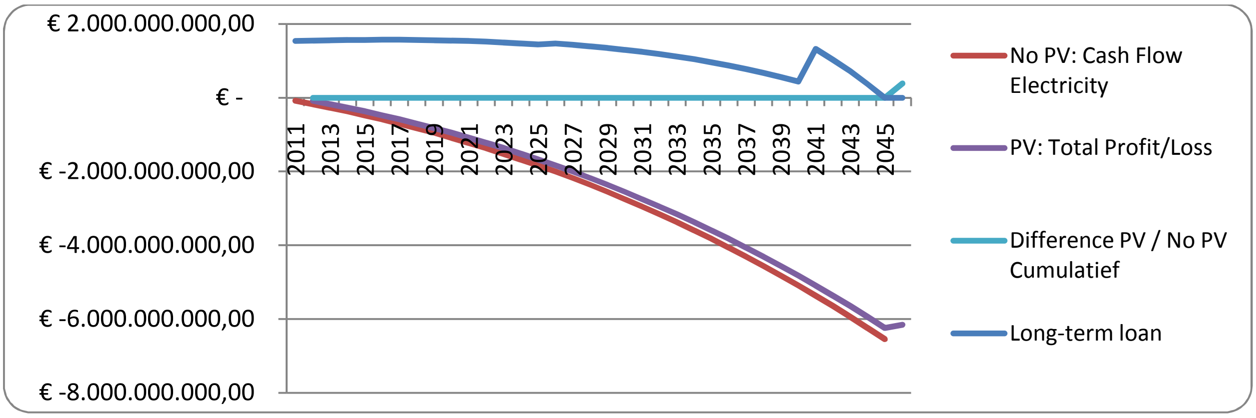

Figure 18: Financial Effects of case-study scenario 1

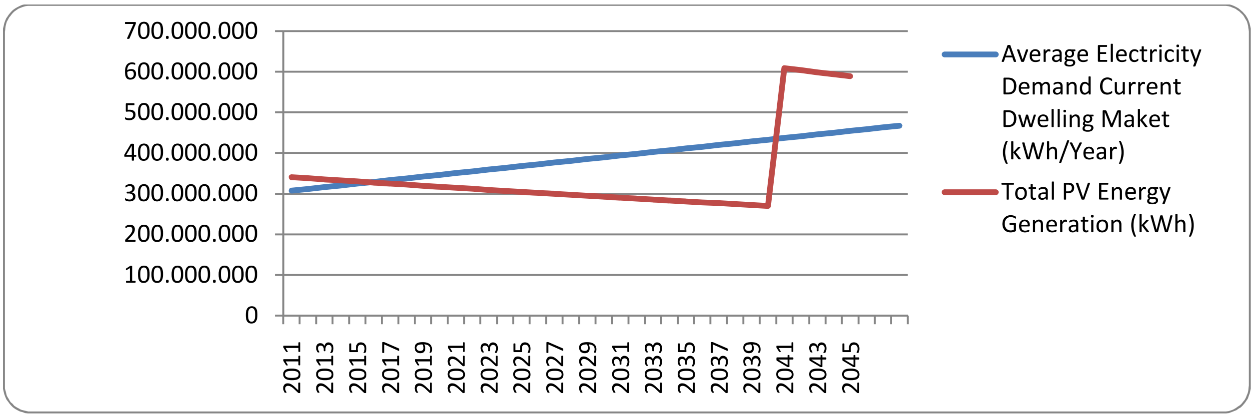

Figure 19: Average energy demand and generation of case-study scenario 1

Scenario 5 can easily be compared with scenario 1 since the only difference between both scenarios is the PV system cost development. All the remaining variables are the same as in scenario 1. The PV system cost development of scenario 5 applies the Paradigm Shift Scenarios. The difference between both cost development scenarios is that the accelerated scenario assumes the same political support as it was in recent years while the Paradigm shift scenario assumes an increasing political support than it was in recent years. The political support has an important influence on the installed capacity of PV systems. The more financial political support PV systems receive, the greater the installed capacity will be. Historical figures show that over that over the past 30 years the price of PV modules has reduced by 22% each time the cumulative installed capacity (in MW) had doubled (EPIA 2011) (Figure 20).

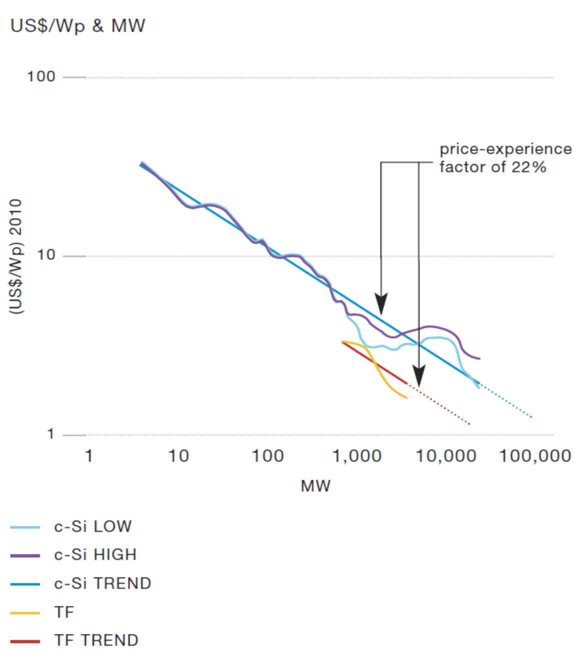

Figure 20: PV price experience curve

Therefore the more political financial support, the quicker system costs will decrease (Appendix C, Table 62 and Table 63).

The energetic effects of scenario 5 are the same as to scenario 1 and are therefore not elaborated once more. The financial effects however are different since scenario 5 assumes a greater and quicker decrease of the PV system costs in time as scenario 1 does. Figure 21 shows the financial effects of scenario 5. The financial statements behave quite the same as they do in case of scenario 1 with the only difference that the total costs of the replacement of the inverters in 2025 and the replacement of the total system in 2040 are a little bit smaller than the corresponding costs of scenario 1. As a result the light blue line reaches zero cost line also in the year 2044, but however at the end of the simulation period it ends with a larger profit of €576.084.711 meaning that the intervention (in case of implementing as to scenario 5) is also in this scenario preferable over the benchmark situation as it comes to the financial effects and in case a timeline is used of 35 years.

Like in the first case-study the interest cost has a huge influence on the total cash flow. Appendix D Figure 36 and Figure 37 show the financial effects in case of an interest cost of zero percent and the financial effects in case of an interest cost of eight percent.

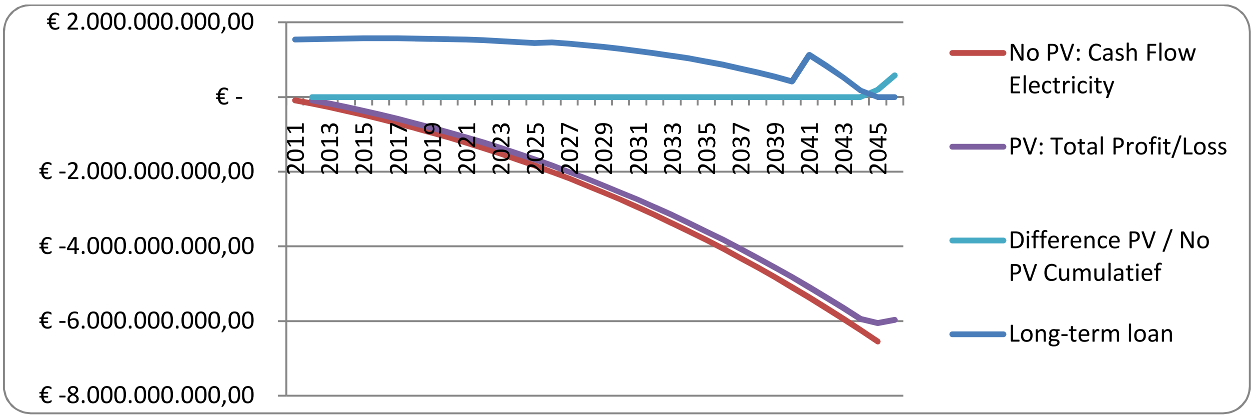

Figure 21: Financial effects case-study scenario 5

4.6.6.2. Case-study Scenario 2, 3 & 4

The second, third and fourth scenario all simulate a situation in which the PV system cost develops according to the accelerated scenario and the implementation of the PV systems takes place according to a gradually implementation of all the systems. The gradually implementation starts in 2011 and ends by 2040. Every five year 14,29% of the total suitable roof area is implemented with PV systems. The scenarios differ from each other in the PV system efficiency development. Scenario 2 adapts the expected efficiency development scenario, scenario 3 adapts the pessimistic scenario and Scenario 4 adapts the optimistic scenario.

As a consequence of the gradually implementation, every five year investment costs needs to be paid over new implemented systems. All the inverters of the systems which are installed in 2011 are replaced in 2025 and all the other components of the systems that are implemented in 2011 are replaced in 2040. Figure 22 and Figure 23 present the financial and energetic results of the second case-study scenario. Both graphs represent the situation in which an interest rate of 3,34% is applied over the long-term loan, and no additional repayments are done (except the normal repayments). Some interesting conclusions can be drawn.

Figure 22 presents the financial effects of the second scenario during the simulation period. The red line describes the cumulative costs of the benchmark. The purple line describes the total Profit or loss of the implementation of the PV systems according to scenario 2. The light blue line describes the differences between both lines and the dark blue line describes the long-term loan. A positive value of the light blue line represents the fact that the benchmark situation (the red line) has higher costs than the PV scenario situation (the purple line). In case of a negative value obviously the opposites is true. The dark blue line represents the long-term loan.

The red line starts in the year 2011 without any costs and finishes in 2045 with total cumulative electricity costs of €6.546.320.980,-. The development looks like it has an exponential cost curve. This is correct since the distribution of the normal user electricity tariffs and small user electricity tariffs have more effect when electricity demand increases. The purple line starts in 2011 with a minor total loss of €85.242.500,- which is a combination of electricity costs, interest costs over the loan and a repayment fee of the loan. The dark blue, which represents the long-term loan, starts in 2011 with a total amount of €219.551.954,-. This amount of money was borrowed to implement the first 14,29% of the PV systems during that year. Furthermore every 4 year another 14,29 % of all the suitable roof area is filled with PV systems. During the year 2040 the last 14,29% is implemented and the first 14,29% that is build (in 2011) is worn-out and replaced, this explains the twist in the purple line (electricity generation) and the twist in the dark blue line (long-term loan) every five year.

During the simulation period the costs of the purple line only increases with the same rate as the red line. This is logically since the savings as a result of the installed PV installations are used to repay the long-term loan. During the year 2030 the loan was repaid and the annual costs in the situation with PV installations (purple line) slowly decrease, as a consequence of the fact that repayment and interest fee from 2030 fall away. Despite the fall away of these fees, part of the electricity demand still needs to be paid, because electricity demand exceeds electricity generation of the PV systems. As a consequent of the decreased annual system costs and the increased electricity generation, the light blue line strongly increases after 2030.

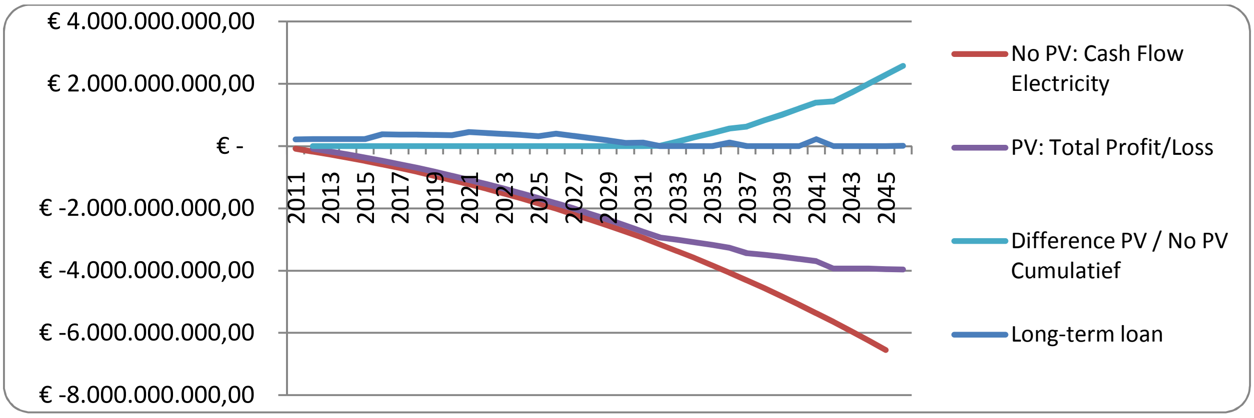

Figure 22: Financial effects of case-study scenario 2

Figure 23 presents the energetic effects of the second case-study scenario during the simulation period. The blue line describes the annual, linear growing, electricity demand rate in time. The red line describes the total amount of electricity that is generated with the PV systems in case of implementation according to case-study scenario 2.

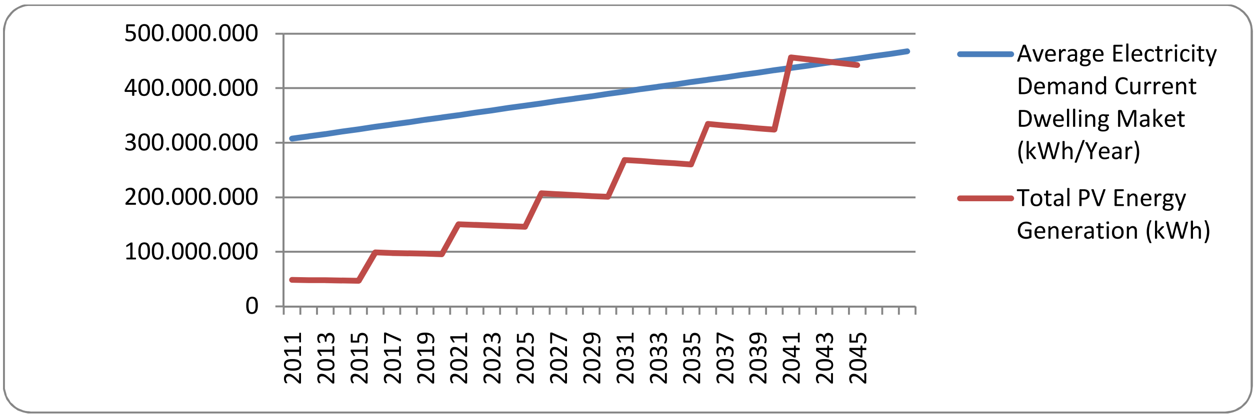

Figure 23: Average energy demand and generation case-study scenario 2

Like in the other scenarios, the interest cost has a huge impact on the total costs. Appendix D Figure 38 and Figure 39 show the financial effects in case of an application of an interest rate of respectively zero and eight percent of scenario 2. In case of zero percent interest the costs of the purple line still follows the red line, except in this situation the loan is repaid a little bit earlier (2027) and as a result the light blue line ends higher at the end of the simulation period (which means that more profit is made). In case of an interest rate of 8%, about the same results are obtained as in scenario 1 and 5; the initial annual costs of the intervention are higher than the initial annual costs of benchmark, as a result no repayment of the loan is possible and as a result of that the interest fee and the total loan increases exponentially.

In case of scenario 2, the total annual amount of electricity generated with PV systems is almost the whole simulation period smaller than the demanded total annual electricity. Not until the last PV systems are installed in the year 2040 electricity generation can meet demand, and this is only the case in the year 2040. During the years that follow, demand again outreaches electricity generation.

In case of an interest rate of 3.34% the annual interest costs have only small effects on the total costs of the intervention according to the second scenario, because of the gradually implementation of PV systems during the simulation period. As an effect the total costs of the scenario with PV systems follows the total costs of the benchmark until the loan is repaid in 2030. As a consequence, until 2030, the light blue line follows the zero cost line, meaning that the PV scenario has the same costs as the benchmark. After 2030 however the blue line crosses the zero cost line and increases, meaning that the scenario with a gradually implementation of the systems is preferable over the scenario without PV. In total the implementation of scenario 2 leads to a profit over the benchmark of €2.581.585.187,- during the simulation period.

Since the second, third and fourth scenario only differ in system efficiency development, it is obvious that the optimistic case-study scenario has a better financial and energetic performance, than the expected scenario and the expected scenario has in turn a better performance than the pessimistic scenario. For that reason it is not interesting to know which scenario has the best performance, but it is interesting to know what the effects are in case the efficiency development of PV systems develops in a different way than the expected way. From that point of view a range of financial and energetic effects is presented.

Figure 24 and Figure 25 present respectively the financial and energetic effects of case-study scenario three and Figure 26 Figure 27 present respectively the financial and energetic effects of case-study scenario four. The financial effects are calculated with an interest rate of 3,4%. Appendix D, Figure 40 to Figure 43 present the different scenarios with an interest rate of zero and eight percent.

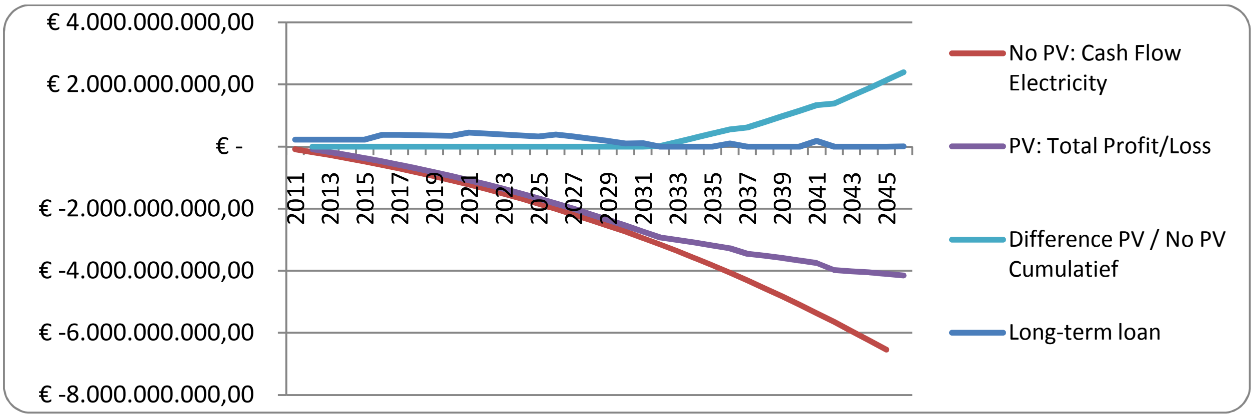

Figure 24: Financial effects case-study scenario 3

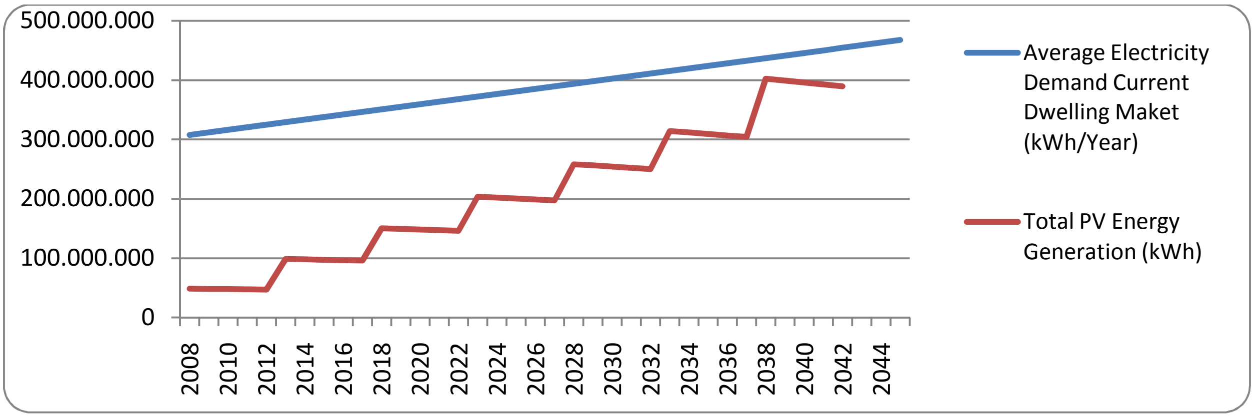

Figure 25: Average energy demand and generation case-study scenario 3

In case of the pessimistic scenario, the total electricity generation will never meet the electricity demand of the dwellings in Eindhoven. Despite this fact even the pessimistic scenario has a large profit (in comparison with the benchmark) at the end of the simulation period of €2.394.149.960,-. In the optimistic scenario the electricity generation will meet the electricity demand in the year 2036. The optimistic scenario has, as expected, the highest profit (in comparison with the benchmark) at the end of the simulation period. From 2030 the total cumulative costs of conventional electricity generation are more expensive than electricity generation with PV systems. Eventually the optimistic scenario ends with a total profit of €3.686.128.536,-.

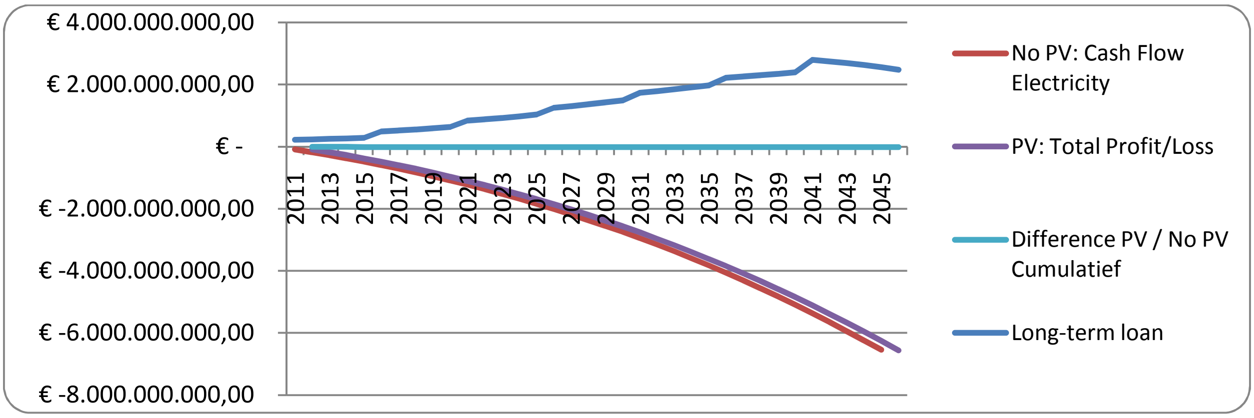

Figure 26: Financial effects case-study scenario 4

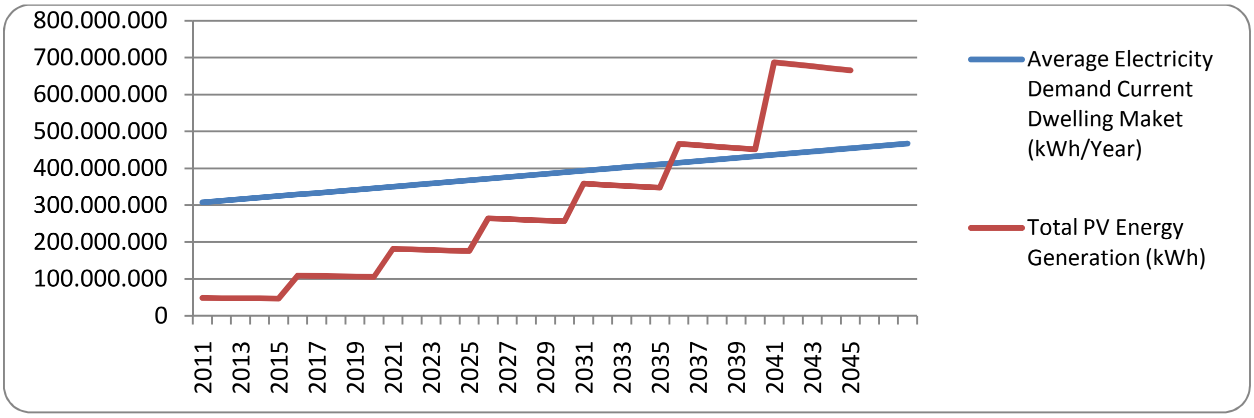

Figure 27: Average energy demand and generation case-study scenario 4

4.6.6.3. Case-study Scenario 6, 7 & 8

The way scenario 1 could easily be compared with 5, scenario 6 can be compared with scenario 2, scenario 7 can be compared with scenario 3 and scenario 4 can be compared with scenario 8. The only difference between the scenarios is the PV system cost development. All the remaining variables are the same as in the previous scenarios. The PV system cost development of scenario 6, 7 and 8 all applies the Paradigm Shift Scenarios. Like stated before the difference between both cost development scenarios is that the accelerated scenario assumes the same political support as it was in recent years while the Paradigm shift scenario assumes an increase of political support. The political support has is an important influence on the installed capacity of PV systems. The more financial political support PV systems receive, the greater the installed capacity will be, and the cheaper PV systems will be. The mathematical differences between both variables can be found in Appendix C, Table 62 and Table 63. Since the cost development has no influence on the total amount of electricity that is generated, only the financial effects of the scenarios will be elaborated in this part.

Figure 28, Figure 29 and Figure 30 present respectively the financial results of case-study scenario 6, 7 and 8. The three scenarios are all three simulated with an interest rate of 3,34%, and show similar financial results during the simulation period as is the case in scenario 2, 3 and 4. A tiny difference is caused by the Paradigm shift scenario, and has as result that the financial effects differ in a positive small way. The Paradigm shift scenario has as effect that the PV system costs decrease faster in time than it does in the accelerated scenario. As a consequence the investment costs are less high and therefore the long-term loan is also smaller which has a reduction of the interest costs as a result. The smaller costs lead to an increase of the total profit after the simulation period. Compared with the benchmark, scenario 6 leads to a profit of €2.776.06.561,-, scenario 7 leads to a profit of €2.577.645.331,-, and finally scenario 8 leads to a profit of €3.950.715.185,-.

Appendix D, Figure 44 to Figure 49, present for respectively scenarios 6, 7 and 8 the financial results in case an interest rate of respectively zero and eight percent would be applied. The results of these simulates confirm the earlier conclusions about the interest rate.

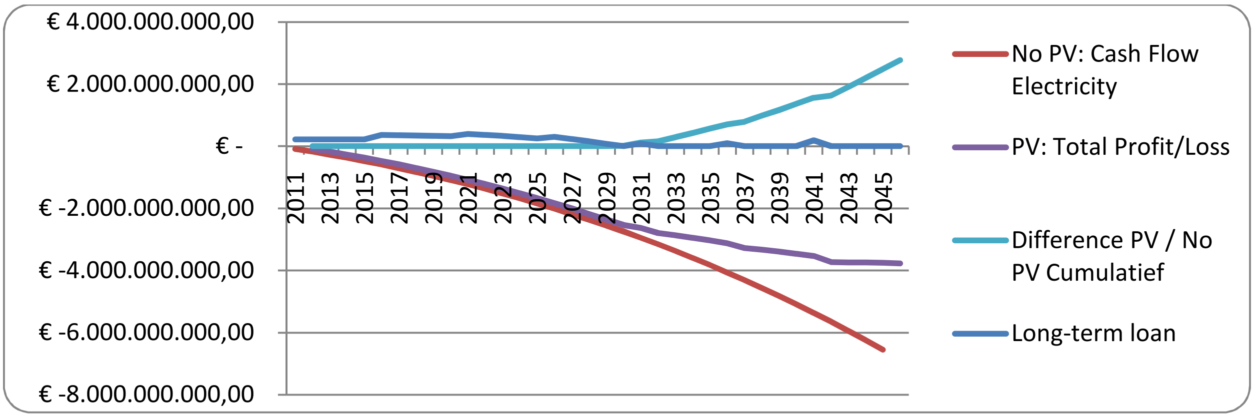

Figure 28: Financial effects case-study scenario 6

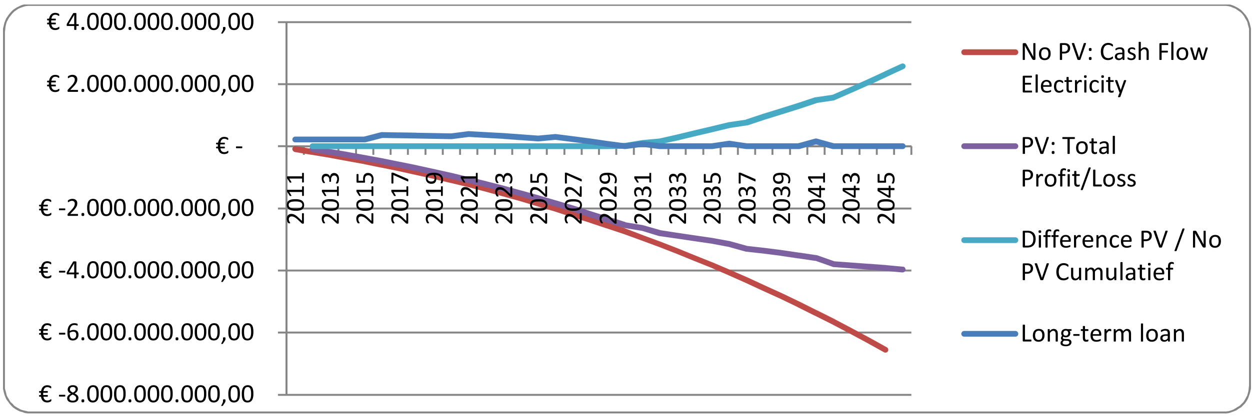

Figure 29: Financial effects case-study scenario 7

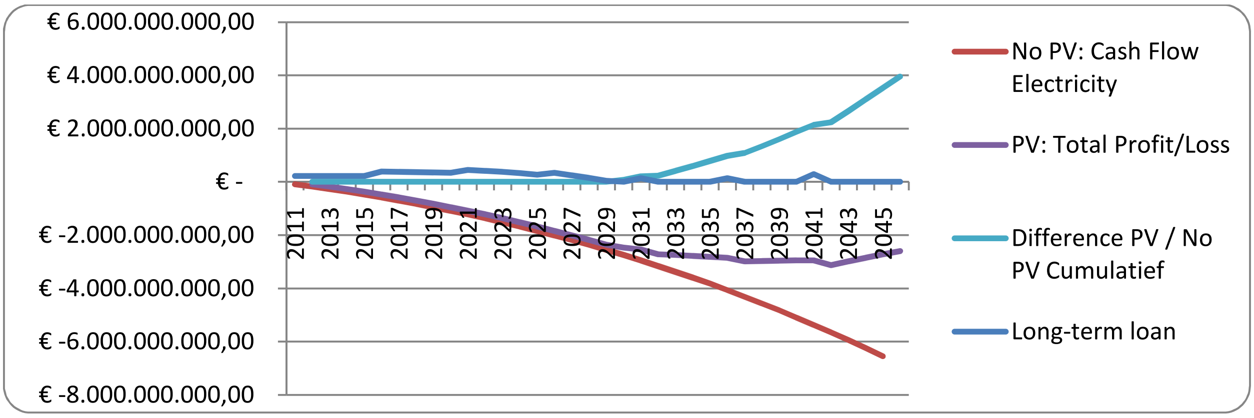

Figure 30: Financial effects case-study scenario 8

4.6.7 Conclusion & Discussion

This section discusses the results of the case-study on PV systems. The section interprets the different scenarios and tries to connect some logically conclusions on them. Furthermore the section tries to find answers on the research questions of the case-study.

Although the previous section dealt with eight different case-study scenarios, the existences of most of these scenarios depend on time rather than choice. Only time can tell how direct variables like module efficiency and PV system cost, and indirect variables like conventional electricity prices, the globally installed capacity of PV systems, and the interest costs of investments, will develop. The only variable one can manipulate as it comes to the city of Eindhoven is the decision and the moment to invest in PV systems. Therefore one can argue that the case-study only simulated two different scenarios, all the other scenarios are alternatives of these two basic variables and have as main purpose to develop a range of possible energetic and financial effects of these concerning 'basic' scenarios.

As stated before the case-study investigated the financial and energetic effects of two basic scenarios. Furthermore also the status of the long-term loan at the end of the simulation period is included. The first basic scenario simulates a direct 100% installed capacity of the complete suitable roof area of all dwellings in Eindhoven. This basic scenario is only simulated with the expected system efficiency development, it is simulated with two different system costs development scenarios (accelerated and Paradigm shift scenario) and it is simulated with three different interest scenario rates (0%, 3,34% and 8%). This leads to a financial performance, an energetic performance and a status of the long-term loan:

- ***Financial performance*** is the difference between the cumulative costs in case of the benchmark and the cumulative costs in case PV was installed according to the scenario and measured in the year 2045 (according to cumulative costs during the period between 2011 and 2045).
- ***Energetic performance*** is the difference between the total cumulative electricity demand of all dwellings and the total cumulative electricity generated by means of the installed PV systems according to the scenario (measured in the period between 2011 and 2045).
- ***Unpaid balance long-term loan*** is the status of the long-term loan at the end of the simulation period. A positive amount represents an unpaid amount meaning that the investment is not yet repaid. Table 21 shows financial and energetic performances of the first basic scenario.

Table 21: Total performance of basic scenario 1

System cost development	System efficiency development	Interest rates	Financial performance	Energetic performance	Unpaid balance long-term loan
Accelerated	Expected	0%	€3.213.172.922,-	-1.673.188.042 kWh	€0,-
Accelerated	Expected	3,34%	€387.044.126,-	-1.673.188.042 kWh	€0,-
Accelerated	Expected	8%	€-16.052.682.411 ,-	-1.673.188.042 kWh	€24.490.531.772,-
Paradigm Shift	Expected	0%	€3.339838.243 ,-	-1.673.188.042 kWh	€0,-
Paradigm Shift	Expected	3,34%	€576.084.711,-	-1.673.188.042 kWh	€0,-
Paradigm Shift	Expected	8%	€-15.988.320.139,-	-1.673.188.042 kWh	€24.193.121.683,-

As Table 21 shows the interest rate is, as it comes to the financial performances, the most important variable. The applied interest rate depends in most cases on the organization form of the implementation. In case the total implementation of PV takes place individually and all the different dwelling owners are themselves responsible for the investment of the PV systems, probably a high interest rate would be applied and the total financial performance would be enormous negative. The enormous negative result is a consequence of the fact that due to the high annual interest fee of the enormous investment the initial annual costs are higher, than the initial annual costs in case no PV systems were installed. Therefore in this situation no repayment of the investment costs is possible and as a result the long-term loan increases exponential as a result of the high interest rate. The total electricity costs in case of the benchmark during the period is about 6,5 billion euro. The total costs in case PV systems are installed according to the scenario and in case of an interest rate of 8% are about 22.6 billion euro. Almost 21.9 billion euro of the 22.6 billion euro exists of interest costs, and only about 0,7 billion euro exists of electricity costs in case not enough electricity could be generated by the PV modules. Furthermore at the end of the simulation period the long-term loan accounts for almost 24.5 billion euro. For this reason a decentralist organization form scenario with a corresponding interest rate of 8% is not viable.

A better scenario would be a central organized implementation plan of all PV systems. Not only does this implementation method ensure a lot of financial benefits as a result of economies of scale, it also ensures the total investment would probably have to deal with a much lower interest rate. As a comparison the government has to pay about 3,34 % interest over its public debt. In case this 3,34% would be applied on the total investment that has to be made to install all the PV systems according to the first scenario. The financial performance would be a lot better than the situation with an interest rate of 8%. Depending on the system cost development the financial performance would be in the range between 387 million euro and 576 million euro.

The financial performances of the first basic scenario (in case of an interest rate of 3,34 percent) can also be expressed in monthly costs per dwelling. In case of the benchmark, the average electricity costs per dwelling will be €72,- per month in 2011. Due to the increase electricity demand and the increase electricity price the average electricity costs per dwellings increases to €261,- per month in 2045. During the simulation period the average electricity costs per month and per dwelling will be €159,- In case PV systems were installed according to the first basic scenario the monthly average electricity costs during the simulation period will be €150,- in case of the accelerated scenario and €145,- in case of the paradigm shift scenario. This results in an average monthly electricity cost reduction of €9,- to €14,- euro per dwelling.

Since for the system efficiency only the expected scenario is simulated, the energetic effects are the same, irrespective of the different financial scenarios. So in case the complete suitable roof area was provided with PV systems in 2011, in total about 340 million kWh electricity is generated while only about 317 million kWh electricity is demanded. This means that in potential, roof and dwelling mounted PV systems, can provide enough energy to meet its own demand. However, because of the minor yearly power loss of the systems and next to that, a yearly increasing electricity demand, this is only a small period the case (only the first three years). After that demand exceeds production. In case, the total amount of generated electricity is compared with the cumulative electricity demand (during the simulation period), than in total there is deficit of almost 1.7 billion kWh electricity. That is about 12 percent of the total demand during the period, meaning that during the simulation period 88% of the total electricity demand was generated with PV systems.

All in all the first basic scenario is, in case of an interest rate of 3,34% and in case of the expected PV system efficiency development, feasible. During the simulation period of 34 years an average minor reduction of €9,- to €14,- per month per dwelling could be achieved and in total about 88% of the total electricity demand could be generated by dwelling and roof mounted PV systems. Furthermore it is at the moment theoretical possible to generate enough electricity to cover the complete demand of the housing market of Eindhoven. However due to the increase in demand and the decrease in electricity generation (due to the efficiency loss of the system), this is only in short term possible.

The second basic scenario simulates a gradually implementation over time. One can argue that a 100% implementation of PV system, even in the range of the upcoming couple of years, is simply not possible. Therefore an alternative, perhaps easier to achieve, scenario was simulated as well. This second basic scenario simulated a situation in which every five year another portion of the total available and suitable roof area is provided with PV systems. Meaning that every five year about 14,29% of these roofs will be implemented with PV systems. Like the first basic scenario, the most important variables were simulated with different values, leaving a range of possible financial and energetic effects. The second basic scenario is simulated with two different system cost development scenarios (the accelerated scenario and the paradigm scenario), with three system efficiency developments (the pessimistic scenario, the expected scenario and the optimistic scenario) and with three different interest rates (0%, 3,34% and 8%).

Table 22 presents the obtained financial and energetic performances of the second basic scenarios.

Table 22: Total performance of basic scenario 2

System cost development	System efficiency development	Interest rates	Financial performance	Energetic performance	Unpaid balance Long-term loan
Accelerated	Pessimistic	0%	€2.828.856.397,-	-6.518.586.411 kWh	€0,-
Accelerated	Pessimistic	3,34%	€2.394.149.960,-	-6.518.586.411 kWh	€0,-
Accelerated	Pessimistic	8%	€-2.116.548.783,-	-6.518.586.411 kWh	€6.914.116.866,-
Paradigm Shift	Pessimistic	0%	€2.948.279.709,-	-6.518.586.411 kWh	€0,-
Paradigm Shift	Pessimistic	3,34%	€2.577.645.331,-	-6.518.586.411 kWh	€0,-
Paradigm Shift	Pessimistic	8%	€-1.667.636.403,-	-6.518.586.411 kWh	€6.344.738.730,-
Accelerated	Expected	0%	€3.021.641.778,-	-6.083.737.646 kWh	€0,-
Accelerated	Expected	3,34%	€2.581.585.187,-	-6.083.737.646 kWh	€0,-
Accelerated	Expected	8%	€-1.931.387.744,-	-6.083.737.646 kWh	€7.059.358.599,-
Paradigm Shift	Expected	0%	€3.151.079.856,-	-6.083.737.646 kWh	€0,-
Paradigm Shift	Expected	3,34%	€2.776.060.561,-	-6.083.737.646 kWh	€0,-
Paradigm Shift	Expected	8%	€-1.470.710.358,-	-6.083.737.646 kWh	€6.467.570.391,-
Accelerated	Optimistic	0%	€4.175.148.204,-	-3.371.694.280 kWh	€0,-
Accelerated	Optimistic	3,34%	€3.686.128.536,-	-3.371.694.280 kWh	€0,-
Accelerated	Optimistic	8%	€-1.372.435.850,-	-3.371.694.280 kWh	€8.369.301.606,-
Paradigm Shift	Optimistic	0%	€4.360.650.685,-	-3.371.694.280 kWh	€0,-
Paradigm Shift	Optimistic	3,34%	€3.950.715.185,-	-3.371.694.280 kWh	€0,-
Paradigm Shift	Optimistic	8%	€-735.307.012,-	-3.371.694.280 kWh	€7.496.643.637,-

Again the interest rate is the most important variable as it comes to the total financial effects and as it comes to the status of the long-term loan. Although the financial implications are less than for the first basic scenario, a high interest rate still has an enormous negative financial effect and an exponential increase of the long-term loan. Depending on the system cost development and the system efficiency development, the financial performance in case an interest rate of eight percent is used will be between -0,7 billion euro and -2,1 billion euro and the unpaid balance of the long-term loan will be between 8.4 billion euro and the 6.3 billion euro. So also in this case, a high interest rate must be avoided as much as possible. Therefore this scenario only has a chance of success in case of a central organized implementation of the scenario or another organization form which guarantees a low interest rate.

In case of a gradually implementation of the PV systems and the application of a low interest rate, the financial performance looks promising. Still the financial effects depend for an important part on the system costs development and the system efficiency development. But independently of these developments, and in case an interest rate of 3,34% would be applied, the financial performance would be somewhere between the €2.4 billion euro and the 4.0 billion euro.

The financial performances of the second basic scenario (in case of an interest rate of 3,34%) can also be expressed in monthly costs per dwelling. In case of the benchmark, the average electricity costs per dwelling will be €72,- per month in 2011. Due to the increase electricity demand and the increase electricity price the average electricity costs per dwellings increases to €261,- per month in 2045. During the simulation period the average electricity costs per month and per dwelling will be €159,- In case PV systems were installed according to the first basic scenario the monthly average electricity costs during the simulation period will be, depending on the system cost and system efficiency development, somewhere between €63,- and €101,-. This results in an average monthly electricity cost reduction of €58,- to €96,- euro per dwelling, which is a monthly average reduction of 52% of the total electricity costs.

In case the changeable variables of the case-study develop according to the most expected scenario, meaning that the system cost develops according to the accelerated scenario, which implicates a continuation of the current globally political support, the system efficiency develops according to the expected scenario, which implicates systems efficiency from 140 Wp in 2011 to 250 Wp in 2040, and an interest rate of 3.34% would be applied, the model simulates a financial performance of about 2,581 billion euro. This means that in case PV systems were gradually installed (according to the second basic scenario) according to the most expected scenario, an average monthly reduction of 65,11% could be achieved (compared with a situation in which conventional energy demand continued and no PV systems were installed).

The energetic effects of the different scenarios only depend on the systems efficiency development. The differences are quite large. In case the efficiency develops according to the pessimistic scenario and all suitable dwelling roofs were gradually provided with PV systems, in total about 7.3 billion kWh electricity could be generated. In case of an expected efficiency development about 7.7 billion kWh electricity could be generated and in case of an optimistic efficiency development about 10.4 billion kWh could be generated. During the simulation period the total electricity demand (in case of a linear growth of the current and historical demand) will probably be about 13.8 billion kWh. This means that a gradually implementation strategy has as result that during the simulation period in case of a pessimistic efficiency development about 52,72% of the total electricity demand is generated with PV systems, in case of an expected efficiency development about 55,87% of the total electricity demand is generated with PV systems and in case of the optimistic efficiency development about 75,54% of the total electricity demand is generated with PV.

Gradually implementing PV systems also has as effect that during the simulation period at best at the end of the period electricity generation meets electricity demand. In case of the pessimistic efficiency development, this is not the case, and electricity generation will never meet electricity demand. In case of the expected scenario only during the year 2041 enough electricity is generated to meet demand. But due to decreasing system power and increasing electricity demand, this is only for one year the case. In case of the optimistic scenario electricity generation will largely meet energy demand from 2036 on.

All in all the second basic scenario is, in case of an interest rate of 3,34% and irrespective of the systems cost and efficiency development, like the first basic scenario, feasible. During the simulation period of 34 years a monthly average reduction of of €58,- to €96,- euro per dwelling could be achieved and in total, depending on the efficiency development 52,72% to 75,54% of the total demand could be generated by PV systems.

As already concluded the average interest rate is, as it comes to the financial performance and the status of the long-term loan, the key variable. Where, for both the basic scenarios, an interest rate of 3,34% leads to a positive financial performance, an interest rate of 8 % leads to an extreme negative financial performance. This means that a breakpoint exists between both scenarios. This breakpoint depends on the costs and efficiency development and is therefore unique for each scenario. It is interesting to determine the breakpoint, because it determines the border between a financial healthy investment and a financial unhealthy investment. Table 23 presents, for each scenario, the interest breakpoints.

- ***Interest breakpoint*** is the minimum interest rate in which it is possible to repay the long-term loan. In other words; it is the minimum interest rate in which it is possible to decreases the long-term loan in absolute way, during the simulation period.

Table 23: Interest breakpoints of the eight different PV scenarios

Cost developm.	Efficiency developm.	Basic Scenario	Breakpoint interest rate	Cost developm.	Efficiency developm.	Basic Scenario	Breakpoint interest rate
Accelatered	Expected	1	4,1%	Paradigm	Expected	1	4,1%
Accelatered	Expected	2	6,2%	Paradigm	Expected	2	6,6%
Accelatered	Pessimistic	2	6,1%	Paradigm	Pessimistic	2	6,5%
Accelatered	Optimistic	2	6,7%	Paradigm	Optimistic	2	7,1%

Now both basic scenarios are elaborated and discussed, it is interesting to know what the main differences are between both scenarios. Although the scenarios are, in a way, very explicit, the conclusions between the differences can be placed in a larger perspective. In this perspective the first scenario disputes a situation in which as soon as possible PV systems are at large scale implemented and the second scenario disputes a situation in which implementation is more spread over the simulation period. Both situations are only compared with a situation that simulates the most expected variable development. This means that the system cost development follows the accelerated scenario, the PV system efficiency development follows the expected scenario and all financial calculations are calculated with an interest rate of 3.34%. All calculations are collected in

Table 24.

Table 24: Differences between basic scenario 1 and basic scenario 2

Variable	Basic scenario 1	Basic scenario 2
General properties		
PV system implementation	Direct 100% implementation in 2011; system replacement in 2040	Gradually implementation of 14,29% in 2011, 2015, 2020, 2025, 2030, 2035, 2040; system replacement of 2011 in 2040
PV system cost development	Accelerated (3,41 €/Wp – 0,83 €/Wp)	Accelerated (3,41 €/Wp – 0,83 €/Wp)
PV system efficiency development	Expected (140 Wp/m^2 – 250 Wp/m^2)	Expected (140 Wp/m^2 – 250 Wp/m^2)
Interest rate over annual costs	3,34%	3,34%
Simulation Period (SP)	2011 – 2045	2011 – 2045
Energetic Results		
Cumulative electricity demand without PV systems	13.786.631.027 kWh	13.786.631.027 kWh
Total electricity generated during SP	12.113.442.985 kWh	7.702.893.381 kWh
Percentage electricity generated of total demand	87,86%	55,87%
Financial results		
Total investment and maintenance costs PV systems during SP	€2.612.338.220,-	€1.056.755.367,-
Total interest costs during SP	€1.413.064.398,-	€220.028.296,-
Total extra electricity costs during SP	€1.213.915.127,-	€2.479.469.940,-
Total electricity revenues during SP	€493.105.289,-	€4.364.448,-
Total repayments during SP with PV	€4.025.402.618,-	€1.269.602.005,-
Total costs during SP with PV	€6.159.276.854,-	€3.964.735.793,-
Total electricity costs during SP without PV	€6.546.574.151,-	€6.546.574.151,-
Financial performance during SP (total)	€387.044.126	€2.581.585.187,-
Financial performance during SP (per month / per dwelling)	€10,-	€64,50

Basically the table shows that is it is not possible to select the best scenario. Both scenarios have their own strengths and weaknesses. It really depends on what is thought to be important and what the goal is.

If the main goal is to optimize the total amount of generated electricity than the first basic scenario is better. Implementing this scenario leads to a situation in which about 88% of all future electricity demand, originating from the dwelling market, can be provided with PV electricity. In case an equal implementation spread is chosen only about 56% of all future electricity demand originating from the dwelling market can be provided with PV electricity. This is understandable since the first basic scenario uses all suitable and potential roof area from the beginning of the simulation period and the second scenario only uses half of the suitable and potential roof area, because it takes the whole simulation period to provide the complete suitable roof area. The difference in electricity generation is slightly reduced because of the fact that future systems have an increased efficiency.

If the goal is to optimize the financial results, then the second basic scenario is preferable over the first basic scenario, which in turn is preferable over the benchmark situation. But if one looks at the individual items one could notice the investment costs of the first basic scenario are more than twice as high as the investment costs of the second basic scenario. As a result the interest costs of the first scenario are higher (almost 7 times!!) than those of the second scenario and this in turn leads. In case of basic scenario 1 the repayment costs are almost four times as high as the repayment costs of the second basic scenario. Logically the possible extra electricity costs of the first basic scenario are lower than those of the second basic scenario (about twice as high) and the revenues of electricity that is sold back into the grid is higher in case of implementing the first scenario (almost exceed by a factor of 100). All the different items together causes the second basic scenario to have a financial performance which is about twice as high as the first one.

The results show, regardless of the first or second basic scenario, that it’s theoretical possible and financial feasible to invest in PV systems. The financial feasibility however strongly depends on the interest costs. The basic principle must be to reduce the interest costs as much as possible. If the rate exceeds the so-called interest breakpoint, it is financial better to stick with the current situation without PV. One of the ways to reduce the interest rate is to implement PV systems on a large-scale base. In case of individually implementation, the interest costs will probably exceeds the interest breakpoint and as a result the long-term loan will explode, because interest costs over minor investments are much higher than interest costs over major investments.

Furthermore one must accept the fact that the transition process from conventional energy production methods to more sustainable energy production methods takes time and money. In case the interest breakpoint is not a feasible case, the model shows that, despite the rising electricity demand and rising electricity prices it’s still cheaper to embrace conventional ways of electricity production. However in case of an interest rate of 3,34% it is, depending on the implementation strategy, theoretical possible to both generate between the 56% and the 88% of the total electricity demand of all dwellings in Eindhoven with PV systems and to make a profit between €10,- and €64,50 per month per dwelling.

Despite the positive outcome of practically all the different scenarios, at the moment, especially in the Netherlands, the implementation of PV systems is restricted to only little and small initiative. It seems that the market as well as the government has some dominating barriers that prevent large scale initiatives of implementation.

Although at the moment research on these barriers is missing, especially the determination of the most important barriers of public authorities is not really that hard. The most important barriers can be found in the type of organization and its possibilities. In case of the municipality currently manpower and knowledge is lacking to organize these kinds of large-scale projects.

The missing manpower and knowledge is mainly an effect of all kinds of cuts. The type of organization questions the necessity from a public agency point of view to implement PV systems. The Western capitalistic countries are characterized by their free markets. It fits the culture of those countries that most pioneering initiatives are market driven. The last couple of decades the influence of governments has only been reduced due to large scale privatization of all kind of organizations and therefore a public interference, does not fit the current Western philosophy anymore.

Furthermore a possible barrier could be the uncertainty of the development of key variables. The case study describes a development of the key variables according to the most expected scenario. For example the study assumes an increase in energy demand and a linear increase of energy prices and the study assumes an absence of any restricted production limits. Most important variables are simulated with different values; however the total future development of the energy market depends on a tremendous amount of variables and as a result it seems almost impossible to be certain about its development. Most of the scenarios that are simulated in this study have a payback period of about 20 years. But, given the uncertainty of the future development, this means that doing these investments leads, irrevocable, to risks. One can imagine that public agencies (or other big agencies) consider these risks as too high. Apparently, at the moment, the disadvantages of the consumption of fossil fuels, does not balance the risks of a large scale PV investment.

Another barrier could be the effect of other sustainable energy techniques in case of a large scale implementation. The case study only assumes the implementation of PV systems. Large scale implementation of other sustainable techniques could lead to a competition between these techniques. This is especially plausible in case the conventional energy prizes increase in an equal way as they did the last couple of decades and the total energy consumption decrease.

Finally an important barrier is the lack of knowledge. Despite the simplicity of calculating the results of the implementation of PV systems, up to now, this information was missing. At the moment most municipalities are searching for ways to get a more sustainable city. They are searching for reliable information in order to find out which technique or techniques to bet on. This study provides that information for PV systems, however there are more techniques which can, and have to, be examined in a similar way.

At the moment one must realize, that from this study's view of point, it seems like the European Union backs the wrong horse. Conventional electricity prices do not reflect actual production costs. The European Union invests more in nuclear energy research (€540 million yearly in average over five years through the EURATOM treaty) than in research for all renewable energy sources, smart grids and energy efficiency measures combined (€335 million yearly in average of seven years through the Seventh framework program). Actually today in Europe fossil fuels and nuclear power are still receiving four times the level of subsidies than all types of renewable energies do (IEA, World Energy Outlook, 2011). If governments reduce the financial aids on conventional methods and instead invest those aids in sustainable methods like for instance PV systems then perhaps the transition process could even be cheaper and be feasible with a reduction of the interest breakpoints. After the transition process energy prices will probably rise to current conventional energy prizes, since most of the current energy prices consist of all kinds of taxations.

4.6.8 Limitations

Although the case-study on PV systems is quite clear about the boundaries of its study. A few additional and basic limitations are worth mentioning.

To begin with the starting point of the study; the study uses average values of dwelling in the Netherlands. First the total amount of dwellings is categorized in example dwellings of AgentschapNL, and after that, calculations are performed with an average roof area of these example dwellings. The average roof area is determined by the total amount of example dwellings in the Netherlands. This means that the actual total available area could differ from the model. Also the model assumes a random distribution of the orientation of all dwellings and it assumes a standard roof angle of all sloping angle in the city.

The model neglects other renewable energy sources, which ensures the impossibility to compare the results with other sustainable energy generation techniques. The model assumes an average obstruction loss of all roof area of 10%. This is based on research, but not on actual values of the city. So in practice real numbers could differ from this assumption.

The model neglects the difference between summer and winter and instead executes it calculates with an average value. Possible inconveniencies that are caused by the difference between summer and winter electricity generation are beyond the scope of this study.

Finally the simulation model is designed in a way that possible investment costs are repaid with money received from electricity that is sold back to the grid and from a certain repayment fee which represents the gap between the electricity costs in a situation PV was installed and a benchmark situation. The model does not accept a repayment from any other source. The underlying principle is that no other cash flows can be involved otherwise it is not possible to make an honest comparison between the scenarios of PV installations and the scenarios with only conventional energy. The advantage of this system is that no additional yearly costs are possible, this ensures the fact that no turbity arises. The disadvantage of the current architecture of the model depends on this restriction. In case extra repayments were allowed the financial result would probably even be better since an extra repayment ensures a decrease of the interest rates. Also an extra repayment has an important influence on the interest breakpoints. In case extra repayments were allowed the interest breakpoints could be reduced.

Finally, the simulation model calculates all future calculations during the simulation period of 34 year with an unchanging dwelling stock of Eindhoven, and unchanging population of Eindhoven. In practice this is obviously not de case and one could wonder the effects theses variables have on the case-study.

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Appendix A

Table 25: Siderea Market study PV system yield

Year archive National income calculations consultancy firm Siderea									
Jaar	**Station**	**Optimal orientation**				**Average orientation**			
		Yield	Global	Inclined	PR	Yield	Global	Inclined	PR
		kWh/kWp	*kWh/m2*	*kWh/m2*		*kWh/kWp*	*kWh/m2*	*kWh/m2*	
2004	Eindhoven	901	1020	1082	0,83	836	1020	1000	0,84
2005	Eindhoven	950	1056	1145	0,83	877	1056	1054	0,83
2006	Eindhoven	909	1036	1100	0,83	843	1036	1019	0,83
2007	Eindhoven	904	1016	1094	0,83	836	1016	1008	0,83
2008	Eindhoven	914	1017	1097	0,83	843	1017	1009	0,84
2009	Eindhoven	958	1075	1157	0,83	888	1075	1068	0,83
2010	Eindhoven	921	1053	1113	0,83	858	1053	1033	0,83
Average		***922,43***	***1039,00***	***1112,57***	***0,83***	***854,43***	***1039,00***	***1027,29***	***0,83***

Siderea publiceert voor een vijfta locaties in Nederland de opbrengsten van twee pv ystemen. Het doel is u een idee te geven van de maand ijkse productie. U zult zien dat er landelijk product verschillen optreden omdat de zonnestraling per loka e zelden gelijk is.

PV-systeem met optimale orient tie ->Het 'optimale' systeem heeft een hellingshoe van 40 graden, staat precies op het zuiden gericht en eeft een beetje last van beschaduwing door omrin ende bebouwing en bomen. Deze obstakels bedekke n totaal 2,5% van de hemelkoepel. Beschouw dit a s een systeem onder redelijk ideale omstandigheden.

PV-systeem met 'gemiddeldeH' ientatie ->Het 'gemiddelde' pv-systeem is gelijk aa het 'optimale' pv-systeem behalve dat de orientati minder gunstig is, namelijk op het zuidwesten. Dit ysteem heeft bovendien iets meer last van bes haduwing door omringende bebouwing en bomen De obstakels bedekken 5% van de hemelkoepel. Beschou v dit als een systeem met een gemiddelde opbreng t.

Alle gebruikte pv-systemen hebb n gelijke specificaties:
Vermogen (STC) - 1000 Wp.
Paneelrendement - 13%.
Temperatuurcoefficient - 0,47%/
Max. rendement inverter - 95%.

Appendix B

Table 26: PV system sample 'Brabant Bespaart'

Date	Supplier	Type	Module	Inverter	Bevest. + bekap.	Instal.	VAT	Tot. Wp	Cost/Wp	Cost/Wp	Costs/Wp	Wp/m^2
			price	*Price*	*price*	*Cost.*			*System*	*Installation*	*Total*	
18-01-11	Eco-dome	Onb.	€ 2.611,41			€ 212,21	Incl.					
13-01-11	Solar NRG	Mono	€ 7.238,-			€ 900,-	incl.	2.350	€ 3,08	€ 0,38	€ 3,46	
27-02-11	Eco-dome	Onb.	€ 7.917,51			€ 508,80	incl.	2.880	€ 2,75	€ 0,18	€ 2,93	
02-02-10	Yingli	Mono	€ 2.048,44				Incl.	690	€ 2,97		€ 2,97	138,-
03-03-11	Eco-dome	Onb.	€ 1.950,01			€ 181,53	Incl.	690	€ 2,83	€ 0,26	€ 3,09	
11-02-11	Intersolar	Poly	€ 3.754,80			€ 954,-	Incl.	1.230	€ 3,05	€ 0,78	€ 3,83	139,44
22-06-10	Freenergics	Onb.	€ 3.508,07				Incl.	1.110	€ 3,16		€ 3,16	
01-03-11	Jouw Energie	Onb.	€ 2.610,-				Incl.	800	€ 3,26	€ 0,33	€ 3,59	
27-12-10	Duurzaem	Poly	€ 2.779,84			€ 751,16	Incl.	1.120	€ 2,48	€ 0,67	€ 3,15	144,30
16-06-10	Coro	Poly	€ 6.000,-				Incl.	1.840	€ 3,26		€ 3,26	141,23
24-01-11	Kozion	Onb.	€ 6.000,-				Incl.	1.680	€ 3,57		€ 3,57	
01-09-10	Alius Energy	Poly	€ 8.042,-	€ 1.681,-	€ 1.575,-	€ 571,-	Incl.	2.800	€ 4,04	€ 0,20	€ 4,24	133,78
01-09-10	Alius Energy	Poly	€ 6.512,-	€ 1.681,-	€ 1.575,-	€ 571,-	Incl.	2.940	€ 3,32	€ 0,19	€ 3,52	142,84
14-12-09	MM Totaal	Poly	€ 9.108,74				Incl.	2.300	€ 3,96	€ 0,40	€ 4,36	137,97
23-07-10	DE Go tech	Poly	€ 13.095,-				Incl.	4.200	€ 3,12	€ 0,31	€ 3,43	140,-

Table 27: PV system sample (Icon Publishers 2008)

Date	Supplier	Type	Module	Inverter	Bevest. + bekap.	Instal.	VAT	Tot. Wp	Cost/Wp	Cost/Wp	Costs/Wp	Wp/m2
			price	*price*	*price*	*Cost.*			*System*	*Installation*	*Total*	
April 2008	Nuon	Onb.	€ 639				Incl.	119	€ 5,37	€ 0,54	€ 5,91	119
April 2008	Solar NRG	Onb.	€ 654				Incl.	131	€ 4,99	€ 0,50	€ 5,49	131
April 2008	Beldezon	Onb.	€ 900				Incl.	133	€ 6,77	€ 0,68	€ 7,45	133
April 2008	Beldezon	Onb.	€ 901				Incl.	137	€ 6,57	€ 0,66	€ 7,23	137
April 2008	Sunkit	Onb.	€ 693				Incl.	125	€ 5,54	€ 0,55	€ 6,10	125
April 2008	EasySolar	Onb.	€ 947				Incl.	129	€ 7,34	€ 0,73	€ 8,08	129
April 2008	Solarpan.	Onb.	€ 738				Incl.	138	€ 5,35	€ 0,54	€ 5,89	138
April 2008	Eneco	Onb.	€ 848				Incl.	141	€ 6,01	€ 0,60	€ 6,61	141

Table 28: PV system sample (Icon Publishers 2009)

Date	Supplier	Type	Module	Inverter	Bevest. + bekap	Instal.	VAT	Tot. Wp	Cost/Wp	Cost/Wp	Costs/Wp	Wp/m^2
			price	*Price*	*price*	*Cost.*			*System*	*Installation*	*Total*	
1-09-09	PFIXX	Onb.	€ 13.953				Incl.	3360	€ 4,15	€ 0,42	€ 4,57	
1-09-09	Solar NRG	Onb.	€ 19.890				Incl.	4680	€ 4,25	€ 0,43	€ 4,68	
1-09-09	Beldezon	Onb.	€ 4.753				Incl.	1050	€ 4,53	€ 0,45	€ 4,98	
1-09-09	Beldezon	Onb.	€ 8.840				Incl.	1850	€ 4,78	€ 0,58	€ 5,26	
1-09-09	Solarpanels.nl	Onb.	€ 3.490				Incl.	700	€ 4,99	€ 0,50	€ 5,48	
1-09-09	Wako (Suntech)	Onb.	€ 6.000				Incl.	1200	€ 5,00	€ 0,50	€ 5,50	
1-09-09	Miracle-moon.nl	Onb.	€ 2.153				Incl.	350	€ 6,15	€ 0,62	€ 6,77	
1-09-09	Easy Solar	Onb.	€ 16.101				Incl.	2200	€ 7,32	€ 0,73	€ 8,05	
1-09-09	Easy Solar	Onb.	€ 9.320				Incl.	1100	€ 8,47	€ 0,85	€ 9,32	
1-09-09	Energieker	Onb.	€ 18.900				Incl.	3500	€ 5,40		€ 5,40	
1-09-09	ENECO	Onb.	€ 12.995				Incl.	2280	€ 5,70		€ 5,70	
1-09-09	ENECO	Onb.	€ 3.995				Incl.	642	€ 6,22		€ 6,22	
1-09-09	Energieker	Onb.	€ 7.700				Incl.	1050	€ 7,33		€ 7,33	

Appendix C

Table 29: dwelling stock Eindhoven and corresponding average electricity consumption

Nr.	Example Dwellings		Total amount of Dwellings 2008			Average Electricity Consumption 2008	Average Gas Consumption 2008	Total Electricity Consumption
	Dwelling Type	*Construction Period*	*Accord. municipality*	*(kWh/Dwelling type) Sample*	*Extrapolation Sample*	*Accord. sample in (kWh/dwelling)*	*Accord. sample in (m^3/dwelling)*	(kWh/Dwelling type)
1	Detached	< 1965	4.123	186	806	7.034	3.859	5.666.128
2	Detached	1965 - 1974		86	372	6.686	3.594	2.490.207
3	Detached	1975 - 1991		317	1.373	7.097	3.172	9.742.890
4	Detached	1992 - 2005		363	1.572	6.644	2.652	10.445.304
5	Two-family	< 1965	5.840	438	1.631	4.198	2.528	6.847.813
6	Two-family	1965 - 1974		145	540	4.816	2.640	2.601.000
7	Two-family	1975 - 1991		479	1.784	4.675	2.120	8.340.245
8	Two-family	1992 - 2005		506	1.885	4.597	1.652	8.663.461
9	Terraced (corner)	< 1946	13.855	806	2.971	3.502	2.055	10.402.257
10	Terraced (corner)	1946 - 1964		1.151	4.242	3.207	1.845	13.604.026
11	Terraced (corner)	1965 - 1974		727	2.680	3.694	1.901	9.898.063
12	Terraced (corner)	1975 - 1991		806	2.971	3.952	1.789	11.739.746
13	Terraced (corner)	1992 - 2005		269	991	3.883	1.382	3.849.854
14	Terraced (Middle)	< 1946	42.858	2.807	10.076	3.131	1.666	31.552.654
15	Terraced (Middle)	1946 - 1964		3.419	12.273	3.028	1.577	37.164.238
16	Terraced (Middle)	1965 - 1974		2.248	8.070	3.355	1.644	27.071.601
17	Terraced (Middle)	1975 - 1991		2.321	8.332	3.803	1.571	31.684.896
18	Terraced (Middle)	1992 - 2005		1.144	4.107	4.100	1.417	16.836.245
19	Duplex property	< 1965	5.179	38	170	1.900	790	322.698
20	Duplex property	1965 - 1974		762	3.405	2.250	894	7.662.145
21	Duplex property	1975 - 1991		206	921	2.112	788	1.944.381
22	Duplex property	1992 - 2005		93	416	2.148	707	892.647
23	Portico	< 1946	899	60	268	2.140	848	573.812
24	Portico	1946 - 1964		56	298	2.052	846	611.155
25	Portico	1965 - 1974		56	298	2.347	892	699.108
26	Portico	1975 - 1991		53	282	2.206	928	621.936
27	Portico	1992 - 2005		4	21	1.629	407	34.656

28	Other + Gallery	< 1965	25.304	864	5.928	2.408	951	14.274.483
29	Other + Gallery	1965 - 1974		696	4.775	2.055	755	9.813.291
30	Other + Gallery	1975 - 1991		1.264	8.673	2.011	732	17.441.436
31	Other + Gallery	1992 - 2005		864	5.928	2.359	926	13.982.141
	Total		***98.058***	**23.234**	***98.058***	***3.375***	**49.529**	**317.474.517**

Table 30: Total electricity demand per example dwelling per type of user

Nr.	Example Dwellings		Total amount of Dwellings 2008			Average Electricity Usage 2008
	Dwelling Type	*Construction Period*	*Extrapolation Sample*	*Users <2500 kWh/Dwelling*	*Users >2500 kWh/Dwelling*	*Of sample in (kWh/dwelling)*
1	Detached	< 1965	806		806	7.034
2	Detached	1965 - 1974	372		372	6.686
3	Detached	1975 - 1991	1.373		1.373	7.097
4	Detached	1992 - 2005	1.572		1.572	6.644
5	two-family	< 1965	1.631		1.631	4.198
6	two-family	1965 - 1974	540		540	4.816
7	two-family	1975 - 1991	1.784		1.784	4.675
8	two-family	1992 - 2005	1.885		1.885	4.597
9	Terraced (corner)	< 1946	2.971		2.971	3.502
10	Terraced (corner)	1946 - 1964	4.242		4.242	3.207
11	Terraced (corner)	1965 - 1974	2.680		2.680	3.694
12	Terraced (corner)	1975 - 1991	2.971		2.971	3.952
13	Terraced (corner)	1992 - 2005	991		991	3.883
14	Terraced (middle)	< 1946	10.076		10.076	3.131
15	Terraced (middle)	1946 - 1964	12.273		12.273	3.028
16	Terraced (middle)	1965 - 1974	8.070		8.070	3.355
17	Terraced (middle)	1975 - 1991	8.332		8.332	3.803
18	Terraced (middle)	1992 - 2005	4.107		4.107	4.100
19	Duplex property	< 1965	170	170		1.900
20	Duplex property	1965 - 1974	3.405	3.405		2.250
21	Duplex property	1975 - 1991	921	921		2.112
22	Duplex property	1992 - 2005	416	416		2.148
23	Portico	< 1946	268	268		2.140
24	Portico	1946 - 1964	298	298		2.052
25	Portico	1965 - 1974	298	298		2.347
26	Portico	1975 - 1991	282	282		2.206
27	Portico	1992 - 2005	21	21		1.629
28	Other + gallery	< 1965	5.928	5.928		2.408
29	Other + gallery	1965 - 1974	4.775	4.775		2.055
30	Other + gallery	1975 - 1991	8.673	8.673		2.011
31	Other + gallery	1992 - 2005	5.928	5.928		2.359
	Total		***98.058***	***66.676***	***31.382***	***3.375***
	Percentage		***100%***	***32%***	***68%***	

Table 31: Total Gas demand per example dwelling per type of user

Nr.	Example Dwellings		Total amount of Dwellings 2008			Average Gas Usage 2008
	Dwelling Type	*Construction Period*	*Extrapolation Sample*	*Users <1250 m^3/Dwelling*	*Users >1250 m^3/Dwelling*	*Of sample in (m^3/dwelling)*
1	Detached	< 1965	806		806	3.859
2	Detached	1965 - 1974	372		372	3.594
3	Detached	1975 - 1991	1.373		1.373	3.172
4	Detached	1992 - 2005	1.572		1.572	2.652
5	two-family	< 1965	1.631		1.631	2.528
6	two-family	1965 - 1974	540		540	2.640
7	two-family	1975 - 1991	1.784		1.784	2.120
8	two-family	1992 - 2005	1.885		1.885	1.652
9	Terraced (corner)	< 1946	2.971		2.971	2.055
10	Terraced (corner)	1946 - 1964	4.242		4.242	1.845
11	Terraced (corner)	1965 - 1974	2.680		2.680	1.901
12	Terraced (corner)	1975 - 1991	2.971		2.971	1.789
13	Terraced (corner)	1992 - 2005	991		991	1.382
14	Terraced (middle)	< 1946	10.076		10.076	1.666
15	Terraced (middle)	1946 - 1964	12.273		12.273	1.577
16	Terraced (middle)	1965 - 1974	8.070		8.070	1.644
17	Terraced (middle)	1975 - 1991	8.332		8.332	1.571
18	Terraced (middle)	1992 - 2005	4.107		4.107	1.417
19	Duplex property	< 1965	170	170		790
20	Duplex property	1965 - 1974	3.405	3.405		894
21	Duplex property	1975 - 1991	921	921		788
22	Duplex property	1992 - 2005	416	416		707
23	Portico	< 1946	268	268		848
24	Portico	1946 - 1964	298	298		846
25	Portico	1965 - 1974	298	298		892
26	Portico	1975 - 1991	282	282		928
27	Portico	1992 - 2005	21	21		407
28	Other + gallery	< 1965	5.928	5.928		951
29	Other + gallery	1965 - 1974	4.775	4.775		755
30	Other + gallery	1975 - 1991	8.673	8.673		732
31	Other + gallery	1992 - 2005	5.928	5.928		926
	Total		***98.058***	***66.676***	***31.382***	***1598***
	Percentage		***100%***	***32%***	***68%***	

Table 32: Translation of municipality database to example dwelling types

Dwelling type municipality database	Total amount Eindhoven	Percentage of total	Translation to dwelling type tool
Agrarisch met woongedeelte	2	0,00%	Vrijstaand
appartement met praktijkruimte	3	0,00%	Flat overage
bedrijfswoning bovenwoning	6	0,01%	Flat overage
bedrijfswoning geschakeld standaard/alg	7	0,01%	Rij Midden
bedrijfswoning vrijstaand	5	0,00%	Vrijstaand
bedrijfswoning vrijstaand standaard/alg	12	0,01%	Vrijstaand
bedrijfswoning, 2^1 kap, bungalow	2	0,00%	2/1 kap
bedrijfswoning, 2^1 kap, standaard/alg	7	0,01%	2/1 kap
bedrijfswoning, eind, bungalow	2	0,00%	2/1 kap
bedrijfswoning, eind, standaard/algemeen	3	0,00%	Rij Hoek
bedrijfswoning, geschakeld, bungalow	1	0,00%	2/1 kap
bedrijfswoning, hoek, standaard/algemeen	4	0,00%	Rij Hoek
bedrijfswoning, rij, standaard/algemeen	2	0,00%	Rij Hoek
bedrijfswoning, tussen, standaard/alg	2	0,00%	Rij Midden
bedrijfswoning, vrijstaand woonboerderij	1	0,00%	Vrijstaand
bedrijfswoning, vrijstaand, bungalow	1	0,00%	Vrijstaand
bejaarden/aanleun 2^1 kap standaard/alg	55	0,05%	2/1 kap
bejaarden/aanleun geschakeld semi-bung	78	0,07%	2/1 kap
bejaarden/aanleun vrijst semi-bungalow	37	0,03%	Vrijstaand
bejaarden/aanleun vrijstaand stand/alg	38	0,03%	Vrijstaand
bejaarden/aanleun, 2^1 kap semi-bungalow	27	0,02%	2/1 kap
bejaarden/aanleun, eind, standaard/alg	1	0,00%	Rij Hoek
bejaarden/aanleun, etage, appartement	732	0,64%	Flat overige
bejaarden/aanleun, etage, flat	2573	2,25%	Flat overige
bejaarden/aanleun, geschakeld, stand/alg	10	0,01%	Rij Midden
bejaarden/aanleun, hoek, bungalow	17	0,01%	Rij Hoek
bejaarden/aanleun, hoek, standaard/alg	166	0,15%	Rij Hoek
bejaarden/aanleun, rij, bungalow	28	0,02%	Rij Midden
bejaarden/aanleun, rij, standaard/alg	292	0,26%	Rij Midden
bejaarden/aanleun, tussen, standaard/alg	19	0,02%	Rij Midden
bejaarden/aanleun, vrijstaand, bungalow	2	0,00%	Vrijstaand
bejaarden/aanleunwoning benedenwoning	213	0,19%	Flat overige
bejaarden/aanleunwoning bovenwoning	166	0,15%	Flat overige
bejaarden/aanleunwoning duplexwoning	1	0,00%	Rij Midden

bejaarden/aanleunwoning maisonette	4	0,00%	Maisonnette
bejaarden/aanleunwoning penthouse	7	0,01%	Flat overige
bejaarden/aanleunwoning portiekwoning	56	0,05%	Portiek
benedenwoning met praktijkruimte	11	0,01%	Flat overige
bovenwoning met praktijkruimte	16	0,01%	Flat overige
eengezinswoning vrijstaand	291	0,25%	Vrijstaand
Hoek stud. patio-woning	4	0,00%	Rij Hoek
Molen met woonbestemming met praktijkruimte	1	0,00%	Vrijstaand
Moskee	5	0,00%	nvt / onbekend
Normaal hoek zonder grond met praktijkruimte	3	0,00%	Flat overige
Normaal rij zonder grond met praktijkruimte	7	0,01%	Flat overige
normaal, 2^1 kap, bungalow	56	0,05%	2/1 kap
normaal, 2^1 kap, herenhuis	26	0,02%	2/1 kap
normaal, 2^1 kap, patio	34	0,03%	2/1 kap
normaal, 2^1 kap, semi-bungalow	48	0,04%	2/1 kap
normaal, 2^1 kap, standaard/algemeen	5397	4,73%	2/1 kap
normaal, 2^1 kap, villa/landhuis	2	0,00%	2/1 kap
normaal, 2^1 kap, woonboerderij	14	0,01%	2/1 kap
normaal, eind, herenhuis	2	0,00%	Rij Hoek
normaal, eind, standaard/algemeen	238	0,21%	Rij Hoek
normaal, etage, appartement	8261	7,24%	Flat overige
normaal, etage, benedenwoning	1229	1,08%	Flat overige
normaal, etage, bovenwoning	2345	2,05%	Flat overige
normaal, etage, duplex	105	0,09%	Flat overige
normaal, etage, flat	8666	7,59%	Flat overige
normaal, etage, maisonnette	870	0,76%	Maisonnette
normaal, etage, penthouse	88	0,08%	Flat overige
normaal, etage, portiek	5051	4,42%	Portiek
normaal, geschakeld, bungalow	469	0,41%	Rij Midden
normaal, geschakeld, kwadrant	33	0,03%	Rij Midden
normaal, geschakeld, patio	222	0,19%	Rij Midden
normaal, geschakeld, semi-bungalow	67	0,06%	Rij Midden
normaal, geschakeld, standaard/algemeen	1840	1,61%	Rij Midden
normaal, hoek, bungalow	70	0,06%	Rij Hoek
normaal, hoek, drive-in	53	0,05%	Rij Hoek
normaal, hoek, geen grond	54	0,05%	Rij Hoek

normaal, hoek, herenhuis	6	0,01%	Rij Hoek
normaal, hoek, kwadrant	4	0,00%	Rij Hoek
normaal, hoek, patio	62	0,05%	Rij Hoek
normaal, hoek, semi-bungalow	34	0,03%	Rij Hoek
normaal, hoek, standaard/algemeen	12807	11,22%	Rij Hoek
normaal, rij, bungalow	104	0,09%	Rij Midden
normaal, rij, drive-in	184	0,16%	Rij Midden
normaal, rij, geen grond	214	0,19%	Rij Midden
normaal, rij, herenhuis	19	0,02%	Rij Midden
normaal, rij, patio	145	0,13%	Rij Midden
normaal, rij, semi-bungalow	43	0,04%	Rij Midden
normaal, rij, standaard/algemeen	37920	33,22%	Rij Midden
normaal, tussen, herenhuis	1	0,00%	Rij Midden
normaal, tussen, standaard/algemeen	554	0,49%	Rij Midden
normaal, vrijstaand, bungalow	391	0,34%	Vrijstaand
normaal, vrijstaand, herenhuis	27	0,02%	Vrijstaand
normaal, vrijstaand, patio	4	0,00%	Vrijstaand
normaal, vrijstaand, semi-bungalow	316	0,28%	Vrijstaand
normaal, vrijstaand, standaard/algemeen	2213	1,94%	Vrijstaand
normaal, vrijstaand, villa/landhuis	560	0,49%	Vrijstaand
normaal, vrijstaand, woonboerderij	75	0,07%	Vrijstaand
normaal, woonwagen/-boot, standaard/alg	173	0,15%	nvt / onbekend
Onbekend	15906	13,93%	nvt / onbekend
openbaar ongebouwd	2	0,00%	nvt / onbekend
Parkeerterrein/parkeerplaats	1	0,00%	nvt / onbekend
particulier ongebouwd	3	0,00%	nvt / onbekend
poort-bovenwoning alleen opgang op bg	4	0,00%	Flat overige
poort-tussenwoning doorgankelijk vr auto	5	0,00%	Flat overige
praktijkwoning vrijstaand villa/landhuis	20	0,02%	Vrijstaand
praktijkwoning, 2^1 kap, herenhuis	2	0,00%	2/1 kap
praktijkwoning, 2^1 kap, standaard/alg	62	0,05%	2/1 kap
praktijkwoning, 2^1 kap, woonboerderij	3	0,00%	2/1 kap
praktijkwoning, eind, standaard/algemeen	8	0,01%	Rij Hoek
praktijkwoning, etage, flat	2	0,00%	Flat overige
praktijkwoning, geschakeld standaard/alg	14	0,01%	Rij Midden
praktijkwoning, geschakeld, bungalow	6	0,01%	Rij Midden

praktijkwoning, hoek, drive-in	3	0,00%	Rij Hoek
praktijkwoning, hoek, standaard/algemeen	97	0,08%	Rij Hoek
praktijkwoning, rij, standaard/algemeen	44	0,04%	Rij Midden
praktijkwoning, tussen, standaard/alg	20	0,02%	Rij Midden
praktijkwoning, vrijstaand semi-bungalow	2	0,00%	Vrijstaand
praktijkwoning, vrijstaand standaard/alg	68	0,06%	Vrijstaand
praktijkwoning, vrijstaand woonboerderij	1	0,00%	Vrijstaand
praktijkwoning, vrijstaand, bungalow	7	0,01%	Vrijstaand
praktijkwoning, vrijstaand, herenhuis	5	0,00%	Vrijstaand
specifieke woning duplex	61	0,05%	Flat overige
Speeltuin	1	0,00%	nvt / onbekend
studenten/kamerverh etage benedenwoning	68	0,06%	Flat overige
studenten/kamerverh geschakeld stand/alg	1	0,00%	Rij Midden
studenten/kamerverh geschakeld villa/lan	1	0,00%	Rij Midden
studenten/kamerverh vrijst villa/landh	1	0,00%	Vrijstaand
studenten/kamerverhuur 2^1 kap stand/alg	24	0,02%	2/1 kap
studenten/kamerverhuur duplexwoning	16	0,01%	Flat overige
studenten/kamerverhuur etage appartement	115	0,10%	Flat overige
studenten/kamerverhuur etage bovenwoning	445	0,39%	Flat overige
studenten/kamerverhuur hoek villa/landh	1	0,00%	Rij Hoek
studenten/kamerverhuur maisonette	25	0,02%	Maisonnette
studenten/kamerverhuur rij standaard/alg	488	0,43%	Rij Midden
studenten/kamerverhuur vrijst stand/alg	4	0,00%	Vrijstaand
studenten/kamerverhuur vrijstaand	22	0,02%	Vrijstaand
studenten/kamerverhuur, eind, stand/alg	44	0,04%	Rij Hoek
studenten/kamerverhuur, etage, flat	157	0,14%	Flat overige
studenten/kamerverhuur, etage, portiek	72	0,06%	Portiek
studenten/kamerverhuur, hoek, drive-in	5	0,00%	Rij Hoek
studenten/kamerverhuur, hoek, stand/alg	170	0,15%	Rij Hoek
studenten/kamerverhuur, tussen stand/alg	110	0,10%	Rij Midden
Tuinbouwbedrijf met woongedeelte	2	0,00%	nvt / onbekend
Volkstuin	3	0,00%	nvt / onbekend
Vrijst. stud. Herenhuis	1	0,00%	Vrijstaand
woning met praktijkruimte vrijstaand	16	0,01%	Vrijstaand
Total	***114.154***	***100,00%***	

Table 33: Summarization of translation example dwelling types

Dwelling type	Total amount of Eindhoven	Percentage of total
Total Portico	5.179	5,28%
Total two-family	5.840	5,96%
Total other + gallery	25.304	25,81%
Total Duplex property	899	0,92%
Total Terraced (corner)	13.855	14,13%
Total Detached	4.123	4,20%
Total Terraced (middle)	42.858	43,71%
Total dwelling	*98.058*	*100,00%*

Table 34: Ownership distribution of the example dwellings

Dwelling Type	Total amount of example dwellings target area	Ownership distribution example dwellings		
	(total = 98.058)	*Private ownership*	*Social renting*	*Private renting*
Detached	806	81,72%	7,53%	10,75%
Detached	372	93,02%	0,00%	6,98%
Detached	1.373	92,74%	1,26%	5,99%
Detached	1.572	93,66%	0,55%	5,79%
Two-family	1.631	75,34%	17,81%	6,85%
Two-family	540	93,79%	2,07%	4,14%
Two-family	1.784	88,94%	0,42%	6,47%
Two-family	1.885	79,64%	1,38%	18,97%
Terraced (Corner)	2.971	49,50%	44,04%	6,45%
Terraced (Corner)	4.242	39,44%	57,86%	2,69%
Terraced (Corner)	2.680	50,07%	46,77%	3,16%
Terraced (Corner)	2.971	68,24%	28,66%	3,10%
Terraced (Corner)	991	69,14%	23,05%	7,81%
Terraced (Middle)	10.076	48,52%	45,99%	5,49%
Terraced (Middle)	12.273	35,30%	62,77%	1,93%
Terraced (Middle)	8.070	49,15%	47,91%	2,94%
Terraced (Middle)	8.332	67,94%	29,64%	2,41%
Terraced (Middle)	4.107	77,45%	16,87%	5,68%
Duplex Property	170	42,11%	52,63%	5,26%
Duplex Property	3.405	30,84%	61,81%	7,35%
Duplex Property	921	25,73%	65,05%	9,22%
Duplex Property	416	27,96%	69,89%	2,15%
Portico	268	23,33%	75,00%	1,67%
Portico	298	10,71%	85,71%	3,57%
Portico	298	17,86%	71,43%	10,71%
Portico	282	7,55%	88,68%	5,66%
Portico	21	25,00%	75,00%	0,00%
Other + Gallery	5.928	25,58%	62,96%	11,46%
Other + Gallery	4.775	31,61%	59,77%	8,62%
Other + Gallery	8.673	30,93%	54,51%	14,56%
Other + Gallery	5.928	15,39%	63,77%	20,83%

Table 35: Total sloping roof area per dwelling type

Total Roof Area			Suitable PV Roof Area and Orientation		
Dwelling Type	*Total (m^2)*	*Total per dwelling*	*South*	*South-East & South-West*	*West & East*
Detached	128	128	16,00	32,00	32,00
Detached	121	121	15,13	30,25	30,25
Detached	126	126	15,75	31,50	31,50
Detached	121	121	15,13	30,25	30,25
Two-family	64	64	8,00	16,00	16,00
Two-family	65	65	8,13	16,25	16,25
Two-family	73	73	9,13	18,25	18,25
Two-family	74	74	9,25	18,50	18,50
Terraced (Corner)	56	56	7,00	14,00	14,00
Terraced (Corner)	57	57	7,13	14,25	14,25
Terraced (Corner)	65	65	8,13	16,25	16,25
Terraced (Corner)	69	69	8,63	17,25	17,25
Terraced (Corner)					
Terraced (Middle)	56	56	7,00	14,00	14,00
Terraced (Middle)	57	57	7,13	14,25	14,25
Terraced (Middle)	65	65	8,13	16,25	16,25
Terraced (Middle)	69	69	8,63	17,25	17,25
Terraced (Middle)					
Duplex Property	75	52,7	6,59	13,18	13,18
Duplex Property	79	48,7	6,09	12,18	12,18
Duplex Property	72	52,2	6,53	13,05	13,05
Duplex Property	0	0	0	0	0
Portico	0	0	0	0	0
Portico	0	0	0	0	0
Portico	0	0	0	0	0
Portico	0	0	0	0	0
Portico	0	0	0	0	0
Other + Gallery	0	0	0	0	0
Other + Gallery	0	0	0	0	0
Other + Gallery	0	0	0	0	0
Other + Gallery	0	0	0	0	0

Table 36: Total Flat roof area per dwelling type

Dwelling Type	Area (absolute)		Area suitable for PV
	Total (m^2)	*Average per dwelling (m^2)*	*Average per dwelling (m^2)*
Detached	0	0	0
Detached	0	0	0
Detached	0	0	0
Detached	17	17	8,39
Two-family	15	15	7,40
Two-family	14	14	6,91
Two-family	17	17	8,39
Two-family	16	16	7,90
Terraced (Corner)	18	18	8,88
Terraced (Corner)	0	0	0
Terraced (Corner)	0	0	0
Terraced (Corner)	0	0	0
Terraced (Corner)	56	56	27,63
Terraced (Middle)	18	18	8,88
Terraced (Middle)	0	0	0
Terraced (Middle)	0	0	0
Terraced (Middle)	0	0	0
Terraced (Middle)	56	56	27,63
Duplex Property	0	0	0
Duplex Property	0	0	0
Duplex Property	0	0	0
Duplex Property	52	27,3	13,47
Portico	63	8,9	4,39
Portico	72	19,4	9,57
Portico	75	21,2	10,46
Portico	82	18,9	9,33
Portico	82	13,1	6,46
Other + Gallery	71	13,6	6,71
Other + Gallery	82	7,8	3,85
Other + Gallery	75	23,7	11,69
Other + Gallery	88	15,3	7,55

Table 37: Total Roof area and its suitable PV roof area

Dwelling Type	Total Roof Area (m^2)	Total Roof Area Suitable for PV (m^2)
Detached	103.110	64.444
Detached	45.067	28.167
Detached	172.984	108.115
Detached	216.951	132.079
Two-family	128.875	77.328
Two-family	42.664	25.670
Two-family	160.563	96.362
Two-family	169.613	102.042
Terraced (Corner)	219.837	130.364
Terraced (Corner)	241.816	151.135
Terraced (Corner)	174.173	108.858
Terraced (Corner)	204.983	128.115
Terraced (Corner)	55.523	27.398
Terraced (Middle)	745.655	442.176
Terraced (Middle)	699.581	437.238
Terraced (Middle)	524.534	327.834
Terraced (Middle)	574.895	359.309
Terraced (Middle)	229.974	113.482
Duplex Property	8.949	5.593
Duplex Property	165.824	103.640
Duplex Property	48.051	30.032
Duplex Property	11.345	5.598
Portico	2.386	1.177
Portico	5.779	2.852
Portico	6.315	3.116
Portico	5.329	2.629
Portico	279	138
Other + Gallery	80.622	39.783
Other + Gallery	37.248	18.380
Other + Gallery	205.539	101.425
Other + Gallery	90.699	44.756

Table 38: Technical Cell Characteristics (Expected Scenario)

Year	Efficiency (%)	Area (m^2)	Power (Wp)
2011	14%	1,00	140
2015	15%	1,00	150
2020	16%	1,00	160
2025	18%	1,00	180
2030	20%	1,00	200
2035	22%	1,00	220
2040	25%	1,00	250

Table 39: Technical Cell Characteristics (Pessimistic Scenario)

Year	Efficiency (%)	Area (m2)	Power (Wp)
2011	14%	1,00	140
2015	15%	1,00	150
2020	16%	1,00	160
2025	17%	1,00	170
2030	18%	1,00	180
2035	19%	1,00	190
2040	20%	1,00	200

Table 40: Technical Cell Characteristics (Optimistic Scenario)

Year	Efficiency (%)	Area (m2)	Power (Wp)
2011	14%	1,00	140
2015	18%	1,00	180
2020	22%	1,00	220
2025	26%	1,00	260
2030	30%	1,00	300
2035	35%	1,00	350
2040	40%	1,00	400

Table 41: Total Generation per household (Technology 2011 / Expected Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	8.268	0	8.268	3.910
Detached	7.816	0	7.816	4.007
Detached	8.139	0	8.139	4.103
Detached	7.816	993	8.808	2.972
Two-family	4.134	876	5.010	4.274
Two-family	4.198	817	5.016	4.899
Two-family	4.715	993	5.708	4.063
Two-family	4.780	934	5.714	3.977
Terraced (Corner)	3.617	1.051	4.668	3.905
Terraced (Corner)	3.682	0	3.682	4.591
Terraced (Corner)	4.198	0	4.198	4.571
Terraced (Corner)	4.457	0	4.457	4.576
Terraced (Corner)	0	3.270	3.270	5.693
Terraced (Middle)	3.617	1.051	4.668	3.527
Terraced (Middle)	3.682	0	3.682	4.408
Terraced (Middle)	4.198	0	4.198	4.225
Terraced (Middle)	4.457	0	4.457	4.424
Terraced (Middle)	0	3.270	3.270	5.914
Duplex Property	3.404	0	3.404	3.535
Duplex Property	3.146	0	3.146	4.151
Duplex Property	3.372	0	3.372	3.784
Duplex Property	0	1.594	1.594	5.598
Portico	0	520	520	6.664
Portico	0	1.133	1.133	5.961
Portico	0	1.238	1.238	6.157
Portico	0	1.103	1.103	6.148
Portico	0	765	765	5.897
Other + Gallery	0	794	794	6.663
Other + Gallery	0	455	455	6.642
Other + Gallery	0	1.384	1.384	5.669
Other + Gallery	0	893	893	6.514

Table 42: Total Generation per household (Technology 2015 / Expected Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	8.858	0	8.858	3.566
Detached	8.374	0	8.374	3.683
Detached	8.720	0	8.720	3.771
Detached	8.374	1.063	9.437	2.576
Two-family	4.429	938	5.367	4.063
Two-family	4.498	876	5.374	4.710
Two-family	5.052	1.063	6.115	3.819
Two-family	5.121	1.001	6.122	3.730
Terraced (Corner)	3.875	1.126	5.001	3.695
Terraced (Corner)	3.945	0	3.945	4.440
Terraced (Corner)	4.498	0	4.498	4.401
Terraced (Corner)	4.775	0	4.775	4.396
Terraced (Corner)	0	3.503	3.503	5.595
Terraced (Middle)	3.875	1.126	5.001	3.304
Terraced (Middle)	3.945	0	3.945	4.252
Terraced (Middle)	4.498	0	4.498	4.043
Terraced (Middle)	4.775	0	4.775	4.239
Terraced (Middle)	0	3.503	3.503	5.824
Duplex Property	3.647	0	3.647	3.359
Duplex Property	3.370	0	3.370	4.005
Duplex Property	3.613	0	3.613	3.617
Duplex Property	0	1.708	1.708	5.560
Portico	0	557	557	6.702
Portico	0	1.214	1.214	5.952
Portico	0	1.326	1.326	6.151
Portico	0	1.182	1.182	6.146
Portico	0	819	819	5.900
Other + Gallery	0	851	851	6.691
Other + Gallery	0	488	488	6.681
Other + Gallery	0	1.483	1.483	5.640
Other + Gallery	0	957	957	6.533

Table 43: Total Generation per household (Technology 2020 / Expected Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	9.449	0	9.449	3.231
Detached	8.932	0	8.932	3.368
Detached	9.301	0	9.301	3.447
Detached	8.932	1.134	10.066	2.188
Two-family	4.724	1.001	5.725	3.858
Two-family	4.798	934	5.732	4.526
Two-family	5.389	1.134	6.523	3.581
Two-family	5.463	1.068	6.530	3.489
Terraced (Corner)	4.134	1.201	5.335	3.488
Terraced (Corner)	4.208	0	4.208	4.293
Terraced (Corner)	4.798	0	4.798	4.235
Terraced (Corner)	5.094	0	5.094	4.221
Terraced (Corner)	0	3.737	3.737	5.503
Terraced (Middle)	4.134	1.201	5.335	3.084
Terraced (Middle)	4.208	0	4.208	4.098
Terraced (Middle)	4.798	0	4.798	3.864
Terraced (Middle)	5.094	0	5.094	4.058
Terraced (Middle)	0	3.737	3.737	5.739
Duplex Property	3.890	0	3.890	3.185
Duplex Property	3.595	0	3.595	3.862
Duplex Property	3.853	0	3.853	3.453
Duplex Property	0	1.822	1.822	5.524
Portico	0	594	594	6.743
Portico	0	1.294	1.294	5.945
Portico	0	1.415	1.415	6.148
Portico	0	1.261	1.261	6.147
Portico	0	874	874	5.904
Other + Gallery	0	907	907	6.722
Other + Gallery	0	520	520	6.723
Other + Gallery	0	1.581	1.581	5.614
Other + Gallery	0	1.021	1.021	6.554

Table 44: Total Generation per household (Technology 2025 / Expected Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	10.630	0	10.630	2.314
Detached	10.049	0	10.049	2.502
Detached	10.464	0	10.464	2.550
Detached	10.049	1.276	11.325	1.179
Two-family	5.315	1.126	6.441	3.300
Two-family	5.398	1.051	6.449	3.990
Two-family	6.062	1.276	7.338	2.941
Two-family	6.145	1.201	7.346	2.845
Terraced (Corner)	4.651	1.351	6.002	2.953
Terraced (Corner)	4.734	0	4.734	3.888
Terraced (Corner)	5.398	0	5.398	3.774
Terraced (Corner)	5.730	0	5.730	3.733
Terraced (Corner)	0	4.204	4.204	5.181
Terraced (Middle)	4.651	1.351	6.002	2.534
Terraced (Middle)	4.734	0	4.734	3.686
Terraced (Middle)	5.398	0	5.398	3.391
Terraced (Middle)	5.730	0	5.730	3.564
Terraced (Middle)	0	4.204	4.204	5.426
Duplex Property	4.377	0	4.377	2.770
Duplex Property	4.044	0	4.044	3.497
Duplex Property	4.335	0	4.335	3.050
Duplex Property	0	2.049	2.049	5.376
Portico	0	668	668	6.749
Portico	0	1.456	1.456	5.861
Portico	0	1.591	1.591	6.059
Portico	0	1.419	1.419	6.072
Portico	0	983	983	5.856
Other + Gallery	0	1.021	1.021	6.698
Other + Gallery	0	586	586	6.735
Other + Gallery	0	1.779	1.779	5.492
Other + Gallery	0	1.149	1.149	6.515

Table 45: Total Generation per household (Technology 2030 / Expected Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	11.811	0	11.811	1.405
Detached	11.165	0	11.165	1.645
Detached	11.626	0	11.626	1.663
Detached	11.165	1.418	12.583	178
Two-family	5.906	1.251	7.157	2.747
Two-family	5.998	1.168	7.165	3.460
Two-family	6.736	1.418	8.154	2.307
Two-family	6.828	1.335	8.163	2.207
Terraced (Corner)	5.167	1.501	6.669	2.422
Terraced (Corner)	5.260	0	5.260	3.486
Terraced (Corner)	5.998	0	5.998	3.317
Terraced (Corner)	6.367	0	6.367	3.249
Terraced (Corner)	0	4.671	4.671	4.865
Terraced (Middle)	5.167	1.501	6.669	1.989
Terraced (Middle)	5.260	0	5.260	3.278
Terraced (Middle)	5.998	0	5.998	2.921
Terraced (Middle)	6.367	0	6.367	3.075
Terraced (Middle)	0	4.671	4.671	5.118
Duplex Property	4.863	0	4.863	2.357
Duplex Property	4.494	0	4.494	3.135
Duplex Property	4.817	0	4.817	2.651
Duplex Property	0	2.277	2.277	5.232
Portico	0	742	742	6.758
Portico	0	1.618	1.618	5.778
Portico	0	1.768	1.768	5.973
Portico	0	1.576	1.576	6.000
Portico	0	1.093	1.093	5.810
Other + Gallery	0	1.134	1.134	6.678
Other + Gallery	0	651	651	6.750
Other + Gallery	0	1.977	1.977	5.372
Other + Gallery	0	1.276	1.276	6.479

Table 46: Total Generation per household (Technology 2035 / Expected Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	12.992	0	12.992	507
Detached	12.282	0	12.282	797
Detached	12.789	0	12.789	785
Detached	12.282	1.560	13.841	-814
Two-family	6.496	1.376	7.872	2.200
Two-family	6.598	1.284	7.882	2.937
Two-family	7.410	1.560	8.969	1.679
Two-family	7.511	1.468	8.979	1.575
Terraced (Corner)	5.684	1.651	7.336	1.895
Terraced (Corner)	5.786	0	5.786	3.089
Terraced (Corner)	6.598	0	6.598	2.866
Terraced (Corner)	7.004	0	7.004	2.771
Terraced (Corner)	0	5.138	5.138	4.554
Terraced (Middle)	5.684	1.651	7.336	1.448
Terraced (Middle)	5.786	0	5.786	2.873
Terraced (Middle)	6.598	0	6.598	2.456
Terraced (Middle)	7.004	0	7.004	2.591
Terraced (Middle)	0	5.138	5.138	4.816
Duplex Property	5.349	0	5.349	1.947
Duplex Property	4.943	0	4.943	2.776
Duplex Property	5.298	0	5.298	2.254
Duplex Property	0	2.505	2.505	5.091
Portico	0	817	817	6.769
Portico	0	1.780	1.780	5.699
Portico	0	1.945	1.945	5.891
Portico	0	1.734	1.734	5.931
Portico	0	1.202	1.202	5.766
Other + Gallery	0	1.248	1.248	6.662
Other + Gallery	0	716	716	6.767
Other + Gallery	0	2.174	2.174	5.256
Other + Gallery	0	1.404	1.404	6.446

Table 47: Total Generation per household (Technology 2040 / Expected Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	14.764	0	14.764	-973
Detached	13.956	0	13.956	-601
Detached	14.533	0	14.533	-664
Detached	13.956	1.772	15.729	-2.425
Two-family	7.382	1.564	8.946	1.300
Two-family	7.497	1.460	8.957	2.062
Two-family	8.420	1.772	10.192	650
Two-family	8.535	1.668	10.203	542
Terraced (Corner)	6.459	1.877	8.336	1.040
Terraced (Corner)	6.574	0	6.574	2.433
Terraced (Corner)	7.497	0	7.497	2.119
Terraced (Corner)	7.959	0	7.959	1.980
Terraced (Corner)	0	5.838	5.838	4.014
Terraced (Middle)	6.459	1.877	8.336	578
Terraced (Middle)	6.574	0	6.574	2.210
Terraced (Middle)	7.497	0	7.497	1.695
Terraced (Middle)	7.959	0	7.959	1.794
Terraced (Middle)	0	5.838	5.838	4.285
Duplex Property	6.079	0	6.079	1.297
Duplex Property	5.617	0	5.617	2.195
Duplex Property	6.021	0	6.021	1.619
Duplex Property	0	2.846	2.846	4.838
Portico	0	928	928	6.747
Portico	0	2.023	2.023	5.541
Portico	0	2.210	2.210	5.723
Portico	0	1.970	1.970	5.786
Portico	0	1.366	1.366	5.670
Other + Gallery	0	1.418	1.418	6.591
Other + Gallery	0	813	813	6.755
Other + Gallery	0	2.471	2.471	5.042
Other + Gallery	0	1.595	1.595	6.353

Table 48: Total Generation per household (Technology 2011 / Pessimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	8.268	0	8.268	3.910
Detached	7.816	0	7.816	4.007
Detached	8.139	0	8.139	4.103
Detached	7.816	993	8.808	2.972
Two-family	4.134	876	5.010	4.274
Two-family	4.198	817	5.016	4.899
Two-family	4.715	993	5.708	4.063
Two-family	4.780	934	5.714	3.977
Terraced (Corner)	3.617	1.051	4.668	3.905
Terraced (Corner)	3.682	0	3.682	4.591
Terraced (Corner)	4.198	0	4.198	4.571
Terraced (Corner)	4.457	0	4.457	4.576
Terraced (Corner)	0	3.270	3.270	5.693
Terraced (Middle)	3.617	1.051	4.668	3.527
Terraced (Middle)	3.682	0	3.682	4.408
Terraced (Middle)	4.198	0	4.198	4.225
Terraced (Middle)	4.457	0	4.457	4.424
Terraced (Middle)	0	3.270	3.270	5.914
Duplex Property	3.404	0	3.404	3.535
Duplex Property	3.146	0	3.146	4.151
Duplex Property	3.372	0	3.372	3.784
Duplex Property	0	1.594	1.594	5.598
Portico	0	520	520	6.664
Portico	0	1.133	1.133	5.961
Portico	0	1.238	1.238	6.157
Portico	0	1.103	1.103	6.148
Portico	0	765	765	5.897
Other + Gallery	0	794	794	6.663
Other + Gallery	0	455	455	6.642
Other + Gallery	0	1.384	1.384	5.669
Other + Gallery	0	893	893	6.514

Table 49: Total Generation per household (Technology 2015 / Pessimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	8.858	0	8.858	3.566
Detached	8.374	0	8.374	3.683
Detached	8.720	0	8.720	3.771
Detached	8.374	1.063	9.437	2.576
Two-family	4.429	938	5.367	4.063
Two-family	4.498	876	5.374	4.710
Two-family	5.052	1.063	6.115	3.819
Two-family	5.121	1.001	6.122	3.730
Terraced (Corner)	3.875	1.126	5.001	3.695
Terraced (Corner)	3.945	0	3.945	4.440
Terraced (Corner)	4.498	0	4.498	4.401
Terraced (Corner)	4.775	0	4.775	4.396
Terraced (Corner)	0	3.503	3.503	5.595
Terraced (Middle)	3.875	1.126	5.001	3.304
Terraced (Middle)	3.945	0	3.945	4.252
Terraced (Middle)	4.498	0	4.498	4.043
Terraced (Middle)	4.775	0	4.775	4.239
Terraced (Middle)	0	3.503	3.503	5.824
Duplex Property	3.647	0	3.647	3.359
Duplex Property	3.370	0	3.370	4.005
Duplex Property	3.613	0	3.613	3.617
Duplex Property	0	1.708	1.708	5.560
Portico	0	557	557	6.702
Portico	0	1.214	1.214	5.952
Portico	0	1.326	1.326	6.151
Portico	0	1.182	1.182	6.146
Portico	0	819	819	5.900
Other + Gallery	0	851	851	6.691
Other + Gallery	0	488	488	6.681
Other + Gallery	0	1.483	1.483	5.640
Other + Gallery	0	957	957	6.533

Table 50: Total Generation per household (Technology 2020 / Pessimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	9.449	0	9.449	3.231
Detached	8.932	0	8.932	3.368
Detached	9.301	0	9.301	3.447
Detached	8.932	1.134	10.066	2.188
Two-family	4.724	1.001	5.725	3.858
Two-family	4.798	934	5.732	4.526
Two-family	5.389	1.134	6.523	3.581
Two-family	5.463	1.068	6.530	3.489
Terraced (Corner)	4.134	1.201	5.335	3.488
Terraced (Corner)	4.208	0	4.208	4.293
Terraced (Corner)	4.798	0	4.798	4.235
Terraced (Corner)	5.094	0	5.094	4.221
Terraced (Corner)	0	3.737	3.737	5.503
Terraced (Middle)	4.134	1.201	5.335	3.084
Terraced (Middle)	4.208	0	4.208	4.098
Terraced (Middle)	4.798	0	4.798	3.864
Terraced (Middle)	5.094	0	5.094	4.058
Terraced (Middle)	0	3.737	3.737	5.739
Duplex Property	3.890	0	3.890	3.185
Duplex Property	3.595	0	3.595	3.862
Duplex Property	3.853	0	3.853	3.453
Duplex Property	0	1.822	1.822	5.524
Portico	0	594	594	6.743
Portico	0	1.294	1.294	5.945
Portico	0	1.415	1.415	6.148
Portico	0	1.261	1.261	6.147
Portico	0	874	874	5.904
Other + Gallery	0	907	907	6.722
Other + Gallery	0	520	520	6.723
Other + Gallery	0	1.581	1.581	5.614
Other + Gallery	0	1.021	1.021	6.554

Table 51: Total Generation per household (Technology 2025 / Pessimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	10.039	0	10.039	2.904
Detached	9.490	0	9.490	3.060
Detached	9.883	0	9.883	3.132
Detached	9.490	1.205	10.696	1.808
Two-family	5.020	1.063	6.083	3.657
Two-family	5.098	993	6.091	4.348
Two-family	5.726	1.205	6.931	3.349
Two-family	5.804	1.134	6.938	3.253
Terraced (Corner)	4.392	1.276	5.668	3.286
Terraced (Corner)	4.471	0	4.471	4.151
Terraced (Corner)	5.098	0	5.098	4.073
Terraced (Corner)	5.412	0	5.412	4.051
Terraced (Corner)	0	3.970	3.970	5.415
Terraced (Middle)	4.392	1.276	5.668	2.868
Terraced (Middle)	4.471	0	4.471	3.949
Terraced (Middle)	5.098	0	5.098	3.690
Terraced (Middle)	5.412	0	5.412	3.883
Terraced (Middle)	0	3.970	3.970	5.660
Duplex Property	4.133	0	4.133	3.013
Duplex Property	3.820	0	3.820	3.722
Duplex Property	4.094	0	4.094	3.291
Duplex Property	0	1.935	1.935	5.490
Portico	0	631	631	6.786
Portico	0	1.375	1.375	5.942
Portico	0	1.503	1.503	6.147
Portico	0	1.340	1.340	6.151
Portico	0	929	929	5.911
Other + Gallery	0	964	964	6.755
Other + Gallery	0	553	553	6.768
Other + Gallery	0	1.680	1.680	5.591
Other + Gallery	0	1.085	1.085	6.579

Table 52: Total Generation per household (Technology 2030 / Pessimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	10.630	0	10.630	2.586
Detached	10.049	0	10.049	2.761
Detached	10.464	0	10.464	2.826
Detached	10.049	1.276	11.325	1.436
Two-family	5.315	1.126	6.441	3.462
Two-family	5.398	1.051	6.449	4.177
Two-family	6.062	1.276	7.338	3.122
Two-family	6.145	1.201	7.346	3.023
Terraced (Corner)	4.651	1.351	6.002	3.088
Terraced (Corner)	4.734	0	4.734	4.012
Terraced (Corner)	5.398	0	5.398	3.917
Terraced (Corner)	5.730	0	5.730	3.886
Terraced (Corner)	0	4.204	4.204	5.332
Terraced (Middle)	4.651	1.351	6.002	2.656
Terraced (Middle)	4.734	0	4.734	3.803
Terraced (Middle)	5.398	0	5.398	3.521
Terraced (Middle)	5.730	0	5.730	3.712
Terraced (Middle)	0	4.204	4.204	5.585
Duplex Property	4.377	0	4.377	2.843
Duplex Property	4.044	0	4.044	3.584
Duplex Property	4.335	0	4.335	3.132
Duplex Property	0	2.049	2.049	5.460
Portico	0	668	668	6.832
Portico	0	1.456	1.456	5.940
Portico	0	1.591	1.591	6.150
Portico	0	1.419	1.419	6.158
Portico	0	983	983	5.919
Other + Gallery	0	1.021	1.021	6.792
Other + Gallery	0	586	586	6.815
Other + Gallery	0	1.779	1.779	5.570
Other + Gallery	0	1.149	1.149	6.607

Table 53: Total Generation per household (Technology 2035 / Pessimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	11.220	0	11.220	2.278
Detached	10.607	0	10.607	2.471
Detached	11.045	0	11.045	2.529
Detached	10.607	1.347	11.954	1.074
Two-family	5.610	1.189	6.799	3.273
Two-family	5.698	1.109	6.807	4.012
Two-family	6.399	1.347	7.746	2.902
Two-family	6.487	1.268	7.755	2.800
Terraced (Corner)	4.909	1.426	6.335	2.896
Terraced (Corner)	4.997	0	4.997	3.878
Terraced (Corner)	5.698	0	5.698	3.765
Terraced (Corner)	6.049	0	6.049	3.726
Terraced (Corner)	0	4.437	4.437	5.254
Terraced (Middle)	4.909	1.426	6.335	2.448
Terraced (Middle)	4.997	0	4.997	3.662
Terraced (Middle)	5.698	0	5.698	3.355
Terraced (Middle)	6.049	0	6.049	3.546
Terraced (Middle)	0	4.437	4.437	5.516
Duplex Property	4.620	0	4.620	2.677
Duplex Property	4.269	0	4.269	3.450
Duplex Property	4.576	0	4.576	2.976
Duplex Property	0	2.163	2.163	5.432
Portico	0	705	705	6.881
Portico	0	1.537	1.537	5.942
Portico	0	1.680	1.680	6.156
Portico	0	1.498	1.498	6.168
Portico	0	1.038	1.038	5.930
Other + Gallery	0	1.078	1.078	6.832
Other + Gallery	0	618	618	6.865
Other + Gallery	0	1.878	1.878	5.552
Other + Gallery	0	1.212	1.212	6.638

Table 54: Total Generation per household (Technology 2040 / Pessimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	11.811	0	11.811	1.980
Detached	11.165	0	11.165	2.191
Detached	11.626	0	11.626	2.243
Detached	11.165	1.418	12.583	721
Two-family	5.906	1.251	7.157	3.090
Two-family	5.998	1.168	7.165	3.854
Two-family	6.736	1.418	8.154	2.689
Two-family	6.828	1.335	8.163	2.582
Terraced (Corner)	5.167	1.501	6.669	2.707
Terraced (Corner)	5.260	0	5.260	3.748
Terraced (Corner)	5.998	0	5.998	3.619
Terraced (Corner)	6.367	0	6.367	3.572
Terraced (Corner)	0	4.671	4.671	5.182
Terraced (Middle)	5.167	1.501	6.669	2.245
Terraced (Middle)	5.260	0	5.260	3.525
Terraced (Middle)	5.998	0	5.998	3.195
Terraced (Middle)	6.367	0	6.367	3.386
Terraced (Middle)	0	4.671	4.671	5.453
Duplex Property	4.863	0	4.863	2.512
Duplex Property	4.494	0	4.494	3.319
Duplex Property	4.817	0	4.817	2.823
Duplex Property	0	2.277	2.277	5.407
Portico	0	742	742	6.932
Portico	0	1.618	1.618	5.946
Portico	0	1.768	1.768	6.165
Portico	0	1.576	1.576	6.181
Portico	0	1.093	1.093	5.943
Other + Gallery	0	1.134	1.134	6.875
Other + Gallery	0	651	651	6.918
Other + Gallery	0	1.977	1.977	5.537
Other + Gallery	0	1.276	1.276	6.672

Table 55: Total Generation per household (Technology 2011 / Optimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	8.268	0	8.268	3.910
Detached	7.816	0	7.816	4.007
Detached	8.139	0	8.139	4.103
Detached	7.816	993	8.808	2.972
Two-family	4.134	876	5.010	4.274
Two-family	4.198	817	5.016	4.899
Two-family	4.715	993	5.708	4.063
Two-family	4.780	934	5.714	3.977
Terraced (Corner)	3.617	1.051	4.668	3.905
Terraced (Corner)	3.682	0	3.682	4.591
Terraced (Corner)	4.198	0	4.198	4.571
Terraced (Corner)	4.457	0	4.457	4.576
Terraced (Corner)	0	3.270	3.270	5.693
Terraced (Middle)	3.617	1.051	4.668	3.527
Terraced (Middle)	3.682	0	3.682	4.408
Terraced (Middle)	4.198	0	4.198	4.225
Terraced (Middle)	4.457	0	4.457	4.424
Terraced (Middle)	0	3.270	3.270	5.914
Duplex Property	3.404	0	3.404	3.535
Duplex Property	3.146	0	3.146	4.151
Duplex Property	3.372	0	3.372	3.784
Duplex Property	0	1.594	1.594	5.598
Portico	0	520	520	6.664
Portico	0	1.133	1.133	5.961
Portico	0	1.238	1.238	6.157
Portico	0	1.103	1.103	6.148
Portico	0	765	765	5.897
Other + Gallery	0	794	794	6.663
Other + Gallery	0	455	455	6.642
Other + Gallery	0	1.384	1.384	5.669
Other + Gallery	0	893	893	6.514

Table 56: Total Generation per household (Technology 2015 / Optimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	10.630	0	10.630	1.795
Detached	10.049	0	10.049	2.009
Detached	10.464	0	10.464	2.027
Detached	10.049	1.276	11.325	688
Two-family	5.315	1.126	6.441	2.990
Two-family	5.398	1.051	6.449	3.635
Two-family	6.062	1.276	7.338	2.596
Two-family	6.145	1.201	7.346	2.506
Terraced (Corner)	4.651	1.351	6.002	2.694
Terraced (Corner)	4.734	0	4.734	3.651
Terraced (Corner)	5.398	0	5.398	3.501
Terraced (Corner)	5.730	0	5.730	3.441
Terraced (Corner)	0	4.204	4.204	4.895
Terraced (Middle)	4.651	1.351	6.002	2.303
Terraced (Middle)	4.734	0	4.734	3.463
Terraced (Middle)	5.398	0	5.398	3.143
Terraced (Middle)	5.730	0	5.730	3.284
Terraced (Middle)	0	4.204	4.204	5.124
Duplex Property	4.377	0	4.377	2.629
Duplex Property	4.044	0	4.044	3.331
Duplex Property	4.335	0	4.335	2.895
Duplex Property	0	2.049	2.049	5.218
Portico	0	668	668	6.591
Portico	0	1.456	1.456	5.709
Portico	0	1.591	1.591	5.886
Portico	0	1.419	1.419	5.910
Portico	0	983	983	5.736
Other + Gallery	0	1.021	1.021	6.521
Other + Gallery	0	586	586	6.584
Other + Gallery	0	1.779	1.779	5.344
Other + Gallery	0	1.149	1.149	6.341

Table 57: Total Generation per household (Technology 2020 / Optimistic Scenario)

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	12.992	0	12.992	-312
Detached	12.282	0	12.282	18
Detached	12.789	0	12.789	-41
Detached	12.282	1.560	13.841	-1.587
Two-family	6.496	1.376	7.872	1.711
Two-family	6.598	1.284	7.882	2.376
Two-family	7.410	1.560	8.969	1.135
Two-family	7.511	1.468	8.979	1.040
Terraced (Corner)	5.684	1.651	7.336	1.487
Terraced (Corner)	5.786	0	5.786	2.716
Terraced (Corner)	6.598	0	6.598	2.435
Terraced (Corner)	7.004	0	7.004	2.311
Terraced (Corner)	0	5.138	5.138	4.102
Terraced (Middle)	5.684	1.651	7.336	1.083
Terraced (Middle)	5.786	0	5.786	2.520
Terraced (Middle)	6.598	0	6.598	2.065
Terraced (Middle)	7.004	0	7.004	2.148
Terraced (Middle)	0	5.138	5.138	4.338
Duplex Property	5.349	0	5.349	1.726
Duplex Property	4.943	0	4.943	2.514
Duplex Property	5.298	0	5.298	2.008
Duplex Property	0	2.505	2.505	4.840
Portico	0	817	817	6.520
Portico	0	1.780	1.780	5.460
Portico	0	1.945	1.945	5.617
Portico	0	1.734	1.734	5.674
Portico	0	1.202	1.202	5.576
Other + Gallery	0	1.248	1.248	6.381
Other + Gallery	0	716	716	6.528
Other + Gallery	0	2.174	2.174	5.021
Other + Gallery	0	1.404	1.404	6.171

Table 58: Total Generation per household (Technology 2025 / Optimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	15.354	0	15.354	-2.411
Detached	14.515	0	14.515	-1.964
Detached	15.114	0	15.114	-2.100
Detached	14.515	1.843	16.358	-3.855
Two-family	7.677	1.626	9.304	437
Two-family	7.797	1.518	9.315	1.124
Two-family	8.757	1.843	10.600	-321
Two-family	8.877	1.735	10.612	-420
Terraced (Corner)	6.718	1.952	8.669	285
Terraced (Corner)	6.837	0	6.837	1.784
Terraced (Corner)	7.797	0	7.797	1.374
Terraced (Corner)	8.277	0	8.277	1.186
Terraced (Corner)	0	6.072	6.072	3.313
Terraced (Middle)	6.718	1.952	8.669	-133
Terraced (Middle)	6.837	0	6.837	1.582
Terraced (Middle)	7.797	0	7.797	991
Terraced (Middle)	8.277	0	8.277	1.018
Terraced (Middle)	0	6.072	6.072	3.558
Duplex Property	6.322	0	6.322	825
Duplex Property	5.842	0	5.842	1.699
Duplex Property	6.262	0	6.262	1.124
Duplex Property	0	2.960	2.960	4.466
Portico	0	965	965	6.452
Portico	0	2.104	2.104	5.213
Portico	0	2.299	2.299	5.352
Portico	0	2.049	2.049	5.442
Portico	0	1.420	1.420	5.419
Other + Gallery	0	1.475	1.475	6.245
Other + Gallery	0	846	846	6.475
Other + Gallery	0	2.570	2.570	4.701
Other + Gallery	0	1.659	1.659	6.005

Table 59: Total Generation per household (Technology 2030 / Optimistic Scenario

Per dwelling (per type and construction period)				'Salderings' border
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	17.717	0	17.717	-4.500
Detached	16.748	0	16.748	-3.938
Detached	17.440	0	17.440	-4.150
Detached	16.748	2.127	18.875	-6.113
Two-family	8.858	1.877	10.735	-832
Two-family	8.997	1.752	10.748	-122
Two-family	10.104	2.127	12.231	-1.770
Two-family	10.242	2.002	12.244	-1.874
Terraced (Corner)	7.751	2.252	10.003	-913
Terraced (Corner)	7.889	0	7.889	856
Terraced (Corner)	8.997	0	8.997	318
Terraced (Corner)	9.550	0	9.550	66
Terraced (Corner)	0	7.006	7.006	2.530
Terraced (Middle)	7.751	2.252	10.003	-1.345
Terraced (Middle)	7.889	0	7.889	648
Terraced (Middle)	8.997	0	8.997	-78
Terraced (Middle)	9.550	0	9.550	-108
Terraced (Middle)	0	7.006	7.006	2.783
Duplex Property	7.294	0	7.294	-74
Duplex Property	6.741	0	6.741	888
Duplex Property	7.225	0	7.225	242
Duplex Property	0	3.416	3.416	4.094
Portico	0	1.113	1.113	6.387
Portico	0	2.427	2.427	4.969
Portico	0	2.652	2.652	5.089
Portico	0	2.365	2.365	5.212
Portico	0	1.639	1.639	5.264
Other + Gallery	0	1.701	1.701	6.111
Other + Gallery	0	976	976	6.425
Other + Gallery	0	2.965	2.965	4.384
Other + Gallery	0	1.914	1.914	5.841

Table 60: Total Generation per household (Technology 2035 / Optimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	20.669	0	20.669	-7.171
Detached	19.539	0	19.539	-6.461
Detached	20.346	0	20.346	-6.772
Detached	19.539	2.481	22.020	-8.993
Two-family	10.335	2.189	12.524	-2.452
Two-family	10.496	2.043	12.540	-1.720
Two-family	11.788	2.481	14.269	-3.621
Two-family	11.949	2.335	14.285	-3.731
Terraced (Corner)	9.043	2.627	11.670	-2.439
Terraced (Corner)	9.204	0	9.204	-330
Terraced (Corner)	10.496	0	10.496	-1.033
Terraced (Corner)	11.142	0	11.142	-1.367
Terraced (Corner)	0	8.174	8.174	1.518
Terraced (Middle)	9.043	2.627	11.670	-2.887
Terraced (Middle)	9.204	0	9.204	-546
Terraced (Middle)	10.496	0	10.496	-1.443
Terraced (Middle)	11.142	0	11.142	-1.547
Terraced (Middle)	0	8.174	8.174	1.780
Duplex Property	8.510	0	8.510	-1.214
Duplex Property	7.864	0	7.864	-145
Duplex Property	8.429	0	8.429	-877
Duplex Property	0	3.985	3.985	3.611
Portico	0	1.299	1.299	6.287
Portico	0	2.832	2.832	4.647
Portico	0	3.094	3.094	4.741
Portico	0	2.759	2.759	4.907
Portico	0	1.912	1.912	5.056
Other + Gallery	0	1.985	1.985	5.924
Other + Gallery	0	1.139	1.139	6.344
Other + Gallery	0	3.459	3.459	3.971
Other + Gallery	0	2.233	2.233	5.617

Table 61: Total Generation per household (Technology 2040 / Optimistic Scenario)

Per dwelling (per type and construction period)				**'Salderings' border**
Dwelling Type	*Sloping Roof (kWh/year)*	*Flat Roof (kWh/year)*	*Total Roof (kWh/year)*	*Extra permitted production*
Detached	23.622	0	23.622	-9.831
Detached	22.330	0	22.330	-8.974
Detached	23.253	0	23.253	-9.384
Detached	22.330	2.836	25.166	-11.862
Two-family	11.811	2.502	14.313	-4.067
Two-family	11.996	2.335	14.331	-3.312
Two-family	13.472	2.836	16.308	-5.465
Two-family	13.656	2.669	16.326	-5.580
Terraced (Corner)	10.335	3.003	13.337	-3.961
Terraced (Corner)	10.519	0	10.519	-1.512
Terraced (Corner)	11.996	0	11.996	-2.379
Terraced (Corner)	12.734	0	12.734	-2.795
Terraced (Corner)	0	9.342	9.342	511
Terraced (Middle)	10.335	3.003	13.337	-4.424
Terraced (Middle)	10.519	0	10.519	-1.735
Terraced (Middle)	11.996	0	11.996	-2.803
Terraced (Middle)	12.734	0	12.734	-2.981
Terraced (Middle)	0	9.342	9.342	782
Duplex Property	9.726	0	9.726	-2.351
Duplex Property	8.987	0	8.987	-1.175
Duplex Property	9.633	0	9.633	-1.994
Duplex Property	0	4.554	4.554	3.130
Portico	0	1.485	1.485	6.190
Portico	0	3.236	3.236	4.328
Portico	0	3.536	3.536	4.397
Portico	0	3.153	3.153	4.604
Portico	0	2.185	2.185	4.850
Other + Gallery	0	2.269	2.269	5.741
Other + Gallery	0	1.301	1.301	6.267
Other + Gallery	0	3.953	3.953	3.560
Other + Gallery	0	2.552	2.552	5.395

Table 62: Price development PV system 'Paradigm Shift Scenario'

Year	EPIA Objectives Turnkey Price Large Systems			Module Lifetime	Inverter Lifetime
	Large Systems (€/Wp)	*Correction Factor Small systems*	*Small Systems (€/Wp)*		
2010	2,80	22%	3,42	25-30 jaar	15
2015	1,84	22%	2,25	30-35 jaar	20
2020	1,30	22%	1,58	35-40 jaar	25
2025	1,07	22%	1,30	40-45 jaar	30
2030	0,94	22%	1,14	45-50 jaar	35
2035	0,86	22%	1,05	50 jaar	35
2040	0,80	22%	0,98	50 jaar	35

Table 63: Price development PV system 'Accelerated Scenario'

Year	EPIA Objectives Turnkey Price Large Systems			Module Lifetime	Inverter Lifetime
	Large Systems (€/Wp)	*Correction Factor Small systems*	*Small Systems (€/Wp)*		
2010	2,50	37%	3,43	25-30 jaar	15
2015	1,44	37%	1,97	30-35 jaar	20
2020	0,91	37%	1,25	35-40 jaar	25
2025	0,78	37%	1,07	40-45 jaar	30
2030	0,70	37%	0,96	45-50 jaar	35
2035	0,65	37%	0,89	50 jaar	35
2040	0,61	37%	0,83	50 jaar	35
2045	0,58	37%	0,80	50 jaar	35
2050	0,56	37%	0,77	50 jaar	35

Table 64: Financial System Characteristics of the Paradigm Shift Scenario

Year	Module (€/Wp)	Inverter (€/Wp)	BOS + Installation (€/Wp)	Engineering & Procurement (€/Wp)	Total System Costs (€/Wp)
2011	€ 2,05	€ 0,34	€ 0,78	€ 0,24	€ 3,41
2015	€ 1,38	€ 0,23	€ 0,53	€ 0,16	€ 2,30
2020	€ 1,04	€ 0,17	€ 0,40	€ 0,12	€ 1,73
2025	€ 0,80	€ 0,13	€ 0,31	€ 0,09	€ 1,33
2030	€ 0,80	€ 0,09	€ 0,22	€ 0,07	€ 0,94
2035	€ 0,52	€ 0,09	€ 0,20	€ 0,06	€ 0,86
2040	€ 0,47	€ 0,09	€ 0,20	€ 0,06	€ 0,79

Table 65: Financial System Characteristics of the Accelerated Scenario

Year	Module (€/Wp)	Inverter (€/Wp)	BOS + Installation (€/Wp)	Engineering & Procurement (€/Wp)	Total System Costs (€/Wp)
2011	€ 2,05	€ 0,34	€ 0,78	€ 0,24	€ 3,41
2015	€ 1,18	€ 0,20	€ 0,45	€ 0,14	€ 1,97
2020	€ 0,75	€ 0,13	€ 0,29	€ 0,09	€ 1,25
2025	€ 0,64	€ 0,11	€ 0,25	€ 0,07	€ 1,07
2030	€ 0,58	€ 0,10	€ 0,22	€ 0,07	€ 0,96
2035	€ 0,53	€ 0,09	€ 0,20	€ 0,06	€ 0,89
2040	€ 0,50	€ 0,08	€ 0,19	€ 0,06	€ 0,83

Table 66: Annual total electricity demand of the dwelling market*

Year	Total Electricity demand NL		Total electricity demand Eindhoven		Total simulated electricity Demand
	Fluctuation	*PJ*	*kWh*	*Yearly Difference Eindhoven*	*With linear growth function*
1995	N/A	70,92	251.237.289	N/A	251.237.289
1996	1,52%	72,00	255.122.401	3.885.113	255.560.515
1997	2,00%	73,44	260.328.981	5.206.580	259.883.741
1998	1,96%	74,88	265.535.561	5.206.580	264.206.966
1999	2,64%	76,86	272.747.638	7.212.077	268.530.192
2000	2,11%	78,48	278.620.194	5.872.557	272.853.418
2001	1,38%	79,56	282.507.918	3.887.724	277.176.644
2002	3,17%	82,08	291.748.831	9.240.913	281.499.870
2003	2,19%	83,88	298.290.285	6.541.454	285.823.096
2004	0,86%	84,60	300.872.885	2.582.600	290.146.322
2005	2,98%	87,12	310.110.210	9.237.325	294.469.548
2006	0,00%	87,12	310.110.210	0	298.792.774
2007	0,25%	87,34	310.895.299	785.089	303.116.000
2008	2,07%	89,15	317.474.517	6.579.218	307.439.226
2009	-2,62%	86,81	309.141.479	-8.333.038	311.762.451
2010	2,25%	88,76	316.085.677	6.944.199	316.085.677
2011			a	4.323.226	320.408.903
2012			b	-8.373.598.393	324.732.129
2013					329.055.355
2014					333.378.581
2015					337.701.807
2016					342.025.033
2017					346.348.259
2018					350.671.485
2019					354.994.710
2020					359.317.936
2021					363.641.162
2022					367.964.388
2023					372.287.614
2024					376.610.840
2025					380.934.066
2026					385.257.292
2027					389.580.518
2028					393.903.744
2029					398.226.970
2030					402.550.195

2031	406.873.421
2032	411.196.647
2033	415.519.873
2034	419.843.099
2035	424.166.325
2036	428.489.551
2037	432.812.777
2038	437.136.003
2039	441.459.229
2040	445.782.454

*Black data is actual historical data; red data is predicted data using the average annual deviation of historical data. The calculations were done using the linear function: y= -8.373.598.393 + 4.323.226x.

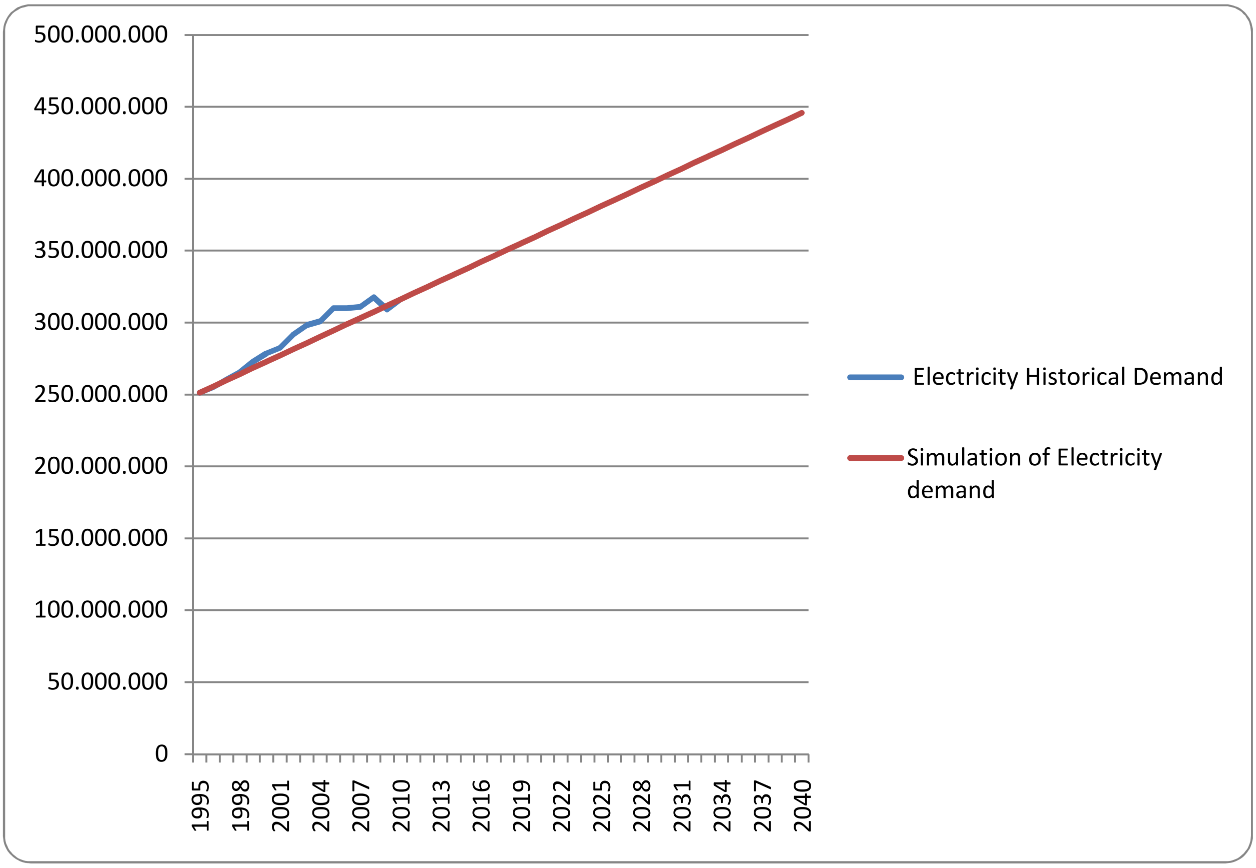

Figure 31: Annual total electricity demand of target area with linear prediction of future demand

Table 67: Annual electricity price development dwelling market*

Year	<2500 kWh (DT)	Fluctuation	Total Simulated Electricity Demand	>2500 kWh (DT)	Fluctuation	Total Simulated Electricity Demand
1996	€ 0,10		€ 0,10	€ 0,09		€ 0,09
1997	€ 0,10	0,0020	€ 0,11	€ 0,10	0,0020	€ 0,10
1998	€ 0,10	0,0010	€ 0,13	€ 0,10	0,0010	€ 0,11
1999	€ 0,11	0,0060	€ 0,14	€ 0,10	0,0070	€ 0,12
2000	€ 0,12	0,0150	€ 0,15	€ 0,12	0,0160	€ 0,13
2001	€ 0,16	0,0370	€ 0,16	€ 0,15	0,0300	€ 0,14
2002	€ 0,17	0,0060	€ 0,18	€ 0,16	0,0050	€ 0,16
2003	€ 0,17	0,0050	€ 0,19	€ 0,16	0,0040	€ 0,17
2004	€ 0,18	0,0090	€ 0,20	€ 0,17	0,0080	€ 0,18
2005	€ 0,19	0,0130	€ 0,22	€ 0,18	0,0120	€ 0,19
2006	€ 0,21	0,0130	€ 0,23	€ 0,19	0,0130	€ 0,20
2007	€ 0,22	0,0160	€ 0,24	€ 0,21	0,0170	€ 0,21
2008	€ 0,22	-0,0040	€ 0,25	€ 0,21	-0,0040	€ 0,22
2009	€ 0,30	0,0780	€ 0,27	€ 0,26	0,0580	€ 0,23
2010	€ 0,28	-0,0180	€ 0,28	€ 0,25	-0,0160	€ 0,24
2011	A	0,012785	€ 0,29	a	0,01092	€ 0,25
2012	B	-25,420285	€ 0,30	b	-21,723428	€ 0,26
2013			€ 0,32			€ 0,28
2014			€ 0,33			€ 0,29
2015			€ 0,34			€ 0,30
2016			€ 0,36			€ 0,31
2017			€ 0,37			€ 0,32
2018			€ 0,38			€ 0,33
2019			€ 0,39			€ 0,34
2020			€ 0,41			€ 0,35
2021			€ 0,42			€ 0,36
2022			€ 0,43			€ 0,37
2023			€ 0,45			€ 0,39
2024			€ 0,46			€ 0,40
2025			€ 0,47			€ 0,41
2026			€ 0,48			€ 0,42
2027			€ 0,50			€ 0,43
2028			€ 0,51			€ 0,44
2029			€ 0,52			€ 0,45
2030			€ 0,53			€ 0,46
2031			€ 0,55			€ 0,47
2032			€ 0,56			€ 0,48

2033	€ 0,57	€ 0,49
2034	€ 0,59	€ 0,51
2035	€ 0,60	€ 0,52
2036	€ 0,61	€ 0,53
2037	€ 0,62	€ 0,54
2038	€ 0,64	€ 0,55
2039	€ 0,65	€ 0,56
2040	€ 0,66	€ 0,57

*Black data is actual historical data; red data is predicted data using the average annual deviation of historical data. The calculations regarding to the small consumption were done using the linear function: y= -25,420285 + 0,012785x. The calculations regarding to the normal consumption were done using the linear function: y = -21,723428 + 0,01092x.

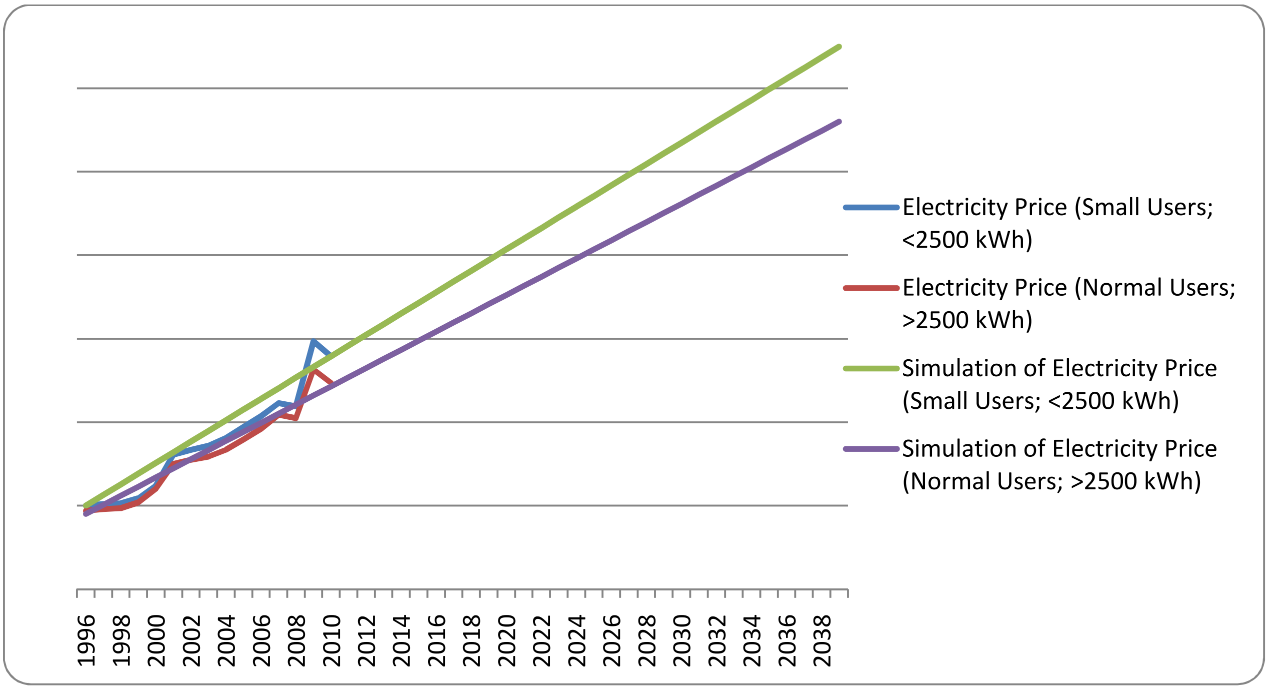

Figure 32: Annual electricity price development dwelling market

Table 68: Annual gas price development dwelling market*

Year	< 1250 m^3	Fluctuation	Total Simulated Electricity Demand	> 1250 m^3	Fluctuation	Total Simulated Electricity Demand
2003	€ 0,52		€ 0,52	€ 0,42		€ 0,42
2004	€ 0,56	€ 0,04	€ 0,55	€ 0,44	€ 0,01	€ 0,44
2005	€ 0,70	€ 0,14	€ 0,59	€ 0,50	€ 0,07	€ 0,45
2006	€ 0,76	€ 0,06	€ 0,62	€ 0,56	€ 0,05	€ 0,47
2007	€ 0,79	€ 0,03	€ 0,66	€ 0,58	€ 0,03	€ 0,49
2008	€ 0,80	€ 0,01	€ 0,69	€ 0,60	€ 0,02	€ 0,50
2009	€ 0,82	€ 0,02	€ 0,73	€ 0,59	€ -0,01	€ 0,52
2010	€ 0,76	€ -0,05	€ 0,76	€ 0,53	€ -0,06	€ 0,53
2011	a	0,0353	€ 0,80	a	0,0159	€ 0,55
2012	b	-70,1603	€ 0,83	b	-31,3389	€ 0,57
2013			€ 0,87			€ 0,58
2014			€ 0,91			€ 0,60
2015			€ 0,94			€ 0,61
2016			€ 0,98			€ 0,63
2017			€ 1,01			€ 0,64
2018			€ 1,05			€ 0,66
2019			€ 1,08			€ 0,68
2020			€ 1,12			€ 0,69
2021			€ 1,15			€ 0,71
2022			€ 1,19			€ 0,72
2023			€ 1,22			€ 0,74
2024			€ 1,26			€ 0,76
2025			€ 1,29			€ 0,77
2026			€ 1,33			€ 0,79
2027			€ 1,36			€ 0,80
2028			€ 1,40			€ 0,82
2029			€ 1,43			€ 0,84
2030			€ 1,47			€ 0,85
2031			€ 1,51			€ 0,87
2032			€ 1,54			€ 0,88
2033			€ 1,58			€ 0,90
2034			€ 1,61			€ 0,91
2035			€ 1,65			€ 0,93
2036			€ 1,68			€ 0,95
2037			€ 1,72			€ 0,96
2038			€ 1,75			€ 0,98
2039			€ 1,79			€ 0,99

2040	€ 1,82	€ 1,01

*Black data is actual historical data; red data is predicted data using the average annual deviation of historical data. The calculations regarding to the small consumption were done using the linear function: y= -70,1603 + 0,0353x. The calculations regarding to the normal consumption were done using the linear function: y = -31,3389 + 0,0159x.

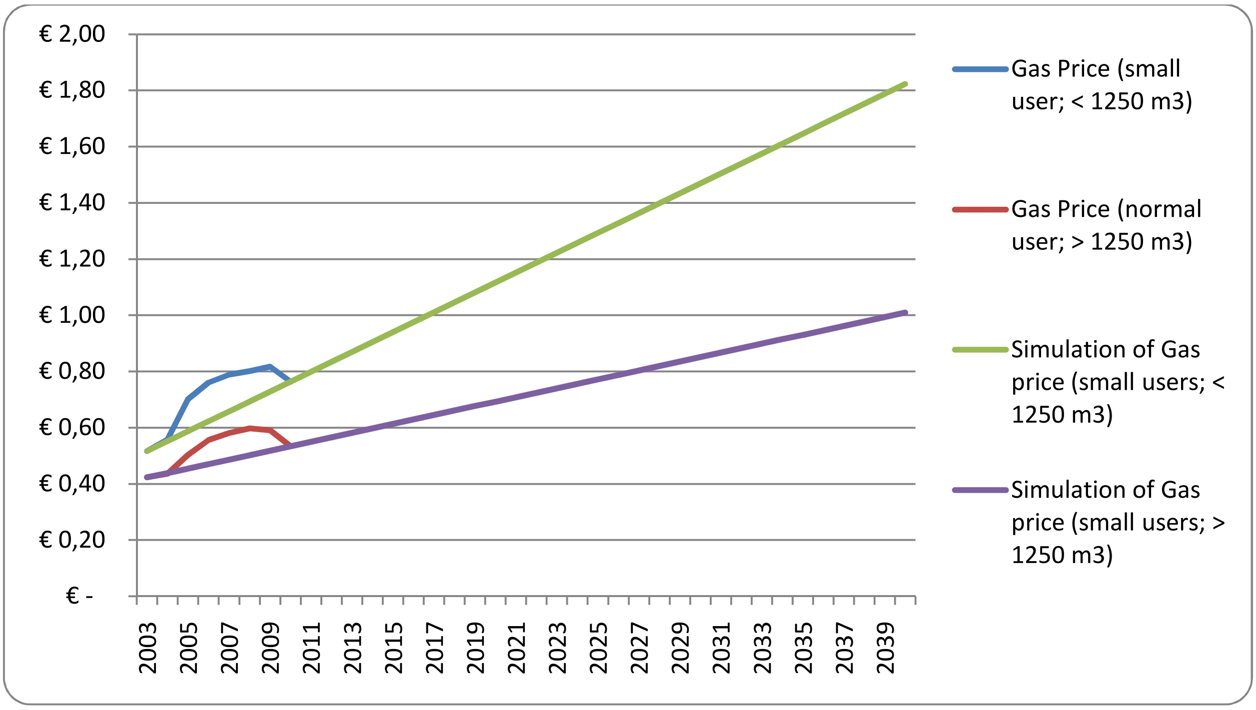

Figure 33: Annual gas price development dwelling market

Appendix D

Energetic effects of fluctuating interest rate; Case-study II

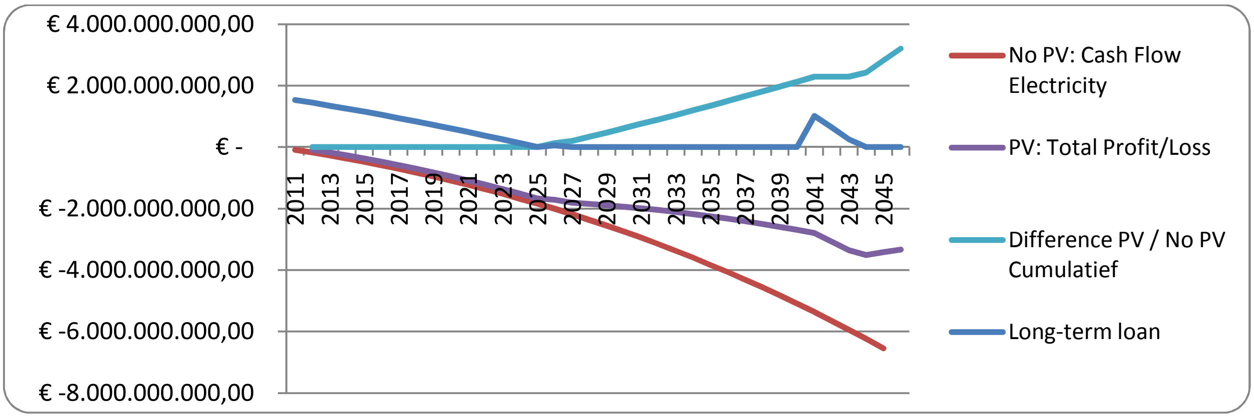

Figure 34: Financial Effects Scenario 1 (in case of an interest rate of 0%)

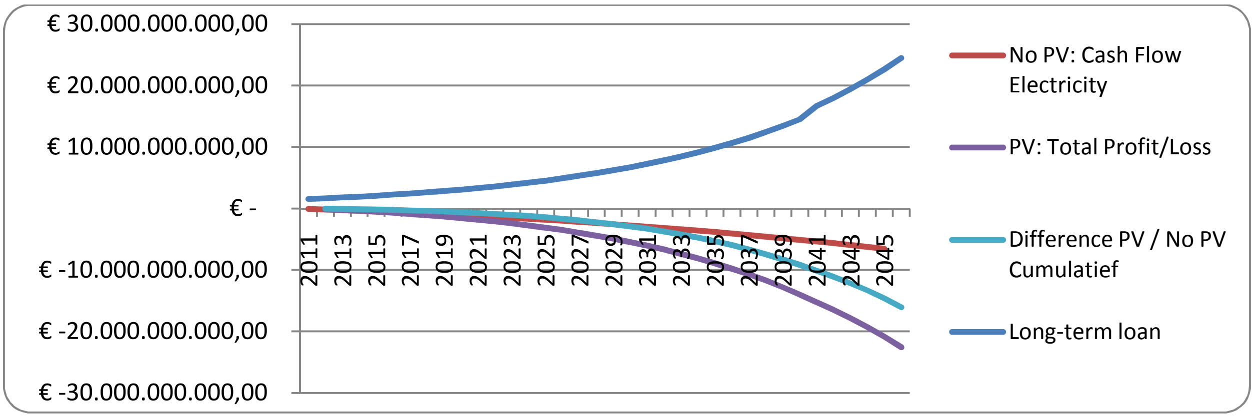

Figure 35: Financial Effects Scenario 1 (in case of an interest rate of 8%)

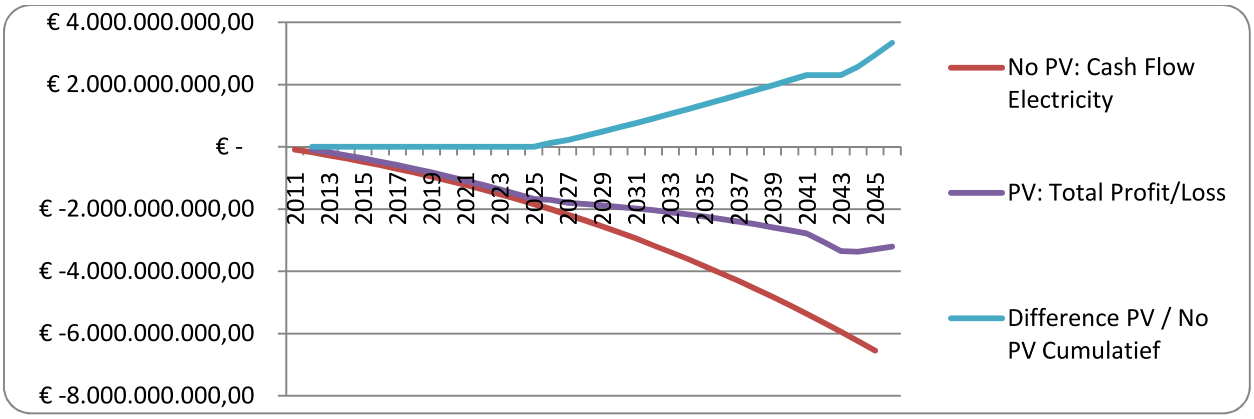

Figure 36: Financial Effects Scenario 5 (in case of an interest rate of 0%)

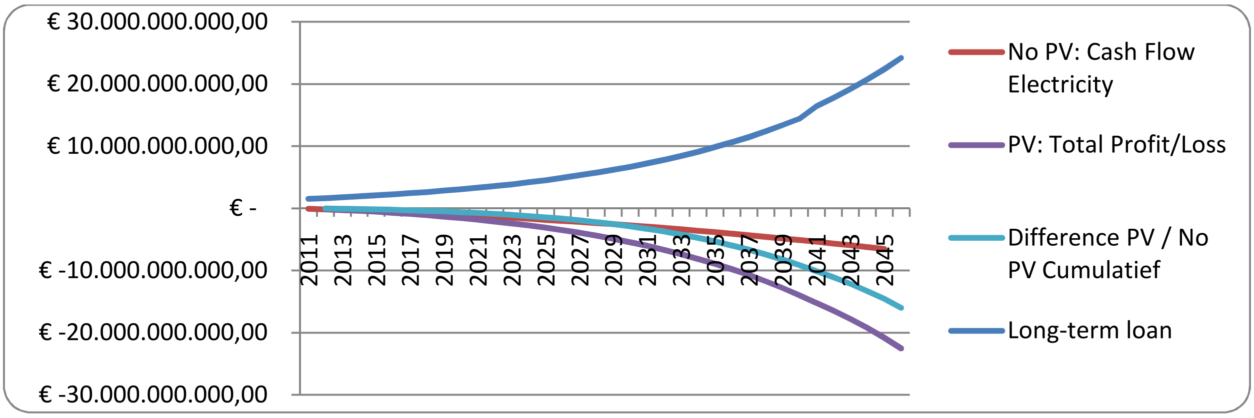

Figure 37: Financial Effects Scenario 5 (in case of an interest rate of 8%)

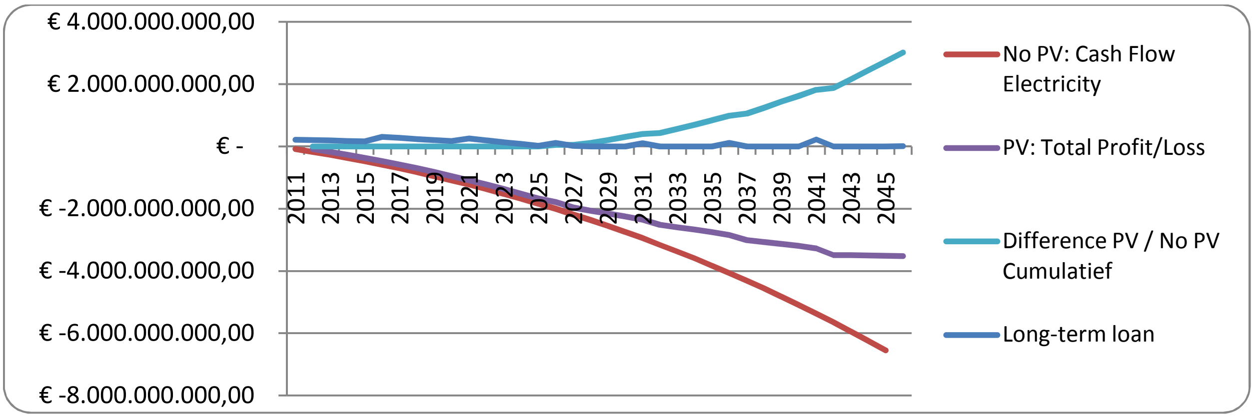

Figure 38: Financial Effects Scenario 2 (in case of an interest rate of 0%)

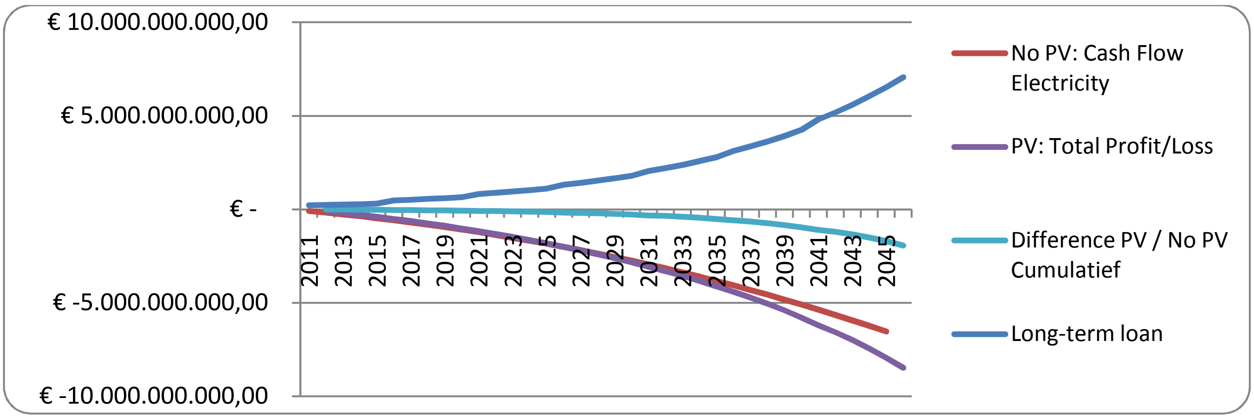

Figure 39: Financial Effects Scenario 2 (in case of an interest rate of 8%)

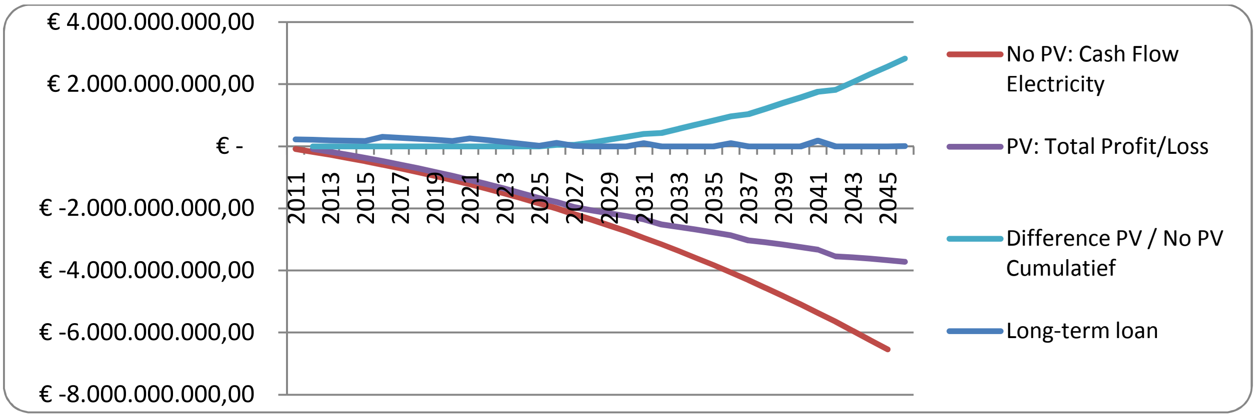

Figure 40: Financial Effects Scenario 3 (in case of an interest rate of 0%)

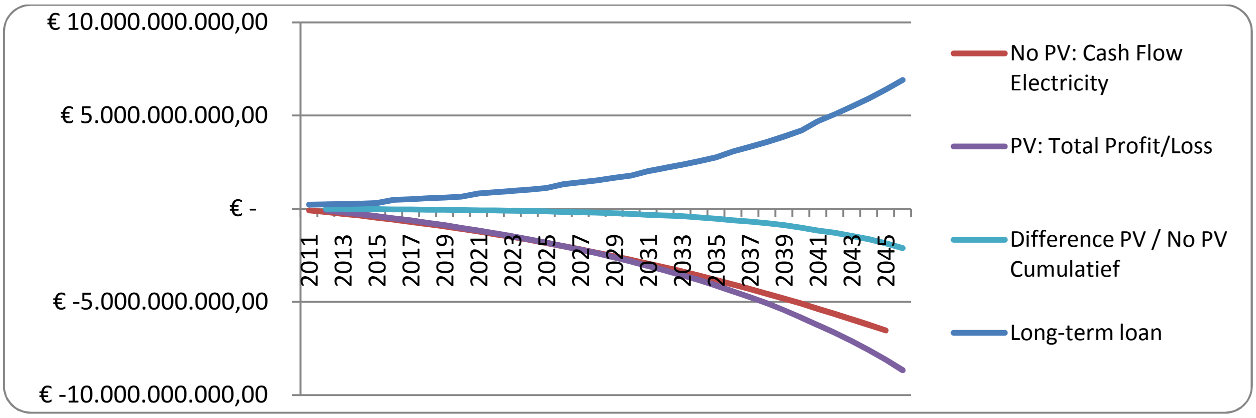

Figure 41: Financial Effects Scenario 3 (in case of an interest rate of 8%)

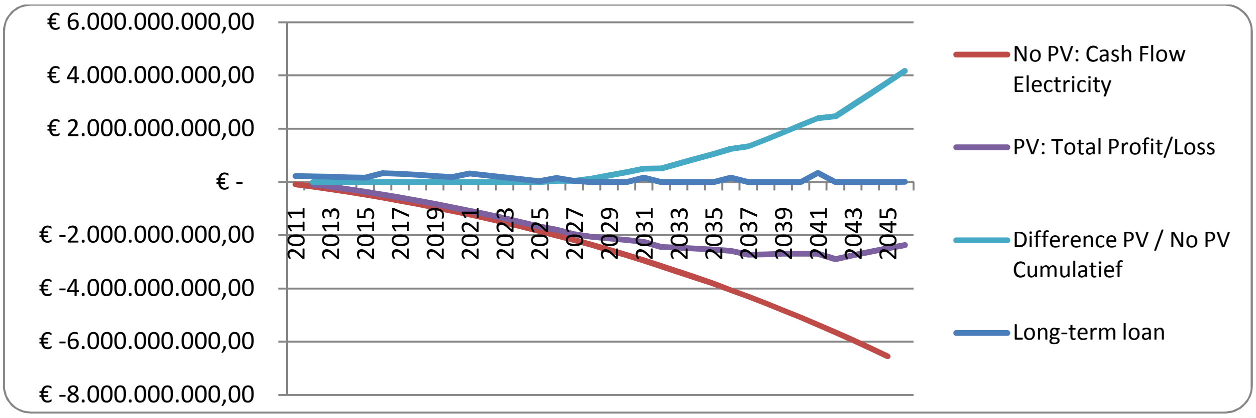

Figure 42: Financial Effects Scenario 4 (in case of an interest rate of 0%)

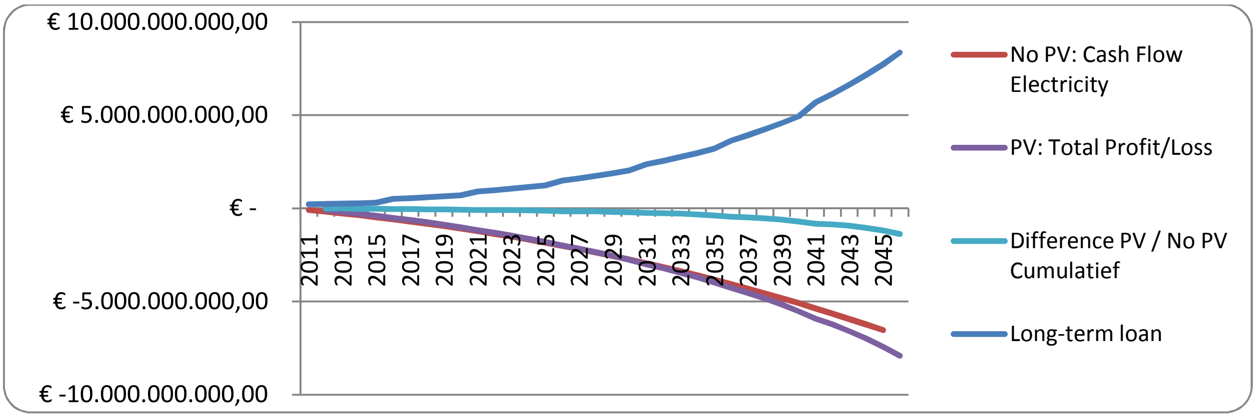

Figure 43: Financial Effects Scenario 4 (in case of an interest rate of 8%)

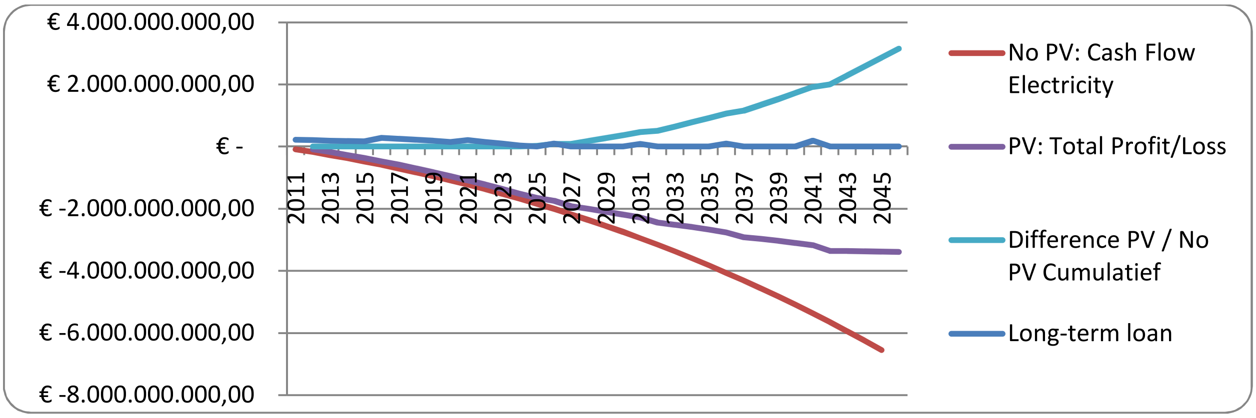

Figure 44: Financial Effects Scenario 6 (in case of an interest rate of 0%)

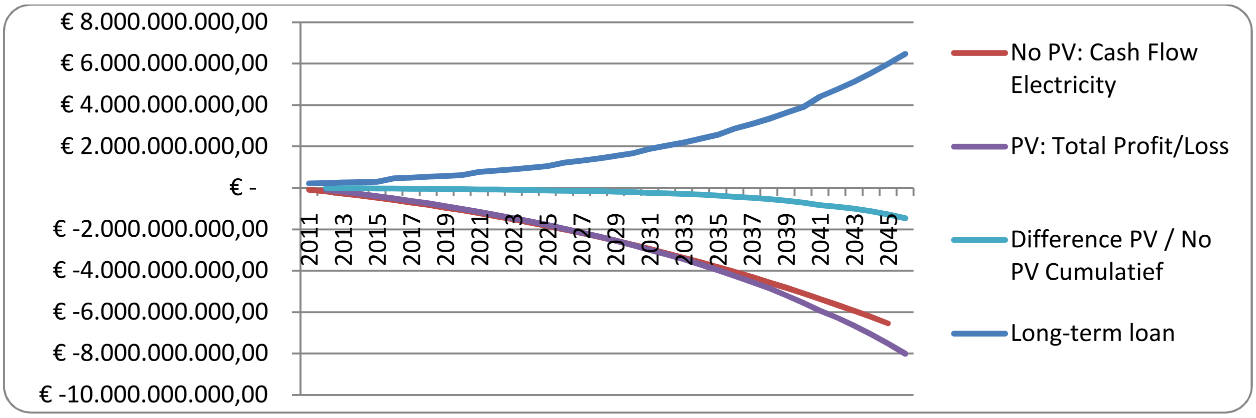

Figure 45: Financial Effects Scenario 6 (in case of an interest rate of 8%)

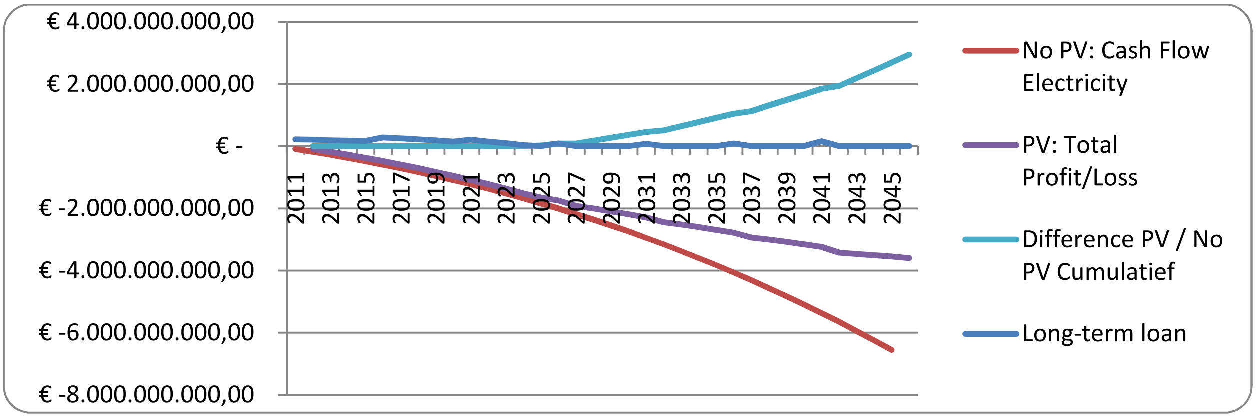

Figure 46: Financial Effects Scenario 7 (in case of an interest rate of 0%)

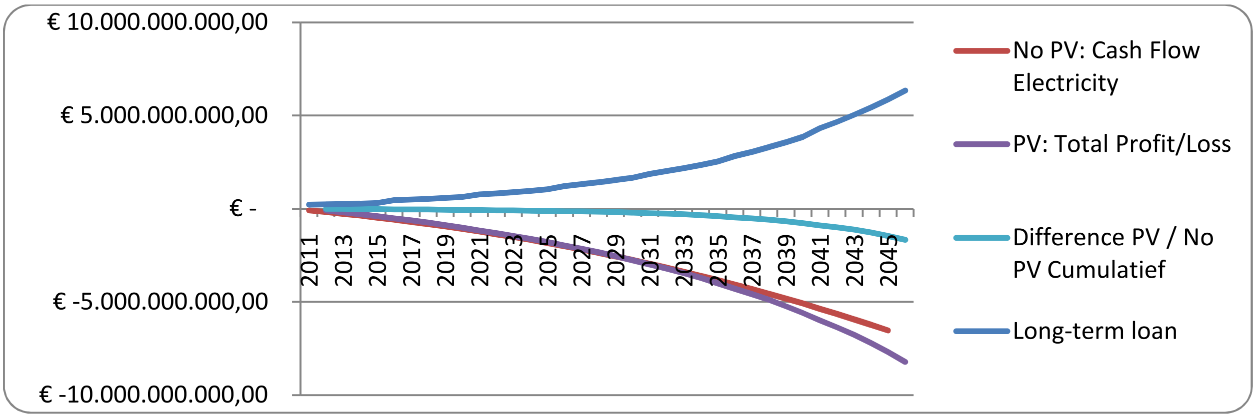

Figure 47: Financial Effects Scenario 7 (in case of an interest rate of 8%)

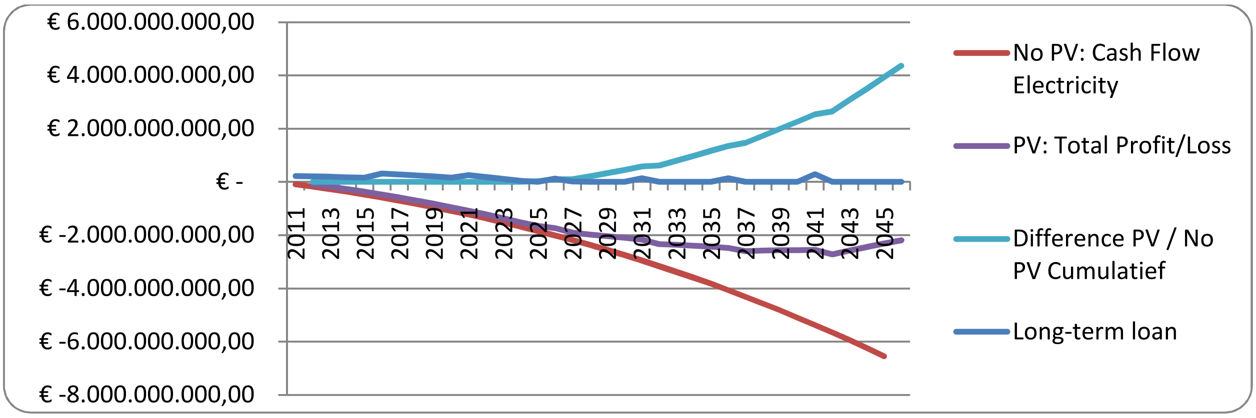

Figure 48: Financial Effects Scenario 8 (in case of an interest rate of 0%)

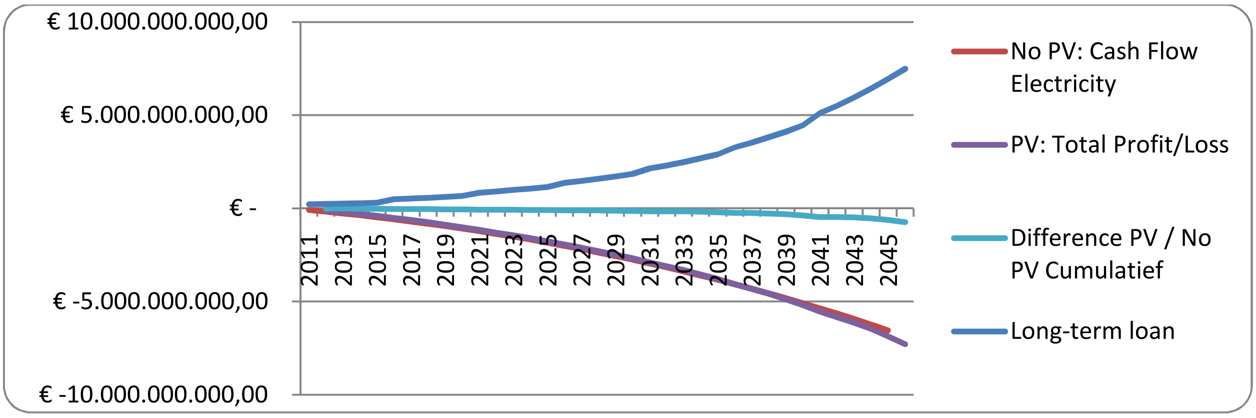

Figure 49: Financial Effects Scenario 8 (in case of an interest rate of 8%)

Appendix F

Table 69: Energy values 'Original State' Calculation Tool AgenschapNL

Example dwelling	*Average Gas Consumption*	*Average (installation) Electricity Consumption*	*Energy-Index*	*Energy Label*	*Total energy*
	(m^3 / year / dwelling)	*(kWh / year / dwelling)*	*EI*		*(Mega Joule / year / dwelling)*
Detached	6.053	1.030	3,74	G	253.641
Detached	5.452	1.127	3,06	G	225.336
Detached	3.364	1.195	2,00	D	145.653
Detached	2.093	2.018	1,34	C	105.520
Two-family	4.899	965	3,79	G	201.453
Two-family	4.453	1.043	3,28	G	183.942
Two-family	2.436	982	1,89	D	106.226
Two-family	1.576	1.580	1,34	C	79.589
Terraced (corner)	5.895	612	4,53	G	227.410
Terraced (corner)	4.190	522	3,64	G	164.835
Terraced (corner)	3.990	941	3,28	G	164.751
Terraced (corner)	2.182	865	1,91	D	94.948
Terraced (corner)	1.324	1.383	1,30	B	66.891
Terraced (Middle)	4.525	612	4,07	G	182.618
Terraced (Middle)	3.131	522	3,33	G	131.185
Terraced (Middle)	2.988	941	2,96	G	129.904
Terraced (Middle)	1.899	865	1,96	D	85.419
Terraced (Middle)	1.261	1.383	1,43	C	64.261
Duplex property	2.038	354	3,35	G	89.066
Duplex property	2.057	396	3,07	G	90.555
Duplex property	1.961	731	2,74	F	85.895
Duplex property	1.082	617	1,63	D	49.477
Portico	790	945	1,28	B	40.761
Portico	3.541	528	3,92	G	145.787
Portico	2.148	833	2,63	F	94.468
Portico	1.292	686	1,71	D	58.600
Portico	857	1.055	1,34	C	44.518
Other + Gallery	1.930	402	2,94	G	85.901
Other + Gallery	1.885	504	2,79	F	80.282
Other + Gallery	1.093	617	1,69	D	49.947
Other + Gallery	841	1.033	1,35	C	43.615

Table 70: Energy values 'Current State' Calculation Tool AgentschapNL

Example dwelling	*Average Gas Consumption*	*Average (installation) Electricity Consumption*	*Energy-Index*	*Energy Label*	*Total energy*
	(m^3 / year / dwelling)	*(kWh / year / dwelling)*	*EI*		*(Mega Joule / year / dwelling)*
Detached	4.731	1.103	2,96	G	201.179
Detached	4.110	1.207	2,42	F	177.897
Detached	2.616	1.282	1,63	D	118.880
Detached	1.882	2.018	1,22	B	96.624
Two-family	3.453	954	2,79	F	148.217
Two-family	3.046	1.051	2,38	E	133.274
Two-family	1.915	1.051	1,56	C	87.804
Two-family	1.497	1.580	1,29	B	76.169
Terraced (corner)	4.274	895	3,59	G	180.218
Terraced (corner)	2.948	783	2,79	F	126.078
Terraced (corner)	2.707	924	2,25	E	118.208
Terraced (corner)	1.740	924	1,59	C	79.208
Terraced (corner)	1.186	1.383	1,19	B	61.080
Terraced (Middle)	3.337	895	3,18	G	142.772
Terraced (Middle)	2.246	783	2,49	F	98.017
Terraced (Middle)	2.030	924	2,08	E	91.097
Terraced (Middle)	1.542	924	1,64	D	71.259
Terraced (Middle)	1.135	1.383	1,31	C	58.991
Duplex property	1.889	354	3,15	G	83.690
Duplex property	1.580	590	2,35	E	69.456
Duplex property	1.286	664	1,86	D	58.199
Duplex property	858	657	1,34	C	40.585
Portico	765	945	1,25	B	39.649
Portico	2.501	791	2,91	G	108.081
Portico	1.462	791	1,85	D	66.550
Portico	1.059	731	1,44	C	49.403
Portico	751	1.055	1,20	B	40.024
Other + Gallery	1.512	597	2,28	E	66.655
Other + Gallery	1.570	504	2,34	E	67.334
Other + Gallery	1.004	617	1,56	C	46.352
Other + Gallery	724	1.033	1,20	B	38.658

Table 71: Energy values 'Improvement Package 1' Calculation Tool AgentschapNL

Example dwelling	Average Gas Consumption	Average (installation) Electricity Consumption	Energy-Index	Energy Label	Total energy
	(m^3 / year / dwelling)	(kWh / year / dwelling)	EI		(Mega Joule / year / dwelling)
Detached	1.496	1.103	1,06	B	71.430
Detached	1.602	1.207	1,05	A	77.152
Detached	1.581	1.282	1,06	B	77.056
Detached	1.702	2.018	1,13	B	89.148
Two-family	1.194	954	1,08	B	57.518
Two-family	1.233	1.051	1,08	B	60.383
Two-family	1.234	1.051	1,07	B	60.220
Two-family	1.296	1.580	1,15	B	67.850
Terraced (corner)	1.143	895	1,09	B	35.879
Terraced (corner)	1.011	783	1,07	B	48.323
Terraced (corner)	1.106	924	1,07	B	53.803
Terraced (corner)	1.093	924	1,07	B	53.074
Terraced (corner)	1.127	1.383	1,14	B	58.672
Terraced (Middle)	1.106	895	1,19	B	53.110
Terraced (Middle)	953	783	1,17	B	45.890
Terraced (Middle)	1.050	924	1,18	B	51.491
Terraced (Middle)	1.037	924	1,17	B	50.749
Terraced (Middle)	1.077	1.383	1,26	B	56.585
Duplex property	565	575	1,05	A	27.895
Duplex property	612	627	1,04	A	30.496
Duplex property	645	664	1,03	A	32.269
Duplex property	634	657	1,04	A	31.488
Portico	663	945	1,11	B	39.649
Portico	789	791	1,06	B	39.219
Portico	741	791	1,04	A	37.372
Portico	753	731	1,08	B	37.018
Portico	717	1.055	1,16	B	38.626
Other + Gallery	601	634	1,03	A	30.053
Other + Gallery	883	504	1,36	C	39.012
Other + Gallery	624	657	1,05	A	31.091
Other + Gallery	701	1.033	1,17	B	37.736

Table 72: Energy values 'Improvement Package 2' Calculation Tool AgentschapNL

Example dwelling	*Average Gas Consumption*	*Average (installation) Electricity Consumption*	*Energy-Index*	*Energy Label*	*Total energy*
	(m^3 / year / dwelling)	*(kWh / year / dwelling)*	*EI*		*(Mega Joule / year / dwelling)*
Detached	1.319	-259	0,78	A	
Detached	1.426	-155	0,80	A	
Detached	1.401	-80	0,80	A	
Detached	1.521	656	0,89	A	
Two-family	1.017	-408	0,73	A	
Two-family	1.057	-311	0,75	A	
Two-family	1.057	-311	0,74	A	
Two-family	1.119	218	0,83	A	
Terraced (corner)	966	-467	0,72	A	
Terraced (corner)	848	-579	0,67	A	
Terraced (corner)	938	-438	0,71	A	
Terraced (corner)	925	-438	0,70	A	
Terraced (corner)	950	21	0,78	A	
Terraced (Middle)	929	-467	0,77	A	
Terraced (Middle)	789	-579	0,70	A	
Terraced (Middle)	882	-438	0,76	A	
Terraced (Middle)	869	-438	0,75	A	
Terraced (Middle)	900	21	0,84	A	
Duplex property	421	-333	0,55	A	
Duplex property	467	-281	0,58	A	
Duplex property	500	-244	0,60	A	
Duplex property	490	-251	0,60	A	
Portico	519	37	0,69	A	
Portico	625	-117	0,68	A	
Portico	577	-117	0,65	A	
Portico	590	-177	0,67	A	
Portico	553	147	0,74	A	
Other + Gallery	457	-274	0,57	A	
Other + Gallery	792	-401	0,96	A	
Other + Gallery	479	-251	0,60	A	
Other + Gallery	537	125	0,73	A	

Table 73: Technical Values example dwellings; roof, surface area, and crack sealing

Example dwelling	Roof type	Dwelling surface area	Crack sealing	Crack sealing
		(m^2)	*Current state*	*Improvement package (1 and 2)*
Detached	Sloping	130	No	Yes
Detached	Sloping	144	Yes	Yes
Detached	Sloping	154	Yes	Yes
Detached	Combi	172	Yes	Yes
Two-family	Combi	110	No	Yes
Two-family	Combi	123	No	Yes
Two-family	Combi	123	Yes	Yes
Two-family	Combi	132	Yes	Yes
Terraced (corner)	Combi	102	No	Yes
Terraced (corner)	Sloping	87	No	Yes
Terraced (corner)	Sloping	106	No	Yes
Terraced (corner)	Sloping	106	Yes	Yes
Terraced (corner)	Flat	114	Yes	Yes
Terraced (Middle)	Combi	102	No	No
Terraced (Middle)	Sloping	87	No	No
Terraced (Middle)	Sloping	106	No	No
Terraced (Middle)	Sloping	106	No	No
Terraced (Middle)	Flat	114	No	No
Duplex property	Sloping	88	No	Yes
Duplex property	Sloping	88	No	Yes
Duplex property	Sloping	80	Yes	Yes
Duplex property	Flat	84	Yes	Yes
Portico	Flat	59	No	Yes
Portico	Flat	66	No	Yes
Portico	Flat	71	No	Yes
Portico	Flat	70	Yes	Yes
Portico	Flat	74	Yes	Yes
Other + Gallery	Flat	67	No	Yes
Other + Gallery	Flat	77	No	Yes
Other + Gallery	Flat	70	Yes	Yes
Other + Gallery	Flat	82	Yes	Yes

Table 74: Technical Values example dwellings; floor surface area and isolation value

Example dwelling	Floor surface area	Floor surface area	Floor Isolation value	Floor Isolation value
	Total (m^2)	*Average (m^2)*	*Current state ($Rc*m^2K/W$)*	*Impovement package 1 ($Rc*m^2K/W$)*
Detached	93	93	0,32	2,53
Detached	101	101	0,17	2,53
Detached	95	95	0,52	2,53
Detached	104	104	2,53	2,53
Two-family	66	66	0,32	2,53
Two-family	60	60	0,17	2,53
Two-family	66	66	1,30	2,53
Two-family	67	67	2,53	2,53
Terraced (corner)	55	55	0,15	2,53
Terraced (corner)	47	47	0,32	2,53
Terraced (corner)	52	52	0,17	2,53
Terraced (corner)	51	51	0,52	2,53
Terraced (corner)	56	56	2,53	2,53
Terraced (Middle)	55	55	0,15	2,53
Terraced (Middle)	47	47	0,32	2,53
Terraced (Middle)	52	52	0,17	2,53
Terraced (Middle)	51	51	0,52	2,53
Terraced (Middle)	56	56	2,53	2,53
Duplex property	34	10,5	0,15	2,53
Duplex property	42	11,2	0,17	2,53
Duplex property	36	8,6	1,30	2,53
Duplex property	40	6,6	2,53	2,53
Portico	59	18,5	0,15	2,53
Portico	66	14,4	0,32	2,53
Portico	71	18	0,17	2,53
Portico	70	24	1,30	2,53
Portico	74	35,8	2,53	2,53
Other + Gallery	67	20	0,32	2,53
Other + Gallery	77	8,1	0,17	2,53
Other + Gallery	70	13,4	0,52	2,53
Other + Gallery	82	20,4	2,53	2,53

Table 75: Technical values example dwellings; roof area and isolation value

Example dwelling	Slop. roof area	Slop. roof area	Slop. roof Iso. value	Slop. roof Iso. value	Flat roof area	Flat roof area	Flat roof Iso. Value	Flat roof Iso. value
	Total (m^2)	*Av. (m^2)*	*Cur. state ($Rc*m^2K/W$)*	*Impr. Pack. ($Rc*m^2K/W$)*	*Total (m^2)*	*Av. (m^2)*	*Cur. state ($Rc*m^2K/W$)*	*Impr. Pack ($Rc*m^2K/W$)*
Detached	128	128	0,39	2,53				
Detached	121	121	0,86	2,53				
Detached	126	126	1,30	2,53				
Detached	121	121	2,53	2,53	17	17	2,53	2,53
Two-family	64	64	0,39	2,53	15	15	0,39	2,53
Two-family	65	65	0,86	2,53	14	14	0,86	2,53
Two-family	73	73	1,30	2,53	17	17	1,30	2,53
Two-family	74	74	2,53	2,53	16	16	2,53	2,53
Terraced (corner)	56	56	0,22	2,53	18	18	0,22	2,53
Terraced (corner)	57	57	0,39	2,53				
Terraced (corner)	65	65	0,86	2,53				
Terraced (corner)	69	69	1,30	2,53				
Terraced (corner)					56	56	2,53	2,53
Terraced (Middle)	56	56	0,22	2,53	18	18	0,22	2,53
Terraced (Middle)	57	57	0,39	2,53				
Terraced (Middle)	65	65	0,86	2,53				
Terraced (Middle)	69	69	1,30	2,53				
Terraced (Middle)					56	56	2,53	2,53
Duplex property	75	52,7	0,22	2,53				
Duplex property	79	48,7	0,86	2,53				
Duplex property	72	52,2	1,30	2,53				
Duplex property					52	27,3	2,53	2,53
Portico					63	8,9	0,22	2,53
Portico					72	19,4	0,39	2,53
Portico					75	21,2	0,86	2,53
Portico					82	18,9	1,30	2,53
Portico					82	13,1	2,53	2,53
Other + Gallery					71	13,6	0,39	2,53
Other + Gallery					82	7,8	0,86	2,53
Other + Gallery					75	23,7	1,30	2,53
Other + Gallery					88	15,3	2,53	2,53

Table 76: Technical Values example dwellings; Façade area and isolation value (1)

Example dwelling	Façade (total)	Façade (total)	Façade (Front/back)	Façade (Front/back)	Isolation value	Isolation value
	Area total (m^2)	*Area average (m^2)*	*Area total (m^2)*	*Area average (m^2)*	*Current state ($Rc*m^2K/W$)*	*Impr. Pack. ($Rc*m^2K/W$)*
Detached	137	137			0,36	2,35
Detached	165	165			0,43	2,53
Detached	144	144			1,30	2,53
Detached	151	151			2,53	2,53
Two-family	98	98			0,36	2,53
Two-family	105	105			0,43	2,53
Two-family	97	97			1,30	2,53
Two-family	109	109			2,53	2,53
Terraced (corner)			49	49	0,19	2,35
Terraced (corner)			42	42	0,36	2,53
Terraced (corner)			41	41	0,43	2,53
Terraced (corner)			41	41	1,30	2,53
Terraced (corner)			50	50	2,53	2,53
Terraced (Middle)			49	49	0,19	2,35
Terraced (Middle)			42	42	0,36	2,53
Terraced (Middle)			41	41	0,43	2,53
Terraced (Middle)			41	41	1,30	2,53
Terraced (Middle)			50	50	2,53	2,53
Duplex property			39	41,3	0,19	2,53
Duplex property			39	32,7	0,43	2,53
Duplex property			39	32,7	1,30	2,53
Duplex property			39	31,4	2,53	2,53
Portico			35	33,1	0,19	2,53
Portico			35	35,9	0,36	2,53
Portico			35	38,3	0,43	2,53
Portico			35	34,5	1,30	2,53
Portico			35	39,3	2,53	2,53
Other + Gallery			30	36,4	0,36	2,53
Other + Gallery			30	24,3	0,43	2,53
Other + Gallery			30	29,7	1,30	2,53
Other + Gallery			30	33,4	2,53	2,53

Table 77: Technical Values example dwellings; Façade area and isolation value (2)

Example dwelling	Façade (Side)	Façade (Side)	Isolation value	Isolation value
	Area total (m^2)	*Area average (m^2)*	*Current state ($Rc*m^2K/W$)*	*Impr. Pack. ($Rc*m^2K/W$)*
Detached			0,36	2,35
Detached			0,43	2,53
Detached			1,30	2,53
Detached			2,53	2,53
Two-family			0,36	2,53
Two-family			0,43	2,53
Two-family			1,30	2,53
Two-family			2,53	2,53
Terraced (corner)	49	49	0,19	2,35
Terraced (corner)	53	53	0,36	2,53
Terraced (corner)	58	58	0,43	2,53
Terraced (corner)	58	58	1,30	2,53
Terraced (corner)	59	59	2,53	2,53
Terraced (Middle)			0,19	2,35
Terraced (Middle)			0,36	2,53
Terraced (Middle)			0,43	2,53
Terraced (Middle)			1,30	2,53
Terraced (Middle)			2,53	2,53
Duplex property	35	9,2	0,19	2,53
Duplex property	35	9,7	0,43	2,53
Duplex property	35	8,8	1,30	2,53
Duplex property	35	19,3	2,53	2,53
Portico	23	3,4	0,19	2,53
Portico	23	6,8	0,36	2,53
Portico	23	9,3	0,43	2,53
Portico	23	8,6	1,30	2,53
Portico	23	8	2,53	2,53
Other + Gallery	26	7	0,36	2,53
Other + Gallery	26	10,1	0,43	2,53
Other + Gallery	26	9,7	1,30	2,53
Other + Gallery	26	12,4	2,53	2,53

Table 78: Technical Values example dwellings; Type of Window and area, front and back façade

Example dwelling	Single Glazing	Double Glazing	HR Glazing	Single Glazing	Double Glazing	HR Glazing
	Current state (m^2)	*Current state (m^2)*	*Current state (m^2)*	*Improvement Pack. (m^2)*	*Improvement Pack. (m^2)*	*Improvement Pack. (m^2)*
Detached	8,0	20,3				28,3
Detached	5,8	29,5				35,3
Detached	2,9	31,8				34,7
Detached		18,1	21,5			39,6
Two-family	6,5	19,5				26,0
Two-family	6,7	24,6				31,3
Two-family	3,4	23,0				26,4
Two-family		25,9	3,1			29,0
Terraced (corner)	6,9	14,2				21,1
Terraced (corner)	6,5	14,9				21,4
Terraced (corner)	4,3	21,3				25,6
Terraced (corner)	3,1	16,2				19,3
Terraced (corner)		7,0	14,8			21,8
Terraced (Middle)	6,9	14,2				21,1
Terraced (Middle)	6,5	14,9				21,4
Terraced (Middle)	4,3	21,3				25,6
Terraced (Middle)	3,1	16,2				19,3
Terraced (Middle)		7,0	14,8			21,8
Duplex property	8,4	10,5				18,9
Duplex property	4,2	14,7				18,9
Duplex property	2,7	11,9				14,6
Duplex property		2,8	14,2			17
Portico	5,6	8,0				13,6
Portico	2,9	14,7				17,6
Portico	1,3	16,8				18,1
Portico		12,5				12,5
Portico		14,6				14,6
Other + Gallery	2,8	12,0				14,8
Other + Gallery	4,6	13,6				18,2
Other + Gallery	1,1	12,4				13,5
Other + Gallery		0,3	16,6			16,9

Table 79: Technical Values example dwellings; Type of Window and area, side façade

Example dwelling	Single Glazing	Double Glazing	HR Glazing	Single Glazing	Double Glazing	HR Glazing
	Current state (m^2)	*Current state (m^2)*	*Current state (m^2)*	*Improvement Pack. (m^2)*	*Improvement Pack. (m^2)*	*Improvement Pack. (m^2)*
Detached						
Detached						
Detached						
Detached						
Two-family		4,6				
Two-family		4,6				
Two-family		4,6				
Two-family		4,6				
Terraced (corner)		1,8				1,8
Terraced (corner)		1,8				1,8
Terraced (corner)		1,8				1,8
Terraced (corner)		1,8				1,8
Terraced (corner)			1,8			1,8
Terraced (Middle)						
Terraced (Middle)						
Terraced (Middle)						
Terraced (Middle)						
Terraced (Middle)						
Duplex property		0,4				0,4
Duplex property		0,4				0,4
Duplex property		0,4				0,4
Duplex property			0,8			0,8
Portico		0,2				0,2
Portico		0,4				0,4
Portico		0,6				0,6
Portico		0,5				0,5
Portico		0,5				0,5
Other + Gallery		0,4				0,4
Other + Gallery		0,5				0,5
Other + Gallery		0,5				0,5
Other + Gallery			0,7			0,7

Table 80: Technical Values example dwellings; Door area and isolation value

Example dwelling	Door area (m^2)	Isolated	Isolation value ($Rc*m^2K/W$)	Ventilation system
		Current state / Improvement Package 1 and 2		
Detached	2,9	No	3,5	Natural
Detached	2,9	No	3,5	Natural
Detached	2,8	No	3,5	Natural
Detached	4,0	No	3,5	Mechanic
Two-family	2,3	No	3,5	Natural
Two-family	1,9	No	3,5	Natural
Two-family	1,9	No	3,5	Natural
Two-family	2,7	No	3,5	Mechanic
Terraced (corner)	2,5	No	3,5	Natural
Terraced (corner)	1,3	No	3,5	Natural
Terraced (corner)	1,6	No	3,5	Natural
Terraced (corner)	1,8	No	3,5	Natural
Terraced (corner)	2,3	No	3,5	Mechanic
Terraced (Middle)	2,5	No	3,5	Natural
Terraced (Middle)	1,3	No	3,5	Natural
Terraced (Middle)	1,6	No	3,5	Natural
Terraced (Middle)	1,8	No	3,5	Natural
Terraced (Middle)	2,3	No	3,5	Mechanic
Duplex property	2,3	No	3,5	Natural
Duplex property	2,3	No	3,5	Natural
Duplex property	2,3	No	3,5	Natural
Duplex property	2,2	No	3,5	Mechanic
Portico	2,6	No	3,5	Natural
Portico	2,1	No	3,5	Natural
Portico	2,5	No	3,5	Natural
Portico	2,2	No	3,5	Natural
Portico	2,4	No	3,5	Mechanic
Other + Gallery	2,1	No	3,5	Natural
Other + Gallery	2,1	No	3,5	Natural
Other + Gallery	2,2	No	3,5	Natural
Other + Gallery	2,4	No	3,5	Mechanic

Table 81: Technical Values example dwellings; Installation (heating system) and isolations

Example dwelling	Pipes in unheated space	Isolation of pipes	Installed heating system	Pipes in unheated space	Isolation of pipes	Installed installation
	Current State	*Current state*	*Current state*	*Improvement package*	*Improvement package*	*Improvement package*
Detached	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Detached	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Detached	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Detached	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Two-family	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Two-family	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Two-family	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Two-family	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (corner)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (corner)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (corner)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (corner)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (corner)	No	No	HR 107 ketel	No	No	HR 107 ketel
Terraced (Middle)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (Middle)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (Middle)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (Middle)	Yes	No	HR 107 ketel	Yes	Yes	HR 107 ketel
Terraced (Middle)	No	No	HR 107 ketel	No	No	HR 107 ketel
Duplex property	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel
Duplex property	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel
Duplex property	No	N/A	HR 107 ketel	Yes	Yes	HR 107 ketel
Duplex property	No	N/A	HR 107 ketel	Yes	Yes	HR 107 ketel
Portico	No	N/A	Local	No	N/A	HR 107 ketel
Portico	No	N/A	VR ketel	No	N/A	HR 107 ketel
Portico	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel
Portico	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel
Portico	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel
Other + Gallery	No	N/A	VR ketel	No	N/A	HR 107 ketel
Other + Gallery	No	N/A	Collectief	No	N/A	Collectieve HR 107 ketel
Other + Gallery	No	N/A	VR ketel	No	N/A	HR 107 ketel
Other + Gallery	No	N/A	HR 107 ketel	No	N/A	HR 107 ketel

Table 82: Technical Values example dwellings; Installation (water heating system) and isolations

Example dwelling	Water heating system	Presence of bath	Pipe length reduction	Water heating system	Presence of bath	Pipe length reduction
	Current State	*Current state*	*Current state*	*Improvement package*	*Improvement package*	*Improvement package*
Detached	Combitap HR	Yes	No	Combitap HR	Yes	No
Detached	Combitap HR	Yes	No	Combitap HR	Yes	No
Detached	Combitap HR	Yes	No	Combitap HR	Yes	No
Detached	Combitap HR	Yes	No	Combitap HR	Yes	No
Two-family	Combitap HR	Yes	No	Combitap HR	Yes	No
Two-family	Combitap HR	Yes	No	Combitap HR	Yes	No
Two-family	Combitap HR	Yes	No	Combitap HR	Yes	No
Two-family	Combitap HR	Yes	No	Combitap HR	Yes	No
Terraced (corner)	Combitap HR	Yes	No	Combitap HR	Yes	No
Terraced (corner)	Combitap HR	No	No	Combitap HR	No	No
Terraced (corner)	Combitap HR	No	No	Combitap HR	No	No
Terraced (corner)	Combitap HR	No	No	Combitap HR	No	No
Terraced (corner)	Combitap HR	Yes	No	Combitap HR	Yes	No
Terraced (Middle)	Combitap HR	Yes	No	Combitap HR	Yes	No
Terraced (Middle)	Combitap HR	No	No	Combitap HR	No	No
Terraced (Middle)	Combitap HR	No	No	Combitap HR	No	No
Terraced (Middle)	Combitap HR	No	No	Combitap HR	No	No
Terraced (Middle)	Combitap HR	Yes	No	Combitap HR	Yes	No
Duplex property	Combitap HR	No	No	Combitap HR	No	No
Duplex property	Combitap HR	No	Yes	Combitap HR	No	Yes
Duplex property	Combitap HR	No	No	Combitap HR	No	No
Duplex property	Combitap HR	No	No	Combitap HR	No	No
Portico	Keuken geiser	No	Yes	Combitap HR	No	Yes
Portico	Combitap VR	No	Yes	Combitap HR	No	Yes
Portico	Combitap HR	No	Yes	Combitap HR	No	Yes
Portico	Combitap HR	No	No	Combitap HR	No	No
Portico	Combitap HR	No	No	Combitap HR	No	No
Other + Gallery	Combitap VR	No	Yes	Combitap HR	No	Yes
Other + Gallery	Collectief	No	No	Collectief	No	No
Other + Gallery	Combitap VR	No	No	Combitap HR	No	No
Other + Gallery	Combitap HR	No	No	Combitap HR	No	No

Table 83: Technical values example dwellings; Improvement package 2

Example dwelling	Solar Boiler			PV system (First generation technology)		
	Surface area	*Orientation*	*Angle of pitch*	*Surface area*	*Orientation*	*Angle of pitch*
Detached	2,7	South	45 degree	15	South	45 degree
Detached	2,7	South	45 degree	15	South	45 degree
Detached	2,7	South	45 degree	15	South	45 degree
Detached	2,7	South	45 degree	15	South	45 degree
Two-family	2,7	South	45 degree	15	South	45 degree
Two-family	2,7	South	45 degree	15	South	45 degree
Two-family	2,7	South	45 degree	15	South	45 degree
Two-family	2,7	South	45 degree	15	South	45 degree
Terraced (corner)	2,7	South	45 degree	15	South	45 degree
Terraced (corner)	2,7	South	45 degree	15	South	45 degree
Terraced (corner)	2,7	South	45 degree	15	South	45 degree
Terraced (corner)	2,7	South	45 degree	15	South	45 degree
Terraced (corner)	2,7	South	45 degree	15	South	45 degree
Terraced (Middle)	2,7	South	45 degree	15	South	45 degree
Terraced (Middle)	2,7	South	45 degree	15	South	45 degree
Terraced (Middle)	2,7	South	45 degree	15	South	45 degree
Terraced (Middle)	2,7	South	45 degree	15	South	45 degree
Terraced (Middle)	2,7	South	45 degree	15	South	45 degree
Duplex property	2,7	South	45 degree	10	South	45 degree
Duplex property	2,7	South	45 degree	10	South	45 degree
Duplex property	2,7	South	45 degree	10	South	45 degree
Duplex property	2,7	South	45 degree	10	South	45 degree
Portico	2,7	South	45 degree	10	South	45 degree
Portico	2,7	South	45 degree	10	South	45 degree
Portico	2,7	South	45 degree	10	South	45 degree
Portico	2,7	South	45 degree	10	South	45 degree
Portico	2,7	South	45 degree	10	South	45 degree
Other + Gallery	2,7	South	45 degree	10	South	45 degree
Other + Gallery	2	South	45 degree	10	South	45 degree
Other + Gallery	2,7	South	45 degree	10	South	45 degree
Other + Gallery	2,7	South	45 degree	10	South	45 degree

Table 84: Investment costs floor improvements on project and individual base

Example dwelling	*Area*	*Current state*	*Improvement Package*	*Investment costs Project base*		*Investment costs Individually base*	
	(m²)	*Rc*	*Rc*	*€ / m²*	*Total*	*€ / m²*	*Total*
Detached	93,0	0,32	2,53	20	€ 1.860	22	€ 2.046
Detached	101,0	0,17	2,53	20	€ 2.020	22	€ 2.222
Detached	95,0	0,52	2,53	20	€ 1.900	22	€ 2.090
Detached	104,0	2,53	2,53		€ -		€ -
Two-family	66,0	0,32	2,53	20	€ 1.320	22	€ 1.452
Two-family	60,0	0,17	2,53	20	€ 1.200	22	€ 1.320
Two-family	66,0	1,30	2,53	20	€ 1.320	22	€ 1.452
Two-family	67,0	2,53	2,53		€ -		€ -
Terraced (corner)	55,0	0,15	2,53	20	€ 1.100	22	€ 1.210
Terraced (corner)	47,0	0,32	2,53	20	€ 940	22	€ 1.034
Terraced (corner)	52,0	0,17	2,53	20	€ 1.040	22	€ 1.144
Terraced (corner)	51,0	0,52	2,53	20	€ 1.020	22	€ 1.122
Terraced (corner)	56,0	2,53	2,53		€ -		€ -
Terraced (Middle)	55,0	0,15	2,53	20	€ 1.100	22	€ 1.210
Terraced (Middle)	47,0	0,32	2,53	20	€ 940	22	€ 1.034
Terraced (Middle)	52,0	0,17	2,53	20	€ 1.040	22	€ 1.144
Terraced (Middle)	51,0	0,52	2,53	20	€ 1.020	22	€ 1.122
Terraced (Middle)	56,0	2,53	2,53		€ -		€ -
Duplex property	18,5	0,15	2,53	20	€ 370	22	€ 407
Duplex property	14,4	0,32	2,53	20	€ 288	22	€ 317
Duplex property	18,0	0,17	2,53	20	€ 360	22	€ 396
Duplex property	24,0	1,30	2,53	20	€ 480	22	€ 528
Portico	35,8	2,53	2,53		€ -		€ -
Portico	10,5	0,15	2,53	20	€ 210	22	€ 231
Portico	11,2	0,17	2,53	20	€ 224	22	€ 246
Portico	8,6	1,30	2,53	20	€ 172	22	€ 189
Portico	6,6	2,53	2,53	20	€ -	22	€ -
Other + Gallery	20,0	0,32	2,53	20	€ 400	22	€ 440
Other + Gallery	8,1	0,17	2,53	20	€ 162	22	€ 178
Other + Gallery	13,4	0,52	2,53	20	€ 268	22	€ 295
Other + Gallery	20,4	2,53	2,53		€ -		€ -

Table 85: Investment costs flat roof improvements on project and individual base

Example dwelling	*Area*	*Current state*	*Improvement Package*	*Investment costs Project base*		*Investment costs Individually base*	
	(m²)	*Rc*	*Rc*	*€ / m²*	*Total*	*€ / m²*	*Total*
Detached	0			193	€ -	198	€ -
Detached	0			193	€ -	198	€ -
Detached	0			193	€ -	198	€ -
Detached	17,4	2,53	2,53	193	€ -	198	€ -
Two-family	15,4	0,39	2,53	193	€ 2.972	198	€ 3.049
Two-family	14	0,86	2,53	193	€ 2.702	198	€ 2.772
Two-family	16,9	1,30	2,53	193	€ 3.262	198	€ 3.346
Two-family	16,4	2,53	2,53	193	€ -	198	€ -
Terraced (corner)	17,7	0,22	2,53	193	€ 3.416	198	€ 3.505
Terraced (corner)	0			193	€ -	198	€ -
Terraced (corner)	0			193	€ -	198	€ -
Terraced (corner)	0			193	€ -	198	€ -
Terraced (corner)	56,1	2,53	2,53	193	€ -	198	€ -
Terraced (Middle)	17,7	0,22	2,53	193	€ 3.416	198	€ 3.505
Terraced (Middle)	0			193	€ -	198	€ -
Terraced (Middle)	0			193	€ -	198	€ -
Terraced (Middle)	0			193	€ -	198	€ -
Terraced (Middle)	56,1	2,53	2,53	193	€ -	198	€ -
Duplex property	8,9	0,22	2,53	193	€ 1.718	198	€ 1.762
Duplex property	19,4	0,39	2,53	193	€ 3.744	198	€ 3.841
Duplex property	21,2	0,86	2,53	193	€ 4.092	198	€ 4.198
Duplex property	18,9	1,30	2,53	193	€ 3.648	198	€ 3.742
Portico	13,1	2,53	2,53	193	€ -	198	€ -
Portico	0			193	€ -	198	€ -
Portico	0			193	€ -	198	€ -
Portico	0			193	€ -	198	€ -
Portico	27,3	2,53	2,53	193	€ -	198	€ -
Other + Gallery	13,6	0,39	2,53	193	€ 2.625	198	€ 2.693
Other + Gallery	7,8	0,86	2,53	193	€ 1.505	198	€ 1.544
Other + Gallery	23,7	1,30	2,53	193	€ 4.574	198	€ 4.693
Other + Gallery	15,3	2,53	2,53	193	€ -	198	€ -

Table 86: Investment costs sloping roof improvements on project and individual base

Example dwelling	Area	Current state	Improvement Package	Investment costs Project base		Investment costs Individually base	
	(m²)	*Rc*	*Rc*	*€ / m²*	*Total*	*€ / m²*	*Total*
Detached	121	0,86	2,53	53	€ 6.397	57	€ 6.880
Detached	126	1,30	2,53	53	€ 6.657	57	€ 7.159
Detached	121	2,53	2,53	53	€ -	57	€ -
Detached	63,7	0,39	2,53	53	€ 3.376	57	€ 3.631
Two-family	65,2	0,86	2,53	53	€ 3.456	57	€ 3.716
Two-family	73,4	1,30	2,53	53	€ 3.890	57	€ 4.184
Two-family	74,2	2,53	2,53	53	€ -	57	€ -
Two-family	55,9	0,22	2,53	53	€ 2.963	57	€ 3.186
Terraced (corner)	57,3	0,39	2,53	53	€ 3.037	57	€ 3.266
Terraced (corner)	65,5	0,86	2,53	53	€ 3.472	57	€ 3.734
Terraced (corner)	68,6	1,30	2,53	53	€ 3.636	57	€ 3.910
Terraced (corner)	0			53	€ -	57	€ -
Terraced (corner)	55,9	0,22	2,53	53	€ 2.963	57	€ 3.186
Terraced (Middle)	57,3	0,39	2,53	53	€ 3.037	57	€ 3.266
Terraced (Middle)	65,5	0,86	2,53	53	€ 3.472	57	€ 3.734
Terraced (Middle)	68,6	1,30	2,53	53	€ 3.636	57	€ 3.910
Terraced (Middle)				53	€ -	57	€ -
Terraced (Middle)	0			53	€ -	57	€ -
Duplex property	0			53	€ -	57	€ -
Duplex property	0			53	€ -	57	€ -
Duplex property	0			53	€ -	57	€ -
Duplex property	0			53	€ -	57	€ -
Portico	52,7	0,22	2,53	53	€ 2.793	57	€ 3.004
Portico	48,7	0,86	2,53	53	€ 2.581	57	€ 2.776
Portico	52,2	1,30	2,53	53	€ 2.767	57	€ 2.975
Portico	0			53	€ -	57	€ -
Portico	0			53	€ -	57	€ -
Other + Gallery	0			53	€ -	57	€ -
Other + Gallery	0			53	€ -	57	€ -
Other + Gallery	0			53	€ -	57	€ -
Other + Gallery	0			53	€ -	57	€ -

Table 87: Investment costs closed front and back façade improvements

Example dwelling	Area	Current state	Improvement Package	Investment costs Project base		Investment costs Individually base	
	(m^2)	Rc	Rc	€ / m^2	Total	€ / m^2	Total
Detached	136,7	0,36	2,35	21	€ 2.871	23	€ 3.144
Detached	164,7	0,43	2,53	21	€ 3.459	23	€ 3.788
Detached	144	1,30	2,53	21	€ 3.024	23	€ 3.312
Detached	150,9	2,53	2,53	21	€ -	23	€ -
Two-family	97,8	0,36	2,53	21	€ 2.054	23	€ 2.249
Two-family	104,7	0,43	2,53	21	€ 2.199	23	€ 2.408
Two-family	96,6	1,30	2,53	21	€ 2.029	23	€ 2.222
Two-family	108,5	2,53	2,53	21	€ -	23	€ -
Terraced (corner)	49	0,19	2,35	21	€ 1.029	23	€ 1.127
Terraced (corner)	42,3	0,36	2,53	21	€ 888	23	€ 973
Terraced (corner)	40,5	0,43	2,53	21	€ 851	23	€ 932
Terraced (corner)	40,6	1,30	2,53	21	€ 853	23	€ 934
Terraced (corner)	49,9	2,53	2,53	21	€ -	23	€ -
Terraced (Middle)	49	0,19	2,35	21	€ 1.029	23	€ 1.127
Terraced (Middle)	42,3	0,36	2,53	21	€ 888	23	€ 973
Terraced (Middle)	40,5	0,43	2,53	21	€ 851	23	€ 932
Terraced (Middle)	40,6	1,30	2,53	21	€ 853	23	€ 934
Terraced (Middle)	49,9	2,53	2,53	21	€ -	23	€ -
Duplex property	33,1	0,19	2,53	19	€ 629	21	€ 695
Duplex property	35,9	0,36	2,53	19	€ 682	21	€ 754
Duplex property	38,3	0,43	2,53	19	€ 728	21	€ 804
Duplex property	34,5	1,30	2,53	19	€ 656	21	€ 725
Portico	39,3	2,53	2,53	19	€ -	21	€ -
Portico	41,3	0,19	2,53	19	€ 785	21	€ 867
Portico	32,7	0,43	2,53	19	€ 621	21	€ 687
Portico	32,7	1,30	2,53	19	€ 621	21	€ 687
Portico	31,4	2,53	2,53	19	€ -	21	€ -
Other + Gallery	36,4	0,36	2,53	19	€ 692	21	€ 764
Other + Gallery	24,3	0,43	2,53	19	€ 462	21	€ 510
Other + Gallery	29,7	1,30	2,53	19	€ 564	21	€ 624
Other + Gallery	33,4	2,53	2,53	19	€ -	21	€ -

Table 88: Investment costs open front and back façade improvements (1)

Example dwelling	*Façade single glazing*				*Façade double glazing*				*Façade HR glazing*			
	ZTA	*Curr. state (m^2)*	*Impr. Pack. (m^2)*	*U-value*	*ZTA*	*Curr. state (m^2)*	*Impr. Pack. (m^2)*	*U-value*	*ZTA*	*Curr. state (m^2)*	*Impr. Pack. (m^2)*	*U-value*
Detached	0,8	8,0	0,0	5,20	0,7	20,3	0,0	2,90	0,6	0,0	28,3	1,80
Detached	0,8	5,8	0,0	5,20	0,7	29,5	0,0	2,90	0,6	0,0	35,3	1,80
Detached	0,8	2,9	0,0	5,20	0,7	31,8	0,0	2,90	0,6	0,0	34,7	1,80
Detached	0,8	0,0	0,0	5,20	0,7	18,1	0,0	2,90	0,6	21,5	39,6	1,80
Two-family	0,8	6,5	0,0	5,20	0,7	19,5	0,0	2,90	0,6	0,0	26,0	1,80
Two-family	0,8	6,7	0,0	5,20	0,7	24,6	0,0	2,90	0,6	0,0	31,3	1,80
Two-family	0,8	3,4	0,0	5,20	0,7	23,0	0,0	2,90	0,6	0,0	26,4	1,80
Two-family	0,8	0,0	0,0	5,20	0,7	25,9	0,0	2,90	0,6	3,1	29,0	1,80
Terraced (corner)	0,8	6,9	0,0	5,20	0,7	14,2	0,0	2,90	0,6	0,0	21,1	1,80
Terraced (corner)	0,8	6,5	0,0	5,20	0,7	14,9	0,0	2,90	0,6	0,0	21,4	1,80
Terraced (corner)	0,8	4,3	0,0	5,20	0,7	21,3	0,0	2,90	0,6	0,0	25,6	1,80
Terraced (corner)	0,8	3,1	0,0	5,20	0,7	16,2	0,0	2,90	0,6	0,0	19,3	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	7,0	0,0	2,90	0,6	14,8	21,8	1,80
Terraced (Middle)	0,8	6,9	0,0	5,20	0,7	14,2	0,0	2,90	0,6	0,0	21,1	1,80
Terraced (Middle)	0,8	6,5	0,0	5,20	0,7	14,9	0,0	2,90	0,6	0,0	21,4	1,80
Terraced (Middle)	0,8	4,3	0,0	5,20	0,7	21,3	0,0	2,90	0,6	0,0	25,6	1,80
Terraced (Middle)	0,8	3,1	0,0	5,20	0,7	16,2	0,0	2,90	0,6	0,0	19,3	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	7,0	0,0	2,90	0,6	14,8	21,8	1,80
Duplex property	0,8	5,6	0,0	5,20	0,7	8,0	0,0	2,90	0,6	0,0	13,6	1,80
Duplex property	0,8	2,9	0,0	5,20	0,7	14,7	0,0	2,90	0,6	0,0	17,6	1,80
Duplex property	0,8	1,3	0,0	5,20	0,7	16,8	0,0	2,90	0,6	0,0	18,1	1,80
Duplex property	0,8	0,0	0,0	5,20	0,7	12,5	0,0	2,90	0,6	0,0	12,5	1,80
Portico	0,8	0,0	0,0	5,20	0,7	14,6	0,0	2,90	0,6	0,0	14,6	1,80
Portico	0,8	8,4	0,0	5,20	0,7	10,5	0,0	2,90	0,6	0,0	18,9	1,80
Portico	0,8	4,2	0,0	5,20	0,7	14,7	0,0	2,90	0,6	0,0	18,9	1,80
Portico	0,8	2,7	0,0	5,20	0,7	11,9	0,0	2,90	0,6	0,0	14,6	1,80
Portico	0,8	0,0	0,0	5,20	0,7	2,8	0,0	2,90	0,6	14,2	17,0	1,80
Other + Gallery	0,8	2,8	0,0	5,20	0,7	12,0	0,0	2,90	0,6	0,0	14,8	1,80
Other + Gallery	0,8	4,6	0,0	5,20	0,7	13,6	0,0	2,90	0,6	0,0	18,2	1,80
Other + Gallery	0,8	1,1	0,0	5,20	0,7	12,4	0,0	2,90	0,6	0,0	13,5	1,80
Other + Gallery	0,8	0,3	0,0	5,20	0,7	0,0	0,0	2,90	0,6	16,6	16,9	1,80

Table 89: Investment costs open façade improvements (2)

Example dwelling	***Façade glazing investment cost Project base***			***Façade glazing investment cost Individual base***		
	From single to HR glazing	*From double to HR glazing*	*Total costs*	*From single to HR glazing*	*From double to HR glazing*	*Total costs*
Detached	€ 139	€ 142	€ 3.995	€ 174	€ 178	€ 5.005
Detached	€ 139	€ 142	€ 4.995	€ 174	€ 178	€ 6.260
Detached	€ 139	€ 142	€ 4.919	€ 174	€ 178	€ 6.165
Detached	€ 139	€ 142	€ 2.570	€ 174	€ 178	€ 3.222
Two-family	€ 139	€ 142	€ 3.673	€ 174	€ 178	€ 4.602
Two-family	€ 139	€ 142	€ 4.425	€ 174	€ 178	€ 5.545
Two-family	€ 139	€ 142	€ 3.739	€ 174	€ 178	€ 4.686
Two-family	€ 139	€ 142	€ 3.678	€ 174	€ 178	€ 4.610
Terraced (corner)	€ 139	€ 142	€ 2.976	€ 174	€ 178	€ 3.728
Terraced (corner)	€ 139	€ 142	€ 3.019	€ 174	€ 178	€ 3.783
Terraced (corner)	€ 139	€ 142	€ 3.622	€ 174	€ 178	€ 4.540
Terraced (corner)	€ 139	€ 142	€ 2.731	€ 174	€ 178	€ 3.423
Terraced (corner)	€ 139	€ 142	€ 994	€ 174	€ 178	€ 1.246
Terraced (Middle)	€ 139	€ 142	€ 2.976	€ 174	€ 178	€ 3.728
Terraced (Middle)	€ 139	€ 142	€ 3.019	€ 174	€ 178	€ 3.783
Terraced (Middle)	€ 139	€ 142	€ 3.622	€ 174	€ 178	€ 4.540
Terraced (Middle)	€ 139	€ 142	€ 2.731	€ 174	€ 178	€ 3.423
Terraced (Middle)	€ 139	€ 142	€ 994	€ 174	€ 178	€ 1.246
Duplex property	€ 160	€ 164	€ 2.208	€ 183	€ 186	€ 2.513
Duplex property	€ 160	€ 164	€ 2.875	€ 183	€ 186	€ 3.265
Duplex property	€ 160	€ 164	€ 2.963	€ 183	€ 186	€ 3.363
Duplex property	€ 160	€ 164	€ 2.050	€ 183	€ 186	€ 2.325
Portico	€ 160	€ 164	€ 2.394	€ 183	€ 186	€ 2.716
Portico	€ 160	€ 164	€ 3.066	€ 183	€ 186	€ 3.490
Portico	€ 160	€ 164	€ 3.083	€ 183	€ 186	€ 3.503
Portico	€ 160	€ 164	€ 2.384	€ 183	€ 186	€ 2.708
Portico	€ 160	€ 164	€ 459	€ 183	€ 186	€ 521
Other + Gallery	€ 160	€ 164	€ 2.416	€ 183	€ 186	€ 2.744
Other + Gallery	€ 160	€ 164	€ 2.966	€ 183	€ 186	€ 3.371
Other + Gallery	€ 160	€ 164	€ 2.210	€ 183	€ 186	€ 2.508
Other + Gallery	€ 160	€ 164	€ 48	€ 183	€ 186	€ 55

Table 90 Investment costs closed side façade improvements on project and individual base

Example dwelling	*Area*	*Current state*	*Improvement Package*	*Investment costs Project base*		*Investment costs Individually base*	
	(m²)	*Rc*	*Rc*	*€ / m²*	*Total*	*€ / m²*	*Total*
Detached	0	0,36	2,35	21	€ -	23	€ -
Detached	0	0,43	2,53	21	€ -	23	€ -
Detached	0	1,30	2,53	21	€ -	23	€ -
Detached	0	2,53	2,53	21	€ -	23	€ -
Two-family	0	0,36	2,53	21	€ -	23	€ -
Two-family	0	0,43	2,53	21	€ -	23	€ -
Two-family	0	1,30	2,53	21	€ -	23	€ -
Two-family	0	2,53	2,53	21	€ -	23	€ -
Terraced (corner)	48,8	0,19	2,35	21	€ 1.025	23	€ 1.122
Terraced (corner)	53,0	0,36	2,53	21	€ 1.113	23	€ 1.219
Terraced (corner)	58,3	0,43	2,53	21	€ 1.224	23	€ 1.341
Terraced (corner)	58,3	1,30	2,53	21	€ 1.224	23	€ 1.341
Terraced (corner)	59,3	2,53	2,53	21	€ -	23	€ -
Terraced (Middle)	0	0,19	2,35	21	€ -	23	€ -
Terraced (Middle)	0	0,36	2,53	21	€ -	23	€ -
Terraced (Middle)	0	0,43	2,53	21	€ -	23	€ -
Terraced (Middle)	0	1,30	2,53	21	€ -	23	€ -
Terraced (Middle)	0	2,53	2,53	21	€ -	23	€ -
Duplex property	3,4	0,19	2,53	19	€ 65	21	€ 71
Duplex property	6,8	0,36	2,53	19	€ 129	21	€ 143
Duplex property	9,3	0,43	2,53	19	€ 177	21	€ 195
Duplex property	8,6	1,30	2,53	19	€ 163	21	€ 181
Portico	8,0	2,53	2,53	19	€ -	21	€ -
Portico	9,2	0,19	2,53	19	€ 175	21	€ 193
Portico	9,7	0,43	2,53	19	€ 184	21	€ 204
Portico	8,8	1,30	2,53	19	€ 167	21	€ 185
Portico	19,3	2,53	2,53	19	€ -	21	€ -
Other + Gallery	7	0,36	2,53	19	€ 133	21	€ 147
Other + Gallery	10,1	0,43	2,53	19	€ 192	21	€ 212
Other + Gallery	9,7	1,30	2,53	19	€ 184	21	€ 204
Other + Gallery	12,4	2,53	2,53	19	€ -	21	€ -

Table 91: Investment costs open side façade improvements on project and individual base (1)

Example dwelling	Façade single glazing				Façade double glazing				Façade HR glazing			
	ZTA	Curr. state (m^2)	Impr. Pack. (m^2)	U-value	ZTA	Curr. state (m^2)	Impr. Pack. (m^2)	U-value	ZTA	Curr. state (m^2)	Impr. Pack. (m^2)	U-value
Detached	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Detached	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Detached	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Detached	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Two-family	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Two-family	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Two-family	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Two-family	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	1,8	0,0	2,90	0,6	0,0	1,8	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	1,8	0,0	2,90	0,6	0,0	1,8	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	1,8	0,0	2,90	0,6	0,0	1,8	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	1,8	0,0	2,90	0,6	0,0	1,8	1,80
Terraced (corner)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	1,8	1,8	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Terraced (Middle)	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,0	0,0	1,80
Duplex property	0,8	0,0	0,0	5,20	0,7	0,2	0,0	2,90	0,6	0,0	0,2	1,80
Duplex property	0,8	0,0	0,0	5,20	0,7	0,4	0,0	2,90	0,6	0,0	0,4	1,80
Duplex property	0,8	0,0	0,0	5,20	0,7	0,6	0,0	2,90	0,6	0,0	0,6	1,80
Duplex property	0,8	0,0	0,0	5,20	0,7	0,5	0,0	2,90	0,6	0,0	0,5	1,80
Portico	0,8	0,0	0,0	5,20	0,7	0,5	0,0	2,90	0,6	0,0	0,5	1,80
Portico	0,8	0,0	0,0	5,20	0,7	0,4	0,0	2,90	0,6	0,0	0,4	1,80
Portico	0,8	0,0	0,0	5,20	0,7	0,4	0,0	2,90	0,6	0,0	0,4	1,80
Portico	0,8	0,0	0,0	5,20	0,7	0,4	0,0	2,90	0,6	0,0	0,4	1,80
Portico	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,8	0,8	1,80
Other + Gallery	0,8	0,0	0,0	5,20	0,7	0,4	0,0	2,90	0,6	0,0	0,4	1,80
Other + Gallery	0,8	0,0	0,0	5,20	0,7	0,5	0,0	2,90	0,6	0,0	0,4	1,80
Other + Gallery	0,8	0,0	0,0	5,20	0,7	0,5	0,0	2,90	0,6	0,0	0,4	1,80
Other + Gallery	0,8	0,0	0,0	5,20	0,7	0,0	0,0	2,90	0,6	0,7	0,7	1,80

Table 92: Investment costs open side façade improvements on project and individual base (2)

Example dwelling	*Façade glazing investment cost Project base*			*Façade glazing investment cost Individual base*		
	From single to HR glazing	*From double to HR glazing*	*Total costs*	*From single to HR glazing*	*From double to HR glazing*	*Total costs*
Detached	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Detached	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Detached	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Detached	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Two-family	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Two-family	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Two-family	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Two-family	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (corner)	€ 139	€ 142	€ 256	€ 174	€ 178	€ 320
Terraced (corner)	€ 139	€ 142	€ 256	€ 174	€ 178	€ 320
Terraced (corner)	€ 139	€ 142	€ 256	€ 174	€ 178	€ 320
Terraced (corner)	€ 139	€ 142	€ 256	€ 174	€ 178	€ 320
Terraced (corner)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (Middle)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (Middle)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (Middle)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (Middle)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Terraced (Middle)	€ 139	€ 142	€ -	€ 174	€ 178	€ -
Duplex property	€ 160	€ 164	€ 33	€ 183	€ 186	€ 37
Duplex property	€ 160	€ 164	€ 66	€ 183	€ 186	€ 74
Duplex property	€ 160	€ 164	€ 98	€ 183	€ 186	€ 112
Duplex property	€ 160	€ 164	€ 82	€ 183	€ 186	€ 93
Portico	€ 160	€ 164	€ 82	€ 183	€ 186	€ 93
Portico	€ 160	€ 164	€ 66	€ 183	€ 186	€ 74
Portico	€ 160	€ 164	€ 66	€ 183	€ 186	€ 74
Portico	€ 160	€ 164	€ 66	€ 183	€ 186	€ 74
Portico	€ 160	€ 164	€ -	€ 183	€ 186	€ -
Other + Gallery	€ 160	€ 164	€ 66	€ 183	€ 186	€ 74
Other + Gallery	€ 160	€ 164	€ 82	€ 183	€ 186	€ 93
Other + Gallery	€ 160	€ 164	€ 82	€ 183	€ 186	€ 93
Other + Gallery	€ 160	€ 164	€ -	€ 183	€ 186	€ -

Table 93: Investment costs heating system improvements on project and individual base

Example dwelling	*Type*	*Current state*	*Improvement Package*	*Investment costs Project base*	*Investment costs Individually base*
	Individual / collective	*Type of system*	*Type of system*	*(€ / system)*	*(€ / system)*
Detached	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Detached	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Detached	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Detached	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Two-family	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Two-family	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Two-family	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Two-family	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (corner)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (corner)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (corner)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (corner)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (corner)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (Middle)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (Middle)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (Middle)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (Middle)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Terraced (Middle)	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Duplex property	Individual	Local gas or oil	HR 107 ketel	€ 8.361	€ 8.387
Duplex property	Individual	VR ketel	HR 107 ketel	€ 2.534	€ 2.617
Duplex property	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Duplex property	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Portico	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Portico	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Portico	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Portico	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Portico	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -
Other + Gallery	Individual	VR ketel	HR 107 ketel	€ 2.534	€ 2.617
Other + Gallery	Collective	Coll. VR ketel	Coll. HR 107 ketel	€ 1.480	€ -
Other + Gallery	Individual	VR ketel	HR 107 ketel	€ 2.534	€ 2.617
Other + Gallery	Individual	HR 107 ketel	HR 107 ketel	€ -	€ -

Table 94: Investment costs water heating system improvements on project and individual base

Example dwelling	*Type*	*Current state*	*Improvement Package*	*Investment costs Project base*	*Investment costs Individually base*
	Individual / collective	*Type of system*	*Type of system*	*(€ / system)*	*(€ / system)*
Detached	Individual	Combitap HR	Combitap HR	€ -	€ -
Detached	Individual	Combitap HR	Combitap HR	€ -	€ -
Detached	Individual	Combitap HR	Combitap HR	€ -	€ -
Detached	Individual	Combitap HR	Combitap HR	€ -	€ -
Two-family	Individual	Combitap HR	Combitap HR	€ -	€ -
Two-family	Individual	Combitap HR	Combitap HR	€ -	€ -
Two-family	Individual	Combitap HR	Combitap HR	€ -	€ -
Two-family	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (corner)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (corner)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (corner)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (corner)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (corner)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (Middle)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (Middle)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (Middle)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (Middle)	Individual	Combitap HR	Combitap HR	€ -	€ -
Terraced (Middle)	Individual	Combitap HR	Combitap HR	€ -	€ -
Duplex property	Individual	Keukengeiser	Combitap HR	€ -	€ -
Duplex property	Individual	Combitap HR	Combitap HR	€ -	€ -
Duplex property	Individual	Combitap HR	Combitap HR	€ -	€ -
Duplex property	Individual	Combitap HR	Combitap HR	€ -	€ -
Portico	Individual	Combitap HR	Combitap HR	€ -	€ -
Portico	Individual	Combitap HR	Combitap HR	€ -	€ -
Portico	Individual	Combitap HR	Combitap HR	€ -	€ -
Portico	Individual	Combitap HR	Combitap HR	€ -	€ -
Portico	Individual	Combitap HR	Combitap HR	€ -	€ -
Other + Gallery	Individual	Combitap HR	Combitap HR	€ -	€ -
Other + Gallery	Collective	Collectief	Collectief	€ -	€ -
Other + Gallery	Individual	Combitap VR	Combitap HR	€ -	€ -
Other + Gallery	Individual	Combitap HR	Combitap HR	€ -	€ -

Table 95: Investment costs PV system and solar boiler on project and individual base

Example dwelling	*Investment costs PV system*				*Investment costs solar boiler*	
	Costs per m²	*Total costs project base*	*Costs per m²*	*Total costs individual base*	*Total costs project base*	*Total costs individual base*
Detached	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Detached	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Detached	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Detached	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Two-family	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Two-family	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Two-family	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Two-family	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (corner)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (corner)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (corner)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (corner)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (corner)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (Middle)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (Middle)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (Middle)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (Middle)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Terraced (Middle)	€ 513	€ 7.695	€ 532	€ 7.980	€ 3.327	€ 3.543
Duplex property	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Duplex property	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Duplex property	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Duplex property	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Portico	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Portico	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Portico	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Portico	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Portico	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Other + Gallery	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Other + Gallery	€ 513	€ 5.130	€ 532	€ 5.320	€ 2.717	€ -
Other + Gallery	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543
Other + Gallery	€ 513	€ 5.130	€ 532	€ 5.320	€ 3.327	€ 3.543

Table 96: Total investment costs of both improvement packages on both investment bases

Example dwelling	*Total investment costs of improvement package 1 on current state*		*Total investment costs of improvement package 2 on current state*	
	Project base	*Individual base*	*Project base*	*Individual base*
Detached	€ 15.515	€ 17.497	€ 26.537	€ 29.020
Detached	€ 16.871	€ 19.150	€ 27.893	€ 30.673
Detached	€ 16.500	€ 18.726	€ 27.522	€ 30.249
Detached	€ 2.570	€ 3.222	€ 13.592	€ 14.745
Two-family	€ 13.395	€ 14.984	€ 24.417	€ 26.507
Two-family	€ 13.981	€ 15.761	€ 25.003	€ 27.284
Two-family	€ 14.239	€ 15.889	€ 25.261	€ 27.412
Two-family	€ 3.678	€ 4.610	€ 14.700	€ 16.133
Terraced (corner)	€ 12.764	€ 14.199	€ 23.786	€ 25.722
Terraced (corner)	€ 9.253	€ 10.596	€ 20.275	€ 22.119
Terraced (corner)	€ 10.464	€ 12.010	€ 21.486	€ 23.533
Terraced (corner)	€ 9.720	€ 11.050	€ 20.742	€ 22.573
Terraced (corner)	€ 994	€ 1.246	€ 12.016	€ 12.769
Terraced (Middle)	€ 11.483	€ 12.756	€ 22.505	€ 24.279
Terraced (Middle)	€ 7.885	€ 9.056	€ 18.907	€ 20.579
Terraced (Middle)	€ 8.984	€ 10.349	€ 20.006	€ 21.872
Terraced (Middle)	€ 8.240	€ 9.389	€ 19.262	€ 20.912
Terraced (Middle)	€ 994	€ 1.246	€ 12.016	€ 12.769
Duplex property	€ 13.383	€ 13.873	€ 21.840	€ 22.736
Duplex property	€ 10.318	€ 11.011	€ 18.775	€ 19.874
Duplex property	€ 8.418	€ 9.068	€ 16.875	€ 17.931
Duplex property	€ 7.079	€ 7.593	€ 15.536	€ 16.456
Portico	€ 2.476	€ 2.809	€ 10.933	€ 11.672
Portico	€ 7.094	€ 7.860	€ 15.551	€ 16.723
Portico	€ 6.759	€ 7.490	€ 15.216	€ 16.353
Portico	€ 6.176	€ 6.818	€ 14.633	€ 15.681
Portico	€ 459	€ 521	€ 8.916	€ 9.384
Other + Gallery	€ 8.865	€ 9.480	€ 17.322	€ 18.343
Other + Gallery	€ 6.849	€ 5.909	€ 14.696	€ 11.229
Other + Gallery	€ 10.416	€ 11.033	€ 18.873	€ 19.896
Other + Gallery	€ 48	€ 55	€ 8.505	€ 8.918

Table 97: Difference in gas consumption between Actual numbers and calculation tool

Example dwelling	Average gas consumption (m^3)			Difference between AN and OS		Difference between AN and CS	
	Actual numbers (AN)	*Original state (OS)*	*Current state (CS)*	*Absolute (AN – OS)*	*Deviation (AN/OS)*	*Absolute (AN – CS)*	*Deviation (AN/CS)*
Detached	3.859	6.053	4.731	-2194,31	0,64	-872,31	0,82
Detached	3.594	5.452	4.110	-1857,64	0,66	-515,64	0,87
Detached	3.172	3.364	2.616	-192,19	0,94	555,81	1,21
Detached	2.652	2.093	1.882	559,46	1,27	770,46	1,41
Two-family	2.528	4.899	3.453	-2371,06	0,52	-925,06	0,73
Two-family	2.640	4.453	3.046	-1813,25	0,59	-406,25	0,87
Two-family	2.120	2.436	1.915	-316,00	0,87	205,00	1,11
Two-family	1.652	1.576	1.497	76,37	1,05	155,37	1,10
Terraced (corner)	2.055	5.895	4.274	-3839,80	0,35	-2218,80	0,48
Terraced (corner)	1.845	4.190	2.948	-2345,37	0,44	-1103,37	0,63
Terraced (corner)	1.901	3.990	2.707	-2089,14	0,48	-806,14	0,70
Terraced (corner)	1.789	2.182	1.740	-393,22	0,82	48,78	1,03
Terraced (corner)	1.382	1.324	1.186	58,45	1,04	196,46	1,17
Terraced (Middle)	1.666	4.525	3.337	-2859,15	0,37	-1671,15	0,50
Terraced (Middle)	1.577	3.131	2.246	-1553,60	0,50	-668,60	0,70
Terraced (Middle)	1.644	2.988	2.030	-1343,94	0,55	-385,94	0,81
Terraced (Middle)	1.571	1.899	1.542	-327,62	0,83	29,38	1,02
Terraced (Middle)	1.417	1.261	1.135	155,72	1,12	281,72	1,25
Duplex property	790	2.038	1.889	-1248,25	0,39	-1099,25	0,42
Duplex property	894	2.057	1.580	-1163,28	0,43	-686,28	0,57
Duplex property	788	1.961	1.286	-1172,62	0,40	-497,62	0,61
Duplex property	707	1.082	858	-375,00	0,65	-151,00	0,82
Portico	848	790	765	58,38	1,07	83,38	1,11
Portico	846	3.541	2.501	-2695,39	0,24	-1655,39	0,34
Portico	892	2.148	1.462	-1255,76	0,42	-569,76	0,61
Portico	928	1.292	1.059	-364,46	0,72	-131,46	0,88
Portico	407	857	751	-449,56	0,48	-343,56	0,54
Other + Gallery	951	1.930	1.512	-978,81	0,49	-560,81	0,63
Other + Gallery	755	1.885	1.570	-1130,08	0,40	-815,08	0,48
Other + Gallery	732	1.093	1.004	-360,93	0,67	-271,93	0,73
Other + Gallery	926	841	724	85,37	1,10	202,37	1,28

Table 98: Energetic effects of improvement packages (per m^3 / per year / per dwelling)

Example dwelling	*Gas savings (m^3 / year / dwelling)*	*Electricity savings (kWh / year / dwelling)*	*Gas savings (m^3 / year / dwelling)*	*Electricity savings (kWh / year / dwelling)*
	Current state – Improvement package 1		*Current state – Improvement package 2*	
Detached	3235	0	3412	1362
Detached	2508	0	2684	1362
Detached	1035	0	1215	1362
Detached	180	0	361	1362
Two-family	2259	0	2436	1362
Two-family	1813	0	1989	1362
Two-family	681	0	858	1362
Two-family	201	0	378	1362
Terraced (corner)	3131	0	3308	1362
Terraced (corner)	1937	0	2100	1362
Terraced (corner)	1601	0	1769	1362
Terraced (corner)	647	0	815	1362
Terraced (corner)	59	0	236	1362
Terraced (Middle)	2231	0	2408	1362
Terraced (Middle)	1293	0	1457	1362
Terraced (Middle)	980	0	1148	1362
Terraced (Middle)	505	0	673	1362
Terraced (Middle)	58	0	235	1362
Duplex property	1324	-221	1468	687
Duplex property	968	-37	1113	871
Duplex property	641	0	786	908
Duplex property	224	0	368	908
Portico	102	0	246	908
Portico	1712	0	1876	908
Portico	721	0	885	908
Portico	306	0	469	908
Portico	34	0	198	908
Other + Gallery	911	-37	1055	871
Other + Gallery	687	0	778	905
Other + Gallery	380	-40	525	868
Other + Gallery	23	0	187	908

Table 99: Energetic effects of improvement packages (per m^3 / per year / for complete target area)

Example dwelling	*Gas savings (m^3 / year / dwelling)*	*Electricity savings (kWh / year / dwelling)*	*Gas savings (m^3 / year / dwelling)*	*Electricity savings (kWh / year / dwelling)*
	Current state – Improvement package 1		*Current state – Improvement package 2*	
Detached	2.605.935	0	2.748.517	1.097.151
Detached	934.119	0	999.672	507.285
Detached	1.420.941	0	1.668.061	1.869.876
Detached	282.980	0	567.532	2.141.214
Two-family	3.685.167	0	3.973.911	2.221.867
Two-family	979.113	0	1.074.161	735.549
Two-family	1.214.925	0	1.530.698	2.429.850
Two-family	378.803	0	712.376	2.566.814
Terraced (corner)	9.301.486	0	9.827.312	4.046.191
Terraced (corner)	8.217.489	0	8.908.997	5.778.121
Terraced (corner)	4.290.026	0	4.740.198	3.649.604
Terraced (corner)	1.922.089	0	2.421.179	4.046.191
Terraced (corner)	58.498	0	233.991	1.350.404
Terraced (Middle)	22.480.498	0	24.264.025	13.724.087
Terraced (Middle)	15.869.439	0	17.882.268	16.716.300
Terraced (Middle)	7.908.358	0	9.264.077	10.991.004
Terraced (Middle)	4.207.561	0	5.607.305	11.347.918
Terraced (Middle)	238.187	0	965.068	5.593.287
Duplex property	224.820	-37.527	249.271	116.655
Duplex property	3.296.043	-125.985	3.789.768	2.965.757
Duplex property	590.049	0	723.523	835.825
Duplex property	93.088	0	152.930	377.339
Portico	27.347	0	65.955	243.444
Portico	509.994	0	558.848	270.487
Portico	214.781	0	263.636	270.487
Portico	86.272	0	132.227	255.997
Portico	723	0	4.213	19.321
Other + Gallery	5.400.455	-219.338	6.254.095	5.163.333
Other + Gallery	3.280.683	0	3.715.242	4.321.715
Other + Gallery	3.295.558	-346.901	4.553.073	7.527.748
Other + Gallery	136.345	0	1.108.546	5.382.671

Table 100: Total investment costs improvement package 1 and 2

Example dwelling	Total costs individual base (€ / target area)	Total costs Project base(€ / target area)	Total costs individual base (€ / target area)	Total costs Project base(€ / target area)
	Current state – Improvement package 1		*Current state – Improvement package 2*	
Detached	€ 11.520.147	€ 2.283.848	€ 19.105.670	€ 3.906.837
Detached	€ 6.634.912	€ 438.372	€ 10.627.292	€ 724.782
Detached	€ 23.835.791	€ 1.642.574	€ 38.507.789	€ 2.740.478
Detached	€ 4.756.175	€ 256.995	€ 21.723.793	€ 1.354.899
Two-family	€ 18.423.934	€ 5.390.082	€ 32.586.641	€ 9.823.625
Two-family	€ 7.982.922	€ 468.951	€ 13.819.675	€ 838.412
Two-family	€ 25.195.727	€ 1.748.983	€ 43.478.495	€ 3.103.677
Two-family	€ 6.934.479	€ 1.411.731	€ 24.230.149	€ 5.640.017
Terraced (corner)	€ 20.883.123	€ 19.141.646	€ 37.829.336	€ 35.676.068
Terraced (corner)	€ 17.720.910	€ 23.763.407	€ 37.003.067	€ 52.079.113
Terraced (corner)	€ 16.099.665	€ 13.994.987	€ 31.559.368	€ 28.741.904
Terraced (corner)	€ 22.400.575	€ 9.180.937	€ 45.760.017	€ 19.580.967
Terraced (corner)	€ 856.953	€ 305.923	€ 8.756.692	€ 3.677.808
Terraced (Middle)	€ 62.386.659	€ 59.548.892	€ 118.725.333	€ 116.722.052
Terraced (Middle)	€ 39.212.073	€ 62.571.316	€ 89.139.223	€ 150.091.753
Terraced (Middle)	€ 41.015.382	€ 36.845.675	€ 86.723.337	€ 82.069.843
Terraced (Middle)	€ 53.157.094	€ 22.007.165	€ 118.389.171	€ 51.444.418
Terraced (Middle)	€ 3.975.646	€ 926.155	€ 40.624.739	€ 11.134.235
Duplex property	€ 992.152	€ 1.314.465	€ 1.625.822	€ 2.145.849
Duplex property	€ 11.568.943	€ 24.288.473	€ 20.875.973	€ 44.203.891
Duplex property	€ 2.145.688	€ 5.749.762	€ 4.244.720	€ 11.531.658
Duplex property	€ 884.139	€ 2.119.681	€ 1.913.853	€ 4.651.622
Portico	€ 175.791	€ 507.712	€ 730.252	€ 2.246.059
Portico	€ 250.550	€ 1.885.772	€ 533.431	€ 4.135.134
Portico	€ 398.964	€ 1.649.266	€ 870.434	€ 3.718.679
Portico	€ 145.117	€ 1.643.734	€ 333.705	€ 3.893.096
Portico	€ 2.713	€ 7.181	€ 49.860	€ 142.143
Other + Gallery	€ 14.385.317	€ 39.061.486	€ 27.824.451	€ 76.371.513
Other + Gallery	€ 8.935.990	€ 22.371.535	€ 16.966.305	€ 47.999.191
Other + Gallery	€ 29.635.986	€ 62.437.702	€ 53.412.915	€ 113.093.463
Other + Gallery	€ 45.627	€ 250.776	€ 8.133.432	€ 42.666.997

Appendix G

Energetic effects of fluctuating interest rate; Case-study I:

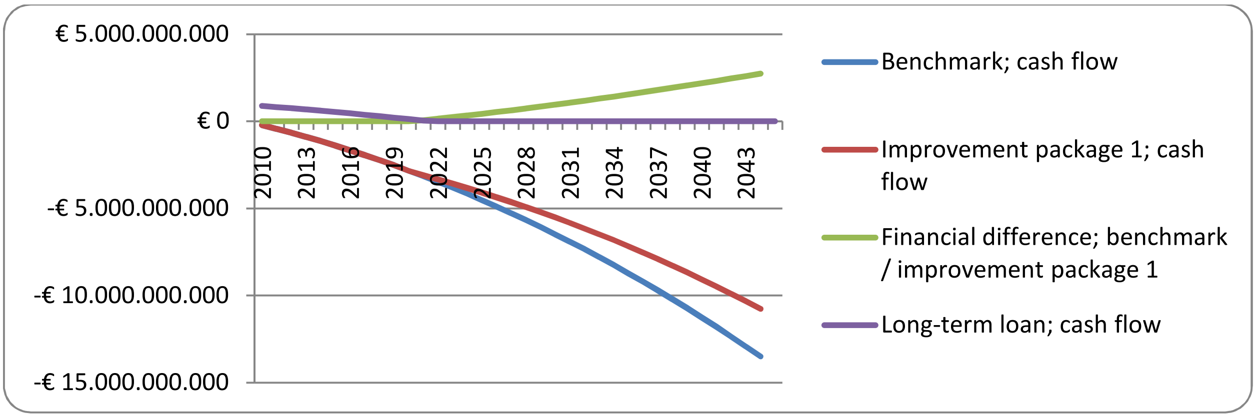

Figure 50: Financial Effects Scenario 1 (in case of an interest rate of 0%)

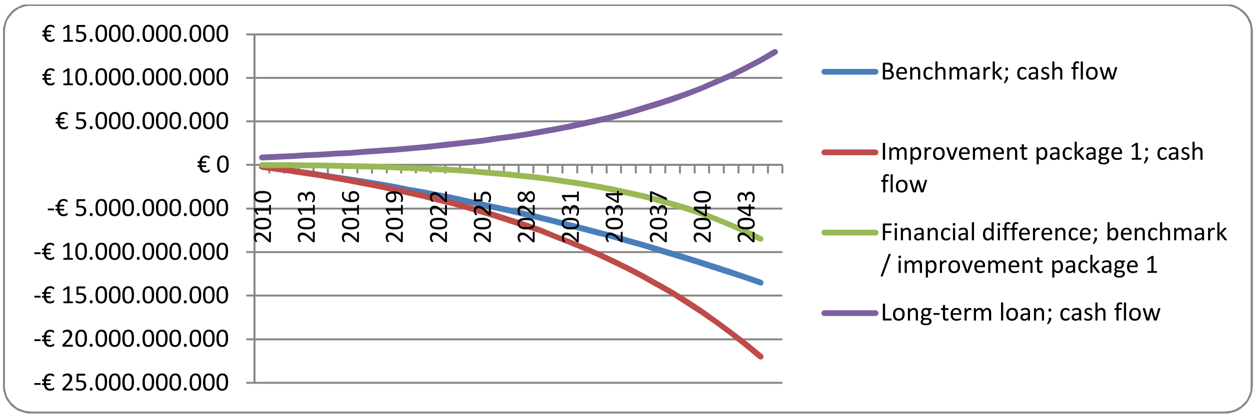

Figure 51: Financial Effects Scenario 1 (in case of an interest rate of 8%)

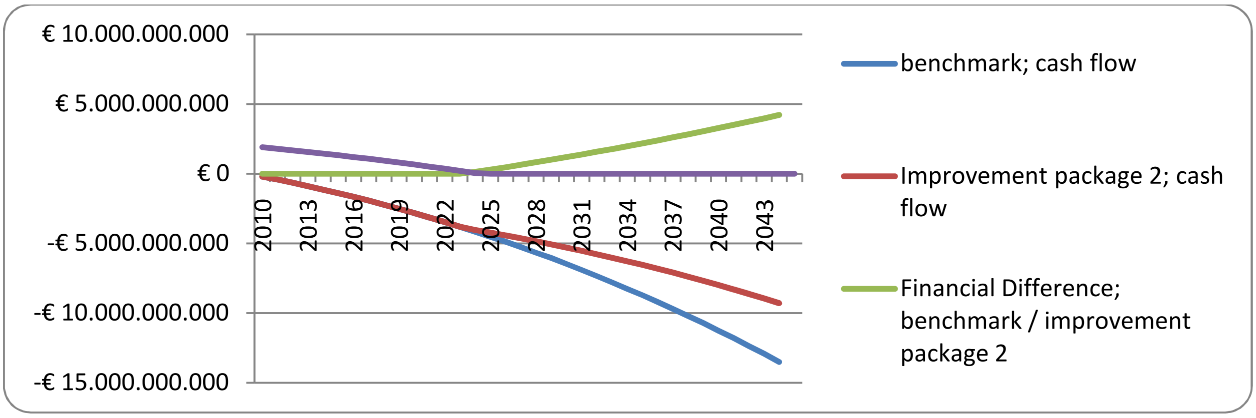

Figure 52: Financial Effects Scenario 2 (in case of an interest rate of 0%)

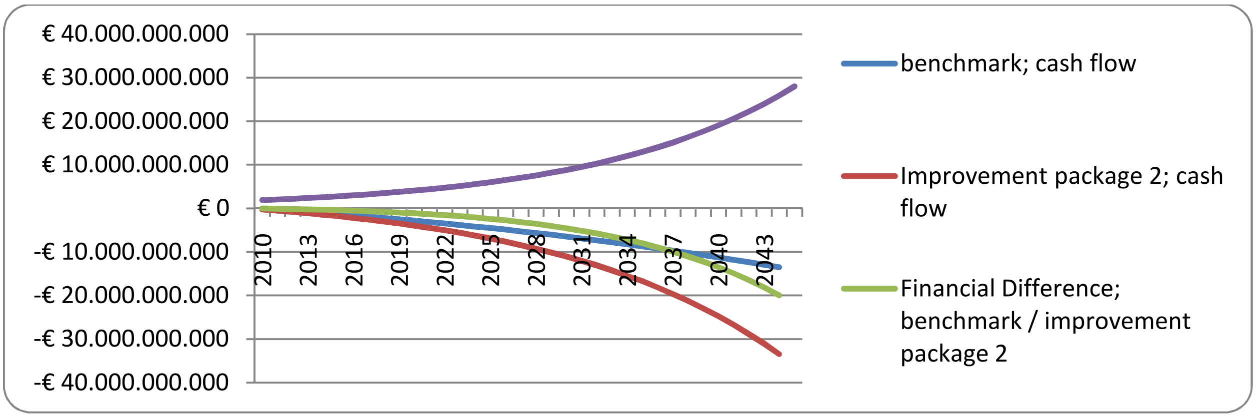

Figure 53: Financial Effects Scenario 2 (in case of an interest rate of 8%)

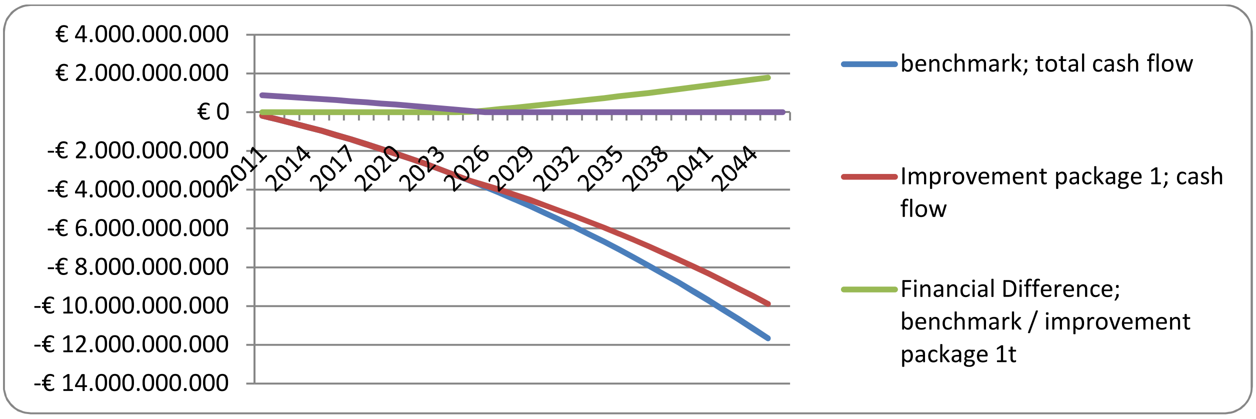

Figure 54: Financial Effects Scenario 3 (in case of an interest rate of 0%)

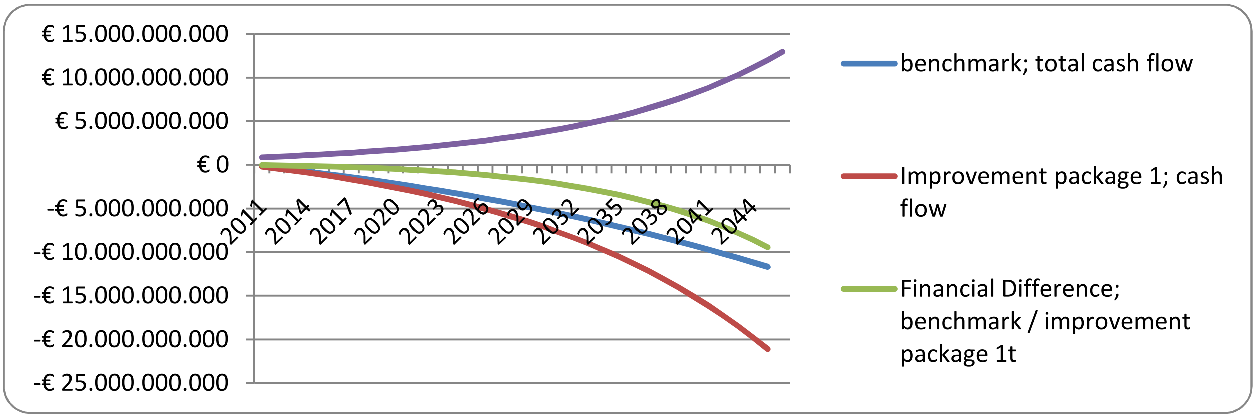

Figure 55: Financial Effects Scenario 3 (in case of an interest rate of 8%)

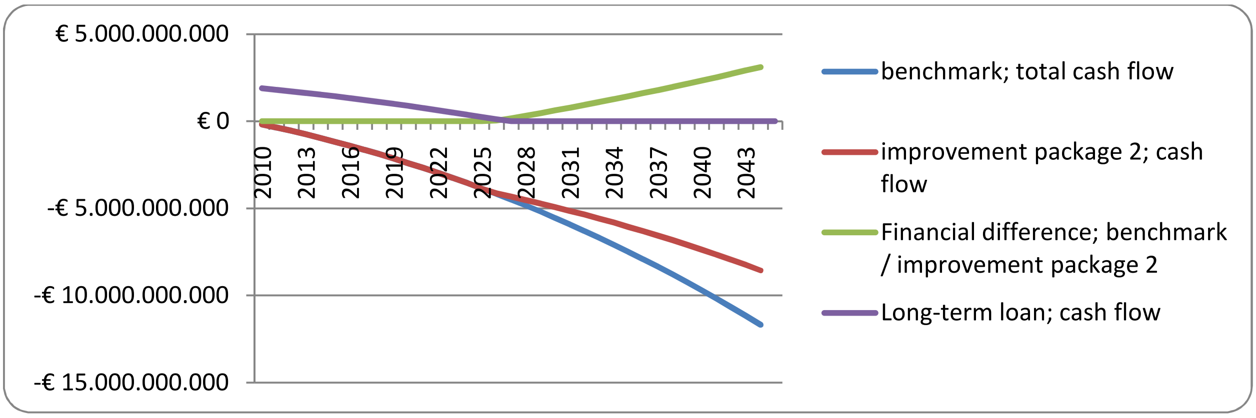

Figure 56: Financial Effects Scenario 4 (in case of an interest rate of 0%)

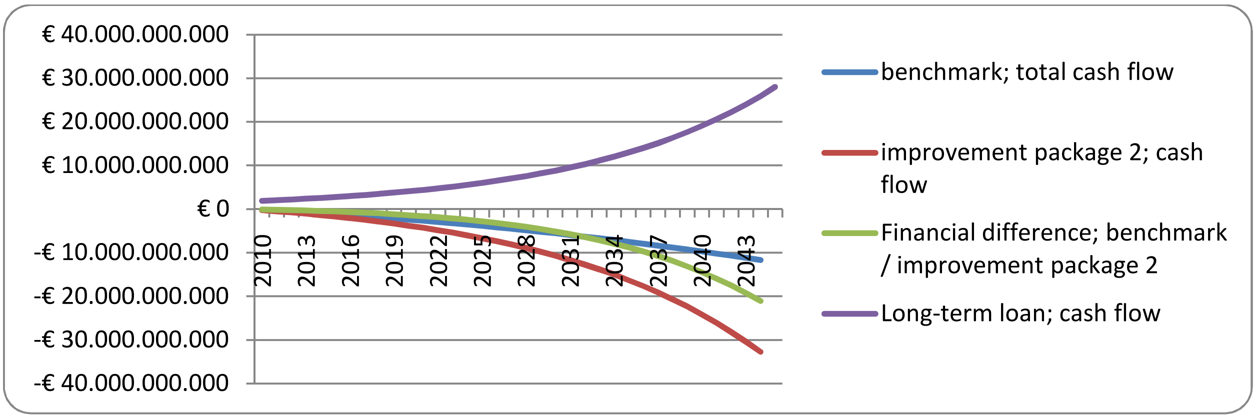

Figure 57: Financial Effects Scenario 4 (in case of an interest rate of 8%)