Deployment strategies for solar PV panels

A latent class conjoint analysis to determine consumer preferences

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1. Introduction:

Solar photovoltaic panels show great potential. Many researches indicate that the technology is at the threshold of a breakthrough. Solar PV panels are getting increasingly important in the sustainable energy generation. The most important question still remains: how to realize the potential? This thesis will focus on individual citizens. They will not only contribute to the energy neutrality of their city but they will profit from it at the same time. The lack of consisting policies has not encouraged consumers to shift to PV panels. The deployment rate was totally depending on the amount of subsidy given and not every applicant could be served. The financial incentives by the national government in the Netherlands have been rescinded for small scale installations (Ministry of EZL&I, 2010). So municipalities should find new alternative ways to reach their goals. To be energy neutral and achieve general understanding, deployment by individuals is essential. PV panels offer civilians an easy way to generate renewable energy and it will increase the awareness needed to complete the transition to sustainable energy resources. The province of 'Noord Brabant' and the municipality of Eindhoven emphasize on solar PV and encourage its deployment (Gemeente Eindhoven, 2011). When a city strives for energy neutrality, solar PV shows much potential, because it is easily applicable and does not negatively affect the surroundings. Furthermore, the electricty use will increase in the future, and thus the need for sustainably generated electrity. Next to this, building a home market will encourage the development of PV panels. This will result in diminshing costs and increasing performance of the solar PV panels.

1.1. Identification of most important problems

The first problem is that the national government is constantly changing the strategies for renewable energy. Local governments have set their goals high. Because of a lack of consistent subsidies and strategies these goals will probably never be reached. The second problem is that, even within the municipality itself, they do not work towards one goal; the different divisions should start collaborating. The third problem is that the national government focuses on energy policy and employment instead of climate policy. On the other hand local governments strive to be energy neutral. This means that local governments have to find new strategies to increase their deployment rate and make the use of PV panels more attractive. The final problem is the lack of knowledge about the willingness of residents to deploy PV panels on their roofs. Which factors will stimulate them to deploy PV panels? Are there other factors besides the financial parameters?

1.1.1. Involved actors:

The national governments' switch from a climate to an energy policy means that it wants to encourage the energy transition with the help of innovation subsidies and by focusing on employment which accompanies this energy transition. Many local governments want to be energy neutral in 2040 according to reports from a few years ago, as is the case in for instance Eindhoven, Groningen, Arnhem and 's Hertogenbosch (Urgenda, 2009). It seems to be difficult to put these plans into action. In order to be energy neutral, a big part of the energy could be produced out of solar energy. Many municipalities set high goals concerning solar PV; Eindhoven for instance wants to generate 70 percent of the energy out of solar energy (BuildDesk, 2009). To achieve these goals, a transition has to be made. Without consistent national subsidies, local governments have to find new innovative ways to deploy solar panels. This will be researched in this thesis. Individual home owners do not yet see the urgency and profits of switching to solar energy. In future, solar panels will become increasingly cheaper and more efficient (IEA, 2010). Even when grid parity is reached, individual consumers have to be encouraged to choose for renewable energy. How can we encourage this group to generate energy from PV panels? The industry will certainly support new ways of incentives to increase the deployment of solar panels. The solar energy industry secures a lot of employment. Furthermore, the technology is developing higher efficiencies and lower production costs will be reached. It is a competitive and maturing industry; this increases the need for innovative policies. All this leads to the following problem definition.

1.1.2. Problem definition:

Although small scale subsidies have been rescinded, solar PV panels still show much potential. However, the deployment rates lag behind. How can new strategies increase the deployment of solar PV panels?

1.2. Target

It is important to get a clear picture of the decision criteria used by individuals considering to switch to solar PV panels. Which parameters do consumers prefer? This knowledge will lead to a better understanding of the market and will form the basis on which municipalities can build their strategy. Furthermore, a segmentation will be determined to make the strategy more effective.

1.3. Research question:

Which deployment strategies will stimulate the deployment of PV solar panels the most?

1.3.1. Sub questions:

1. What is the current status of the technology and the financial parameters?

To have valid results, it is necessary to determine the current status of technology, the costs and the market. This will be answered by doing a literature study.

2. What possibilities are there for stimulating the deployment of PV solar panels in the existing housing stock?

This question outlines the different possibilities to deploy PV panels. There are several possibilities in the Netherlands and around the world. Furthermore there are different initiatives to encourage the deployment without governmental expenses. This will be answered in a literature study.

3. How do individuals behave when purchasing solar PV panels?

With this question a behavior model for purchasing solar PV panels is sketched from the literature. Furthermore possible sociodemographic factors will be derived to use in the experiment.

4. Which decision criteria do consumers prefer in the transition to PV panels?

This is the question that will be answered by means of a conjoint choice experiment. When the most important decision criteria are determined, the most effective strategy for the deployment of small scale Solar PV panels can be determined as well. Are there important differences between various segments within the population?

5. How can the municipality of Eindhoven turn into a PV city?

In this paragraph the result from the scientific research will be used in a case study. The results will be transformed into a project plan for the municipality of Eindhoven.

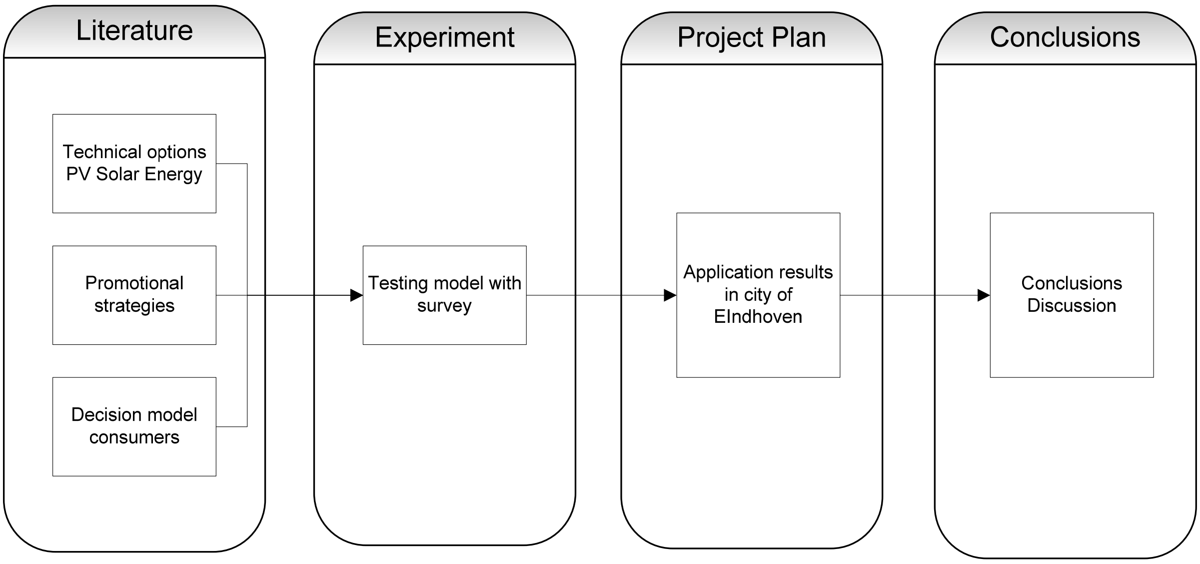


Figure 1: Research Structure

The structure on which the sub questions are based is displayed above. First a literature study is done. This leads to an experiment, and the results of this experiment will be used in the project plan. An answer to the research question will be given in the conclusion.

1.4. Boundaries:

Different studies are done to measure the willingness to invest in different renewable micro energy generation systems. This study is only focusing on the small scale generation of electricity through solar PV panels. There are a few new technologies entering the market, but they are not yet financially attainable, and they will not be taken into account. For the large scale deployment of solar PV and the contribution to energy neutrality they cannot contribute much on the short term. That is why this investigation is focused on the deployment of building applied photovoltaic panels. Furthermore, research is done involving people buying new estate; this research is focusing on the deployment in the current housing stock. This research determines the preferences of individuals. Currently, companies have even better financial preconditions to switch to solar panels. Nevertheless, individuals have a great potential and can also achieve a transition in society, which is needed to achieve an energy neutral city. That is why this research is focused on the preferences of individuals.

1.5. Expected results:

This research will result in knowing the main decision criteria used by individuals to deploy PV panels. The financial parameters are still the most important criteria. The low level of investments costs and payback show the most potential for large scale deployment. The purchase service will be less important. The organization/location is not significant either, placement of the panels on owned roofs is not necessary; this could lead to new ways of organizing the deployment. The certification of the panels does not influence the decision of individuals significantly. Local initiatives in collaboration with local energy companies show big potential.

1.6. Relevancy:

Several investigations have been carried out in order to determine appropriate strategies for increasing the deployment of solar PV panels; these were aimed at large national subsidy systems. In the Netherlands these systems will be rescinded. This thesis will focus on bottom up market strategies to increase the deployment. In this investigation individual decision making is surveyed, so matching strategies for different groups of people can be generated. Researchers have been focusing on deployment strategies of renewable energy in general. None of them have been focusing on deployment strategies in the existing housing stock and specified on solar PV in the Netherlands. In this case new issues like purchase service, organization, location and certification arise.

The social relevance of the thesis lies within the contribution on the energy transition the results will give. Solar PV could play a vital role in these goals, but still lags behind. The deployment rate in the Netherlands is much lower than in several other countries. How can individuals be encouraged to deploy solar panels? Which decision criteria do they prefer? The market environment is constantly changing and strategies should be adapted to it. With this research a strategy to reach energy neutrality could be determined and progress could be made.

Personally, I am interested in getting a general picture of the municipalities that strive for energy neutrality. How can these ambitious plans be achieved? Eindhoven focuses on solar panels, but is this realistic? These were questions I wanted to answer. I became acquainted with solar panels almost 15 years ago, now I am interested in the current status and the possibilities.

2. Technology Chapter:

What is the current state of PV solar energy technology and future trends?

Energy from the sun can be transformed in two ways, to generate electricity and to generate heat. The solar PV cells and the solar PV panels that generate electricity show a high potential for the future (EPIA, 2010). Our electricity use is constantly increasing and will increase further due to, for instance, electrical driving. The electricity can be used for own purposes, but it is also possible to produce extra and bring it back to the energy grid. Panels which can bring electricity back to the grid are called 'grid connected'. This increases the advantages of generating solar electricity. When the electricity is not directly used, other parties could make use of it trough the energy grid. Individual energy generation becomes possible in this way. Many European countries made a lot of progress with this technique. Furthermore solar panels systems are getting increasingly efficient and cheaper to use. In this way the payback time will decrease (EPIA, 2010). An upcoming application is the use of concentrated solar power, in which solar irradiance is concentrated in one point, this is a technology based on solar thermal energy. This will not be considered in this thesis.

2.1. PV panels: Modules:

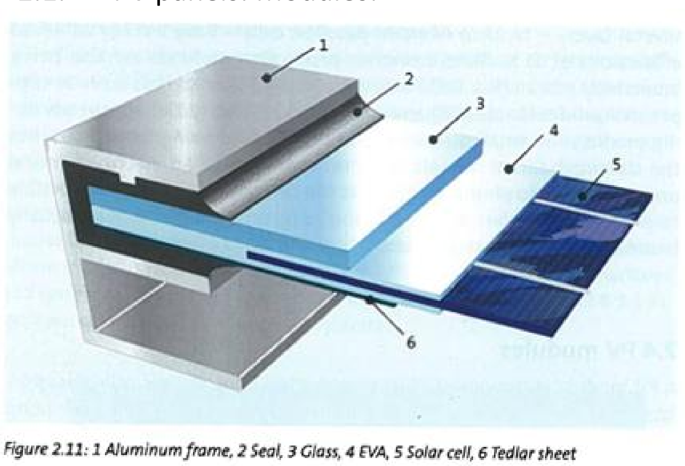


Figure 2: Module structure (Anthony, Durschner, & Remmers, 2007)

A solar cell converts the sunlight to an electrical tension. The Solar cell is placed in a module and this could be compound to a solar array. The module is compound the following way, see figure 3 left (Anthony, Durschner, & Remmers, 2007). The solar cell can be made from different materials. The different cells also differ in efficiency. There are more expensive cells with a much higher efficiency; they are currently applied in new modules and new technologies. The most applied material is crystalline silicon. Solar panels made from this material are the topic of this thesis.

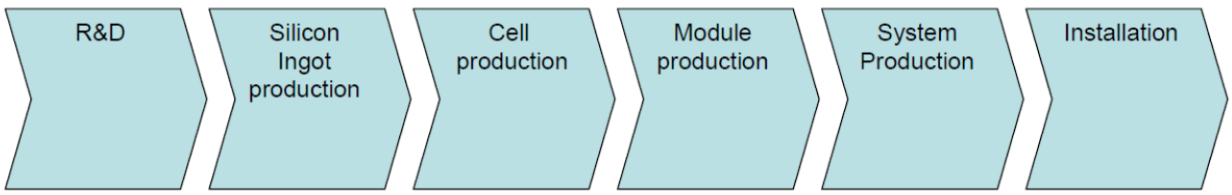


Figure 3: PV Value chain (IEA, 2010)

Above the value chain of PV panels is elaborated, from research and development until installation. The Netherlands and the province of 'Noord Brabant' mainly invest in the chain to create an ecosystem which can compete internationally. Solar PV has a worldwide market; most panels are produced in China because of low labor costs. There is a lot to gain within the chain to reduce costs, especially in the installation and application phase. The Netherlands focuses mainly on research and development (Berenschot, 2011).

2.1.1. Certification:

Solar PV panels have to adapt to certain standards. The following three standards are mandatory in the Netherlands: The national grid code, the Dutch technical agreement (NTA 8493) and the building code (KEMA, 2009). Holland Solar, the branche organisation, tries to introduce an general quality mark which can give the consumer more security when buying solar PV panels. This will go further than the basic safety marks currently available. With the expected increase of deployment of solar PV panels new problems arise. The recyclability and the sustainability of the panels becomes another issue. Solar PV panels are currently built from rare and finite materials, so when the production has to increase we have to find an answer to this upcoming problem. To rank the performance of the different manufacturers a worldwide scorecard is developed by the Silicon Valley Toxics Coalition in the United States (solarscorecard.com).

2.1.2. Efficiency:

Efficiency is the most important characteristic of a solar cell. This determines the profitability and yield of energy of the panels. Three different efficiency percentages could be determined, the cell efficiency, the module efficiency and the system efficiency (Anthony, Durschner, & Remmers, 2007). The module efficiency is currently on average from 5 until 20 percent. Ultimately this could reach the 60 percent, but an efficiency of 30 percent would be boundary breaking (Mackay, 2009). In this picture the efficiencies and materials are displayed:

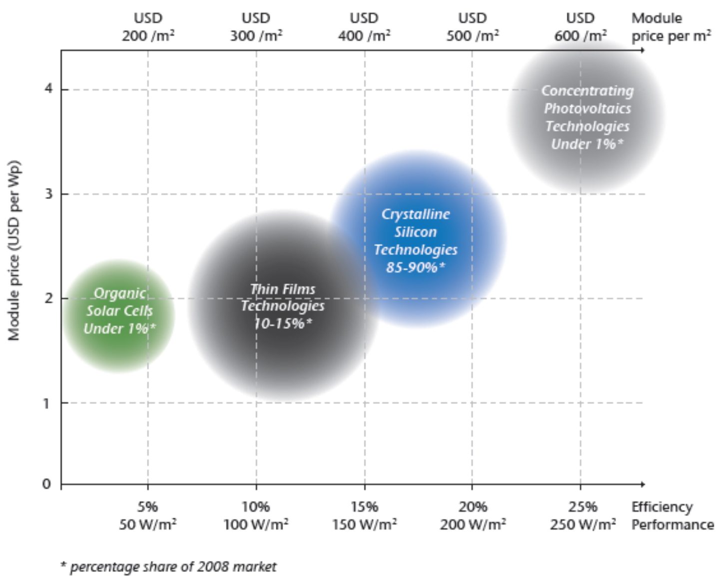


Figure 4: Market share, performance and price of PV module technologies in 2008 (IEA, 2010)

The CSP, concentrated solar power, shows high efficiencies, but is the most expensive and newest in the market. The technology is not yet applicable in the Netherlands, let alone the built environment. The Crystalline Silicon technology is market leader and accounted as the standard implementation. In future, they target for efficiencies up to 40 percent with an operational lifetime of 40 years in 2050 (IEA, 2010). These numbers confirm the study of

MacKay and are derived from the roadmap PV from the International Energy Agency (IEA). Next to the efficiency targets the energy payback times are displayed. This is the time it takes to generate the energy that was used during production. The targeted lifetime of a PV panel will increase until 40 years in 2050 (IEA, 2010).

2.1.3. Solar irradiance:

Obviously the solar irradiance depends on the positioning of the array or panel. In the figure below the efficiency of the position is described in central Europe (Anthony, Durschner, & Remmers, 2007):

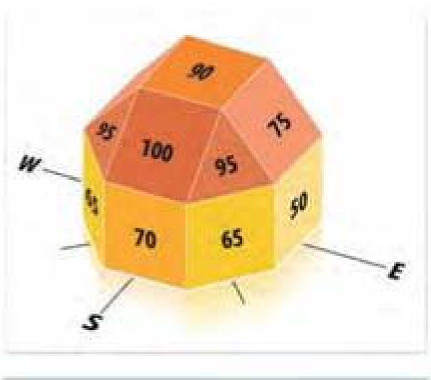


Figure 5: Solar irradiance per orientation: Percentages (Anthony, Durschner, & Remmers, 2007)

As you can derive from figure 5, a south orientation leads to 100 percent efficiency. South west orientation and south east orientation leads to 95 percent. Other orientations are leading to too low efficiencies. In addition, the location equator also matters. The parameters in this thesis are based on the geographical location of the Netherlands.

2.1.4. Inverter:

It is necessary to use an inverter to switch from the direct current power to the alternate current power. This switch is needed to use the electricity and to be able to bring it back to the grid. An inverter is essential and you can separate different inverters on cost, electrical efficiency, wiring losses and access for maintenance. In general the irradiance should be equal of all panels connected to the inverter. The inverter should be located as close as possible to the arrays themselves. It is important that the location of the inverter cannot be overheated, thus good ventilation is essential (Gaiddon, Kaan, & Munro, 2009). The inverter needs to fulfill certain demands, for instance, efficiency safety, reliability. The inverter reaches efficiencies of 98 percent with smart technologies. The installation costs of the inverter could still be reduced to decrease the balance of system costs (Van Zoningen, Sinke, Van der Sanden, Ando, & Van der Vleuten, 2009).

2.1.5. Net metering:

If solar panels are applied an important aspect of it are net meters. This tool measures the energy feed into the grid and the energy taken from the grid. In this way the individual person can see the energy streams. Also, in this way more, less or an equal amount of energy can be produced by the solar PV panels (Anthony, Durschner, & Remmers, 2007). Next to the financial benefits, awareness is created within households by installing net meters; it gives them insight in their energy behavior.

2.2. Financial parameters:

The market for PV will increase further in the next decades. There are several scenarios possible depending on various factors. In the picture below, the three scenarios are displayed (IEA, 2010):

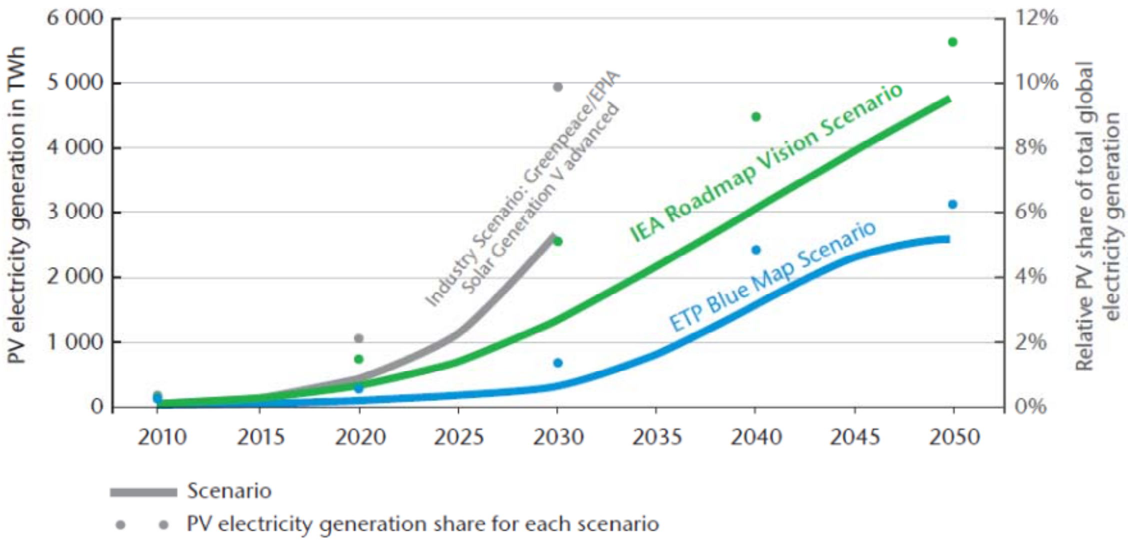


Figure 6: Scenario development (IEA, 2010)

These scenarios are determined by the IEA, an independent energy advisor. This shows that many organizations confirm the large potential of solar PV. If the Netherlands wants to contribute to these scenarios, the deployment of solar PV panels is essential. In this way a home market will be created and the technology will mature. In what way the market price for panels will decrease is explained in the figure below (Haas, 2002):

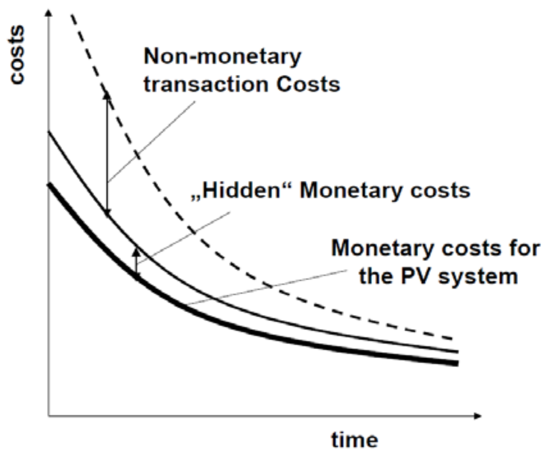


Figure 7: Market price PV

Grid parity is a term which symbolizes the breakthrough of solar PV. Grid parity is reached when the cost price for a kWh of PV energy will be equal to the price of a kWh generated from fossil energy. It has various definitions, but it generally determines the point when PV energy is competitive with fossil energy. It is an effective communication tool and therefore important to enhance (Sinke, 2009). The costs and benefits differ from country to country, depending on the system costs and the irradiance. In this way 'grid parity' is reached at a different time in different stages. Grid parity is difficult to comprehend for individuals, in this research we will talk about investment costs in combination with payback time. This is essentially different from the way energy is currently purchased. Energy is now purchased per kilowatt hour. By using solar panels you invest at the start and you gain your investment back in a certain period of time. Subsequently, you will generate free energy for the remaining lifetime of the panels. Individuals should understand and adapt to this change. This is an important barrier to overcome.

The financial parameters are the most important factors determining the deployment rate of solar PV panels. The prices for a turnkey PV system are between the 2,5 euro/Wp and 5,0 euro/Wp (Berenschot, 2011). The module prices are slightly lower and differ from large and small. Small gird systems differ between the 3,4 and 4,0 euro/Wp and large grid systems range from 3,3 to 3,8 euro/Wp (KEMA, 2009). The costs for a turnkey PV system go beyond the costs for a PV module, due to for instance the installation costs. The Balance of system (BoS) costs are the supplementary costs for the system, next to the module, which contain the costs for materials, electronics, inverters, workload, etc. The BoS costs still cover 30 till 60 percent of the total costs, depending on the application. Due to the diminishing module costs the Balance of System costs are getting even more important (Berenschot, 2011).

The cost breakdown structure is based on market information of the Netherlands. The figure below was published in the roadmap 'Zon op Nederland' and shows the market prices for PV panels:

Table 1: Costs build up Turnkey PV system (Berenschot, 2011)

	1-15 kWp	**15-100 kWp**
Modules	60 %	68 %
Inverter	13 %	9 %
Materials (Cables, frames)	7 %	6 %
Installation costs	18 %	16 %
Other	2 %	1 %
PV-system total	100%	100%

This figure shows the percentages of costs of the turn key market price of a PV system in the Netherlands. There are two columns displayed, one for installation between 1 and 15 kWp and one for an installation above. Per square meter 150 kWp can be generated for a price between 2,5 and 5,0 Euros per Wp (Berenschot, 2011). Below the cost breakdown structure of a turnkey crystalline silicon system is displayed:

Table 2: Cost build up: Wafer silicium (Berenschot, 2011)

Type of costs	**Percentage**
Module	60 %
Inverter	10 %
Installation labor	15 %
Other	15 %

The 60 percent module costs are built up in the following way:

Table 3: Costs build up: Module wafer silicium (Berenschot, 2011)

Type of costs	Percentage
Module assemblage	25 %
Silicium	20 %
Cell production	15 %

In this thesis, we calculate with the crystalline silicon modules. This means that for a turnkey PV system price of 8000 euro, you will pay 4800 euro for the module, 1040 euro for the inverter, 560 euro for the materials, 1440 for installation costs. These are the current average market prices. Systems are delivered in panels, mostly made in sizes of 1,0 meter by 1,6 meter and 5 cm thick. Per square meter 150 kWp could be generated, this means an average household needs to install 28 m2 of PV panels on the roof to cover their energy use. This is currently 3600 kWh on average per household and equals approximately 18 panels. These figures were compared with several installers in the Netherlands. Furthermore the energy price plays an important role. The current energy price consists of several pillars: transportation costs, energy tax and delivery costs. The delivery costs are the price you pay to your provider, it differs from 30 to 70 percent of the total energy price. The taxes contain approximately 30 to 40 percent of the energy price. The transportation costs take 20 percent of the total costs. On top of this price you pay the VAT rate of 18 percent. These numbers are based on the sites of the different energy providers. In total the taxes on electricity almost take 55 percent of the energy price. This is an extremely important part of the government income. These taxes are deleted with balancing and this increases the profitability enormously. Below the energy tax in the Netherlands in 2010 and 2011 is displayed:

Table 4: Energy tax in the Netherlands (www.rijksoverheid.nl)

Electricity per kWh	Tariff in 2010 exclusive BTW	Tariff in 2011 exclusive BTW
Until 10.000	€ 0,1114	€ 0,1121

The net electricity price lies around the 6 eurocent per kilowatt-hour. The other 6 cents are the network/transportation costs. The different parameters that compile the energy price are elaborated in the figure below:

Table 5: Build up Energy price, based on several sources

Part	Price/kWh
Energy price	6 cent
Network price	3 cent
Energy tax	11 cent
VAT	3 cent

Below the prices for a regular PV system in the Netherlands are displayed. After the abolition of the subsidy for small scale systems and the increasing performance of the technology, prices are dropping immensely. This also explains the variance between the prices:

Table 6: Market prices solar PV, several sources

Provider	Capacity	Yield	Yield in euro	PV system costs	Total	Price/Wp	Payback time in years
Wij willen Zon	3 Panels: 555 Wp	472 kWh/year	109 euro	1359 euro	-	2,45 euro/Wp	12.5
	6 panels: 1410 Wp	1200 kWh/year	276 euro	3305	3805	2,70 euro/Wp	13.8
	12 Panels: 2760 Wp	2350 kWh/year	541 euro	6071	6871	2,49 euro/Wp	12.7
	16 Panels: 2960 Wp	2500 kWh/year	575 euro	6439	7238	2,45euro/Wp	12.6
Eneco	3 Panels: 630 Wp	536 kWh/year	123 euro		3195	5,08 euro/Wp	26
	6 panels: 1020 Wp	1020 kWh/year	235 euro		5595	5,49 euro/Wp	23.8
	12 Panels: 2040 Wp	2040 kWh/year	469 euro		10295	5,05 euro/Wp	22
Zonfabriek	6 Panels: 1380 Wp	1173 kWh/year	270 euro		5358	3,88 euro/Wp	19.8
	12 Panels: 2760 Wp	2346 kWh/year	540 euro		9562	3,46 euro/Wp	17.7
	16 Panels: 3680 Wp	3128 kWh/year	719 euro		12.365 euro	3,36 euro/Wp	17.2

The total costs include the cost for installation on a pitched roof, but does not include installation costs for a new meter/group. The adaptations to the meter could lead up to 360 euro extra. Next to this the lack of interest or, on the other hand, the interest paid should be taken into account. In this calculation they are not taken into account. The calculation is based on a price of electricity of 23 cents. The expectation is that the price will rise, so the price for energy rises and you gain more profit. The life expectancy of solar PV is approximately 25 years, so even witch a payback time of 15 years, you will generate electricity without costs for 10 years extra (IEA, 2010). The investment costs will diminish in the future because of better performance of the technology or reductions due to different regulations or strategies, as will be described in the next chapter. The current energy price is around 22 cent/kWh, depending on the utility (IEA, 2010). It is hard to predict how the electricity use will develop in the future. With new technologies like electrical driving the electricity use will increase. This increases the need for electricity and thereby the need for PV panels. An increasing energy price shows great potential for PV panels, because PV panels increase the independency from energy providers. If you generate your own electricity your energy price is secured for the lifetime of the panels.

2.3. Potential in the Netherlands:

This research focuses on consumers on an individual level. How can you encourage individuals to deploy solar panels? The investment potential of individuals is enormous; next to this a change in society could only be achieved when individuals participate. PV panels are an easy way for civilians to generate renewable energy and increase the awareness needed to complete the energy transition. The roadmap Zon op Nederland determined a potential surface of 100 km² in the Netherlands (Berenschot, 2011). On average residential buildings have a roof surface of 50 m², from which 50 percent is suitable for solar PV panels. Forty percent of the buildings will have sufficient orientation. These figures are all assumptions by several respected energy consultancy companies (Ecofys, 2010) (BuildDesk, 2009). According to calculations of Build Desk the potential contribution of solar PV in existing industrial areas is 6.4 percent. For the houses is this 11.5 percent, this contains both rental and owner occupied houses (BuildDesk, 2009). Several pilot projects have started to increase the deployment of solar panels. The municipality of Eindhoven for instance strives to put solar PV panels on all their own property. This implies 42597 m² of roof surface. These figures certainly show the potential of solar PV. The preconditions are set, but are people willing to invest in a PV system?

2.4. Energy use

The correlation between the profit and the energy price was elaborated earlier this chapter. The electricity use plays an essential part too. The average electricity use in the Netherlands is described below:

Table 7: Electricity use in the Netherlands

Electricity use to household size			
Number of persons per household	Average Electricity use in kWh per year	€ per month, excl. Energy repay taxes	€ per month, incl. Energy repay taxes
1	2.405	64	32
2	3.533	85	53
3	4.114	95	63
4	4.733	106	74
5	5.337	117	85
6	5.430	119	87
Average per household	3.480	84	52

2.5. Conclusions:

All aspects of solar PV panels are discussed in this chapter. The technology shows much potential and will change the energy sector in the next few years. Technology is continuously developing, costs will decrease and efficiency will increase. The most important conclusions are the financial parameters derived from this chapter. A complete system to cover for all the energy used in household will cost approximately 12.000 euro and will have a payback time of approximately 12 to 13 years. In the near future prices will decrease further. Next to this a clear picture is created about the energy price and the costs concerning the purchase of solar PV panels.

3. Deployment strategies:

What possibilities are there for stimulating the deployment of PV solar panels in the existing housing stock?

In this research the possible ways of promoting PV panels through bottom up strategies are examined. In the last decade several strategies were developed to encourage the transition from fossil fuels to renewable energy. Several studies investigated the effectiveness of these strategies. The promotional strategies are focused on the potential customers of PV panels. The different areas and actors which could be targeted together with the different deployment strategies are displayed below:

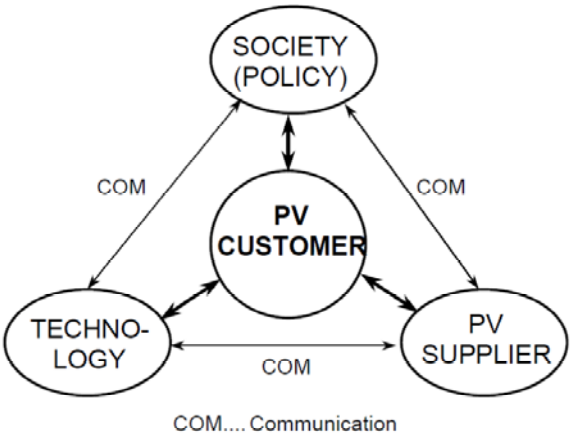


Figure 8: Relevant target areas for successful marketing strategies (Haas, 2002)

The thesis focuses on the different policies that influence the PV customer. First an outline is given concerning the legislation and financial subsidy systems that are available in the Netherlands. Next to this the different (bottom up) initiatives are described and compared. This eventually leads to the most important attributes that have to be questioned in the questionnaire.

3.1. Legislation and financial incentives Netherlands

In the last few years, one important subsidy scheme was provided in the Netherlands, the SDE subsidy. The SDE subsidy guarantees a total yield per kWh for a period of 15 years. In this way a payback time of 15 years is guaranteed. This subsidy is coupled with the current electricity price. If the electricity price increases, the lower the amount of SDE subsidy granted. If the electricity price is lower, the SDE subsidy is higher. This is done to encourage the deployment of solar PV cells. The SDE subsidy consists of three components: The replaceable costs for the use of energy, the price the electricity agency wants to pay for the kWh and the actual SDE subsidy. The difference between the generation costs and the price that is paid by the energy company is the amount of SDE subsidy. The subsidy is bounded by a governmental budget. The SDE subsidy was introduced for both small and large scale installations, but this changed this year. The subsidy for small scale systems is rescinded. (Agentschap NL, 2010). In 2011 the subsidy on only large scale systems will be paid by the consumers for 50 percent and by companies for 50 percent. In total 1.5 billion Euros will be invested over 15 years (Ministry of EZL&I, 2010). Before the costs for the subsidy were paid by the government. The SDE subsidy had a starting point from which people can subscribe. The amount of subsidy per kwh hour increases in time, but the amount of subsidy is limited. This year all the subsidy was finished in one day, this emphasized the public favour of renewable energy. Next to the SDE subsidy other regulations appear in the Netherlands. First the balancing regulation is discussed, which is highly important when deploying solar panels.

Balancing is highly connected to the deployment solar PV panels. Balancing, 'Saldering' in Dutch, is the possibility to scratch your generated energy from your energy bill. For instance, you generate 2000 kWh a year from a solar PV panel and you deliver it back to the net. On the other hand you have a yearly energy bill of 3600 kWh, the average in the Netherlands; with balancing you can subtract the kWh generated from your kWh used, so you only have to pay for 1600 kWh for the regular energy price. This is essential for the profitability of solar PV panels. The legal maximum to balance is currently 3000 kWh, but several large energy companies already balance until 5000 kWh. A strict condition to this regulation is that the generator should be 'before' your own energy meter box. So the generator of the energy and the energy user should clearly be connected. There is a new proposal program called 'Green Deal'. Greenchoice delivered a plan to allow unlimited balancing. In this case the barriers will disappear (Greenchoice, 2011). At the base of balancing lies the energy tax in the Netherlands. The current energy price consists of several parts: transportation costs, energy tax and delivery costs. This was elaborated in the previous chapter. These taxes are deleted with balancing and this increases the profitability of the solar panels enormously. All above the 5000 kWh can only be sold for 6 cents, the net energy price; this diminishes the payback time of PV panels greatly. Individuals pay a higher energy tax than companies and public institutions; this means that they could profit more from the balancing regulation. Changes in the balancing regulations could be made and it can increase the deployment.

Several other governmental subsidy programs for individuals are available to decrease the investment costs of solar PV panels. The province of Noord Brabant for instance wants to profile themselves as a sustainable province (Noord-Brabant, 2010). The province compensated homeowners which improve two classes within the energy labels. For one step 500 euro is granted, for two steps 950 euro is granted. These subsidies were granted within the program 'Meer met Minder'. The limit of this subsidy was reached at the 21st of March in 2011.

Another initiative is to make renewable energy tax free from the own used energy. This will make renewable energy more profitable. Next to this a possibility is to decrease the VAT rate of solar PV panels. This could be done either on labor and/or on the product. The VAT-rate could decrease from 19 percent to 6 percent. The foundation 'Natuur en milieu' started a petition to diminish the VAT-rate on solar panels. To cover the investments costs private parties and municipalities furthermore supply loans for sustainable causes. With low interest rates of two percent they want to diminish the barrier to invest in sustainable energy. Several municipalities offer sustainable loans, for instance the municipality of Eindhoven. In this case the municipality secures the loan. Next to municipalities some banks also give out loans for sustainable purposes, for example green energy (Arcadis, 2011). There are a lot of municipalities that give out loans, because they are linked to the SVn, stimulation fund public housing municipalities. They give out loans with an interest rate of 2/3 percent

(Agentschap NL, 2011). Some municipalities have a pro active attitude towards solar panels. For instance the municipality of Amsterdam will deploy solar panels on 21 school roofs. This is to increase the deployment of solar panels themselves. The municipality of Eindhoven strives to deploy solar panels on their own estate.

3.2. Deployment strategies from the market

As elaborated in the previous chapter, the financial power and the willingness of the governments is decreasing due to savings. Overall national sustainable policies are diminishing and new sustainable frameworks are not likely to be introduced. Municipalities try to encourage bottom up initiatives to deploy solar panels. This can be done in several ways. The possible applications on the own roof of the individual are bounded by certain factors. The roof orientation to the south is essential to catch sufficient sunlight. The presence of objects that create shadow decrease the efficiency. Next to this people could be bounded because they will probably move within certain years, at least before they gain back their investment. The biggest barrier is the housing type. Do they live in a privately owned house or a rental house? In a rental house it is difficult to deploy solar panels. Do you live in a row house or an apartment? In an apartment there is not enough roof surface to place the panels. These boundaries could be overcome due to the new deployment strategies. Several public private initiatives try to deploy PV panels in the Netherlands. One way to do this is the large scale purchasing of PV panels in low cost countries like China. This leads to lower payback times, but does not stimulate the Dutch solar industry. Wij willen Zon, ‘we want sun’ in Dutch, is the main example on the market. These examples are differentiated from the adoption shares, which will be discussed in the next paragraph, because this contains full ownership and thus high investments costs for full photovoltaic systems. In this way cheaper system could be developed, mainly because of the low prices of PV panels in China.

3.2.1. Adoption/Shares:

Adoption structures or share structures are a low boundary way of deployment of solar PV panels. For example for an amount of hundred euros a solar cell could be adopted, with a payback time of 10 years. With a large amount of adopters a sufficient located roof could be filled with PV panels. In this way the only cost for consumers are the investment (Arcadis, 2011). On example of an adoption/share program is BoerZOEKTbuur, ‘farmer searches neighbor’. In the program you can buy a share of 250 euro for which you get 6 coupons of 50 euro to spend at the farm. In this way you do not receive green energy, but other products. If you buy your green energy at a certain energy provider, you get a discount of 20 euro, so you only pay 230 euro. This initiative was expanded to a program in which the investor does get energy for this money. This initiative is called boerENbuur ‘farmer and neighbor’. To participate you buy a share of 3000 euro. For this 3000 euro you gain 800 kWh a year. This installation will be running for 25 years, in which you will pay 15 cents for your kWh of energy. This concept is heavily depending on the balancing regulations for the government. AZEC is another initiative in the east of the Netherlands. This initiative works with shares of 100 euro, this makes you owner of 0,75 m2 of solar panel. This project tries to encourage the deployment of solar PV in an area, so payback time is less important. It is a low boundary initiative, which has now 376 participants. These kinds of initiative could be broadened with industrial areas and so on. In this category it is not necessary to have a sufficient roof and put PV panels on the owner’s roof. The examples above show low investments amounts, but do contain new insights. The possibility to combine adoption with high investment costs will be taken into account.

3.2.2. Leasing:

In this case the roof of a home or business is rented by an investor, which will install PV panels on the roof. The profits for the roof owner contain of rental benefits or charge less energy from the panels. Lease constructions are also developed for consumers which can lease a PV panel for a monthly fee and get energy in kWh in return. For a certain amount of money per year or month green energy for a stable price can be bought. The insurance and maintenance are included in this structure. To participate for a leasing structure it is essential to have a sufficient located roof which can reach high efficiencies. In this initiative ZonVast, the investor, an energy provider, will be owner of the solar panels on your roof for 20 years and a monthly fee is paid for the energy generated. This is an initiative which is bounded by several requirements. To participate in this project you got to have an ideal roof orientation, on space for 10 panels which take up a surface of 18 m2. This installation will generate approximately 1900 kWh a year. From this amount 600 kWh can approximately be used for own purposes for 23 cents for the running time of 20 years. This price is independent of the fluctuating energy price. This increases the independency. After 20 years the roof owner becomes owner of the installation and can use and sell the energy. In this leasing model there are no investment costs for the roof owner (Greenchoice, 2011). Zoneco is a program which provides leasing programs both for own roofs and outside roofs. This program tries to encourage public private partnerships. ZonEco establishes a local corporation which will generate and use their own energy. Municipalities can be a member in three different ways. To invest in realization of a corporation for 5000 euro, to scan and see the improvements for 1000 euro a year and to sponsor locally produced energy for 500 euro a year. For individuals there are different possibilities. You can buy your energy through the cooperation and use energy for a fixed price. You can buy an installation through the program for 100 euro a year administration costs and the installation costs. You can also lease within this program for a variable amount of euro a month, in which you will have low initial cost of 250 or 1000 euro and a monthly fee of 25 to 45 euro a month. This leads to an energy price of 25 cent for a small installation over 15 years, and 20 cents for large installation over 15 years. Zoneco works with the panels of Wij Willen Zon. The leasing options show potential, but this thesis will focused itself on the investment side. Do people want to invest in leasing constructions or do they prefer to participate in local initiatives for instance?

3.2.3. Local initiatives:

With the start of local energy companies, the possibilities are increasing. On local level people can cooperate and generate and sell their own energy. These local energy companies are set up all over the Netherlands. The role of the municipalities differs among the different organizations. In Amsterdam an interesting project has been developed, called 'Zon op Noord'. This project deploys panels on central roofs. You could buy a panel for 640 euro for 210 Wp. The panels are deployed in central places in the neighborhood. In this way individuals could subscribe to a program and buy the panels through an organisation. For the first project they earned SDE subsidy, these were 70 panels with had a capacity of 14600 Wp (www.zonopnoord.nl, 2011). These forms of organizing show a great potential, but it is never measured in conjoint choice analysis. The balancing regulations are a clear boundary for these initiatives; several initiatives within the national government try to rescind this barrier for local initiatives.

3.3. Conclusions:

With the abolition of small scale exploitation subsidy, governments put their focus on bottom up market strategies and exhaust the willingness of individuals to pay. This leads to a new focus, namely on the decision behavior of individuals. New strategies appear to encourage the deployment of solar PV panels. These strategies derive bottom up from the market. Governments can adapt to these strategies and enlarge the deployment rate. When looking at the various strategies they mainly differ on the two following parameters, purchase service and organizational form.

Purchase service:

The purchase service is the service delivered during the purchase of the solar PV panels. These depend on the labor one has to carry out to have a working PV system. The first level is the self service level: In this case the panels are bought individually on the internet. The installer is also assigned through the internet individually. The second level is called standard panel. In this case a standard system with installer is bought on the website of the municipality of Eindhoven. The last attribute level contains personal guidance. You get personal guidance to accompany you throughout the purchase to adapt the system on your personal needs.

Organizational form

The geographical location of the panel can differ between the different strategies. The principal category is a panel which is installed on their own roof. This could be preferred because the panels are present and give a sustainable and high tech image to the house for the owner and the surrounding residents. Nevertheless the panels are attached to the house and this could be a disadvantage. Next to this the panels could be placed within the neighborhood so that with a corporation of residents PV panels could be bought and place within the neighborhood on sufficient roof surface, but still with the visibility aspect. This level related to the new developing local energy companies which could be a major actor in the process. In the last case the panels are placed externally, as an adoption or leasing structure. In this way the panels do not have a physical connection with the owner. Large companies purchase panels on large scale and put on for instance industrial roofs, so small scale solar energy plants are created with the investments of consumers.

The two different parameters lead to the following strategies which will be compared:

Table 8: Deployment strategies and their attribute levels

Number	Strategy	Purchase service	Organisation/ Location
1	Standard Panel	Medium	Individual
2	Adoption	Low	Investment
3	Individual	Low	Individual
4	Local energy company	Medium	Local cooperation
5	Individual High service	High	Individual

4. Consumer behavior model

How do individuals behave when purchasing solar PV panels?

The effectiveness of the deployment strategy is depending on the transaction rate of consumers to switch to solar panels. How can consumers be convinced to deploy solar PV panels? In this chapter an overview of consumer behavior is given.

Governmental strategies are primarily focused on exhausting the willingness to pay by the consumers. This is the most important criteria to determine the success of the strategies. In this chapter the focus lies on the willingness to pay for consumers and how the willingness to pay can be influenced. Consumers are most willing to deploy solar panels at natural moments, like when they buy a newly built house or when they choose to renovate their house (Berenschot, 2011). Next to these moments, there a various other moments when people could deploy solar panels. Every individual could invest at all time in solar PV panels. Consumers will be influenced by different factors when making a decision whether or not to invest. The influential factors can be divided in four main categories: marketing mix influences, socio-cultural influences, psychological influences and situational influences (Kerin, Hartley, & Berkowitz, 2005). The marketing mix influences and socio cultural influences will be investigated in this thesis. How can product, price and promotion influence the consumer purchase decision? And does the deployment rate differ within the different socio cultural backgrounds? In this way the most important parameters for large scale deployment of Solar PV could be determined.

4.1. Behavior model:

Bouwfonds investigated people’s willingness to pay for sustainable measures when people are buying new estate. This study of Bouwfonds developed a behavioral model based on the theory of Ajzen, which is also applicable in this research (Bouwfonds Ontwikkeling, 2010):

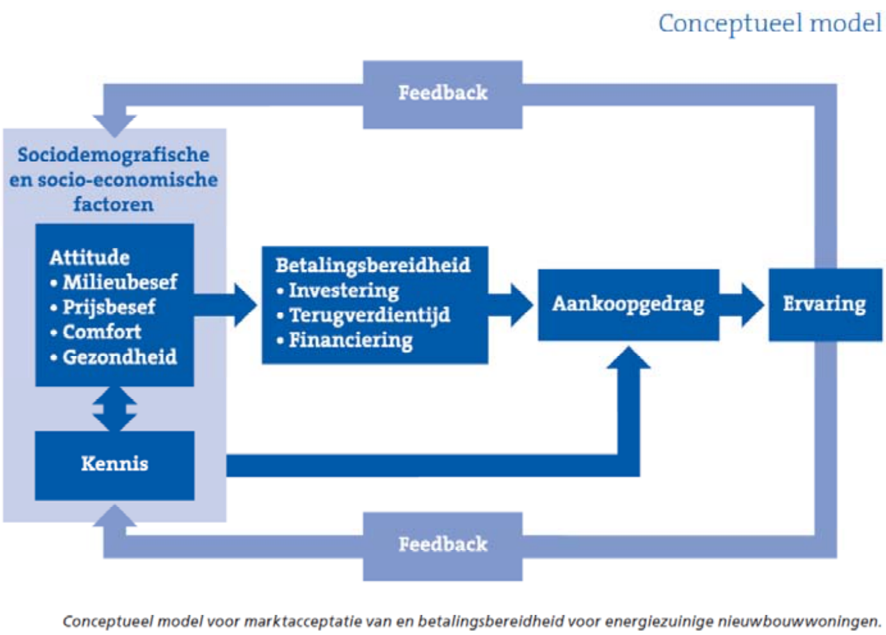


Figure 9: Conceptual model (Bouwfonds Ontwikkeling, 2010)

This research of Bouwfonds contained three parts, including a part where a willingness to pay study for sustainable energy generators for new buildings was done. The model developed by Bouwfonds and founded by Ajzen is used to examine the willingness to pay for solar PV panels. On the left side the socio demographic factors are displayed. These factors will be questioned in the first part of the questionnaire in this research. Do the different demographic characteristics have a significant influence on the willingness to pay? The criteria which influence the willingness to pay will be measured with a conjoint analysis. The criteria as developed by Bouwfonds will be enlarged with new criteria. These criteria determine the purchase behavior of consumers, this leads to the experience of a purchase which leads to a feedback loop. This model will be the foundation for the chapter of decision behavior of consumers.

4.2. Socio demographic factors:

Several socio demographic factors influence the purchase decision. The social status and the years of education have an positive influence on the adoption rate, the higher the years of education, the likelier people will adopt innovations are described by Robers (Rogers, 2003). Next to this young people have a more positive attitude towards sustainable measures than older people. Furthermore the research of Bouwfonds confirmed that people with a higher education are more eager to invest in sustainable applications. Income is an important factor, it is essential for people to be able to invest (Bouwfonds Ontwikkeling, 2010). This study furthermore showed that there was a lack of knowledge among consumers concerning the possibilities. Sustainability is not a good selling point. The financial parameters determine the purchase decision (Bouwfonds Ontwikkeling, 2010). The lack of information is also emphasized by Jager in 2006. He pointed out the use of information meetings. Furthermore he emphasized on the on the social network effects of further diffusion. This relates to Rogers who also built his theory on this phenomenon. Next to this Jager emphasizes on the importance of a home market and the 'normalization' of solar PV panels (Jager, 2006). According to the study of Haas in 2002 the main determants on willingness to pay are available income, magnitude of electricity prices and affordability (Haas, 2002).
The lack of information was investigated by Bouwfonds study. The level of knowledge, among the respondents, will also be questioned in the questionnaire. The respondents will be asked what they think the payback time of solar panels currently is. Furthermore the attitude will be questioned towards PV panels, as showed in the model, figure 12. What is their opinion about solar PV panels? What will be their main reason to purchase solar panels? What will be their main reason to not do it? In this way the attitude can be determined of the respondents.

4.3. Willingness to pay

The socio-demographic factors influence the willingness to invest. According to the model used by Bouwfonds, the willingness to pay is determined by investment costs, payback time and the way of financing. Other researchers used other parameters to determine the willingness to pay. The main researches and their attributes on the decision behavior of sustainable energy generation are elaborated in the table below:

Table 9: Decision criteria different researches

Study:	**(Haas, 2002)**	**(Burton & Hubacek, 2007)**	**(Ren, Gao, Zhou, & Nakagami, 2009)**	**(Wang, Jing, Zhang, & Zhao, 2009)**	**(Scarpa & Willis, 2010)**	**(Yang, 2010)**
Criteria 1	Pure Investment costs	Capital costs	Investment costs	Investment cost	Capital cost	Capital costs per kW
Criteria 2	Affordability	Operation and maintenance	Running costs	Operation and maintenance cost	Energy bill per month	Annual fixed maintenance costs
Criteria 3	Transaction costs	Generation capacity	CO2 emissions	Fuel cost	Maintenance cost	Variable O&M
Criteria 4	Technical performance	Lifespan	Primary Energy consumption	Electric cost	Recommended to you by	Lifetime
Criteria 5	Environmental benignity	Carbon emissions		NPV	Contract length	Interest rate
Criteria 6	Social acceptance of PV	Noise		Payback period	Inconvenience of system	Energy generated
Criteria 7		Natural environment		Service life		
Criteria 8		Social score		EAC		

Figure 9 displays the attributes used by other researchers. Wang listed all possible financial attributes. These attributes are reviewed on relevancy in the specific case of PV deployment by consumers. An important research in the Netherlands was done by Bouwfonds. The study of Bouwfonds showed that buyers of new estate where primarily financial focused concerning their willingness to pay. It highlights that when due to renewable energy generation the energy bill further diminishes, the willingness to invest increases among consumers. The Bouwfonds study found that people were generally willing to invest until a payback time of 10 years (Bouwfonds Ontwikkeling, 2010). Currently PV panels are reaching this barrier. This results in the conclusion that people in the Netherlands are willing to pay for solar PV panels when buying a new home, but are they also willing to pay when staying in their old home?

According to a research by Motivaction approximately 50 percent of the Dutch citizens are interested in deploying solar panels. The biggest barriers indentified by the respondents were the investment en installation costs (45%), the payback time too long (20%) or where waiting for a drop in the energy price (21%). The financial parameters were identified as the most important (www.motivaction.nl, 2011). Reinhard Haas researched the different subsidy schemes and evaluated the success of the different schemes. He also defines the theory behind the governmental schemes, as stated in the deployment strategies chapter. Haas determines that these strategies are aimed at exhausting the willingness to pay of consumers. Haas highlighted several factors which are determinant for the willingness to pay. The factors are: "Pure investment costs, affordability, transaction costs/efforts, technical performance/technical reliability, environmental benignity and the social acceptance of PV" (Haas, 2002). Pure investment cost represent the starting costs for a PV system, this will be taken into account. The transaction costs are in the case of solar PV low and will be redefined to purchase service, as described in previous chapter. The financial aspects (attributes in the conjoint analysis) can be separated in the (pure) investments costs and the technical performance. The technical performance is the determining factor for the payback time of the panel and the investment. To make the factor the easiest to understand for the respondents the term payback time is used to describe the technical performance. The maintenance costs for PV panels are negligible currently, so this will not be taken into account. The study of Bouwfonds presented that environmental issues have no influence on the willingness to invest for consumers. To test this assumption, the environmental benignity will be questioned in the first part of the questionnaire and will come back in the quality mark attribute, in which a sustainable level is incorporated. In this way sufficient attributes for the conjoint analysis are determined. These attributes are still comprehensible for the respondents and give a clear overview of solar PV panels. These topics will thus be included in the choice experiment. The purchase service and organisation derived from the deployment strategies chapter. The levels are determined by the financial analysis in the technology chapter. The attributes and attribute levels will be elaborated below.

4.4. Segmentation

The deployment of solar PV panels contributes to the energy transition towards renewable energy sources. Consumers in general are an enormous investment group. Do the preferences of the different groups within the respondent's pool differ? Rogers has developed a theory which establishes a segmentation when people deploy new innovations. This theory divides consumers on their willingness to adopt. This is an important factor in the transition to solar energy. This theory is displayed below:

The Innovation – Decision process					
1. Knowledge	2. Persuasion	3. Decision		4. Implementation	5. Confirmation
Adopter Categories					
1. 'early adopters' (2.5%)	2. Early Adopters (12.5%)	THE CHASM	3. Early Majority (35%)	4. Late Majority (35%)	5. Laggards (15%)
Attributes of Innovations					
Relative advantage	Compatibility	Observability		Trialability	Complexity

Fig. 1. The 3 key components of Diffusion Theory (Rogers, 1995), including the point of the Chasm suggested by Moore (1999).

Figure 10: Diffusion theory of Rogers (Faiers & Neame, 2006)

This shows the different steps in the adoption process. Five major segments could be distinguished in this research: the innovators, the early adopters, the early majority (currently willing to invest), the late majority and the laggards. In the figure below the adopter segments and their percentages are elaborated:

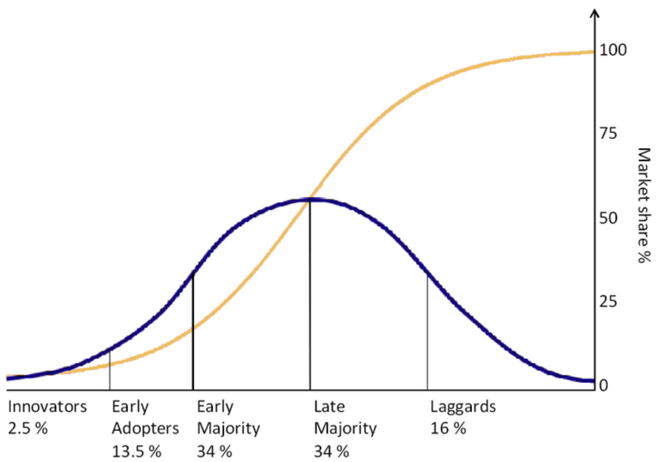


Figure 11: Diffusion model segmentation (Rogers, 2003)

The two main categories that should be convinced are the early adopters and the early majority. The early adopters consist of 13,5 percent of the total adopters. These people are greatly respected by other people. In this way they are in a way opinion leaders. By adopting they give their blessing to the innovation in a way (Rogers, 2003).The early majority consist of one third of the adopters. The early majority are characterized as considerate. They have a longer decision process than the innovators and early adopters. They follow the experiences and opinions of others (Rogers, 2003). Furthermore the early majority seeks confirmation and that they like to choose between competitors. The Early majority is vulnerable for financial aspects, but is also willing to pay for quality. They intend to avoid risks and stick to their brand (Moore, 1991). The survey will be pointed to this segment to determine their needs. This segmentation in the population is also found by Ingrid Nieuwenhuijsen. In her research she determined three segments: the conscious residents, the financially focused residents and the older residents. The conscious residents are the most eager to save energy. They can be determined as the innovators and early adopters as described by Rogers. They have an individual focus and a high knowledge about energy saving measures. The financially focused group focuses on investing in energy saving measures to save money. The older residents do not embrace intervention strategies to change their energy saving behavior. They have low knowledge of energy problems (Nieuwenhuijsen, 2010). This segmentation is an addition to the segmentation of Rogers.

When looking at the different categories, you could argue which group we have to address, and in what part of the adoption process we are currently in the diffusion process. The currently installed PV power is 10,5 MW in 2009, this lead to a total installed amount of 67,5 MW (KEMA, 2009). This is extremely low compared to the 3000 MWp installed in for instance Germany only in 2009 (Berenschot, 2011). Solar PV is aimed to produce 14 percent of the total sustainable energy supply in 2020 according to the government. Now the share of solar PV on the total sustainable energy production is 0,3 percent en 0,5 percent on the sustainable electricity generation (CBS, 2010). This leads to the conclusions that only the innovators have deployed solar panels, and the early adopters are still to be convinced.

4.5. Attributes used in conjoint analysis:

As elaborated in the previous chapters the following attributes will be used in a conjoint experiment to determine the preferences of consumers when purchasing solar PV panels. This research will investigate the relative influence of the different attributes. In a conjoint experiment the different attributes are independent. The following decision criteria derived from the literature:

Attributes	
Investment Costs	4000 – 8000 - 12000
Purchase service	Self-service – Standard – Personal guidance
Payback time	8-10-12 years
Organisation/ Location	Own roof – Local - external
Quality mark	No quality mark – Quality mark – Sustainable mark

Investment costs

The investment costs can differ largely. In this investigation the levels range from no investment costs to 12.000 investment costs. For 12.000 euro's you can buy an installation to generate the average energy use of an average household in the Netherlands.

Purchase service:

The purchase service is the service delivered during the purchase of the solar PV panels. These depend on the labor one has to carry out to have a working PV system. The first level is the self service level: In this case the panels are bought individually on the internet. The installer is also assigned through the internet individually. The second level is called standard panel. In this case a standard system with installer is bought on the website of the municipality of Eindhoven. The last attribute level contains personal guidance. You get personal guidance to accompany you throughout the purchase to adapt the system to your personal needs.

Pay Back Time

The payback time of solar panels depends on several factors. Currently the most important factors are the efficiency of the system. How many kWh can the system generate? This determines the possible reduction on the energy bill and this determines the payback time. The life expectancy of the panels is estimated on 25 years. This means that with a payback time of 10 years, 15 years of energy free of charge will follow. In the next years a payback time of 8 years could be reached. That is why the attribute levels will differ from 8 to 12 years.

Organizational form

The geographical location of the panel can differ between the different strategies. The principal category is a panel which is installed on their own roof. This could be preferred because the panels are present and give a sustainable and high tech image to the house for the owner and the surrounding residents. Nevertheless the panels are attached to the house and this could be a disadvantage. Next to this the panels could be placed within the neighborhood so that with a corporation of residents PV panels could be bought and place within the neighborhood on sufficient roof surface, but still with the visibility aspect. In the last case the panels are placed externally, as an adoption or leasing structure. In this way the panels do not have a physical connection with the owner. Large companies purchase panels on large scale and put on for instance industrial roofs, so small scale solar energy plants are created with the investments of consumers.

Quality mark:

The quality mark is taken into account because it could influence the decision process. Next to this it tests whether or not sustainability plays a role in the decision. Are people more eager to deploy solar panels when it is sustainably made? This has resulted in three attribute levels: no quality mark, a quality mark on the origin of the materials and the production process and sustainable produce panels which will be totally recyclable after 25 years.

5. Conjoint choice experiment:

5.1. Questionnaire:

The questionnaire was made in the online questionnaire tool NetQ. The questionnaire was send with a personal link to the respondents. First, eleven questions were asked to get the socio demographic characteristics of the respondents. Then, the choice experiment was presented to the respondents. A sample of the municipality of Eindhoven is questioned, using the digital panel. This is a sample of citizens of Eindhoven which applied to cooperate with surveys now and then. The questionnaire is attached as appendix C.

5.2. Conjoint choice experiment design:

Conjoint choice analysis is an often used marketing tool to estimate the preferences of consumers. Next to this it is used in various scientific fields. When you want to examine consumer behavior conjoint choice experimenting is a valid approach. It can provide the relative importance of the different attributes; this was stated by Kemperman as follows: "The conjoint preference and choice modeling approaches provide quantitative measures of the relative importance of attributes influencing people's preferences and choices" (Kemperman, 2000). This method presents a choice to someone between two profiles; a profile is a combination of attributes, aspects, with varying levels. In this case the profile consist of five attributes, investment costs, purchase service, payback time, organization/location and quality mark, the attribute levels are described in the table below.

Table 10: Attributes and their attribute levels

Attributes	
Investment Costs	4000 – 8000 – 12000
Service level	Self-service – Standard – Personal guidance
Payback time	8-10-12 year
Organisation/ Location	Own roof – Local – external
Quality mark	No quality mark – Quality mark – Sustainable mark

The attributes and attribute levels are validated by experts in the field. In this way the most important decision criteria are taken into account. Furthermore the decision criteria are designed in such a way that they are comprehensible for the respondents. All these attributes have three levels, as explained in the previous chapter. In this way with the conjoint experiment 3^5 = 243 profiles can be generated. Only the main effects are of interests in this study, the Independence from irrelevant attributes, the IIA assumption, is assumed. This means that the choice probabilities of the alternatives are independent of the appearance of other alternatives in the choice set (Oppewal & Timmermans, 1993). When only searching for the main effects a full fractional factorial design can be used, this leads to only 18 profiles. These profiles are coded using effect coding (Kemperman, 2000).

Table 11: Effect coding scheme (Kemperman, 2000)

Levels	A1	A2
0	1	0
1	0	1
2	-1	-1

These eighteen profiles will be presented in a choice experiment with two alternatives. The profiles are randomly divided into 9 pairs. The pairs are presented to the respondents in a random order. This is to prevent the results to be biased. The choice sets are incorporated in the questionnaire in the appendix. Below the choice set coding scheme is displayed:

Table 12: Choice sets and profile coding

Choice set	Profile	a1	a2	b1	b2	c1	c2	d1	d2	e1	e2
1	16	1	0	0	1	0	1	0	1	-1	-1
1	2	0	1	0	1	0	1	1	0	0	1
2	6	0	1	-1	-1	-1	-1	0	1	1	0
2	10	0	1	1	0	0	1	0	1	0	1
3	4	1	0	-1	-1	0	1	-1	-1	-1	-1
3	18	1	0	1	0	1	0	1	0	1	0
4	8	-1	-1	-1	-1	0	1	1	0	1	0
4	13	-1	-1	-1	-1	1	0	0	1	0	1
5	11	1	0	1	0	-1	-1	1	0	0	1
5	14	0	1	-1	-1	1	0	1	0	-1	-1
6	7	-1	-1	1	0	-1	-1	0	1	-1	-1
6	17	0	1	1	0	1	0	-1	-1	-1	-1
7	3	-1	-1	0	1	-1	-1	1	0	-1	-1
7	12	0	1	0	1	-1	-1	-1	-1	1	0
8	9	-1	-1	1	0	0	1	-1	-1	1	0
8	1	1	0	-1	-1	-1	-1	-1	-1	0	1
9	5	-1	-1	0	1	1	0	-1	-1	0	1
9	15	1	0	0	1	1	0	0	1	1	0

In this research, the no-choice alternative is not included. This is because it was expected that this choice would be chosen in a too often. That is why the dual response format was used (Brazell, Diener, Karniouchina, Moore, Severin, & Uldry, 2006). This means the choice experiment is divided in two questions. One question to determine the choice between profiles, and one question to choose whether or not to purchase the panels. Below an example is displayed:

gemeente Eindhoven

TU/e Technische Universiteit Eindhoven University of Technology

Lees de keuzeprofielen zorgvuldig door en geef uw voorkeur aan:

	Keuzeprofiel 16	Keuzeprofiel 2
Investeringskosten	4000 euro	8000 euro
Aanschafservice	Standaard	Standaard
Terugverdientijd	10 jaar	10 jaar
Organisatie/Locatie	Lokale samenwerking	Individueel
Keurmerk	Duurzaam	Keurmerk

Welke keuzeprofiel heeft uw voorkeur?

- Keuzeprofiel 16
- Keuzeprofiel 2

Zou u, bij het hierboven gekozen profiel, aanschaf overwegen?

- Ja
- Nee

Verstuur

Figure 12: Example choice set

This dual response format implies that the data can be analyzed in different models. For the analysis for different models are used. The multinomial model is the main model used in this thesis, to use this model the dual response data was recoded by including a no choice option. This multinomial model is extended with a Latent Class analysis to determine different segments within the respondents' pool. After this the different socio demographic factors are compared, so influential socio demographic factors are taken into account. The binary logistic model was used to determine the preference without considering purchasing. Furthermore this binary logistic model was used on only the preferred models including the purchasing question. At last an ordinal regression model was used to determine the acceptance of the different strategies. In this analysis, only the preferred profiles are taken into account. In this way the results of this model are partly biased.

5.2.1. Theory: Random Utility:

This research is based on the random utility theory. In this theory the utility term is separated in two parts. One is the systematic component and one is the random and uncertain component (Kemperman, 2000). This is displayed in the following formula:

$$U_i = V_i + \varepsilon_i$$

The systematic component can be defined further. This is done by putting together the different path worth utilities. In this way low appreciation of one attribute can be leveraged by another attribute with high appreciation. In this way this component can estimate the utility of the total profile (Kemperman, 2000):

$$U_i = \sum_k \beta_k X_{ik} + \varepsilon_i$$

The formula shows that utility for a certain alternative is compound of the path worth utilities of the different attributes.

5.2.2. Multinomial logit model:

The multinomial model (MNL model) is used to estimate the path worth utilities. These utilities are a1 for level 1, a2 for level 2 and –(a1+a2) for level three of every attribute, see the effect coding explanation earlier this chapter. In this way the utilities for every attribute are determined. This was done in the questionnaire by recoding the dual response questions and thereby including a 'no choice' alternative in the model. The MNL model is built on the assumption of the error term. This model says that the distributions of the error term are 'Independently and identically distributed '(IID) according to a Gumbel distribution. This assumption leads to the following form to determine the choice probabilities (Kemperman, 2000):

$$P(i \ / A) = \frac{\exp\ (\mu V_i)}{\sum_{i' \epsilon A} \exp\ (\mu V_{i'})}$$

In this way the composition of the profile determines the choice probability of the profile. This will be used in the validation of the results. The goodness of fit of the MNL model is estimated by the McFadden's rho square. This term is built up in the following way:

$$McFadden's\ Rho\ square\ =\ 1 -\ LL(B)/LL(0)$$

$$LL(B) =\ log\ likelihood\ at\ convergence$$

$$LL(0) =\ log\ likelihood\ of\ the\ null\ choice\ model$$

The McFadden's Rho square should be above 0.2 to suffice. At last the results will be validated. On the first 600 respondents a regression is done and the results will be used to determine the choice probabilities of the different choice sets. These will be compared with the rest of the respondents.

5.2.3. Latent Class model:

With a latent class model a possible segmentation will be derived. In this way the result can be estimated more accurately. The utility formula is described below (Kemperman & Timmermans, 2006)

$$U_{jit} = \beta_c' X_{jit} + \varepsilon_{jit}$$

For this multinomial model to predict the choice probabilities can be described in the following way (Kemperman & Timmermans, 2006):

$$P(y_{it} = j \ / class = c) = \frac{\exp\ (\beta_c' X_{jit})}{\sum_{j'=1}^{J_i} \exp\ (\beta_c' X_{j'it})}$$

So every respondent has a choice probability for every class. The class with the highest choice probability is most likely to be chosen. The actual choice can be compared with the prediction by validation. The validation of the latent class model is done by Limdep, Limdep predicts the choice of individuals and it compares the prediction with the actual choice of individuals.

5.2.4. Binary logistic model:

Next to the multinomial model a binary model was used. This model can be described in the following formula's (SPSS, 2010):

$$z_i = b_0 + b_1 \cdot x_{i1} + b_2 \cdot x_{i2}x + \cdots + b_p \cdot x_{ip}$$

The parameters in the equation can be described as follows:

$$x_{ij} \; is \; the \; \; j^{th} \; predictor \; for \; the \; i^{th} \; case$$

$$b_j is \; the \; j^{th} \; coefficient$$

$$p \; is \; the \; number \; of \; predictors$$

Probability function is described in the following way:

$$P_i = \frac{1}{1 + e^{-(b_0 + b_1 * x_{i1} + \cdots + b_p * x_{ip}}}$$

The formulas were used to predict the preferences between the different profiles. Therefore only the first question of the dual response format could be used. The utilities of the model will be estimated by SPSS, the goodness of fit is measured by the pseudo rho squared of Nagelkerke.

5.2.5. Ordinal regression model:

With an ordinal regression the threshold is estimated. This threshold stands for the likelihood to purchase a certain profile or package. If a profile's value is above the threshold, people are likely to purchase the package. This regression was done by SPSS and will be analyzed in the results. This model is represented by the following formula (SPSS, 2010):

$$link \; (y_{ij}) = \theta_j - \; [\beta_1 \cdot x_{i1} + \beta_{12} \cdot x_{i2} + \cdots + \beta_p \cdot x_{iJ}$$

In which:

$$Link(..) = \; link \; function$$

$$y_{ij} = cumulative \; probability \; of \; the \; j^{th} \; category \; for \; the \; i^{th} \; case$$

$$p = number \; of \; regression \; coefficients$$

$$x_{i1} \ldots . \; x_{ip} \; are \; the \; values \; of \; the \; predictors \; for \; the \; i^{th} \; case$$

$$\beta_{i1} \ldots . \; \beta_{ip} \; are \; the \; regression \; coefficients$$

5.3. Sample:

The questionnaire is distributed among 1936 respondents from the digital respondent's panel of the municipality of Eindhoven. The digipanel is a voluntary respondent pool which is questioned once in a month about important topics within the municipality.

The following table shows the sample characteristics:

Table 13: Sample characteristics

		Sample:	Population of Eindhoven (* NL)
Gender	Male	60% (# 547)	51 % (# 110.0001)
	Female	40 % (# 364)	49 % (# 106.067)
Age:	18-30	6,8 % (# 57)	21% (# 35518)
	31-40	17,6 % (# 148)	19% (# 32604)
	41-50	21,1 % (# 178)	18% (# 31111)
	51-60	25,1 % (# 212)	15 % (# 26603)
	60+	29,4 % (# 248)	27 % (# 46357)
	Total		172193
Education:	No	0 % (# 2)	
	Primary School	1 % (# 13)	8,2 % (# 905000)
	Secondary School	12% (# 112)	22,8 % (# 2511000)
	Higher Secondary School	13 % (# 116)	9,7 % (# 1067000)
	Lower Vocational college	3 % (# 24)	13,2 % (# 1458000)
	Higher Vocational college	19 % (# 169)	17 % (# 1896000)
	College degree	52 % (# 470)	27,8 % (# 3066000)
	Total		11017.000
Housing Ownership	Buy	74 % (# 673)	48 %
	Private rental	2 % (# 21)	52 % total in Eindhoven
	Corporation rental	24 % (# 215)	''
Housing Type	Apartment	18% (162)	
	Row house	56% (505)	
	Detached house	10 % (94)	
	Different : 2 under 1 roof	16 % (147)	

The differences in demographic factors could be explained by the fact it is a voluntary panel. Individuals, who are interested in what the municipality is working on, can apply for this panel to get frequent questionnaires. The respondents are generally more interested in solar panels according to the literature study earlier. The results can be in this case slightly more positive towards solar panels but still contain valid information. Still every group has a sufficient number of respondents to get valid results.

6. Results:

The result chapter will be separated in different parts. First the sample characteristics and socio-demographic factors will be discussed, and then the regressions will be outlined. Due to the dual response format used there are four main models used. The multinomial model used data which was recoded from the dual response form. A Latent class analysis was done to determine different segments within the respondent's pool. Next the different socio demographic factors will be compared in the result chapter. Next to this the different strategies were compared in the multinomial model and the latent class model. The binary logistic model was used to determine the preference without considering purchasing. This model is transformed and used on the preferred models including the purchasing question. At last an ordinal regression is done to test the different strategies against each other.

Table 14: Respondents results

Total number of respondents	**1936**
Number of respondents started	937 (48%)
Number of respondent finished	878 (45%, 94% of started)
Average time	11 min 49 seconds

The questionnaire was send to 1936 respondents, from which 47 percent started the questionnaire and 44 percent (854 respondents) filled it in completely. The amount is high and underlines the interest of civilians in solar panels. From the completed questionnaires the respondent pool consists for 60 percent out of male's en for 40 percent out of females. 52 percent of the respondents were higher educated, on a college or university. This corresponds with the total respondent pool.

From the respondents 74 percent owned a house, 24 percent lives in a rental house from a corporation and 2 percent in a privately owned rental house. This differs from the total population of Eindhoven in which the division is half owner occupied and half rental. The main housing type was a row house, 56 percent of the respondents lives in this type. 18 percent lives in an apartment and 10 percent in a detached house, the rest, 16 percent, differed but mainly consist of pair wise housing.

Only three percent, 31 respondents, has already purchased solar panels. People's image of solar panels was highly positive, 73 percent defines it as a clear contribution to the building environment and it has a sustainable and modern image. In the purchase reasons questions the respondents could give two answers. The two main reasons to deploy solar panels are the depletion of energy and the independence of energy; these were chosen by 49 and 51 percent of the respondents. For 37 percent one of the main reasons to purchase solar panels is to push back and green house effect and for 36 percent the main reason is that it is an investment which pays itself back. The main reason for not buying solar panels are the investment costs, 79 percent of the respondents answered this option. The second reason is the payback time with 49 percent. The other reasons are less important. The main part of the respondent has a basic knowledge about solar panels, this part is 51 percent. 36 percent knows little about solar panels and 13 percent is well informed. The payback times of solar panels are ranked positively by the respondents. Payback times from 6 to 12 years have been filled in the most times, with 47 percent. 12 to 18 years are filled in 37 percent of the time. The rest is more of less equally divided. TV, internet and magazines are the most important information sources to get information over solar panels. Only 16 percent was informed by friends or relatives. This means there is a lot to be won in this field, with more people deploying this number will increase.

6.1. Multinomial model:

The multinomial model was created by recoding the dual response format into a one choice format with a no choice example; this was explained in the previous chapter. This multinomial model shows the following results:

Figure 13: Utilities Multinomial model

The results follow the results from the binary logistic model in general terms. The constant has a value of 1,3137. In figure 21 the relative importance under the multinomial model is displayed. You can clearly distinguish the two most important attributes, the quality mark and investment costs.

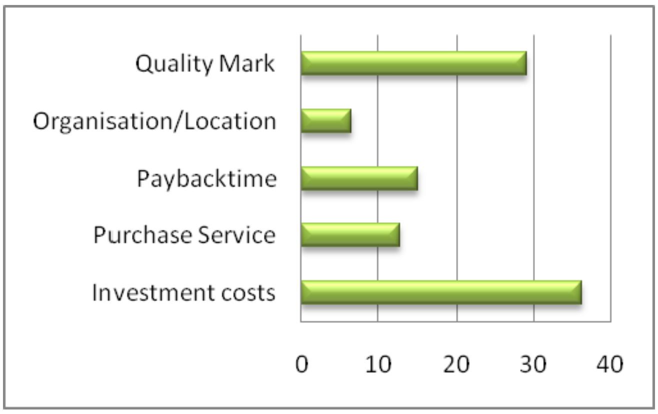


Figure 14; Relative importance Multinomial model

One important results is the negative influence of the attribute level own roof. This means the location of the panel does not matter to individuals. Next to this has the parameter Payback time does not have sufficient results. The null-hypothesis is rejected only at a 10 percent level for the attribute level of 8 years. The null hypothesis of attribute level of 10 years is not rejected. Investment costs of 12.000 are highly depreciated by individuals. The Multinomial model has a McFadden R square of 0.08721 with constants only. With no coefficients this probably will be higher. This is not sufficient and this could be due to two reasons:

- You could define different segments within the respondents which answer the questions differently. That is why a latent class models is used in the next chapter.
- The general background knowledge differs between respondents.

The validation of the results was done with the first 600 respondents that answered the questionnaire. The coded profiles were displayed in the previous chapter, see table 2. On these estimations the choice probabilities are calculated and these are compared with the real life choice the other 254 respondents have made.

Table 15: Validation: Predicted vs. actual choice probabilities

Choice set	Profile	Choice probability calculated	Choice probability Validation sample
1	16	0,712098943	0,705
1	2	0,287901057	0,295
2	6	0,290882878	0,307
2	10	0,709117122	0,693
3	4	0,741312213	0,764
3	18	0,258687787	0,236
4	8	0,156012704	0,134
4	13	0,843987296	0,868
5	11	0,38748412	0,48
5	14	0,61251588	0,52
6	7	0,201797114	25,6
6	17	0,798202886	0,74
7	3	0,542571677	0,543
7	12	0,457428323	0,457
8	9	0,067050813	0,118
8	1	0,939783	0,874
9	5	0,362992	0,335
9	15	0,637008	0,665

The two correspond strongly and the estimation show in this case a sufficient result.

6.2. Latent Class model:

The latent class model can divide the respondents into different classes. These classes have similar preferences; the classes can be characterized by SPSS. First the latent class results from Limdep will be displayed.

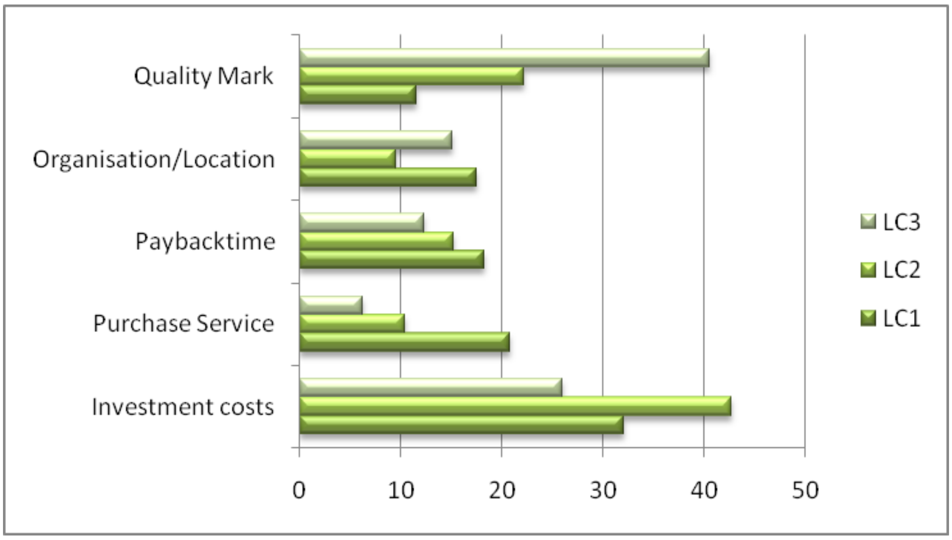


Figure 15: Relative importance latent classes

The relative importance of the attributes differs significantly. For latent class one the financial parameters are less important and the exsistence of a quality mark is more important compared to the other classes. The second class decides on the attribute investment costs and does not care about location of organisation. The third class does care about the purchase service and location and finds the quality mark less important.

	Constant
Latent Class 1	6,515
Latent Class 2	1,328
Latent Class 3	-1,559

The three latent classes differ mostly on the constant. To see important differences between the three latent classes the constant is left out in the figure. At the left side the constants are displayed: The different numbers correspond with the number of the times 'no purchasing' was chosen. In this case you can see that LC1 one has a high rate of 'no choices'. Latent class 2 has answered a medium amount of no choices and latent class three has answered positively most of the time. Beneath the different utilities of the latent class model are displayed:

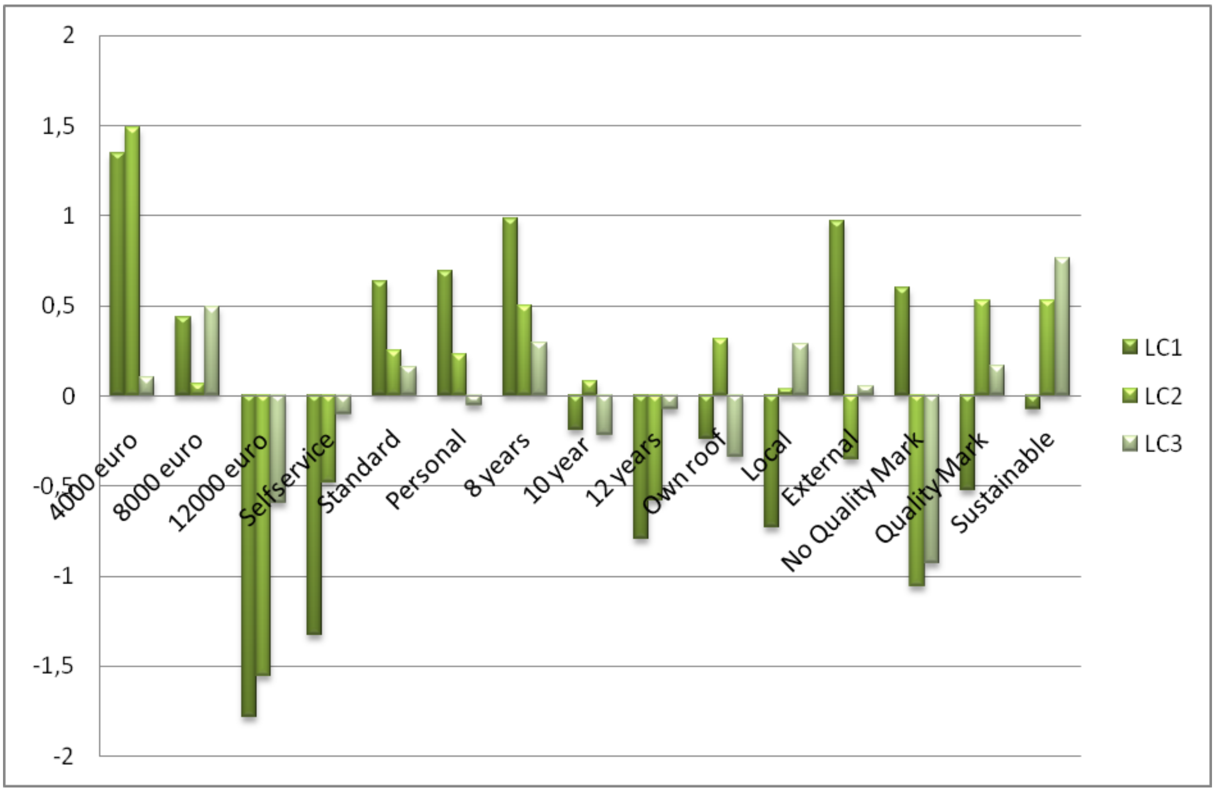


Figure 16: Path worth utilities attribute levels latent class

Looking at the predicted parameters the best segmentation will be to separate the respondents in three classes. The classes are named after the differences in utilities. Latent class one was not willing to purchase. Latent class 2 valued the financial parameters highly and latent class 3 valued the security parameters as quality mark and organisation as important in their choice. The characteristics of the classes are displayed below.

Table 16: Latent class model: characteristics

Characteristic	Latent class 1 'Skeptic'	Latent class 2 'Financially focused'	Latent class 3 'Searching for security'
	Older people	Younger people	All ages
Reason to purchase		Energy depletion	Energy depletion Independence of energy price
Reason not to purchase		Too long payback times	
Image	Not positive, not negative	Sustainable and modern	Sustainable and modern
Information	Badly informed	Medium informed	Well informed
Education	Lower educated	Higher educated	Higher educated
Percentage:	0,342	0,436	0,222
Constant	Not willing to purchase	Medium willing to purchase	Willing to purchase

Above the different characteristics of the different classes are displayed. The different characteristics are further explained in the conclusions.

Table 17: Prediction levels latent class analysis

Latent class					
Segments	Rho square	AIC	BIC	LLB	Difference
1	0,08721	1,73011	1,74005	-6637,8	
2	0,3672	1,396400	1,41719	-5343,36	1294,438
3	0,41588	1,29255	1,32418	-4932,25	411,109
4	0,42171	1,28286	1,32535	-4883,04	49,208

Above the parameters that determine the quality of prediction of the latent class model are displayed (Kemperman & Timmermans, 2006). Three latent classes show the best results with significant results. More than four classes could not be predicted. The results with four classes give one segment in which the utilities are highly insignificant, so the results are not sufficient and four segments cannot be used. That is why three segments show the most importance. With Limdep the validity of the estimations is tested. The predictions of Limdep were in 91 percent of the cases similar to the actual answers.

Table 18: Validation: Latent class analysis

Similarity between predicted and actual choice.	**No similarity between predicted and actual choice.**
6974 (91 percent)	712 (9 percent)

This confirms the high R squared and confirms the good prediction.

6.3. Comparison of socio demographic factors:

The socio demographic factors were also compared in this research. The following results derived from this research. Gender does not show significant differences. Males are slightly more financially focused due to a higher appreciation of the payback time.

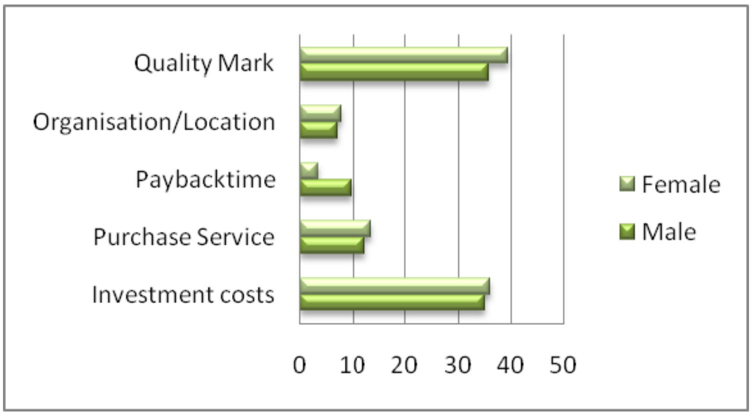
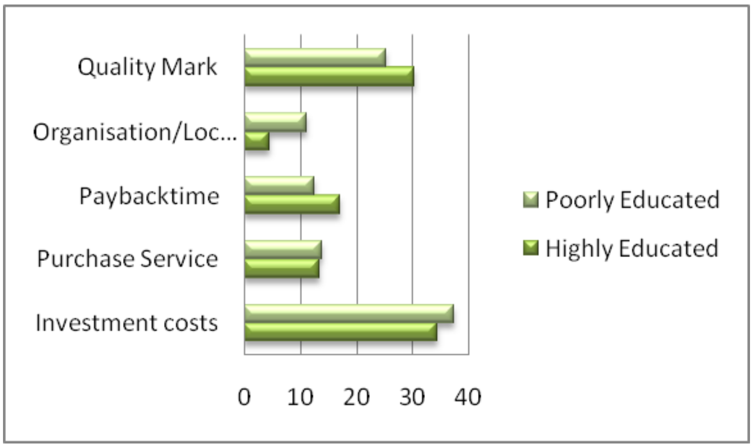


Figure 17: Relative importance gender



Highly educated people care more about payback time of the solar panels and care less for the location of the panels.

Figure 18: Relative importance education

When people are better informed they are willing to investment more in solar PV and care less about the investment costs. The payback time on the other hand will play a larger role with better informed people.

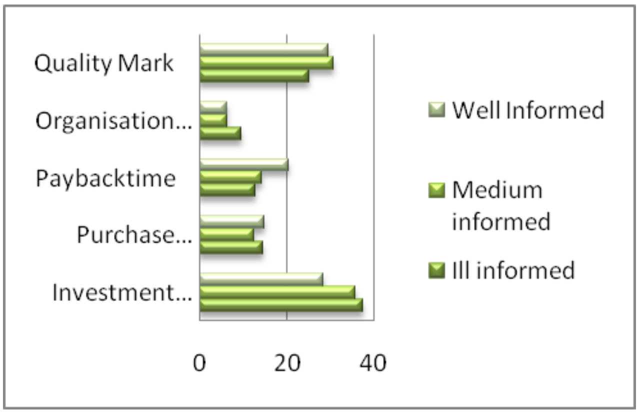
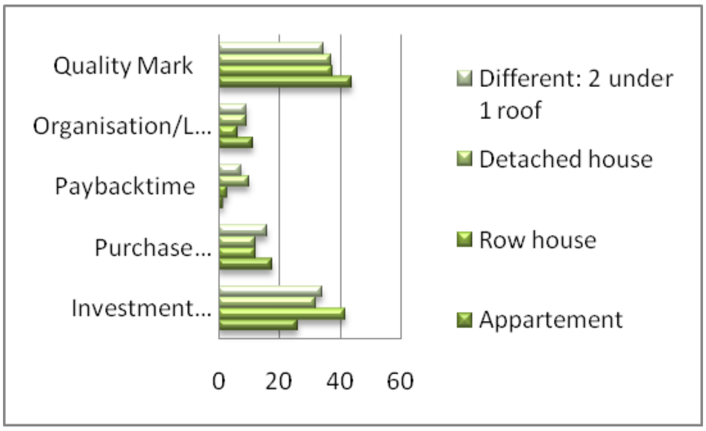


Figure 19: Relative importance Level of information

People answered on the reason to purchase or not purchase the expected answers. When they answered that too high investment costs as a reason not to purchase, they did find the investment cost more important. When they answered that the profitable investment is one of the main reasons to purchase solar PV panels, they did value the financial parameters the importance higher.



In the left figure the differences between housing types are displayed. The differences between the housing types are small and not relevant conclusions could be done.

Figure 20: Relative importance Housing Type

6.4. Comparing strategies:

The different strategies are compared by taking the utilities and sum them as the formulas in the previous chapter show. The method was also used in a thesis by (uit het Broek, 2007):

Table 19: Deployment strategies and their attribute levels

Number	Strategy	Purchase service	Organisation/ Location	Choice probability
1	Standard Panel	Medium	Individual	0,221244
2	Adoption	Low	Investment	0,139668
3	Individual	Low	Individual	0,130225
4	Locally deployed panels	Medium	Local cooperation	0,289821
5	Individual High service	High	Individual	0,219042

When looking at the results from the different strategies the local energy company and the standard panel show the most potential in the multinomial model. These two strategies should be executed by the municipality. The choice probabilities are determined under set circumstances of 4000 investments cost and the current situation. The different situations are described below:

Table 20: Comparing strategies: Situations

Situation	Payback time	Quality Mark
Current	12	No
Within reach	12	Yes
Sustainable	12	Sustainable
Next 2 years	10	Yes
Future	8	Yes

The different situations are described in the following way. The difference in probabilities will change, but the ranking of the strategies between the strategies will not change.

Table 21: Latent class strategy comparisons: Choice probabilities

Number	Strategy	Latent class 1	Latent class 2	Latent class 3
1	Standard Panel	0,304447	0,237983	0,178624
2	Adoption	0,14338	0,101819	0,205056
3	Individual	0,042713	0,114	0,137728
4	Locally deployed panels	0,186512	0,313626	0,334381
5	Individual High service	0,322949	0,232572	0,144212

In the figure above the choice probabilities for the different classes are displayed. The attributes of investment costs, payback time and quality mark are kept constant, on the attribute levels investment costs 4000 and the current situation. In latent class three, the class which is most willing to pay, they prefer the local energy company to deploy the panels. After this adoption has the highest choice probability. This means that the location on their own roof is not necessary anymore. This matters less when people are currently more willing to pay. This is an important result derived from the comparison of strategies.

6.5. Binary logistic model:

In this model only the first question of the questionnaire was considered, so only the preference questions is taken into account and the purchasing question is taken out of consideration. With a rho square (Nagelkerke) of 0,246 this seems a proper estimation. The most important attribute is the quality mark. This is mainly due to the negative influence of the attribute of the omission of a quality mark. Investment cost of 12.000 euro are highly depreciated, on the contrary payback times of 8 year are highly appreciated. A payback difference between 10 and 12 years does not seem to matter. A payback time of 10 years is more depreciated that a payback time of 12 years. People also seek security, they value more purchase service and the quality mark significantly. This can be subscribed to the fact that the immaturity of the technology is still experienced as a weakness.

Figure 21: Binary logistic model choice questions

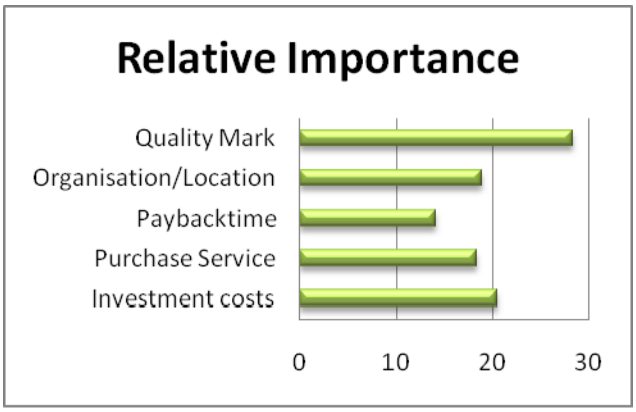


Figure 22: Binary logistic model choice questions: Relative importance

The relative importance is calculated out of the attribute utilities above. This is the difference between the highest and lowest utility per attribute. This is divided by the total difference of all attributes times hundred percent.

The quality mark shows high importance because omission of the quality mark was highly depreciated. As expected the investments costs show the most importance next. The payback time, with a range of 8 to 12 percent, does not matter much.

The biggest differences with the multinomial model are the two financial parameters. Without the purchase question the financial attributes are less important. The quality mark is also less important compared to the results derived from the multinomial model.

6.5.1. Binary logistic model on purchases:

When you included the purchase aspect an interesting difference occurs. Within the attribute organisation/location, the location at the own roof suddenly is positive instead of negative. This means this parameter has a positive influence on the purchasing behavior.

Figure 23: Dual response binary logistic model: Including purchase question

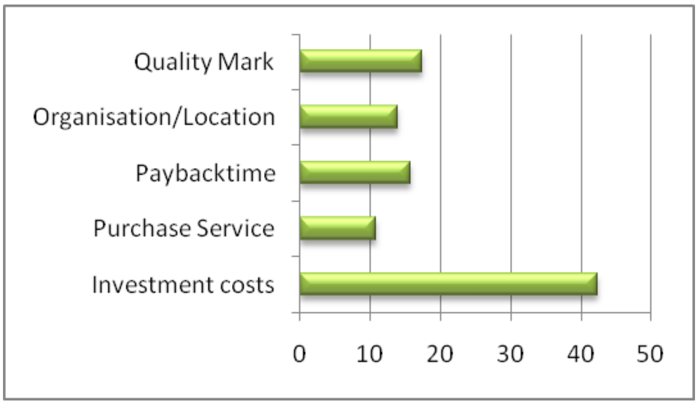


Figure 24: Relative importance, dual response format

When looking at the differences you can clearly determine an increasing importance of financial parameters. The investment costs plays and decisive role in the purchase decision. This was expected looking at the literature. The payback time slightly increases in importance, and the service, organisation and mark decreases significantly. Concerning the location the direction of the parameter even changes, the own roof is appreciated instead of depreciated. The payback time shows an important change in which now both 8 and 10 years show an almost equal positive influence.

The R squared of this regression is relatively low with a Nagelkerke R squared of 0,070. This could be the case due to the fact that only half of the information is used in this case. Only the preferred profiles are taken into account.

6.6. Ordinal regression model:

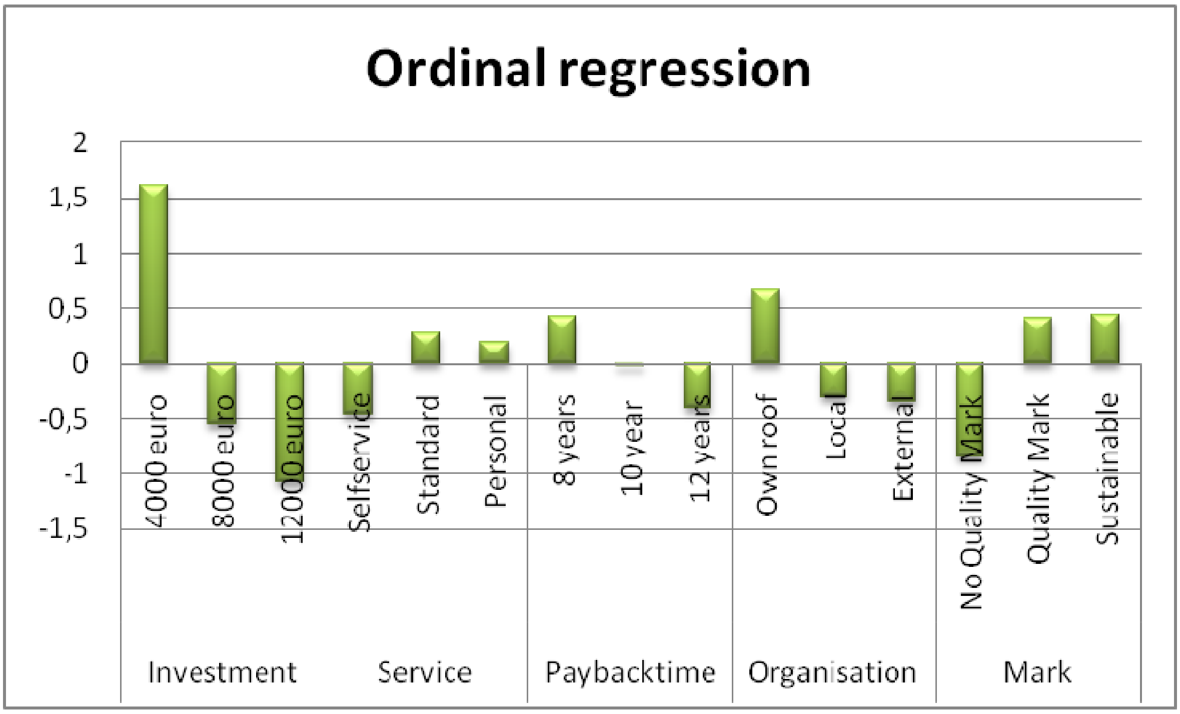


Figure 25: Ordinal Regression: Path worth utilities

An ordinal regression was done with the five different profiles. In this way the threshold, the boundary, for people to purchase can be determined. The threshold is determined on 0,065. When you look at the results of the ordinal regression they differ from the multinomial models. This is due to the fact that for the ordinal regression only the chosen profiles are value by the respondent whether or not to purchase. The main difference with the multinomial results is the location. With the ordinal regression the location on the own roof does play a significant positive role. And the locally oriented and external have both an almost equally negative role. This means that individually installed own roof PV panels show more potential when considering the purchase question. In this analysis only half of the information is used. Therefore the estimation is not very good. These results correspond with the results from the binary logistic model on purchases.

Table 22: Ordinal regression: Strategy comparison

Number	Strategy	Purchase service	Organisation/ Location	Score	Threshold
1	Standard Panel	Medium	Individual	1,306	0,065
2	Adoption	Low	Investment	-0,45	0,065
3	Individual	Low	Individual	0,569	0,065
4	Locally deployed panels	Medium	Local cooperation	0,336	0,065
5	Individual High service	High	Individual	1,212	0,065

The five strategies are compared in set circumstance of 4000 euro investment costs and in the current situation. In this case you can see the strategy of the standard panel is preferred, but important to notice is that the local energy company is still acceptable. Below the threshold and the different scores are displayed:

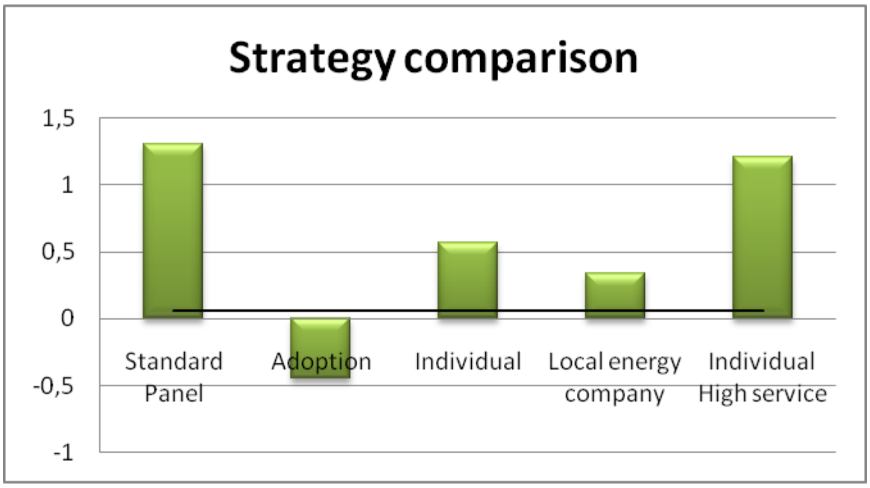


Figure 26: Strategy comparison ordinal regression

The standard panel placed on the own roof is clearly preferred in this regression. Nevertheless the local energy company is still an acceptable alternative. Adoption is highly depreciated and it is not likely to be chosen.

With investment costs of 8000 euro the strategy becomes unacceptable, even when a quality mark is introduced. So it is important to let people participate with a low investment barrier. Standard panels purchased through the municipality show the most potential in this ordinal regression.

7. Application chapter:

How can the municipality of Eindhoven turn into a PV city?

7.1. Current situation:

In Eindhoven several projects to deploy solar panels are developed. In earlier years they subsidized a project, Zon in de Klas, to make primary school children acquainted with solar panels (www.zonindeklas.nl, 2011). The project GOSORE for instance tries to deploy solar PV panels on 1 or 2 municipal roofs. This will be done in collaboration with the company Suncyle. The idea is to deploy a pilot project of 500 m^2 in 2011. In the second phase an increasing enrollment of 100.000 m2 will be strived for. To achieve this new potential; new deployment strategies could be elaborated to increase this potential with the help of civilians. Next to this a project ASORE was carried out to deploy solar panels of Suncycle on the roofs of different farms in the surroundings of Eindhoven with a total surface of 500 m2 (Samenwerkingsverband Regio Eindhoven, 2011). To achieve the high set goal of 100.000 m^2 it is essential to let individuals participate. Furthermore the municipality proposed a project plan to increase the deployment. Through companies the employees could participate (Gemeente Eindhoven, 2011). In this way the roofs of the municipality could be deployed. In the second phase individuals will be contacted to deploy solar panels. This phase will be elaborated below.

7.2. New Vision:

Electricity generated out of PV shows much potential to help a city or municipality to become energy neutral. Several things within society and in the mindset of consumers and developers should be changed to make solar PV successful. In this chapter the goal will be to translate the research goals into a concrete project plan to make Eindhoven a PV city. In this plan the local aspect of the panels will be elaborated. This is a solution for people who do not have a sufficient roof and do not prefer the panels on their own roof. In this case also the 'saldering' boundary should be taken into account. The municipality should be involved in the project to diminish the risk. In this way people will be more secure to invest in the solar panels. Together (municipality and citizens) can the goals can be achieved.

The municipality should make use of the competitive environment to offer their citizens an attractive deal in which they put the risk on a third market party. In this way competitive risk free prices could be offered to the participants. In this way a market party could take the risk of the negotiations with manufacturers and installers for instance. Instead of a general view to be energy neutral, a real bottom up strategy should be elaborated. In this way the energy transition could really be realized from the citizens. Only with small manageable projects the high set goals in the end can be reached.

7.3. Project plan:

The project plan will primarily be focused on three major topics; physical location and organisation. These will be applied in a plan situated in the municipality of Eindhoven.

7.3.1. Location:

Eindhoven has a total built surface of 42480000 m^2 (CBS, 2010). If only a small percentage is sufficient, still a large amount of surface could be deployed with solar panels. Not all the building surface is sufficient to deploy solar panels, but still a large percentage of the total amount could be used to deploy solar panels. The municipality buildings in the city of Eindhoven are planned to be deployed (Gemeente Eindhoven, 2011). The main municipal buildings in Eindhoven are displayed below:

Table 23: Locations Municipality of Eindhoven

Building	Address location	Total roof surface
Ir. Ottenbad	Vijfkamplaan 12, 5624 EB, Eindhoven	4437
Mercado gebouw	Smalle Haven 109, 5611 EH, Eindhoven	1881
Nationaal zwemcentrum de Tongelreep	Anton Coolenlaan 1, 5644 RX, Eindhoven	8430
Parktheater Eindhoven	Theaterpad 1, 5615 EN, Eindhoven	1618
Sporthal Achtste Barrier	Savoiepad 14, 5624 DX, Eindhoven	1067
School en sporthal Bisschop Bekkerscollege	Avignonlaan 1, 5627 GA, Eindhoven	3102
Sporthal Eckart	Weegschaalstraat 1, 5632 CW, Eindhoven	737
Sporthal Haagdijk	Meerkollaan 6, 5613 BW, Eindhoven	1239
Sporthal Tivoli	G. Grootestraat 72, 5645 RE, Eindhoven	1169
Turnhal Vijfkamp	Vijfkamplaan 5, 5624 EB, Eindhoven	2716
Tennishal	Vijfkamplaan 10, 5624 EB, Eindhoven	3760
Schaatsbaan	Antoon Coolenlaan 3, 5644 RX, Eindhoven	12441

Figure 27: Location municipality buildings

The bigger buildings could be used in the first phase of the project. In this phase employees and companies will deploy solar panels. The smaller buildings are sufficient for the second phase in which a local connection is present. These buildings could be coupled with the community centers in the area to broaden this local connection. Local schools and sports facilities can already rely on a number of user s and potential participants to get the connection to persuade the potential participants. Sporthal Eckart, Haagdijk, Achtste Barrier and Tivoli fit the profile. Next to this the school Bisschop Bekkers college is appropriate with the large network. Probably not all buildings could be deployed by citizen, but they can for sure partly contribute. The project Zon in de Klas could be extended with this program. The schools that participated in this project are spread all over Eindhoven:

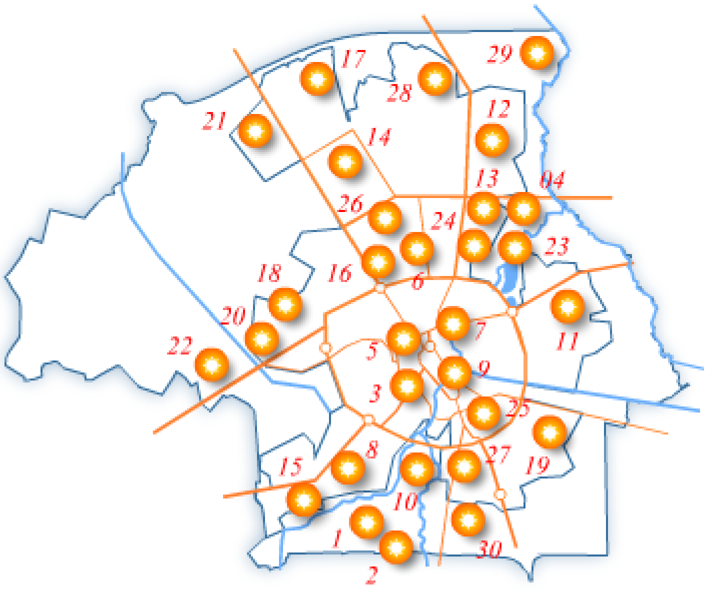


Figure 28: Locations with solar panels (www.studiokraft.nl/dev_e, 2011)

This is an ideal way of using an existing network which is informed about the technology. Schools could broaden the location portfolio, because they can rely on a large network which could be used. There are a lot of community centers in Eindhoven, approximately 15. Next to this the local pubs and carnival associations could be addressed to locate the potential in Eindhoven. Small projects with a limited number of participants seemed to work in the earlier examples. The example of Zon op Noord especially used mouth to mouth advertising and personal advertising to increase their participation. For Eindhoven the research shows there is a large group which shows the willingness to invest in solar panels. This group should be addressed when deploying solar panels; these can be addressed through these local associations. The municipality buildings that are currently on the list have a surface of 42597 m^2 in total. This surface can generate energy for 1561 households. This is 42 percent of the goals set in 2020. This still is an enormous amount and the successful local exploitation can certainly contribute to this. If these buildings could be deployed this is the largest inner city project surface in the Netherlands.

7.3.2. Process:

The process will depend on political developments. Within the process the balancing regulations, these regulations now are a major barrier, should be monitored. This could lead to more possibilities. A new initiative in the national government is accepted to make the collective balancing for home owners associations for instance. This will lead to new possibilities to deploy municipality buildings with solar panels. In the process planning the planning of the local deployment is elaborated. Before already a local energy company could be created which combines all the plans in the city of Eindhoven. In that case the municipality of Eindhoven will be represented by the local energy company. In the process planning it is important to stick to the decision moments. In this way go/no go moments are created and solid business cases are developed.

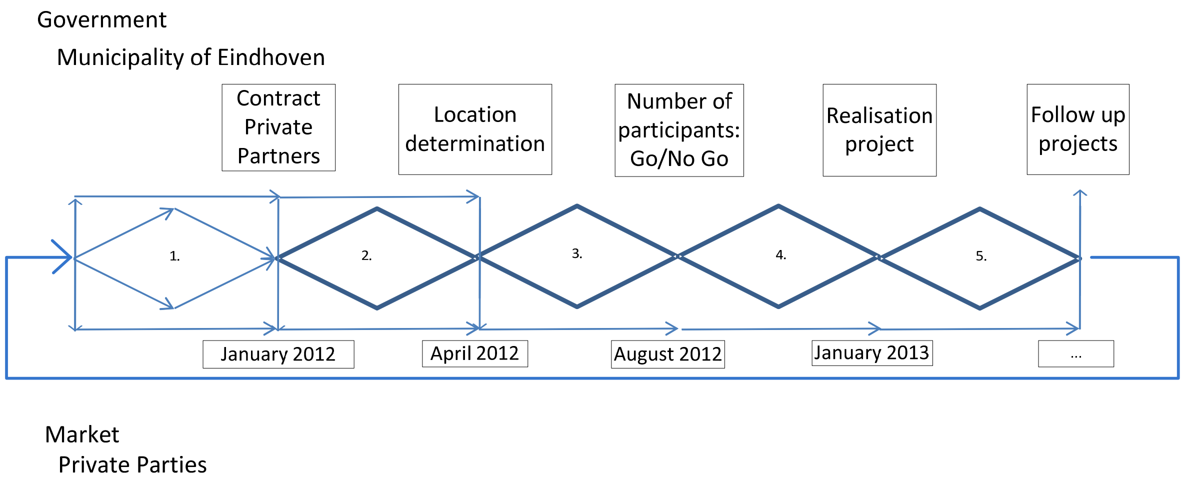


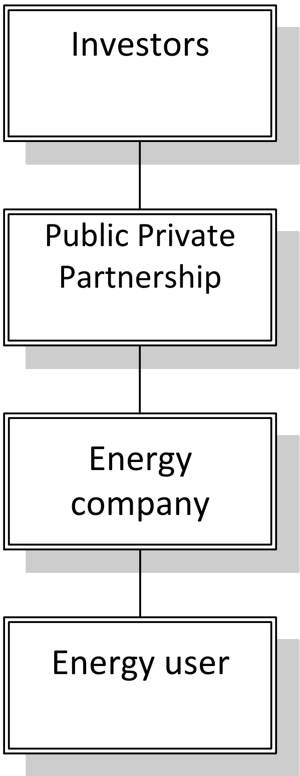
Figure 29: Process time line

Table 24: Decision moments process timeline

Phase	**Who?**	**What?**
1. Public Private Partnership	Public/ Private	During this phase the public private partnership Construction will be elaborated. Several private parties will be asked what they could offer to the individuals.
2. Determining locations/net work	Public/ Private	This phase is important for the enrollment of the different projects. Which are sufficient locations and where are potential network positions? This must be decided at the end of this phase.
3. Finding Participants	Private	In several local organizations, people should be encouraged to participate. This can be done by meetings, flyers, etc. The people interested should be addressed, according to the results latent class three.
4.Realisation phase	Private	The panels will be installed on the roof.
Recurring loop	Public/ Private	When the first roofs are deployed a new phase can be developed with new roofs. Also participants can be offered to deploy more panels.

7.3.3. Organisation:

The organisation of the strategy is adapted to the just founded local energy company. It corresponds with the goals and objectives stated in the program of demands of the company (Gemeente Eindhoven, 2011). The municipality has clearly defined their role in the energy transition. They used Rogers to determine their involvement in the different energy projects. In the first projects the involvement of the municipality is higher than projects started in later phases. The local deployment strategies for solar PV panels can fit in various stages, but high involvement is not needed. This project is in that sense ideal to be part of the local energy company.



In general the organisation of a local initiative should be designed in the following way. The group of investors should not be too large. In this way the connection with the panels diminishes. The results show that it is still important to keep the connection. In Amsterdam there are 21 participants in the pilot project. In this way the different participants have connections with each other and the panels. The investors invest in solar panels which will be bought and installed by the public private partnership. These will sell the generated energy to the energy company and these sell the energy to the energy user. This is preferably the user of the location, when a good price is offered, the owner is eager to lend his roof. Locations with an energy use below 10.000 kWh will be probably most interested to use the electricity generated. They still have to pay a price of 23 cents for their electricity. So it is profitable for small institutions to use the generated energy (www.zonopnoord.nl, 2011).

Within this public private partnership some things are important to take into account. First of all the different departments of the municipality should work together and exchange their knowledge in this way the different plans can learn from each other. In this way sufficient programs could be offered conform the legislation. To get a sufficient project team without much effort from the government a public private partnership is advised. The soon to be established local energy company of Eindhoven can combine all these different fields and use all their expertise. In this way the local energy company can be a strong and decisive player and use his influence. The competitive market should be used to get the lowest prices for the citizens. Next to this the municipality must use the expertise of market parties to make this a success.

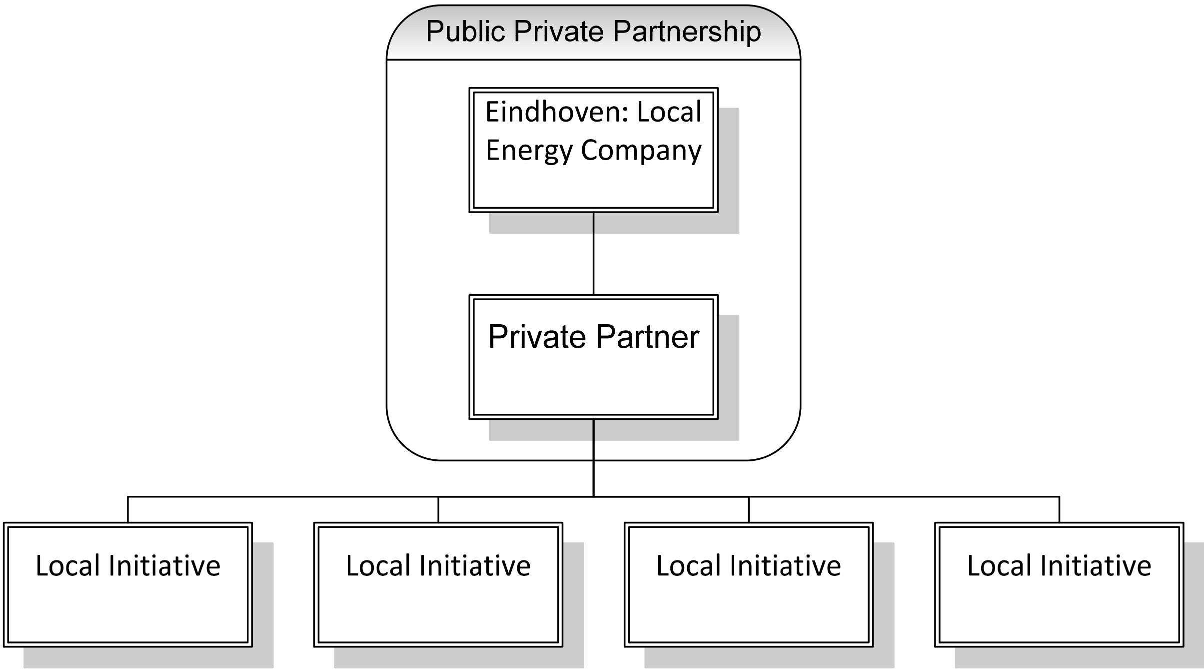


Figure 30: Possible organisation structure

In this way the security of the local government can be offered, with the competitiveness of the market. Every local initiative could also be separated into different local energy companies.

7.4. Results:

To cover all the electricity use in the region of Eindhoven 2.860.287 square meters is needed. This is not the immediate goal, but it outlines that every meter is welcome. This is an ultimate goal; the buildings of the municipality could contribute for 42597 m^2, 1.5 percent of the total electricity use in Eindhoven. Instead of a big picture strategy a bottom up strategy should be elaborated. In this way a small contribution to energy neutrality is achieved, but only through this strategy solar PV can play a more important role in society. People have shown they are willingness to invest, but the barriers should be taken down. With this project plan they are taken down and real progress could be made in the deployment of solar PV. In this way the 100.000 square meters will be reached in 2020.

8. Conclusions:

Which deployment strategies will stimulate the deployment of PV solar panels the most?

On average this research confirms the potential for solar PV panels. Nearly 60 percent of the respondents showed their interest and their willingness to invest in solar PV. 73 percent of the respondents indicated that they considered solar panels to be a contribution to the building environment. This research shows clear and predicted results. Below, the most important results will be discussed. An important result is the depreciation of the own roof attribute of the organization and location attribute. The location on the own roof is inextricably connected with the purchase of solar PV panels. The governmental balancing system is bounded by this assumption. This research shows that, to increase the deployment, these regulations should be abolished. Local organization and location show the most positive effect on deployment. This means that local organized PV panels will have the brightest future. Therefore a combination with the existing local energy company is preferred.

As elaborated in the technology chapter, the lack of a quality mark is a serious issue regarding solar PV panels. This underlines the immaturity of the technology and causes restraint among the respondents. When a quality mark is introduced, people will be more willing to purchase solar panels. Sustainable panels have a positive influence but this does not differ significantly to panels with a regular quality mark. So advertisement based on sustainability will probably have no effect on consumers. This is confirmed by earlier studies. The payback time is less influential on the decision making process compared to the attributes investment costs and quality mark. Below the segmentation of the different groups of people will be discussed.

The investment costs are the most important attribute in the decision making process. People are most willing to pay for the lowest investment costs, but the attribute level of 8000 euro is still slightly positive. As the results show, the municipality of Eindhoven should supply information and an online service to encourage the deployment process. It is not necessary to give personal guidance, according to the results. This emphasizes the need for security among consumers. With the immature technology they are not willing to take the risks. The payback time has a low influence on the decision in general, also looking at the relative importance. Still the minimum payback time is preferred.

The latent class analysis showed clear results and gives a good picture of the respondents. Below, the characteristics of the different classes are summed up. These were the differences among the segments:

Table 25: Latent class model: Characteristics

Characteristic	Latent class 1 'Skeptic'	Latent class 2 'Financially focused'	Latent class 3'Searching for security'
Age	Relatively older	Relatively younger	All ages
Reason to purchase		Energy depletion	Energy depletion Independence of energy price
Reason not to purchase	No trust in possibilities Disturbing objects	Too long payback times Too high investment costs	
Image	Not positive, not negative	Sustainable and modern	Sustainable and modern
Informed by who	Neighbors, not informed		Friends and family, internet
Information	Badly informed	Medium informed	Well informed
Education	Lower educated	Higher educated	Higher educated
Percentage:	0,342	0,436	0,222
Constant	Not willing to purchase	Medium willing to purchase	Willing to purchase

The 'Security' group, latent class 3, is most likely to be persuaded to deploy solar panels and this group is persuadable by means in control of the municipality. To achieve the goals the municipality of Eindhoven should secure a quality mark and supply packages. Furthermore this class prefers the organization locally and they do value sustainable panels. The group consists of 22 percent of the respondents. They are mostly highly educated, well informed and they have a positive image of solar PV panels as sustainable and modern devices. The reason for these people to purchase is the depletion of energy and the possible independence of the energy price. All ages are represented in this latent class. This group should be addressed with communication to let them participate.

The biggest class, latent class 2, is primarily financially focused and consists of 44 percent of the respondents. This group consists of mostly younger people who are medium informed and mostly higher educated. There focus lies on the financial parameters. Overall they are medium willing to purchase. Their main reason for not purchasing solar panels yet is the long payback time of solar panels. They have a sustainable and modern image of the panels and with lower investment costs and shorter payback times they are willing to invest. They slightly prefer to have the panels applied on their own roof and they do not care whether or not the panels are sustainable or only have a quality mark. This group will probably follow latent class three if the financial circumstances are better.

The first latent class consists of 34 percent of the respondents. They are on average not willing to purchase solar panels. This group has low scores on significance, maybe due to a lack of interest. The constant in this case is extremely high. This group mainly consists of older people who are badly informed and lower educated. They have a neutral image towards PV panels.

When comparing the different strategies, the local initiative shows the most potential. After this the standard panel provided by the municipality is preferred. The ordinal regression shows biased results. But still the current situation with a local strategy shows acceptable results. This shows that with low investment costs a local energy company shows much potential to substantially increase the deployment of solar PV. In addition, a program by the municipality to offer solar panels would be an easy way to increase the deployment further.

The local strategies show more potential in the second and third latent class. Latent class 3 values the local deployment strategy the most. The willingness to invest corresponds with the choice probability of the local deployment strategy. This means that this strategy will increase the deployment the most. These choice probabilities are described in the table below:

Table 26: Latent class strategy comparison

Number	Strategy	Latent class 1	Latent class 2	Latent class 3
1	Standard Panel	0,304447	0,237983	0,178624
2	Adoption	0,14338	0,101819	0,205056
3	Individual	0,042713	0,114	0,137728
4	Locally deployed panels	0,186512	0,313626	0,334381
5	Individual High service	0,322949	0,232572	0,144212

The segmentation derived from the latent class models, confirms earlier segmentations, but also shows some differences. The theory of Rogers is followed in general. There are three groups of adopters determined which clearly differ in willingness to pay. The characteristics of the three classes differ. Latent class 3 can be defined as the early adopters, who do not seek financial benefits, but seek security. In Rogers's model the early majority seeks confirmation; but in the latent class model especially the early adopter's value security. Latent class 2, the early majority, is highly financially focused, as the early majority as described by Rogers. The segments distinguished by the latent class method, in particular LC2 and LC3, show the characteristics of the model of Rogers. They seek security and are financially focused, but willing to pay for quality. So that is why new strategies should focus on avoiding risks for the consumers, especially taken into account the immature nature of the technology.

Next to this the segmentation found corresponds with the research of Nieuwenhuijsen (Nieuwenhuijsen, 2010). Similar segments are distinguished with similar characteristics. The 'Skeptic' class is, in her case, also represented by mainly older residents. Furthermore she describes a financially focused group and a group you can determine as 'early adopters' as described by Rogers. The two segmentations correspond significantly.

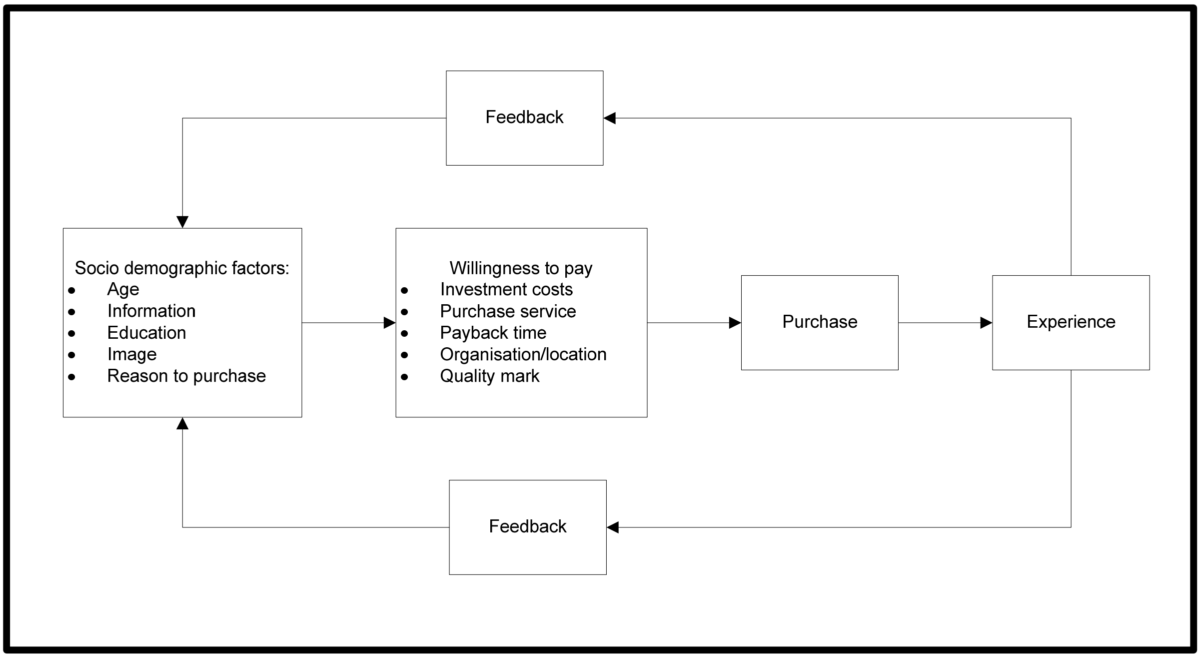


Figure 31: Solar PV purchasing model based on Ajzen (Bouwfonds Ontwikkeling, 2010)

Above, an outline of the consumer behavior model is given. At the left, the socio-demographic factors that influence the willingness to pay. The different strategies can influence the willingness of consumers to pay, and the willingness to pay effects the purchase decision. This leads to an experience which is reflected through feedback to possible other buyers. This is an important loop given the fact that solar PV is an immature technology and that there are many uncertainties among consumers. This barrier could be diminished when positive feedback is given by other consumers.

This research determines the relation between information and the willingness to purchase. When people are better informed, they are more willing to deploy solar PV panels. This corresponds with the results publicized by Jager (Jager, 2006). The latent class which is most willing to invest is in general higher educated, as was predicted by several theories. The financial parameters are the main preconditions to consider buying solar panels. When strategies will be developed further, this should be taken into account. Payback time does not have a decisive influence. Already people are willing to pay for solar PV panels with a 12 years payback time.

A project plan is developed which relates to the location, organization and the process of the strategy. A local strategy should be elaborated in cooperation with the new established local energy company. An efficient public private partnership should be founded to make use of the competitive market. The project team should stick to the project planning and use the decision moments. In this way a solid business plan arises.

Overall you could clearly define a role for the municipality to unroll solar PV panels. Local municipalities can make a difference to increase the deployment. They should strongly support unlimited balancing and use their power to convince national authorities. Location should not be restricted to the own roof and new bottom up initiatives should be embraced. People do want a connection with the panels, but locally placed panels fulfill this need. Furthermore people seek security of a generally accepted quality mark with separated responsibilities by joining a municipal program. In this way Eindhoven could really be 'leading in technology' by turning into a PV city.

9. Discussion:

This research has established a general overview on the major factors concerning the deployment of solar PV panels. The most important attributes in the decision making process are weighed against each other. Further analysis could be done on all these specific attributes. 'A-willingness-to-pay study', only concerning financial costs parameters, could be carried out to get more information on the financial terms on which people are willing to invest in solar panels. The topic could be more specified in general, but the current state is well defined in this thesis.

In this research the interaction effects are not taken into account. That could lead to biased results. Further research should take them into account, so that these effects can be estimated. Also, the real life situation could differ from the answers to the questionnaire. This problem occurs when using questionnaires and doing scientific research. However, the questionnaire was set up in such a way that it was clear to the respondents what was asked from them. Thus the real life situation was simulated as best as possible.

The enormous competition and many developments result in constantly changing markets. Therefore, being up to date in this research is difficult. Next year the research might show a different outcome. During the six months I have been working on this topic, new ideas and initiatives were numerous. This underlines the interest society has in the technology. Some assumptions have been made on future developments, but things might be different, next year. Nevertheless, some essential elements could be derived from this research.

The deployment is depending on political issues. In developments in the future are hard to predict, especially concerning the balancing regulations. These regulations are a major barrier for locally deployed solar PV panels.

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Appendices:

A: Limdep results

Multinomial model:

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+---------------------------------------------+
| Discrete choice and multinomial logit models|
+---------------------------------------------+
+---------------------------------------------+
| Discrete choice (multinomial logit) model   |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 11, 2011 at 03:49:40PM.|
| Dependent variable               Choice     |
| Weighting variable                 None     |
| Number of observations             7686     |
| Iterations completed                 16     |
| Log likelihood function       -6637.799     |
| Number of parameters                 11     |
| Info. Criterion: AIC =          1.73011     |
|   Finite Sample: AIC =          1.73011     |
| Info. Criterion: BIC =          1.74005     |
| Info. Criterion:HQIC =          1.73352     |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| Constants only   -7271.9503  .08721  .08512 |
| Response data are given as ind. choice.     |
| Number of obs.=  7686, skipped   0 bad obs. |
+---------------------------------------------+
| Notes No coefficients=> P(i,j)=1/J(i).      |
|       Constants only => P(i,j) uses ASCs    |
|         only. N(j)/N if fixed choice set.   |
|         N(j) = total sample frequency for j |
|         N    = total sample frequency.      |
|       These 2 models are simple MNL models. |
|       R-sqrd = 1 - LogL(model)/logL(other)  |
|       RsqAdj=1-[nJ/(nJ-nparm)]*(1-R-sqrd)   |
|         nJ   = sum over i, choice set sizes |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
CONSTA|1	1.31374303	.02800991	46.903	.0000
A1|1	.68196990	.03138596	21.729	.0000
A2|1	.12578849	.03317883	3.791	.0001
B1|1	-.34685323	.03375058	-10.277	.0000
B2|1	.18157940	.03704729	4.901	.0000
C1|1	.35533725	.03158026	11.252	.0000
C2|1	-.08848046	.03608182	-2.452	.0142
D1|1	-.11267403	.03378964	-3.335	.0009
D2|1	.15490679	.03186487	4.861	.0000
E1|1	-.76093520	.04015406	-18.950	.0000
E2|1	.32883142	.03144840	10.456	.0000

Latent Class:

```
+---------------------------------------------+
| Latent Class Logit Model                    |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 11, 2011 at 03:49:52PM.|
| Dependent variable              COMBINAT    |
| Weighting variable                  None    |
| Number of observations              7686    |
| Iterations completed                  88    |
| Log likelihood function        -4932.252    |
| Number of parameters                  35    |
| Info. Criterion: AIC =           1.29255    |
|   Finite Sample: AIC =           1.29259    |
| Info. Criterion: BIC =           1.32418    |
| Info. Criterion:HQIC =           1.30340    |
| Restricted log likelihood      -8443.934    |
| McFadden Pseudo R-squared       .4158822    |
| Chi squared                     7023.364    |
| Degrees of freedom                    35    |
| Prob[ChiSqd > value] =          .0000000    |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| No coefficients  -8443.9341  .41588  .41455 |
| Constants only   -7271.9503  .32174  .32020 |
| At start values  -6637.7451  .25694  .25524 |
| Response data are given as ind. choice.     |
+---------------------------------------------+
+---------------------------------------------+
| Notes No coefficients=> P(i,j)=1/J(i).      |
|       Constants only => P(i,j) uses ASCs    |
|         only. N(j)/N if fixed choice set.   |
|         N(j) = total sample frequency for j |
|         N    = total sample frequency.      |
|       These 2 models are simple MNL models. |
|       R-sqrd = 1 - LogL(model)/logL(other)  |
|       RsqAdj=1-[nJ/(nJ-nparm)]*(1-R-sqrd)   |
|         nJ   = sum over i, choice set sizes |
+---------------------------------------------+

+---------------------------------------------+
| Latent Class Logit Model                    |
| Number of latent classes =    3             |
| Average Class Probabilities                 |
|   .342  .436  .222                          |
| ------------------------------------------- |
| LCM model with panel has  854 groups.       |
| Fixed number of obsrvs./group=        9     |
| Discrete parameter variation specified.     |
| ------------------------------------------- |
| Number of obs.=  7686, skipped   0 bad obs. |
+---------------------------------------------+
+--------+--------------+----------------+--------+--------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]|
+--------+--------------+----------------+--------+--------+
---------+Utility parameters in latent class -->> 1
```

CONSTA|1	6.51478684	.66085089	9.858	.0000
A1|1	1.34512851	.51064536	2.634	.0084
A2|1	.43943417	.83125260	.529	.5971
B1|1	-1.32908940	.60038508	-2.214	.0268
B2|1	.63519186	.56864945	1.117	.2640
C1|1	.98499466	.58486804	1.684	.0922
C2|1	-.18767877	.73438978	-.256	.7983
D1|1	-.24066048	.58542497	-.411	.6810
D2|1	-.72821915	.62156643	-1.172	.2414
E1|1	.59876862	.62411952	.959	.3374
E2|1	-.52359521	.73312225	-.714	.4751
---------+Utility parameters in latent class -->> 2				
CONSTA|2	1.32787912	.03814772	34.809	.0000
A1|2	1.48678293	.03695760	40.229	.0000
A2|2	.06584597	.04167658	1.580	.1141
B1|2	-.48261646	.03808247	-12.673	.0000
B2|2	.25302324	.04950846	5.111	.0000
C1|2	.50280310	.04039205	12.448	.0000
C2|2	.07996134	.04864010	1.644	.1002
D1|2	.31853581	.03854475	8.264	.0000
D2|2	.03544546	.04040060	.877	.3803
E1|2	-1.05417869	.05551160	-18.990	.0000
E2|2	.52744590	.04365995	12.081	.0000
---------+Utility parameters in latent class -->> 3				
CONSTA|3	-1.55883647	.06633940	-23.498	.0000
A1|3	.10341604	.04971207	2.080	.0375
A2|3	.49010272	.06201291	7.903	.0000
B1|3	-.10157090	.07428880	-1.367	.1715
B2|3	.15833626	.09897021	1.600	.1096
C1|3	.29393956	.05003671	5.874	.0000
C2|3	-.21778916	.06320092	-3.446	.0006
D1|3	-.34237932	.04825017	-7.096	.0000
D2|3	.28624665	.05163683	5.543	.0000
E1|3	-.93102337	.04640764	-20.062	.0000
E2|3	.16416728	.04497929	3.650	.0003
---------+Estimated latent class probabilities				
PrbCls_1	.34204876	.01286467	26.588	.0000
PrbCls_2	.43598756	.01111704	39.218	.0000
PrbCls_3	.22196368	.01536651	14.445	.0000

Validatie, eerste 600:

```
+----------------------------------------------+
| Discrete choice and multinomial logit models|
+----------------------------------------------+
Normal exit from iterations. Exit status=0.
+----------------------------------------------+
| Discrete choice (multinomial logit) model    |
| Maximum Likelihood Estimates                 |
| Model estimated: Jul 11, 2011 at 04:31:40PM.|
| Dependent variable              Choice       |
| Weighting variable                None       |
| Number of observations            5400       |
| Iterations completed                 6       |
| Log likelihood function      -4756.504       |
| Number of parameters                11       |
| Info. Criterion: AIC =         1.76574       |
|   Finite Sample: AIC =         1.76575       |
| Info. Criterion: BIC =         1.77917       |
| Info. Criterion:HQIC =         1.77043       |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| Constants only   -5190.1388  .08355  .08262 |
| Response data are given as ind. choice.     |
| Number of obs.=  5461, skipped  61 bad obs. |
+----------------------------------------------+

+----------------------------------------------+
| Notes No coefficients=> P(i,j)=1/J(i).       |
|       Constants only => P(i,j) uses ASCs     |
|         only. N(j)/N if fixed choice set.    |
|         N(j) = total sample frequency for j |
|         N    = total sample frequency.       |
|       These 2 models are simple MNL models. |
|       R-sqrd = 1 - LogL(model)/logL(other)  |
|       RsqAdj=1-[nJ/(nJ-nparm)]*(1-R-sqrd)   |
|         nJ   = sum over i, choice set sizes |
+----------------------------------------------+
+--------+--------------+----------------+--------+--------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]|
+--------+--------------+----------------+--------+--------+
 CONSTANT|    1.23170092       .03263406    37.743   .0000
 A1      |     .69158454       .03664119    18.875   .0000
 A2      |     .09478233       .03876998     2.445   .0145
 B1      |    -.32877161       .03941651    -8.341   .0000
 B2      |     .17157315       .04358457     3.937   .0001
 C1      |     .36401067       .03689866     9.865   .0000
 C2      |    -.08836151       .04200278    -2.104   .0354
 D1      |    -.09325435       .03948183    -2.362   .0182
 D2      |     .11954750       .03733312     3.202   .0014
 E1      |    -.71404833       .04598548   -15.528   .0000
 E2      |     .30930743       .03656467     8.459   .0000
```

Binary model (SPSS):

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	18173,753[a]	,185	,246

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	a1	,437	,026	285,304	1	,000	1,548
	a2	,179	,025	51,163	1	,000	1,197
	b1	-,484	,026	353,794	1	,000	,616
	b2	,036	,025	2,088	1	,148	1,037
	c1	,419	,025	270,861	1	,000	1,521
	c2	-,308	,028	125,487	1	,000	,735
	d1	-,629	,026	591,380	1	,000	,533
	d2	,339	,025	183,625	1	,000	1,404
	e1	-,920	,027	1129,122	1	,000	,399
	e2	,382	,025	226,614	1	,000	1,465
	Constant	-,036	,019	3,746	1	,053	,965

a. Variable(s) entered on step 1: a1, a2, b1, b2, c1, c2, d1, d2, e1, e2.

Binary model: Preferred profiles with purchase question (SPSS):

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	9951,702[a]	,052	,070

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	a1	,540	,036	225,553	1	,000	1,716
	a2	-,002	,038	,003	1	,955	,998
	b1	-,153	,040	15,032	1	,000	,858
	b2	,124	,038	10,499	1	,001	1,132
	c1	,142	,035	16,302	1	,000	1,153
	c2	,118	,041	8,554	1	,003	1,126
	d1	,221	,039	32,605	1	,000	1,248
	d2	-,086	,038	5,148	1	,023	,918
	e1	-,284	,046	37,551	1	,000	,753
	e2	,127	,038	11,474	1	,001	1,136
	Constant	-,532	,029	333,644	1	,000	,587

a. Variable(s) entered on step 1: a1, a2, b1, b2, c1, c2, d1, d2, e1, e2.

Ordinal Regression:

Pseudo R-Square

Cox and Snell	,052
Nagelkerke	,070
McFadden	,039

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Aanschaf = 0]	,065	,102	,411	1	,521	-,134	,264
Location	[constante=0]	0[a]	.	.	0	.	.	.
	[a1=-1]	-1,078	,071	232,466	1	,000	-1,217	-,940
	[a1=0]	-,542	,059	83,598	1	,000	-,659	-,426
	[a1=1]	0[a]	.	.	0	.	.	.
	[a2=-1]	0[a]	.	.	0	.	.	.
	[a2=0]	0[a]	.	.	0	.	.	.
	[a2=1]	0[a]	.	.	0	.	.	.
	[b1=-1]	,183	,063	8,288	1	,004	,058	,307
	[b1=0]	,277	,070	15,794	1	,000	,140	,413
	[b1=1]	0[a]	.	.	0	.	.	.
	[b2=-1]	0[a]	.	.	0	.	.	.
	[b2=0]	0[a]	.	.	0	.	.	.
	[b2=1]	0[a]	.	.	0	.	.	.
	[c1=-1]	-,403	,063	41,035	1	,000	-,526	-,280
	[c1=0]	-,024	,065	,134	1	,715	-,151	,103
	[c1=1]	0[a]	.	.	0	.	.	.
	[c2=-1]	0[a]	.	.	0	.	.	.
	[c2=0]	0[a]	.	.	0	.	.	.
	[c2=1]	0[a]	.	.	0	.	.	.
	[d1=-1]	-,356	,063	31,535	1	,000	-,481	-,232
	[d1=0]	-,307	,068	20,322	1	,000	-,441	-,174
	[d1=1]	0[a]	.	.	0	.	.	.
	[d2=-1]	0[a]	.	.	0	.	.	.
	[d2=0]	0[a]	.	.	0	.	.	.
	[d2=1]	0[a]	.	.	0	.	.	.
	[e1=-1]	,440	,075	34,766	1	,000	,294	,586
	[e1=0]	,411	,076	29,324	1	,000	,262	,559
	[e1=1]	0[a]	.	.	0	.	.	.
	[e2=-1]	0[a]	.	.	0	.	.	.
	[e2=0]	0[a]	.	.	0	.	.	.
	[e2=1]	0[a]	.	.	0	.	.	.

Link function: Logit.

B: Paper

Deployment strategies for solar PV panels

A latent class conjoint analysis to determine consumer preferences

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Graduation program:

Construction Management and Urban Development 2010-2011

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Date of graduation:

25-08-2011

ABSTRACT

This paper contains the most important findings of researching deployment strategies for solar PV panels. With the rescinding subsidies on small scale sustainable energy generation new strategies have to be found to increase the deployment. In this thesis the preferences of the consumer on the different strategies are investigated. These preferences are determined using a conjoint analysis. With the use of a latent class model a segmentation is determined. The most important conclusion is that consumers prefer a quality mark, they prefer locally deployed panels and the payback time has a low decisive influence on the decision. You can clearly divide three groups concerning their willingness to invest in solar panels.

Keywords: Deployment strategies, conjoint analysis, latent class, decision behavior, consumer preferences

INTRODUCTION

In the media, solar PV panels get a lot of attention. Several researches highlight the potential of solar PV. The most important question still remains: how to realize the potential? This thesis focuses on consumers as investors. They will not only contribute to the energy neutrality of their city but they will profit from it at the same time. The lack of consisting policies had not encouraged individuals to shift to PV panels. Financial incentives by the national government in the Netherlands are rescinded for small scale installations. So municipalities should find new alternative ways to reach their goals. To be energy neutral and achieve general understanding, the deployment of PV panels by individuals is essential. Solar PV panels offer civilians an easy way to generate renewable energy and it will increase the awareness needed to complete the transition to sustainable energy resources. The province of 'Noord Brabant' and the municipality of Eindhoven emphasize on solar PV and encourage its deployment (Gemeente Eindhoven, 2011). When a city strives for energy neutrality solar PV shows much potential, because it is easily applicable in the urban environment. Furthermore, the electricity use will increase in the future, and thus the need for sustainable generated electrity.

This all leads to the following problem definition. With the rescinding of subsidies on small scale, solar PV still shows much potential, but the deployment rates lag behind. How can new strategies increase the deployment of solar PV panels? The goal was to get a clear picture of the decision criteria of individuals. This leads to a better understanding of the market and a foundation on which municipalities can build their strategy. Furthermore a segmentation will be determined to make the strategy more effective. The following research question will be answered: Which deployment strategies will stimulate the deployment of PV solar panels the most? This question is divided in several steps. First of all the technology is elaborated, than the different deployment strategies are discussed. Thirdly the individual decision behavior for sustainable energy generation is addressed. This is the foundation for the conjoint analysis to determine consumer preferences to answer the main research question. After this the method used will be described. Then the results of this research will be elaborated. The results were transferred into a project plan with concrete recommendations to increase the deployment of solar panels. This all will lead into the conclusion and discussion of the thesis. This research focuses on the small scale generation of solar PV panels by individuals. The focus area is current estate, in this field there is a lot of potential which not have been deployed yet. In this way a true energy transition could take place. With this research municipalities could adapt to consumer preferences and maximize their deployment with low expenses. In this research bottom up market strategies are compared in a scientific way.

Literature study

The literature study contains three parts: the technology, deployment strategies and the sustainable decision behavior. Through solar panels the way of energy consumption can change. Instead of paying a price per kWh you can generate energy yourself and invest in solar panels. The efficiency of the panels determines how much energy could be generated per panel. By using these panels, you cut your energy bill and you can gain back your investment. The energy price plays an important role in the predicted payback times. If the energy price increases, for instance, you will save more on your energy bill and you will gain back your investment sooner. The solar industry is a worldwide market which is constantly evolving. Already in Eindhoven a competitive industry is established (Berenschot, 2011). Solar panels are now reaching payback times of 12 years. In the coming years this could even lead to 8 years. To get full understanding of the deployment strategies one needs to understand the energy taxes system in the Netherlands. There are limits to the success of solar panels. The orientation is extremely important; to get full efficiency panels should be orientated to the south without any obstruction. A new problem is the quality problem. When the deployment rate is increasing, the need for sustainably produced panels is increasing. A totally sustainable solution could be needed.

In the Netherlands, several initiatives have been developed to increase the deployment of solar PV panels. There are adoption programs, leasing programs, investment programs and local initiatives (Arcadis, 2011). Next to these programs, many municipalities still offer some kind of grand to diminish the investment costs. This led to the two parameters which differed among the strategies and these will be used in the conjoint analysis; purchase service and organizational form. Additionally, the decision behavior of individuals was elaborated concerning sustainable energy measures. An important study of Bouwfonds investigated the willingness to pay for sustainable energy generation systems in new estate housing (Bouwfonds, 2010). A research of Haas was conducted which determined the major factors in a willingness to pay study, he defined the major factors as: "Pure investment costs, affordability, transaction costs/efforts, technical performance/technical reliability, environmental benignity and the social acceptance of PV" (Haas, 2002).

The socio-demographic factors which influence the willingness to invest are derived from different sources. Rogers claims the higher the education, the higher the willingness to pay (Rogers, 2003). The Bouwfonds study found out that a lack of knowledge is an important boundary in purchasing renewable energy generation systems (Bouwfonds, 2010). For the segmentation, the adoption theory of Rogers was used. He defines five groups of adopters: 'early adopters', early adopters, the early majority, the late majority and the laggards (Rogers, 2003). This information will be used to compare the segmentation derived from the conjoint analysis.

The different attribute levels result in different strategies. The attributes should be determined independent from each other. The different attributes used in this experiment are listed below:

Table 1: Attribute and attribute levels conjoint experiment

Attributes	
Investment Costs	4000 – 8000 – 12000
Purchase service	Self-service – Standard – Personal guidance
Payback time	8-10-12 year
Organisation/ Location	Own roof – Local – external
Quality mark	No quality mark – Quality mark – Sustainable mark

The investments costs are based on the capacity of the panels. This means the number of panels. The purchase service is the service offered during the purchase. The payback time is based on the efficiency of the panels. The payback time will decrease in the coming years. The organization and location is the fourth attribute. This concerns the location of the panels and how it is bought. The last attribute is the existence of a quality mark. These are the five most important attributes when deciding to purchase solar panels.

Method

To determine consumer preferences a latent class conjoint analysis was done. With conjoint analysis choice profiles are compared due to a full profile choice method to determine consumer preferences, in a dual response format. First the respondent was asked to choose between two profiles, then the respondent was asked whether he or she would purchase the chosen profile. With this method the most valuable results could be distinguished and the actual choice of the respondents could be simulated the best. Firstly, due to the large amount of profiles a full fractional factorial design was used. This leaded tot 18 profiles which were combined randomly, this leads to 9 choice sets. The interaction effects are not taken into account due to the fact that the independence from irrelevant alternative assumption is assumed. The different choice sets were shown in random order to the respondents. The different attributes were coded using effect coding (Kemperman, 2000).

Model

There were several models used to process the results. The multinomial model was the main model and it was used to process the results and construct the questionnaire (Kemperman, 2000). This model is based on the random utility theory which can be described in the following formula: $U_i = V_i + \varepsilon_i$

The systematic component can be defined further. This is done by putting together the different path worth utilities. In this way low appreciation of one attribute can be leveraged by another attribute with high appreciation. In this way this component can estimate the utility of the total profile(Kemperman, 2000):

$$U_i = \sum_k \beta_k X_{ik} + \varepsilon_i$$

Taking into account the IID assumption the choice probability of the profiles are calculated as follows: $P(i \ / A) = \frac{\exp{(\mu V_i)}}{\sum_{i' \epsilon A} \exp{(\mu V_{i'})}}$

A latent class model was used to distinguish a segmentation within the population. The data was processed using Limdep. Next to this a binomial model was used, with and without the inclusion of the purchase question. Finally, an ordinal model was used to test the acceptance of the different strategies. The questionnaire consisted out of eleven socio demographic questions which could influence the choice experiment.

After this the respondent was asked to choose between the 9 different choice sets. The data was collected by doing an on line survey. The data was collected through the online panel of the municipality of Eindhoven, called the Digipanel. The Digipanel consist out of 4000 respondents. 2000 respondents were contacted for this research. The respondent's rate was high, with 42 percent. 854 people filled in the questionnaire completely. The sample has characteristics which indicate a more positive attitude towards solar panels than the average citizen of Eindhoven. Still all groups are represented and thus the sample is valid for further estimations. The sample contains mainly higher educated people and house owners. According to the literature they have a positive attitude towards sustainable energy measures.

Results:

First of all the answers to the first socio demographic questions are discussed. Only three percent, 31 respondents, has already purchased solar panels. People's image of solar panels was highly positive, 73 percent defines it as a clear contribution to the building environment and it has a sustainable and modern image. In the questions which were related to the purchase reasons you can answer two options, this leads to the following percentages. The two main reasons to deploy solar panels are the depletion of energy and the independence of energy; these were chosen by 49 and 51 percent of the respondents. For 37 percent one of the main reasons to purchase solar panels is to push back the green house effect and for 36 percent the main reason is that it is an investment which pays itself back. The main reason for not buying solar panels are the investment costs, 79 percent of the respondents answered this option. The second reason is the payback time with 49 percent. The other reasons are less important. The main part of the respondent has a basic knowledge about solar panels, this part is 51 percents. 36 percent knows little about solar panels and 13 percent is well informed. TV, internet and magazines are the most important information sources to get information over solar panels. Only 16 percent was informed by friends or relatives. This means there is a lot to be won in this field, with more people deploying this number will increase.

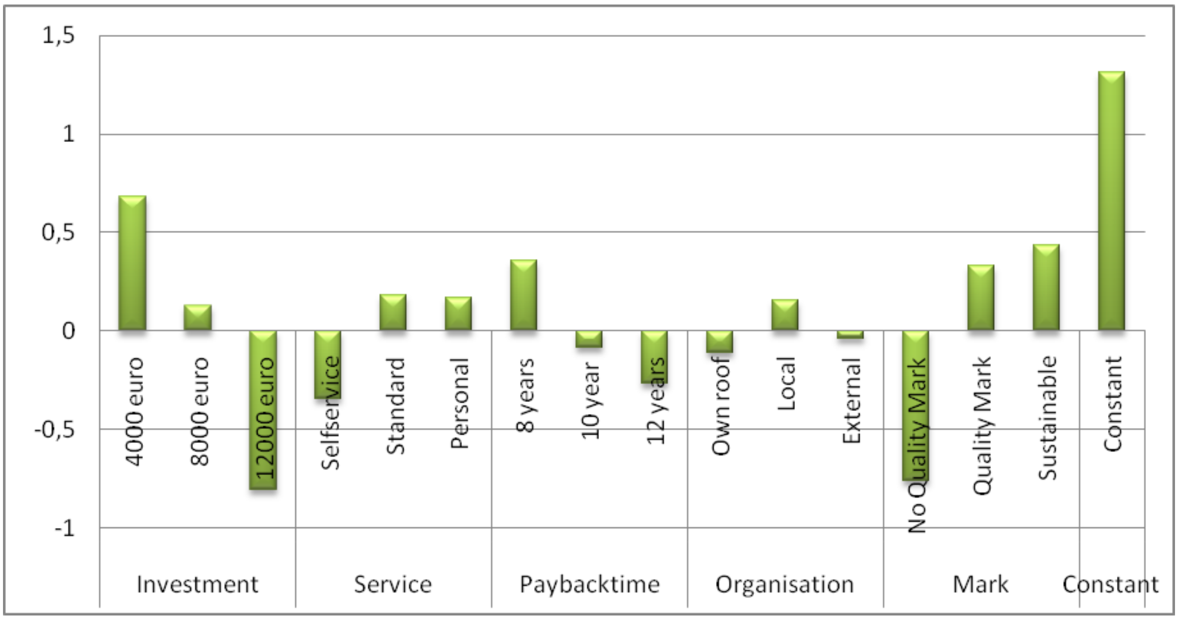

Figure 1: Path worth utilities multinomial model

Below the main results of the conjoint analysis are displayed. The chart gives the relative influence of the attribute levels on the decision. The investment costs play the most important role in the decision whether or not to purchase solar panels. Low investments are appreciated and high investment costs of 12.000 euro are highly depreciated. The lack of a quality mark is also highly depreciated by the respondents. The difference between a regular quality mark and a sustainable quality mark is low. The locally deployed panels are ranked the most positive of the attribute organisation. The payback time is the third important attribute. Self service is highly depreciated compared to the standard panel and the purchase with personal guidance. All these figures were expected by reading the literature.

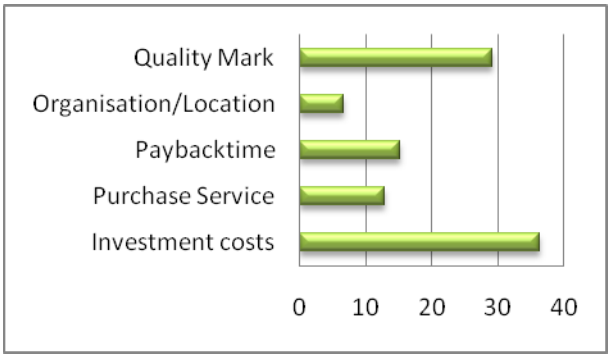

Figure 2: Relative importance multinomial model

These path worth utilities could be transferred into relative importance of the attribute. Which attribute is the most important when making a decision? The relative importance of the attributes is described below:

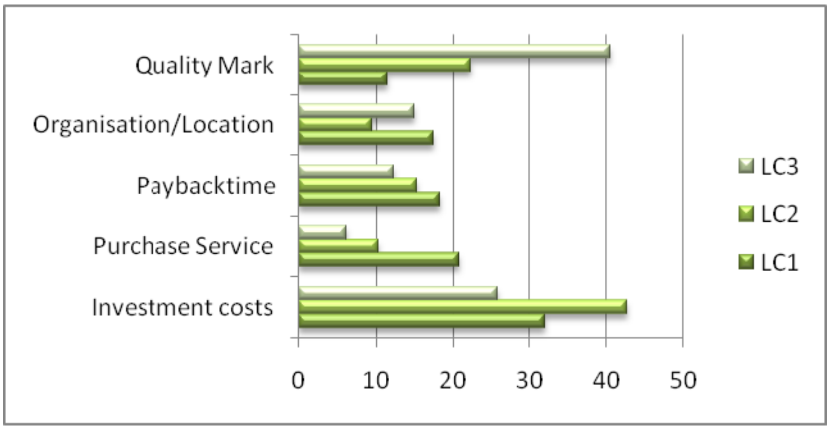

Figure 3: Relative importance latent classes

The latent class model was used to determine different groups which gave corresponding answers. The three classes highly differ in their preferences of the attribute and attribute levels. The differences are displayed in the figure below.

The different classes also relatively differ on socio demographic characteristics. The different characteristics of the classes are described in the table below:

Table 2: Characteristics latent classes

Characteristic	Latent class 1 'Skeptic'	Latent class 2 'Financially focused'	Latent class 3'Searching for security'
Age	Older people	Younger people	All ages
Reason to purchase		Energy depletion	Energy depletion Independence of en.price
Reason not to purchase	No trust in possibilities Disturbing objects	Too long payback times Too high investment costs	
Image	Not positive, not negative	Sustainable and modern	Sustainable and modern
Informed by who	Neighbors, not informed		Friends and family, internet
Information	Badly informed	Medium informed	Well informed
Education	Lower educated	Higher educated	Higher educated
Percentage:	0,342	0,436	0,222
Constant	Not willing to purchase	Medium willing to purchase	Willing to purchase

Three classes gave the most valid results with the highest rho squared. Below the rho square and the other important parameters are described:

Table 3: Prediction levels latent class analysis

Latent class					
Segments	Rho square	AIC	BIC	LLB	Difference
1	0,08721	1,73011	1,74005	-6637,8	
2	0,3672	1,396400	1,41719	-5343,36	1294,438
3	0,41588	1,29255	1,32418	-4932,25	411,109
4	0,42171	1,28286	1,32535	-4883,04	49,208

Project plan

Based on the results a project plan is elaborated to increase the deployment of solar panels in the municipality of Eindhoven. This plan describes location, process and organisation to maximize the local deployment. The vision is to increase the deployment due to local exploitation. In this plan the municipality should be represented by the local energy company. Locations have to be chosen with a local connection and which can build on a network, is this way people are more eager to join the cooperation. The process has clear decision moments in which things have to be chained so the next phase can start. In this way the projects have solid business cases. The new founded local energy company can have a leading role in the project (Gemeente Eindhoven, 2011). In this way the authority of the municipality can make use of the competitive market to offer the best deals to the citizens.

Conclusions:

On average this research confirms the great potential for solar PV panels. Nearly 60 percent of the respondents showed interest en willingness to invest in solar PV. The investment costs are the most important attribute in the decision making process. Lower investment costs are highly preferred and they still medium investments costs are positively appreciated. An important result is the depreciation of the own roof attribute level of the organization and location attribute. The location on the own roof is inextricable bound up with the purchase of solar PV panels. The governmental balancing system requires an own roof. As stated in earlier researches the lack of a quality mark is a serious issue regarding solar PV panels. This underlines the immaturity of the technology and this causes restraint among the respondents. When a quality mark is introduced people show more interest in purchasing solar panels. A sustainable quality mark is not more preferred to the regular quality mark. The regular quality mark is enough for the respondents. As the results show, the municipality of Eindhoven should supply information and an online service to encourage the deployment process. It is not necessary to give personal guidance according to the results of the questionnaire. The payback time has a low influence on the decision in general, also looking at the relative importance. The latent class analysis showed a segmentation which determined three different groups. The ‘Security’ group, latent class 3, is most likely to be persuaded and is persuadable by means in control of the municipality. To increase the willingness to pay the municipality of Eindhoven should secure a quality mark and supply standard packages. Furthermore this class prefers the organisation locally and they do value sustainable panels. The group consists of 22 percent of the respondents. They are mostly high educated, well informed and they have a sustainable and modern image of solar PV panels. The reason for this people to purchase is the depletion of energy and the possible independence of the energy price. All ages are represented in this latent class. The biggest class, latent class 2, is primarily financially focused and consists of 44 percent of the respondents. This group consists of mostly younger people who are medium informed and mostly higher educated. There focus lies on the financial parameters and overall they are medium willing to purchase. Their main reason not to purchase yet is the long payback times. They have a sustainable and modern image of the panels and with lower financial parameters they are willing to invest. They prefer the panels on their own roof and they do not care whether or not the panels are sustainable or only have a quality mark. This group will probably follow the latent class three if financial circumstances are more positive. The first latent class consists of 34 percent of the respondents. They are on average not willing to purchase solar panels. This group has low scores on significance, maybe due to a lack of interest. The constant is in this case extremely high. This group mainly consists of the elderly who are badly informed and lower educated. They have a neutral image towards PV panels.

The local strategies show more potential in the second and third latent class. Latent class 3 values the local deployment strategy the most. The willingness to invest corresponds with the choice probability of the local deployment strategy. This means that this strategy will increase the deployment the most. These choice probabilities are described in the table below:

Table 4: Strategy choice probabilities: Latent Class Analysis

Number	Strategy	Latent class 1	Latent class 2	Latent class 3
1	Standard Panel	0,304447	0,237983	0,178624
2	Adoption	0,14338	0,101819	0,205056
3	Individual	0,042713	0,114	0,137728
4	Locally deployed panels	0,186512	0,313626	0,334381
5	Individual High service	0,322949	0,232572	0,144212

The ordinal regression shows biased results. The current situation with a local strategy is proven to be an acceptable strategy. This shows that with low investment costs a local energy company shows much potential to substantially increase the deployment of solar PV. Overall you could clearly define a role for the municipality to unroll solar PV panels. A new vision should be elaborated to maximize the deployment. Location should not be restricted to the own roof and new initiatives should be embraced. People do want connection with the panels, but locally placed panels are sufficient to fulfill this need. Furthermore people seek security of a generally accepted quality mark with separated responsibilities by joining a municipal program.

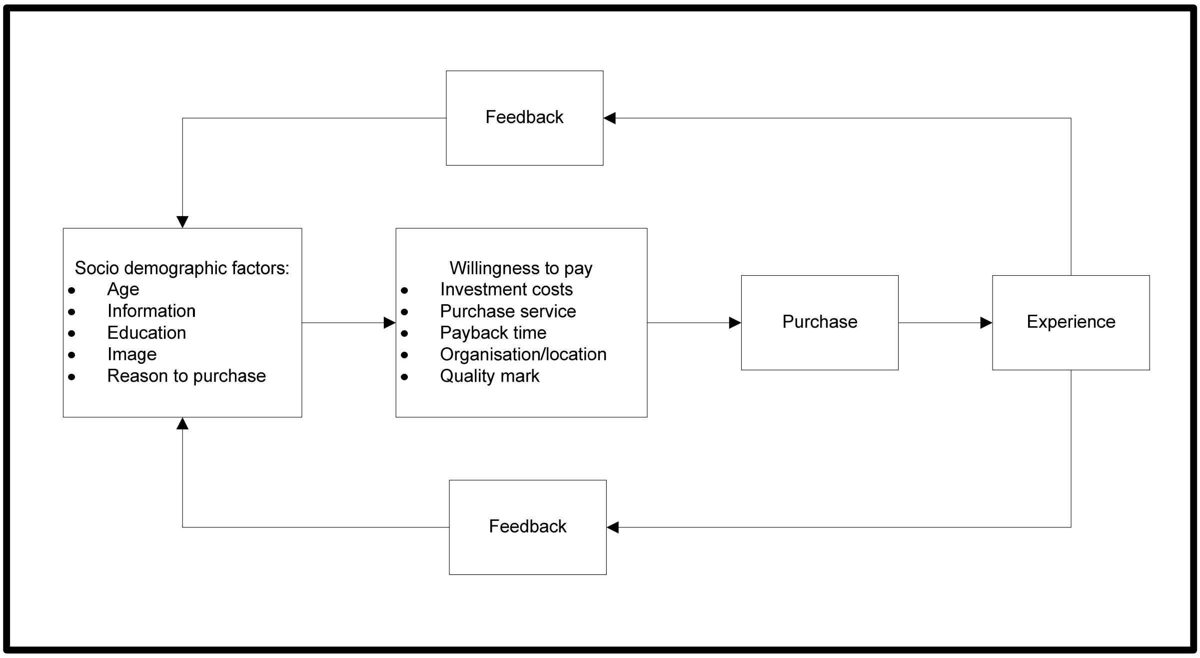

Figure 4: Solar PV purchasing model based on Ajzen (Bouwfonds Ontwikkeling, 2010)

The figure above is based on the model of Ajzen, developed further by the Bouwfonds study (Bouwfonds, 2010). This model is changed and adapted to this research. The latent classes differ on different socio demographic factors as age, knowledge, education, image and reason to purchase. These factors influence the willingness to pay, the attributes used in the conjoint analysis. Important is the feedback loop, this represent the important feedback early adopters will have on the later adopters. This research sets general guidelines for future deployment of solar panels. When using this guidelines, Eindhoven could really be ‘leading in technology’ by turning in to a PV city.

Discussion

Further research could be done to specify this research. The preferences on the different locations could be researched more in depth. The interaction effects could be taken into account to determine the effects of combined attribute levels. This research is in financial aspects temporary of nature. The market is constantly evolving and things are changing continuously. Nevertheless this research was based on the valid researches available. There is a lot to happen in the near future, especially concerning the balancing regulations. These regulations are a major barrier for locally deployed solar PV panels.

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Bsc. Karel Adriaan Sormani

In this thesis all skills and capacities which I have learned the past 2 years came together. I have reached the goals I have set. It was great to get an insight in the market and the public regulations surrounding it. I hope you enjoyed reading it.

2004 – 2008	Bachelor Bouwkunde
2008	Internship Rijndijk Engineering
2008 – 2009	President of board E.S.R. Thêta
2009 – 2011	Master Construction management and Engineering

C: Questionnaire (in Dutch)

1. Wat is de eigendomssituatie van uw woning?
( ) Koopwoning
( ) Particuliere huurwoning
( ) Huurwoning bij corporatie

2. Wat voor type woning is het?
( ) Appartement
( ) Rijtjeshuis
( ) Vrijstaande woning
( ) Anders, namelijk_____________

3. Hoelang woont u al in uw woning?
( ) 0-5 jaar
( ) 5-10 jaar
( ) 10-15 jaar
( ) >15 jaar

4. Hoelang verwacht u nog in deze woning te wonen?
( ) 0-5 jaar
( ) 5-10 jaar
( ) 10-15 jaar
( ) >15 jaar

5. Heeft u al zonnepanelen aangeschaft?
( ) Ja
( ) Nee

6. Wat is uw beeld bij zonnepanelen?
( ) Het is een aantasting van de kwaliteit van de gebouwde omgeving
( ) Ik sta er niet positief en niet negatief tegenover.
( ) Ik vind het een duidelijke toevoeging en een modern en duurzaam image hebben.

7. Wat zou de belangrijkste reden zijn voor u om zonnepanelen aan te schaffen? Maximaal 2 antwoorden mogelijk.
( ) Duurzaamheid, het helpt mee aan het beperken van het broeikaseffect
( ) De olie raakt op, de opwekking van duurzame energie is essentieel om dit op te vangen.
( ) Eigen elektriciteit genereren, onafhankelijk zijn van de energieprijs
( ) Het is een investering die zich terugbetaalt.

8. Wat zou de belangrijkste reden voor u zijn om **geen** zonnepanelen aan te schaffen. Maximaal 2 antwoorden mogelijk.
( ) De investeringskosten zijn te hoog.
( ) Zonnepanelen hebben te lange terugverdientijden.
( ) Ik zie er het nut niet van in.
( ) Ik vind het lelijke en storende objecten in de gebouwde omgeving.

( ) Ik ga waarschijnlijk binnen de terugverdientijd van de panelen verhuizen.

9. In hoeverre bent u geïnformeerd over de terugverdientijden en mogelijkheden van zon PV?

( ) Ik ben goed op de hoogte
( ) Ik lees af en toe wat over zonnepanelen
( ) Ik ben niet goed op de hoogte

10. Wat is volgens u de huidige terugverdientijd van zonnepanelen?

( ) 0-6 Jaar
( ) 6-12 Jaar
( ) 12-18 jaar
( ) 18-24 Jaar
( ) Langer dan 24 jaar

11. Via welke kanalen bent u in contact gekomen met zonnepanelen?

( ) Vrienden, kennissen, buren
( ) TV
( ) Radio
( ) Internet
( ) Tijdschriften
( ) Niet
( ) Anders, namelijk…..

Nieuw pagina, uitleg conjunct keuze experiment:

In dit gedeelte worden u verschillende keuzeprofielen voorgelegd. Telkens zijn er drie opties waartussen een keuze maakt, twee keuzeprofielen en de optie geen van beiden. De verschillende keuzesets bestaan uit verschillende criteria. Deze criteria kunnen 3 verschillende niveaus aannemen. Hieronder worden de criteria en de bijbehorende niveaus besproken, lees ze heel zorgvuldig door:

Investeringskosten:
Dit zijn de investeringskosten van de zonnepanelen.
Niveaus:

- **4000 euro**: Met een zonnepaneel installatie van 4000 euro kunnen ongeveer 6 panelen geïnstalleerd worden en deze panelen genereren ongeveer 1/3 deel van het totale energieverbruik van een gemiddeld huishouden in Nederland.
- **8000 euro**: Met een zonnepaneel installatie van 8000 euro kunnen ongeveer 12 panelen geïnstalleerd worden en deze panelen genereren ongeveer 2/3 deel van het totale energieverbruik van een gemiddeld huishouden.
- **12000 euro**: Met een zonnepaneel installatie van 12000 euro kunnen ongeveer 18 panelen geïnstalleerd worden en deze panelen genereren het totalen energieverbruik van een gemiddeld huishouden.
-

Service:
De service die geleverd wordt bij de aanschaf en bij de installatie van de zonnepanelen.
Niveaus:

- **Laag**: Op dit niveau is het systeem een doe het zelf pakket en zal je hem zelf installeren.
- **Midden**: Op dit niveau moet u de panelen zelf aanschaffen en zelf een installateur aanstellen.
- **Hoog**: Een kant-en-klaar (turn-key) systeem met persoonlijk begeleiding bij de aankoop.

Terugverdientijd:
Dit is de tijd die verstrijkt voordat u uw investeringskosten terug heeft verdiend. De levensduur van zonnepanelen is momenteel 25 jaar. Dus na de terugverdientijd zullen de panelen in totaal 25 jaar energie voor u genereren. De terugverdientijd is in dit geval onafhankelijk van de investeringskosten.
Niveaus:

- **8 jaar**:
- **10 jaar**:
- **12 jaar**:

Organisatie/Locatie:
De organisatievorm en de bijbehorende locatie van de panelen.
Niveaus:

- **Individueel**: Hier koopt u de panelen individueel en worden ze op uw eigen dak geplaatst.

- **Lokaal**: Bij dit niveau worden de panelen met de buurt aangeschaft en in de buurt geplaatst. Voor de locatie zal een geschikte plek in de buurt gezocht worden.
- **Extern**: Op dit niveau zullen de panelen via een investeringsfonds worden aangeschaft. Op dit niveau zullen de panelen niet zichtbaar voor u zijn, alleen in opbrengst.

Kwaliteit:
De technische kwaliteit van de panelen.
Niveaus:
- **Standaard paneel**
- **Extra garantie**: Op dit niveau is de garantie langer en zal de opbrengst hoger blijven.
- **Duurzaam paneel**: Dit paneel is gebouwd uit duurzame materialen en is na zijn levensduur van 25 jaar volledig recyclebaar.

Keuzeset 1	Keuzeprofiel 16	Keuzeprofiel 2
Investeringskosten	4000 euro	8000 euro
Service	Hoog	Midden
Terugverdientijd	8 jaar	10 jaar
Organisatie/Locatie	Individueel	Individueel
Kwaliteit	Duurzaam	Extra garantie

Keuzeset 2	Keuzeprofiel 6	Keuzeprofiel 10
Investeringskosten	8000 euro	8000 euro
Service	Hoog	Laag
Terugverdientijd	12 jaar	10 jaar
Organisatie/Locatie	Lokale samenwerking	Lokale samenwerking
Kwaliteit	Standaard	Extra garantie

Keuzeset 3	Keuzeprofiel 4	Keuzeprofiel 18
Investeringskosten	4000 euro	4000 euro
Installatieservice	Hoog	Laag
Terugverdientijd	10 jaar	8 jaar
Organisatie/Locatie	Investeringsfonds	Individueel
Technische kwaliteit	Duurzaam	Standaard

Keuzeset 4	Keuzeprofiel 8	Keuzeprofiel 13
Investeringskosten	12000 euro	12000 euro
Installatieservice	Hoog	Hoog
Terugverdientijd	8 jaar	8 jaar
Organisatie/Locatie	Individueel	Lokale samenwerking
Technische kwaliteit	Standaard	Extra garantie

Keuzeset 5	Keuzeprofiel 11	Keuzeprofiel 14
Investeringskosten	4000 euro	8000 euro
Installatieservice	Laag	Hoog
Terugverdientijd	12 jaar	8 jaar
Organisatie/Locatie	Individueel	Individueel
Technische kwaliteit	Extra garantie	Duurzaam

Keuzeset 6	Keuzeprofiel 7	Keuzeprofiel 17
Investeringskosten	12000 euro	8000 euro
Installatieservice	Laag	Laag
Terugverdientijd	12 jaar	8 jaar
Organisatie/Locatie	Lokale coöperatie	Investeringsfonds
Technische kwaliteit	Duurzaam	Duurzaam

Keuzeset 7	Keuzeprofiel 3	Keuzeprofiel 12
Investeringskosten	12000 euro	8000 euro
Installatieservice	Midden	Midden
Terugverdientijd	12 jaar	12 jaar
Organisatie/Locatie	Individueel	Investeringsfonds
Technische kwaliteit	Duurzaam	Standaard

Keuzeset 8	Keuzeprofiel 9	Keuzeprofiel 1
Investeringskosten	12000 euro	4000 euro
Installatieservice	Laag	Hoog
Terugverdientijd	10 jaar	12 jaar
Organisatie/Locatie	Investeringsfonds	Investeringsfonds
Technische kwaliteit	Standaard	Extra garantie

Keuzeset 9	Keuzeprofiel 5	Keuzeprofiel 15
Investeringskosten	12000 euro	4000 euro
Installatieservice	Midden	Midden
Terugverdientijd	8 jaar	8 jaar
Organisatie/Locatie	Investeringsfonds	Lokale samenwerking
Technische kwaliteit	Extra garantie	Standaard