Master thesis

Accelerating the diffusion of PV in the province of Utrecht

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Table of Content

Preface

This is the master thesis for the combined graduation thesis at the Utrecht University and the internship at the province of Utrecht. The academic knowledge that was accumulated during the master Sustainable Development – Track Energy & Resources will be put into practice with a research project within the project Sustainable Roofs at the province. The aim of this research is to find ways to accelerate the diffusion of solar photovoltaic (PV) in the province of Utrecht. To reach the challenging goal of a climate neutral province in 2040 a lot of progress has to be made on energy efficiency and renewable energy resources like PV.

Machiel van der Bijl who studied the same master is combining his graduation thesis with an internship at the municipality of Amersfoort (within the province of Utrecht). His research is focussed on the role of municipalities on the diffusion of PV. Our combined insights were useful during our internships and the policy advice in this thesis was written together.

Summary

Our global economy is highly dependent on fossil fuels. Both on an international and national level governments are putting policy into place to limit this dependency. The province of Utrecht formulated its goal to be climate neutral in 2040. To reach this goal the energy demand can be lowered by improving the efficiency while the remaining energy has to be generated by low carbon energy resources instead of fossil fuels. One of the most promising low carbon energy resources is solar photovoltaic (PV). While the worldwide application of PV is growing fast the Netherlands and the province of Utrecht are lacking behind. Therefore this thesis focused on the possibility to accelerate this application within the province of Utrecht.

To get an insight in the role PV could play in the province of Utrecht the technological potential for the application of PV on buildings was calculated. The roof and facade surface combined can cover between 50% and 150% of the current electricity need within the province. Future improvements in PV system efficiency and the ability to cover more of the available roof space can double this potential. With an optimal application this can result in an CO_2 emission reduction of 40% in 2040 compared to the current CO_2 emission caused by the provincial electricity and gas consumption.

The current PV market should focus on small electricity consumers who pay a high price for energy from the grid. The payback time is about half the technical lifetime of a PV system. Still a large initial investment has to be made to buy the PV system. To overcome this barrier a loan or lease construction can be applied. The feasibility of installing PV within the province of Utrecht without subsidies depends on the possibility to get such a loan/lease with low interest/costs due to the long duration of both constructions.

To understand why the application of PV is low all the issues surrounding PV within the province of Utrecht will be analysed. The framework of Innovation Systems (IS) and in particular the Technological Innovation System (TIS) is used to do this. This system focuses on the actors, organizations, and institutions that influence the development, diffusion, and implementation of a single technology.

To gain insight in the dynamics of the TIS, the relevant activities within the Innovation System need to be mapped and linked to the seven System Functions: 1. Entrepreneurial Activity, 2. Knowledge Development, 3. Knowledge Diffusion, 4. Guidance of the Search, 5. Market Formation, 6. Resource Mobilization, 7. Counteracting Resistance to Change. These System Functions are not isolated but influence each other. Certain patterns of interactions are known as Motors of Innovation that were used to compare the PV TIS with earlier TIS research to gain insights in possible improvements.

By applying the TIS research in the form of a historical analysis and a current state analysis with expert interviews the following three points of focus were formulated to accelerate the diffusion of PV within the province of Utrecht: The m*arket formation* should be enhanced, by targeting the small consumer both on an individual basis with low interest/costs loan or lease and a cooperatives basis with knowledge support from municipalities. By doing this the *linkage between supply and demand* is also improved. As a last focus *coalitions should be built* to overcome the lack of coordination and direction. In an early phase this is not a problem but as the market expands it becomes critical to form coalitions and establish networks.

Samenvatting

De wereldwijde economie is sterk afhankelijk van fossiele brandstoffen. Zowel internationale als nationale overheden hebben beleid in het werk gesteld om deze afhankelijkheid te beperken. De provincie Utrecht heeft op zijn beurt het doel gesteld om in 2040 volledig klimaatneutraal te zijn. Om dit doel te bereiken zal het energieverbruik verminderd moeten worden door een hogere efficiëntie.. De resterende vraag naar energie zal voldaan moeten worden door energiebronnen met een lage CO_2-uitstoot. Een van deze energiebronnen is de veelbelovende fotovoltaïsche zonne-energie (PV). Terwijl de wereldwijde toepassing van PV sterk stijgt loopt Nederland, en daarbinnen de provincie Utrecht, achter. Deze scriptie richt zich daarom op de mogelijkheden om de toepassing van PV binnen de provincie Utrecht te versnellen.

Om inzicht te krijgen in de mogelijk rol van PV is het technologisch potentieel berekend voor de toepassing op gebouwen binnen de provincie. Gezamenlijk kunnen de daken en wanden van gebouwen voorzien in 50% tot 150% van de huidige elektriciteitsvraag van de provincie. Toekomstige verbeteringen in de efficiëntie van PV en de mogelijkheid meer dakoppervlak te bedekken kunnen dit potentieel verdubbelen. Wanneer dit volledige potentieel in 2040 benut wordt, kan 40% van de huidige CO_2-emissie worden vermeden.

De huidige PV-markt zou zich moeten richten op kleine elektriciteitsverbruikers die in verhouding een hoog tarief betalen voor hun elektriciteit. Voor hen is de terugverdientijd ongeveer de helft van de technologisch levensduur van een PV-systeem. Voor een dergelijk systeem is er nog wel een hoge investering nodig. Om deze investering te spreiden kan er een lening of leaseconstructie worden aangeboden. De haalbaarheid van het installeren van PV binnen de provincie zonder subsidie hangt daarmee af van de mogelijkheid om een lage rente te krijgen in geval van een lening of lage kosten in geval van een leaseconstructie, gezien de lange loopduur van beide mogelijkheden.

Om de huidige lage penetratiegraad van PV te begrijpen dienen de omstandigheden die van invloed zijn op de PV-markt binnen de provincie Utrecht in kaart te worden gebracht. Het raamwerk van het Innovatiesysteem (IS) zal hiervoor gebruikt worden en met name het Technologisch Innovatiesysteem (TIS). Deze richt zich specifiek op de actoren, organisaties en instituties die invloed hebben op de ontwikkeling, diffusie en implementatie van een enkele technologie.

Voor het verkrijgen van inzicht in de dynamiek van het TIS, dienen de relevante activiteiten binnen het innovatiesysteem in kaart te worden gebracht en gekoppeld te worden aan de zeven Systeemfuncties: 1 Ondernemersactiviteit, 2 Kennisontwikkeling, 3 Kennisdiffusie in netwerken, 4 Richting geven aan het zoekproces, 5 Creëren van markten, 6 Mobiliseren van middelen en 7 Creëren van legitimiteit. Deze systeemfuncties staan niet op zichzelf maar beïnvloeden elkaar. Bepaalde combinaties van interacties zijn bekend als de motoren van Innovatie en deze zullen gebruikt worden om de motoren uit deze analyse te vergelijken met eerdere TIS-onderzoeken. Lessen hieruit kunnen dan doorgetrokken worden naar de PV TIS.

Het TIS-onderzoek is uitgevoerd in de vorm van een historische analyse en een analyse van de huidige staat aan de hand van interviews met experts. Voor het versnellen van de toepassing van PV binnen de provincie Utrecht zijn hieruit drie aandachtspunten naar voren gekomen. de *marktvorming* dient verbeterd te worden. De nadruk zal hierbij moeten liggen op de consumenten. Individuele consumenten kan een leen- of leaseconstructie worden aangeboden. Groeperingen van consumenten dienen ondersteund te worden door de

gemeentes om samen een PV-coöperatie te kunnen vormen. Door deze markstimulering is ook meteen de *link tussen vraag en aanbod* verbeterd. Als laatste aandachtspunt dienen *coalities* te worden gevormd. Het huidige gebrek aan coördinatie en richting is belemmerend. In een vroege fase van de TIS is dit nog niet storend maar naarmate de TIS zich verder ontwikkeld worden coalities en het vormen van netwerken steeds belangrijker.

I. Introduction

I.1 Global problems and policies

Our global economy is highly dependent on fossil fuels (coal, oil and gas) as its primary energy supply (International Energy Agency, 2010-I, p6). The burning of these fossil fuels has several negative effects:

- It causes emission of greenhouse gasses which have a negative effect on our environment. The main problem of which is climate change (IPCC, 2007).
- Fossil fuels are finite. It is estimated that there is enough for 40 to 150 years (Goldemberg, 2007) depending on how fast alternatives come into the picture and how much of the available coal will be used as fuel.
- The main reserves of fossil fuels are concentrated in a few politically unstable regions. This dependency could cause harm to our economy when the continuous delivery is interrupted due to geo-political tensions (Goldemberg, 2007).

To limit these effects (inter)national governments have put policies into place to increase the efficiency of supply, reducing demand and substituting the fossil fuel based supply by renewable energy sources (RES).

The United Nations (UN) has established the Kyoto Protocol which was brought into force in 2005 (UNFCCC, 2005). The legally binding international target was an average reduction in greenhouse gas emission of 5,2% from the 1990 levels by the year of 2012 (the actual level varies per country). The UN are currently working on its successor which also aims to minimize the global green house gas emission (EEA, 2009).

The EU formulated the goal of 20% reduction in green house gas emission, 20% renewable energy and 20% reduction in energy use in 2020 (EU, 2008).

The Netherlands translated the goals of the EU in its policy program Clean and Economical (Schoon en Zuinig) (Ministry of VROM, 2007). This program targets a 30% greenhouse gas emission reduction in 2020 compared to the levels of 1990. It also aims to have 20% of the total energy demand covered by renewable energy sources (RES) (Ministry of VROM, 2007). Recently (Ministry of EL&I, 2010) this target was lowered to 20% greenhouse gas emission reduction and 14% renewable energy sources.

I.2 Goal of the Province of Utrecht

In line with these (inter)national policies the province of Utrecht formulated its goal to be climate neutral in 2040 (province of Utrecht, 2009). The energy efficiency has to be improved to lower the demand. The remaining demand has to be fulfilled by low carbon energy resources, preferable RES.

I.3 Renewable energy sources in Utrecht

RES are naturally regenerated over a short time scale and directly (thermal, photochemical, photovoltaic) or indirectly (wind, hydropower, biomass) derived from the sun or from natural movements and mechanisms of the environment (geothermal and tidal energy) (International Energy Agency, 2006). In comparison with conventional energy sources they have a far lower carbon footprint. The little carbon emission they do have is emitted during the production and recycling of the device. In case of biomass the carbon that is emitted during the burning of the biomass is absorbed in new biomass. The following table (I.1) shows the RES that are currently applied or might be applied within the province of Utrecht. The current application level and its potential are shown qualitatively and are based on interviews with officials working at the province.

Table I.1 RES within the province of Utrecht

RES	Output	Current application	Potential output
Wind large	Electricity	-	+/-
Wind small	Electricity	-	+/-
Geothermal power	Electricity, heat	--	+/-
Biomass	Electricity, fuel, heat	+/-	++
Solar thermal	Heat	-	++
Solar photovoltaic	Electricity	-	++

Wind large: Wind turbines convert the mechanical energy extracted from the wind into electricity. The cumulative installed capacity of large wind mills in the province of Utrecht is one of the lowest in the country (The Boston Consulting Group, 2010 p20). This is mainly because the highest potential for land based wind turbines are near the sea or the IJsselmeer and the province of Utrecht is not near both. The high population density also is of influence since many people do not want a large wind turbine near their home.

Wind small: Small wind turbines with a diameter below 10 meters are quite new for grid-connected application. Within the province only a few pilot wind turbines are installed. They are less noisy compared to large wind turbines and can best be applied on high flat roofs which are available mainly in business districts.

Geothermal power: This technology extracts the heat stored in the earth to heat water or produce electricity. Geothermal power does not include geothermal heat pump technology since this technology does only exchange heat with a reservoir in the earth and does not generate energy. An internal research project at the province showed that geothermal power is not fit for Utrecht because the heat is to deep underground within the province to make it an economically viable source. Future development in this technology may change this.

Biomass: Electricity, fuel and heat can be created from biological materials such as wood, crops or biological waste. Common processes for this conversion are digestion, combustion and gasification. The province of Utrecht has a few biomass plants currently active and future ones are in development.

Solar heating and cooling (SHC): Sunlight can be directly used to heat water to use for heating, hot water and cooling needs. The main application for households is for hot tap water in which the water is heated by sunlight and stored till the tap water is needed. The application of solar thermal is rising as a result of the national subsidies for households to apply solar thermal. The potential is high due to the high amount of available roof space due to the high population density.

Solar photovoltaic (PV) (Also see chapter Background solar energy): By using the photovoltaic effect in which photons of light excite electrons into a higher energy state electricity is generated. Photovoltaic solar cells are packed in solar panels to harvest solar radiation. The current application in the province of Utrecht is low, around 0.09% of the electricity need of households is covered by PV (See appendix I). But as with solar thermal a lot of roof space is available to mount solar panels. It is also expected that within 10 years PV prices will drop to the level of wholesale electricity prices as a result of technological development (Sinke, 2009).

I.4 Focus on PV

From the above RES this research will focus on the application of PV in the province of Utrecht. PV has several advantages, making application within the province interesting:

- PV has a high potential due to the large amount of roof space within the province where it does not compete with other uses on the roof, it can even be combined with a white or green roof[1]. The exact amount of roof space will be calculated in this thesis to know to what extend PV can contribute in reaching a climate neutral province in 2040.
- In comparison with wind turbines PV doesn't produce noise which is a reason for public resistance against the application of wind turbines.
- The Dutch national subsidy (SDE) on PV of 2008, 2009 and 2010 was fully booked on the first week it was available. This shows the large demand for affordable PV systems.
- There are civil initiatives in the province of Utrecht that focus on PV. These often are groups of house owners that want PV on their roofs and try to group up with other actors including the government to reach this goal.
- It is a very robust technology. PV systems do not have moving parts, is very modular and its 'fuel' solar radiation is widely spread (Del Cañizo et al. 2009).

[1] White roofs are coated white to reflect the sunlight which results in a lower cooling demand.

Green roofs are partially or completely covered with vegetation. This vegetation enhances the isolation of the roof, reduces storm water run of and increases its life span.

The PV technology has matured but the worldwide application is just starting to take off (EPIA, 2010). In the Netherlands and in the province of Utrecht the application level is lower compared to the worldwide trends (ECN, 2009). To reach the goal of a climate neutral province in 2040 the application of PV should be stimulated. Therefore the main research question of this thesis is:

> ***How can the diffusion of PV in the Province of Utrecht be accelerated?***

Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, chapter 1). To answer the main research question three sub questions have been defined. The first sub question covers the knowledge gap of how much potential PV has in supplying the province with electricity:

> ***A1. What is the technological potential of PV in the province of Utrecht?***

The second research question focuses on the financial feasibility of the application of PV without (national) subsidies.

> ***A2. To what extend is installing PV within the province of Utrecht financially feasible without subsidies?***

The current low level of PV application and other RES (see table I.1) can be understood in the light of the 'carbon lock-in' (Unruh, 2000). These new technologies have to compete with an incumbent technological system based on fossil fuels. The new technologies are in an early phase of development and are therefore inefficient and badly adapted to the existing functions they need to fulfil in society. This hampers a rapid diffusion (Rosenberg, 1976).

To break through the carbon lock-in it is needed to take a closer look at the influences on the PV diffusion. On a national level a recent study by Negro et al. (2010) analysed the diffusion of PV by using the framework of a Technological Innovation System (TIS). This framework has recently been developed and is often used to analyse the diffusion of an emerging renewable energy technology (Negro 2007, Hekkert et al. 2007, Suurs (2009) Negro et al. 2010). It allows to explain how the components in the innovation system influence the diffusion in a positive or negative way and it shows the relationship between the influences. This study will use the TIS framework with a focus on the regional level of the province. An historical event analysis will be combined with expert interviews to answer the following sub reearch question:

> ***B. How did the provincial PV Technological Innovation System develop and how can its performance be improved?***

The insights gained, using the potential and financial feasibility study as well as the TIS analysis, will allow us to formulate a policy advice for the provincial as well as the municipal government. The sub question for this last part is:

> ***C. What should the regional governments do to accelerate the diffusion of PV within the province of Utrecht?***

This last part will be written together with Machiel van der Bijl. He combined his thesis with an internship at the municipality of Amersfoort and thus focussed on the municipality level. By combining our gained insights both the municipal and provincial level will be covered.

I.5 Schematic overview

In the schematic overview in figure I.1 the input of the different parts of the thesis (in blue) are shown. The theoretical framework is shown in red. The remaining knowledge gained from practice in the internship, interviews and literature are shown in green.

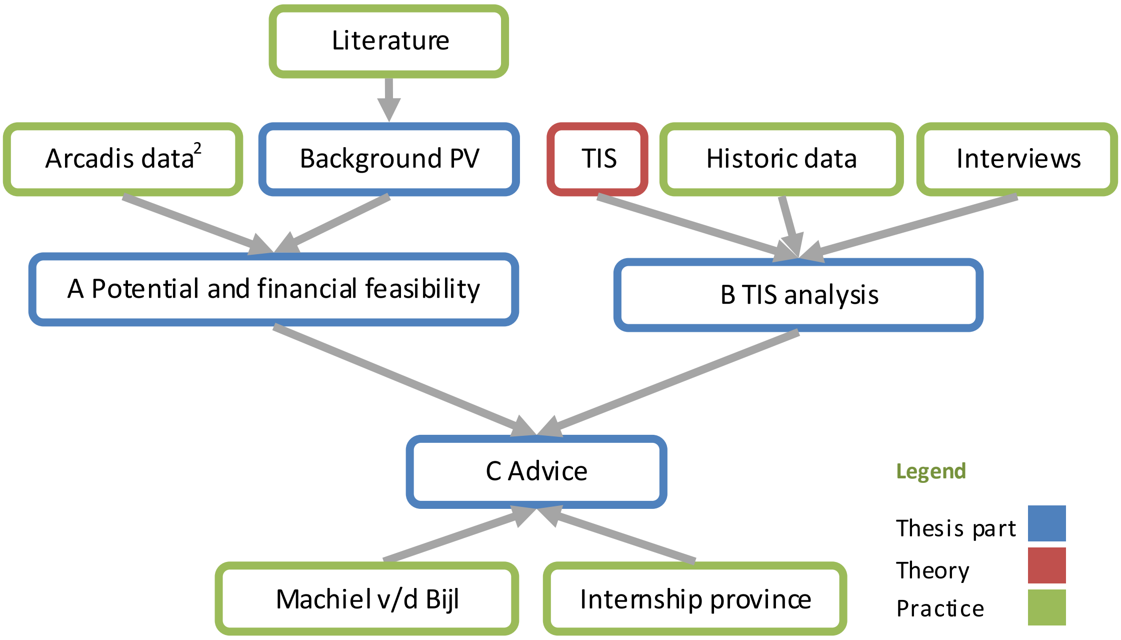

Figure I.1 schematic overview thesis

I.6 Reading guide

The chapter *II Background* gives an overview of the information on solar energy which serves as a background for the thesis. The sub research questions all have their own sections indicated by capital letters as shown in Figure I.1.The first section *A Potential and financial feasibility* covers the research on the technological PV potential within the province and the financial feasibility of applying PV without subsidies. The *Technological Innovation System* analysis is presented in section *B*. The final sub research question on the *Policy advice* is covered in section C. All the results are combined in the overall *Conclusion* in which the main research question is answered.

[2] The Province of Utrecht recently hired Arcadis to map the potential of sustainable roof technologies in the province. These technologies are solar thermal and electric, wind, green and white roofs. In a GIS (Geographic Information System) analysis data was extracted and combined from multiple geographical maps. These maps have information on the amount, orientation (N, NW, W, SW, S, SE, E, NE), angle and height of the roofs. The output of the Arcadis study on the amount, orientation and angle will be used in this thesis.

II. Background solar energy

In this chapter background information is given both on the photovoltaic technology as well as on its market development.

II.1 Harvesting solar energy

Solar irradiation

The most abundant energy resource on earth is solar energy. The amount of solar energy that reaches the earth's surface in one hour is about the same as the amount consumed by all human activity in a year (see figure II.1). In figure II.1 below the amount of solar energy that reaches the earth's surface (IEA, 2005) is compared to the fossil fuel (British Petroleum, 2010) and uranium reserves[3] (IAEA 2006) and the world energy consumption (IEA, 2010-I). To give a rough estimate: only 0,09% of the solar irradiation needs to be captured with 10% efficiency to cover the human energy consumption.

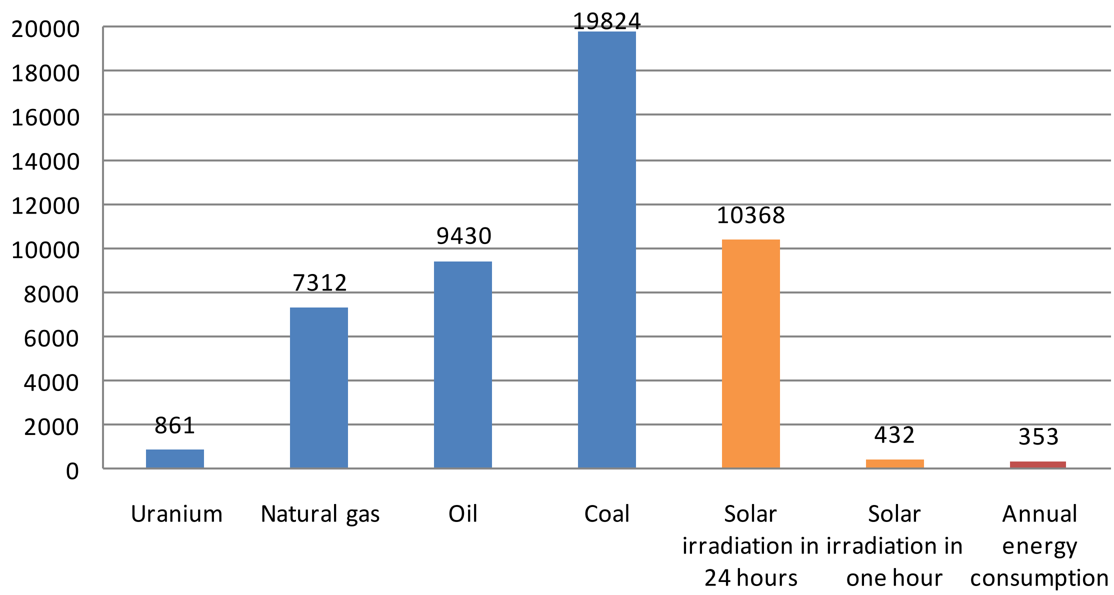

Figure II.1 Fossil fuel and uranium reserves compared to solar irradiation and the annual energy consumption (EJ)

[3] Reusing uranium will extend the amount of energy that can be extracted from the reserves. New technologies, like the fast breeder reactor, can extract 50x the amount of energy from uranium which would also greatly extend the potential for the remaining uranium reserves (IEA, 2008).

Harvesting methods

There are three main energy technologies available that use sunlight as an active source (IEA, 2010-II):

CSP - Concentrating solar power systems (figure II.2) concentrate solar radiation to use it as a high temperature energy source to produce electrical power or drive chemical reactions. CSP is typically applied in relatively large scale plants under very clear skies and bright sun. The availability of thermal storage and fuel back-up allows CSP plants to mitigate the effects of sunlight variability. CSP is not applied in the Netherlands due to the relatively high amount of diffuse sunlight that cannot be concentrated.

SHC - Solar heating and cooling (SHC) uses the thermal energy directly from the sun to heat or cool domestic water or building spaces. In the Netherlands the most common application is the solar boiler (See figure II.3) which is applied to heat tap water or water for the central heating system.

PV - Solar photovoltaic (PV) generates electricity through the direct conversion of sunlight. It can be applied in small scale systems with only a few panels on a roof (figure II.4) or large systems on large roofs or fields.

Figure II.2 CSP[4]

Figure II.3 SHC[5]

Figure II.4. PV[6]

[4] Cleantechnica (2010)

[5] Izen (2010)

[6] Candomar (2010)

II.2 PV System

PV Cell

At the core of the PV system is the PV cell (figure II.5) which uses the photovoltaic effect to generate electricity. The photovoltaic effect was discovered in 1839 by Becquerel. It took until 1954 to be applied as a power source by Chapin, Fuller and Pearson using doped semiconductor silicon. (Twidell & Weir, 2005). Photovoltaic power generation is caused by electromagnetic radiation separating positive and negative charge carriers in absorbing material. If an electric field is present, these charges can produce a current for use in an external circuit. These fields exist permanently at junctions or inhomogenities in photovoltaic cells as electrostatic fields and provide the electromotive force for useful power production (Twidell & Weir, 2005).

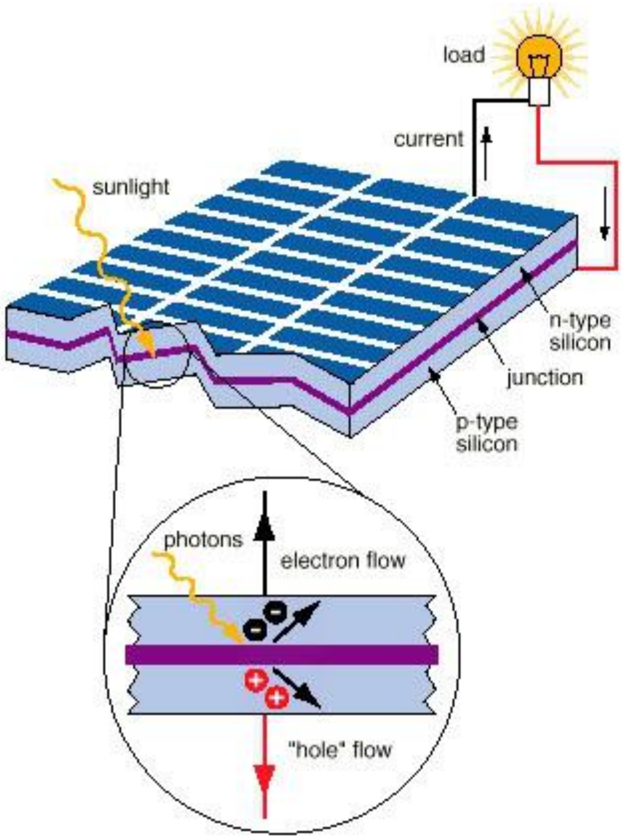

Figure II.5 PV Cell (rise, 2010)

PV Module

The PV cells are fit into panels that protect the cells from the outside conditions. The cells are connected to each other and typically have an output of 50-200 Watt peak (Wp).

Balance-of-system

To make the PV system complete the balance-of-system (B.O.S.) consists of all the other parts that are needed to make use of the modules such as cables, a mounting system, inverter, charge controller and meter (Figure II.6). PV systems are highly modular, i.e. modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW).

In case of a system connected to the electricity grid an inverter is needed to convert the direct current to alternating current. In many cases a meter is also installed to register the amount of solar energy that is fed to the grid.

For a stand alone, off grid, system a charge controller and batteries are needed to store the solar energy. The direct current energy can be directly used or converted to alternating current with an inverter for normal household equipment.

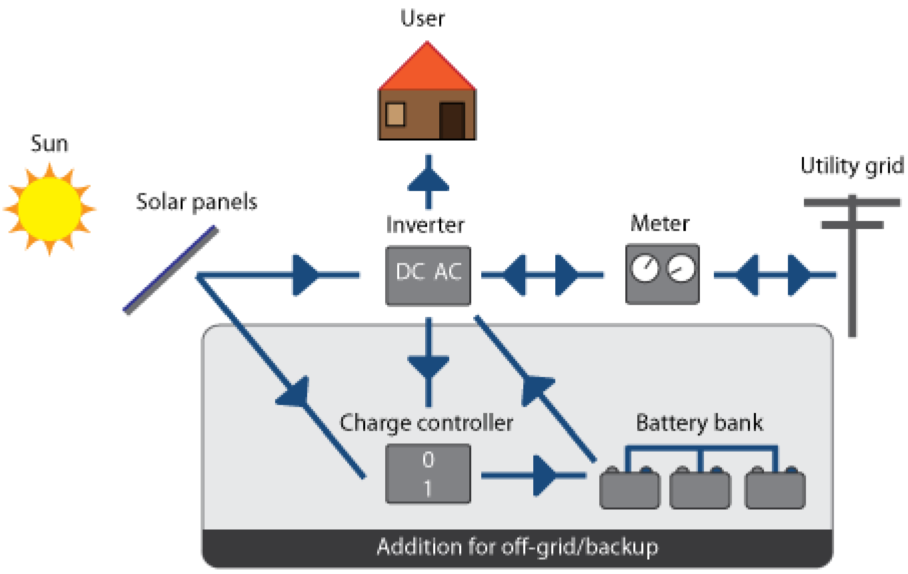

Figure II.6 On and off grid solar energy system

II.3 Technology development

Research and development have led to a wide range of PV technology options at different levels of maturity (Figure II.7). The commercially available PV technology mainly consists of crystalline silicon and thin film. There are a range of emerging technologies, including concentrating photovoltaic (CPV) and organic solar cells, as well as novel concepts with significant potential (IEA, 2010-II). For more information on these technologies see Technology Roadmap. Solar photovoltaic energy by the International Energy Agency, 2010-II.

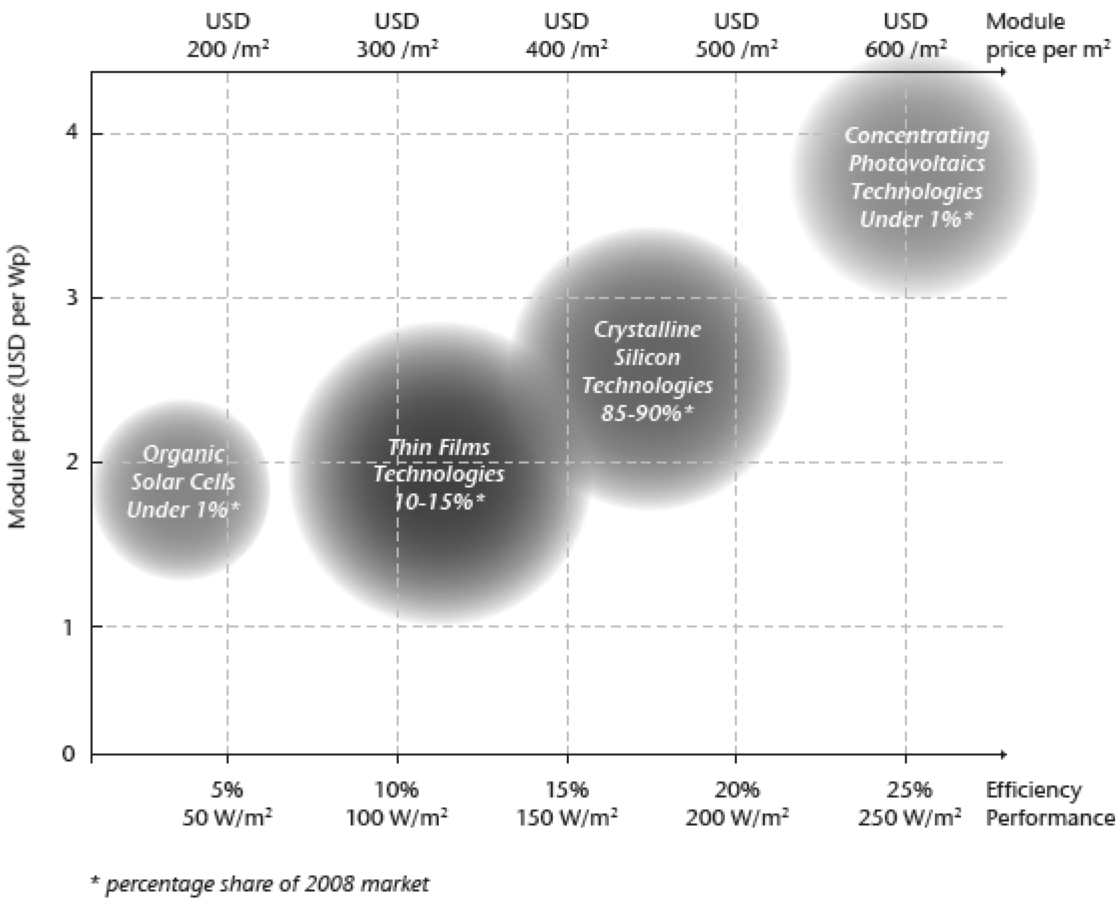

Figure II.7 Current performance and price level of different PV technologies (IEA, 2010-II)

II.4 Market development

Installed capacity

Worldwide

The worldwide installed capacity is growing rapidly with an average growth rate of 37% between 1992 and 2009 (Figure II.8). The cumulative capacity in 2009 reached 20GW. Most of the capacity was installed in Germany and Spain (Figure II.9). Both countries have a successful feed-in tariff which gives a premium for renewable generated energy.

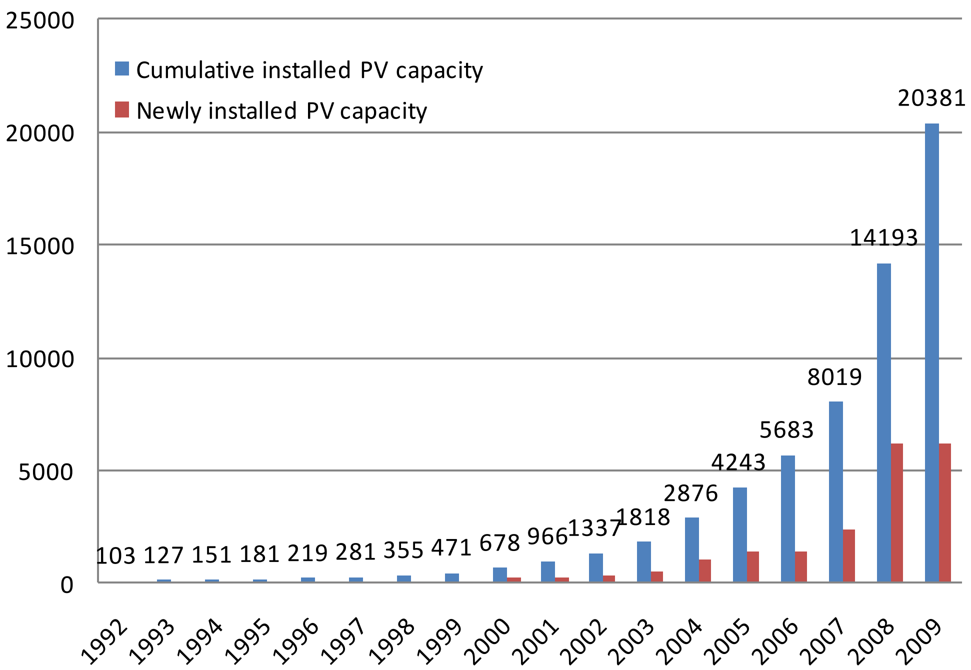

Figure II.8 Worldwide - Cumulative and newly installed PV capacity (MW)

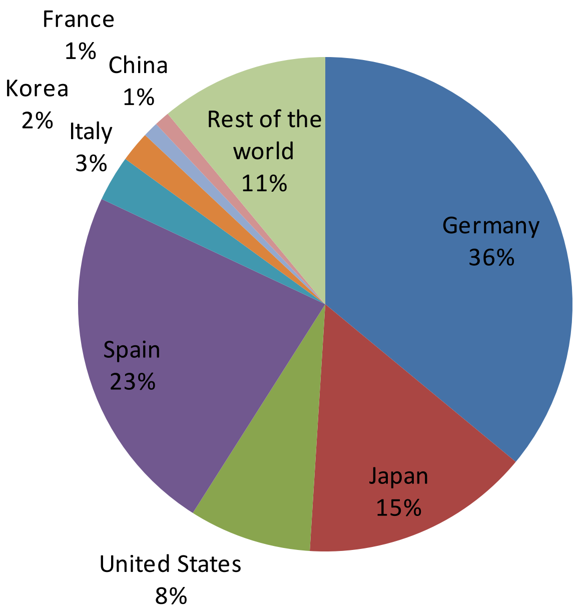

Figure II.9 Solar PV Markets, total installed capacity is more than 14500MW–2008 (IEA, 2010-II)

Netherlands

With only 0,3%[7] of the world population living in the Netherlands we installed up to 2,5% (Figure II.11) of the worldwide installed capacity in the Netherlands in 2003 but in the following years the newly installed capacity in the Netherlands collapsed and even with the rise in 2008 and 2009 our share dropped to an all time low in 2009 of 0,3% (Figure II.11). This means that the amount of PV per capita in the Netherlands is equal to the world average. Around three quarters of the installed capacity is installed in Western countries (Figure II.9) so our share/inhabitant should be higher.

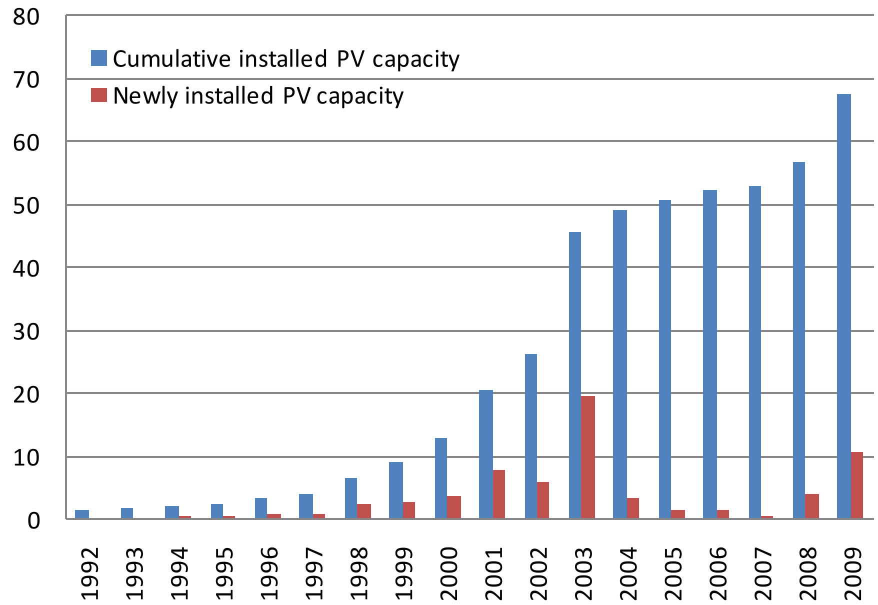

Figure II.10 Netherlands - Cumulative and newly installed PV capacity (MW)

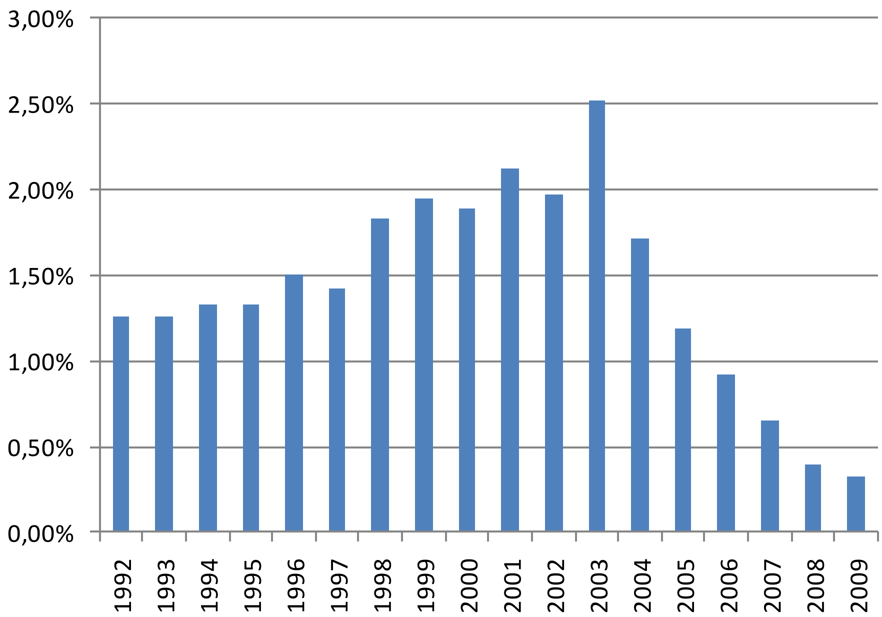

Figure II.11 Percentage of worldwide cumulative installed PV capacity in the Netherlands

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[7] World population of 6 billion divided by the Dutch population of 16 million.

Province of Utrecht

Certiq is the central body where sustainable energy resources should be registered upon installation. This has not always been the case so a lot of PV systems are unmonitored. This makes it hard for a region to monitor its sustainable energy production. A rough estimation without the Certiq data is made for the province of Utrecht in Appendix 1. It is estimated that around 2,5MWp to 5,0 MWp of capacity is currently installed. It is also noticeable that the total average capacity granted per inhabitant in 2009 by the SDE is lower for the province of Utrecht than the average of the entire Netherlands.

Share in energy mix

To get an insight in the relative importance of the currently installed RES the following two figures show the share in the energy mix. In figure II.12 the shares of RES are shown for the OECD, Germany and the Netherlands for 2007. In figure II.13 only PV is taken into account which makes up a small share within the renewable energy resources and even smaller in the total energy mix. Germany is shown in these figures because of its feed-inn tariff and therefore high share of RES.

Figure II.12 Share of RES in energy mix (International Energy Agency, 2009)

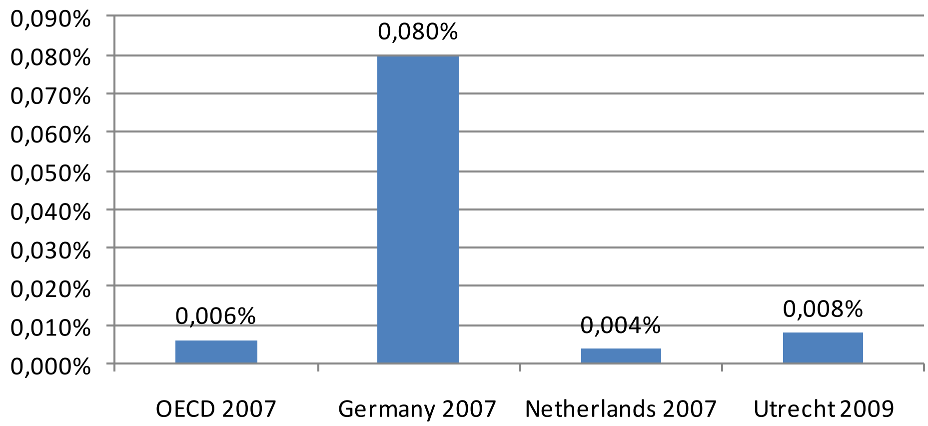

Figure II.13 Share of renewable and solar in energy mix[8]

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[8] For Utrecht the share was calculated in Appendix I the other shares were calculated by the International Energy Agency (2009).

II.5 Electricity generation costs

High investment costs represent the most important barrier to PV deployment today (IEA, 2010-II). In figure II.14 below the generation costs for electricity are shown for the most common energy resources including the renewable wind and solar resources. The method used for calculating these costs can be found in Projected Costs of Generating Electricity by the International Energy Agency (2010-III).

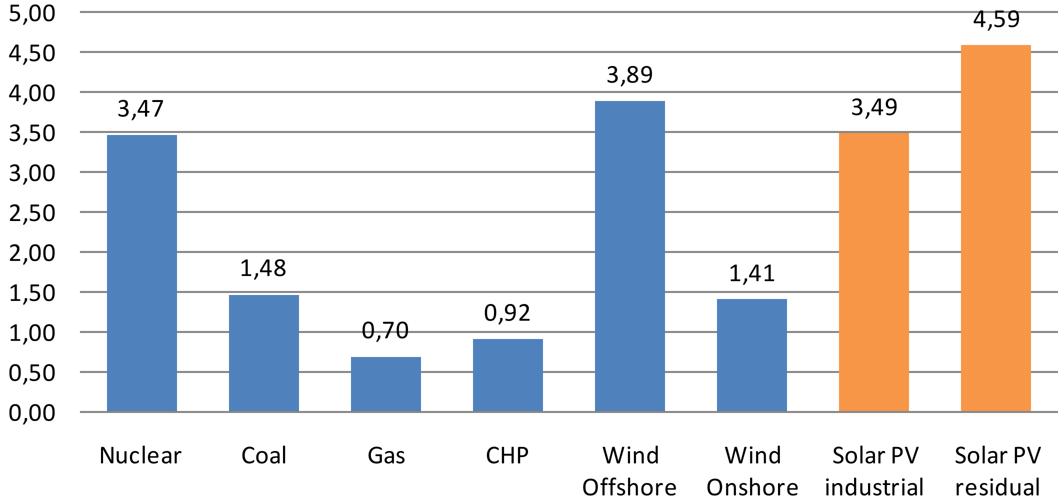

Figure II.14. Cost of electricity (LCOE)in €/We for the Netherlands (IEA 2010-III)

A. PV Potential

A.1 Introduction

To get an insight in the possible role of PV in reaching the goal of a climate neutral province by 2040 a study of the potential and a financial exploration are performed. The first sub research question that will be answered is:

What is the technological potential of PV in the Province of Utrecht?

Both a geographical potential and technological potential for buildings will be calculated[9]. Chapter A2 explains the method for measuring both the geographical and technological potentials. It states which sources of data will be used and which calculations will be made. In A3 and A4 the results are shown. These are evaluated in an sensitivity analysis in A5.

The financial exploration will follow up on the potential study in A6. This part will answer the second sub research question:

To what extend is installing PV within the province of Utrecht financially feasible without subsidies?

The conclusion can be found in chapter A7 and in A8 the performed research is discussed.

A.2 Method

The strength of solar irradiation depends on the geographical location, the orientation and angle towards the sky and the presence of blocking objects. In figure A.1 below the irradiation is shown as percentage of the maximum irradiation for the Netherlands. The solar irradiation per square meter in the Netherlands is 1000 kWh/m2/year (GeoModel Solar, 2010).

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[9] An economic potential is not calculated for a number of reasons:

- The lower the amount of inhabitants the harder it is to make a future estimation of a certain activity. In this case the local stimulating or blocking mechanisms on the application of PV have a very big influence on the application level while these local influences are smoothened on an international estimation.
- A future potential for a technology is often based on learning curves but recent studies showed the value of such simple modelling is limited (Yu, van Sark and Alsema, 2011).
- Another important method is the projection on the diffusion curve (S-curve). In which the current situation is linked to a position on the curve and a future year to another point. The realised potential in between can then easily be read from the curve. The uncertainty of this method is large due to the manual linking of these two positions on the S-curve.
- Since the Netherlands and the province of Utrecht have a low level of PV application compared to worldwide average, projecting international scenarios (Appendix IV) on the province of Utrecht will probably give too low an estimate.
- On an international level the calculated potentials are varying a lot limiting its use (Appendix IV). The International Energy Agency for example doubled the potential of PV for 2050 in a recently published study (IEA, 2010-II) compared to a study published two years earlier (IEA, 2008).

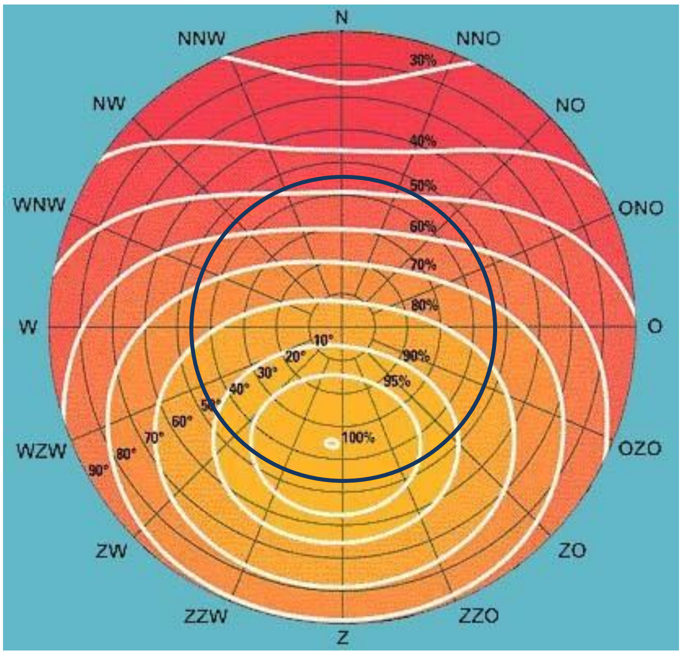

Figure A.1 Irradiation strength as percentage of maximum for the Netherlands (Ecoxtra, 2010)

At an angle of 45 degrees the following percentage of maximal irradiation are deducted from figure A.1 above (blue circle). The difference with horizontally oriented mounting is shown in table A.1 below.

Table A.1 Relative irradiation compared to optimal (South) orientation

Orientation	N	N-E	E	S-E	S	S-W	W	N-W	Flat
% of optimal irradiation	50%	55%	75%	95%	100%	95%	75%	55%	85%

The calculations for the PV potential of the province of Utrecht will be split up in the potentials shown in figure A.2 below:

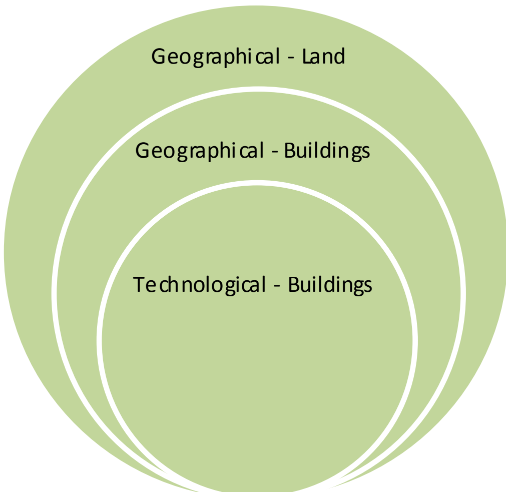

Figure A.2 The potentials (not on scale)

The largest potential is the geographical potential when all land surface is taken into account. Here the total irradiation is calculated. This is narrowed down to only buildings in the geographic potential of buildings. For the technological potential the characteristics of PV are included (efficiency and the part of buildings that are suitable for PV). Both the current characteristics and future improvements will be included in the calculations.

A.2.1 Geographical potential

The geographical potential is first calculated for the available land surface and then narrowed down to the surfaces available on buildings.

Land surface

The land surface of the province consists of the entire surface of the province minus the area that is covered by water. Multiplying this remaining surface with the irradiation on flat surfaces shows the total irradiation that can be harvested.

Land surface (m^2) * irradiation ($kWh/m^2/year$) = Total irradiation (kWh/year)

Buildings

The province of Utrecht has a high population density of 875 people per square kilometre (CBS, 2010). The population density of the whole Netherlands is 489 people per square kilometre (CBS, 2010). Both are high compared to the world average of 13 people per square kilometre. These high densities translate themselves in a lot of buildings per area and limited unused land. PV should therefore ideally be mounted on buildings and not on land where it competes with other uses. In the potential analysis only the walls and roofs are taken into account. PV in glazing would also be an option but it is not yet available and potentials are unknown.

Roofs

Roofs can be flat[10] or sloped. If they are sloped the surface has an orientation and an angle. Depending on these two variables the irradiation differs (see chapter 2.3). For the calculation of the potential of roofs a division is made between optimal roof space and suboptimal roof space. Optimal roof space has an irradiation of 85% or more of the maximum. Suboptimal roof space has an irradiation below 85% of the maximum (see chapter 2.3 for explanation). The calculations for sloped roofs are made with an angle of 45 degrees since the input data from Arcadis[11] only made a distinction between flat roofs and sloped roofs which were 45 degrees on average.

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[10] The irradiation on the flat roofs is 1000kWh/m2/year. Current solar installations on flat roofs are tilted to point south with an angle of 35 degrees to reach the optimum of 1180kWh/m2/year. This is because panels are expansive and roof space is abundantly available. In this setup space is needed between the panels to minimize the light blockage of one panel onto the one behind it. This way 30% of the roof is lost to separation (source). The total irradiation per square meter of roof is then 1180*0.7=826kWh/m2/year which is lower than the 1000kWh/m2/year for the horizontally placed panels. So if price/performance is not taken into account it is better to install the panels horizontal instead of in angle with space in between. In the this potential calculation panels are placed horizontal to reach the optimum potential.

[11] The Province of Utrecht recently hired Arcadis to map the potential of sustainable roof technologies in the province. These technologies are solar thermal and electric, wind, green and white roofs. In a GIS (Geographic

Another division that Arcadis made is on the application of the building. They were split up in residential, business and other application.

For every wind orientation (N, N-E, E, S-E, S, S-W, W, N-W) and for flat roofs the following calculation is made:

Roof surface of orientation (m^2) * irradiation (kWh/m^2/year) * Orientation correction (%) = Total irradiation of orientation (kWh/year)

Walls

To calculate the roof surface Arcadis also calculated the ground surface occupied by buildings. In a study by the IEA (2002) it was calculated that per square meter of ground surface of a building it has roughly 0.15m2 square meters of façade suitable for PV.

Ground surface (m^2) * Amount of façade/ground surface (m^2/m^2) * irradiation on vertical surface (kWh/m^2/year) = Total irradiation façades (kWh/year)

A.2.2 Technological potential

The amount of solar irradiation that can be converted into electricity by PV is the technological potential. This potential is split up in the current and future potentials. The current potential shows how much electricity can be produced by applying currently available PV-technology while the future potential gives a rough estimate of the maximum electricity output of PV in 2020 and 2040.

The PV technology keeps on developing and its main component, the PV cells, are expected to become more efficient in converting solar energy into electricity (IEA, 2010-II, see table A.2 below). The performance ratio, the fraction of the output of the solar cells that is fed to the grid, is also expected to grow in the future (Jahn and Nasse, 2004). The overall system efficiency is the multiplication of the cells efficiency with the performance ratio (PR). The current and expected future efficiencies of the cells and system and performance ratio are shown in table A.2 below.

Table A.2 – Specifications PV now and future

	2010	2020	2040
Efficiency PV cells	16,0%	23,0%	30,0%
Performance ratio	0,750	0,800	0,850
Efficiency PV system	12,0%	18,4%	25,5%

Information System) analysis data was extracted and combined from geographical maps. These maps have information on the amount, orientation (N, NW, W, SW, S, SE, E, NE), angle and height of the roofs. The output of the Arcadis study on the amount, orientation and angle will be used.

For roofs half the surface is expected to be suitable for installation of PV panels (IEA, 2002 and Arcadis, 2010). This is due to:

- The PV module has a certain size and covering the entire roof will therefore leave empty space around other objects on the roof and the edges.
- Unavailable roof space by other objects such as chimneys and roof windows.
- Monumental buildings where it is not allowed to place PV modules on roofs.
- Limiting roof strength, therefore limiting the amount of PV modules the roof can carry.

Available surface (m^2) * Percentage of surface that is available for PV (%) *
Efficiency solar system (%) * Irradiation ($kWh/m^2/year$) = electricity output/year (kWh/year)

The calculated electricity output will be compared to the current electricity and energy (only gas and electricity) demand within the province. The CO_2 emission that is avoided by using electricity from PV instead of electricity from the grid will also be calculated and compared to the CO_2 emitted by activity within the province. The avoided CO_2 emission per kWh produced by PV is based on the average emission of CO_2 of a kWh of electricity used in the Netherlands which is 0,566 kg/kWh (Agentschap NL, former Senternovem, 2007). This amount is close to the 0,51 kg/kWh estimated by the IEA for the worldwide production of electricity (IEA, 2010-II).

A.2.3 Energy use and CO2 emission

The province of Utrecht has an electricity consumption of 5TWh/year (internal documentation province of Utrecht). The total gas and electricity consumption combined amounts to 77PJ/year which is equal to 22 TWh/year. The corresponding CO_2 emission is 3,9 Mton and the overall emission within the province adds up to 9,3 Mton. This data will be used to calculate the share PV can provide in the provincial energy demand and corresponding CO_2 emission reduction.

A.2.4 Sensitivity analysis

To test the calculated potentials on the uncertainty of the used variables a sensitivity analysis will be performed. The following variables will be tested with an uncertainty of +20% and -20%:

- *Available roof space*. The GIS analysis performed by Arcadis involved multiple steps of generalisation and extrapolation which inherently generate uncertainty.
- The *usable roof space* is estimated by the international energy for Western countries. The estimation itself gives uncertainty and in these calculations only the province of Utrecht is taken into account. The type of buildings and corresponding usable roof space might differ compared to the general estimate for Western countries.
- The *efficiency of solar systems* varies depending on the type of solar cells and inverter. Some are more costly than others and depending on the mix that is chosen to apply the overall efficiency may vary.

These variables will be varied independent and combined to see what their individual influence and combined influence is on the potential.

A.3 Geographic potential

A.3.1 Land surface

The total irradiation of sunlight in the province of Utrecht on land surface is:

$$1385 \cdot 10^3 \cdot 1000 / 1 \cdot 10^9 = \mathbf{1385\ TWh}$$

This amount is higher than the total energy need in the Netherlands (2615PJ = 726TWh, CBS, 2010-II). If this amount of sunlight could be harvested with 10% efficiency it would be more than enough to supply the entire Netherlands in its electricity need of 87,22TWh (CBS, 2010-II).

A.3.2 Buildings

Buildings cover 54 km^2 which accounts to around 4%[12] of the surface within the province of Utrecht. Due to the sloped roofs the total roof space is higher: 71 km^2.

The irradiation on buildings is split up in roofs where the entire surface is accounted for and the walls only the PV-fit walls with sufficient irradiation are taken into account.

Roofs

The figure (A.3) below shows the division of roof space. Most of the available roof space is on residential buildings (58%). Businesses only account for 27% and the remaining 15% consists of governmental, public and uncategorised buildings.

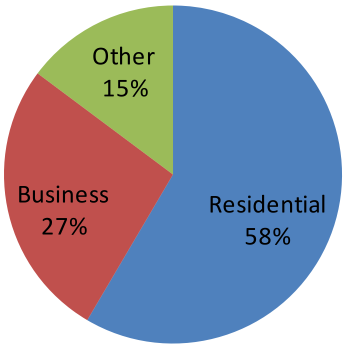

Figure A.3 Roof space per building application

[12] The building area of 54km^2 divided by the total surface of 1385km^2.

The table (A.3) below shows for every roof orientation its available surface, its irradiation strength compared to the optimal surface and the total irradiation per orientation. The irradiation on the optimal roof space (South-East, South, South-West and flat) is 40,4TWh and on suboptimal roof space (North, North-East, East, West and North-West) adds up to 24,6TWh. The total irradiation on roofs in the province of Utrecht combined, leads up to 64,9TWh.

Table A.3 Surface and irradiation of different wind directions (blue is optimal roof space)

Orientation	N	N-E	E	S-E	S	S-W	W	N-W	Flat	Total
Surfaces (km2)	6,8	6,6	7,2	6,6	7,2	6,8	6,7	6,3	17,0	71,0
% of optimal irradiation	50%	55%	75%	95%	100%	95%	75%	55%	85%	78%[13]
Total irradiation (TWh/y)	4,0	4,2	6,3	7,4	8,5	7,5	5,9	4,1	17,0	64,9

In figure A.4 below the total irradiation is shown for every orientation and flat roofs. By far the highest irradiation is on flat roofs due to its large surface. All the wind orientations have around the same size (see table A.3 above) but differ in irradiation due to their orientation relative to the sun's course.

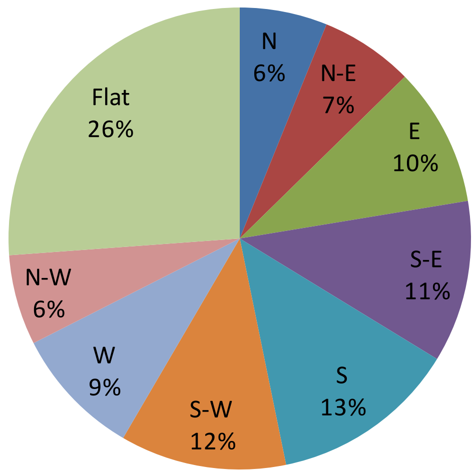

Figure A.4 Total irradiation split up in wind orientations

Walls

Using the potential data from the International Energy Agency (2002) the following irradiation is found for PV-fit walls in the province of Utrecht:

$$54 * 10^6 \text{ (m2)} * 0{,}15 * 1000 / 1*10^9 = 8{,}10 \text{ (TWh/year)}$$

[13] This is the average for all the available surface.

A.4 Technological potential

The geographical potential for buildings calculated in this chapter narrows the geographical potential of buildings further down by including the efficiency of the PV system and by only using the parts of buildings that are suitable for PV.

Figure (A.5) below shows the total irradiation split up in the final electricity output potential (6%) and the loss due to the efficiency (44%) of the PV technology and the loss due to the unused area of 50% (IEA, 2002). PV technology will improve in efficiency but will also be designed for currently unusable areas (for example for rounded surfaces with thin film technology that is bendable). Buildings that are yet to be built can also be designed in such a way that the unusable area is lowered and the usable areas are optimally orientated for PV application.

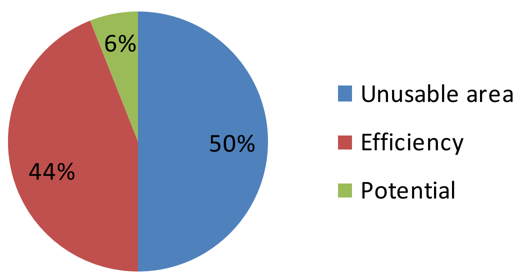

Figure A.5 Technological potential of roofs as a fraction of total potential

The figure (A.6) below shows the technological potential that can be reached with current (2010) and expected improved technology (2020 and 2040). With current technology 4,4TWh can be produced by using all the suitable surfaces on buildings. When only optimal orientated roof space is used this is lowered to 2,4TWh which is roughly half of the current electricity demand in the province.

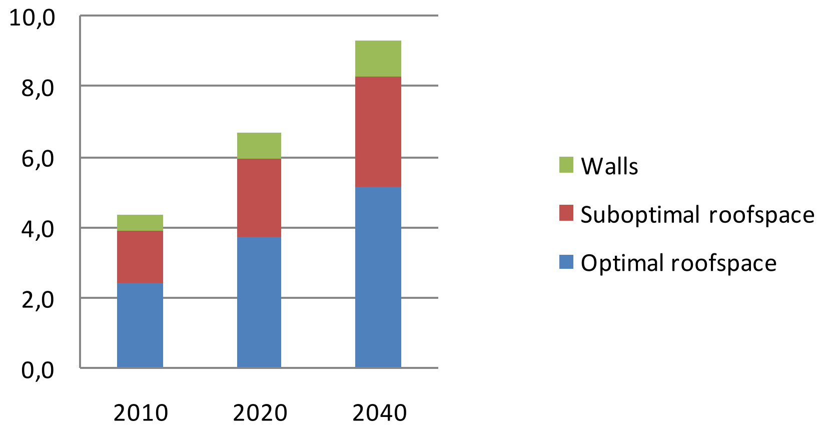

Figure A.6 Technological potential (TWh/year) for different surfaces

In table A.4 below the calculated technological potential for optimal, suboptimal roof space and walls is combined and compared to the current electricity and energy need and its corresponding CO_2 emission.

Table A.4 Technological potential of PV compared to current energy demand province of Utrecht

	2010	2020	2040
Electricity demand	84%	129%	178%
Energy demand (electricity + gas)	20%	31%	43%
Avoided CO_2 emission (Mton)	1,9	2,9	4,0
Percentage of avoided CO_2 emission	20%	31%	43%

With the currently available PV technology 84% of the electricity demand could be covered which corresponds to a 20% reduction in the total provincial energy demand/CO_2 emission. Improvements in PV technology can double this technological potential in 2040 when almost half the current energy demand could be covered by PV.

A.5 Sensitivity analysis

In table A.5 below the influence of the variation in the input variables is shown for the potential electricity output with current technology. All three variables have a linear influence on the electricity output.

Table A.5 Influence of variation of input variables - Total electricity output 2010 (TWh)

Variation	-20%	0	20%
Available surface	3,6	4,4	5,2
Usable roof space	3,5	4,4	5,3
Efficiency of solar system	3,5	4,4	5,3
All combined	2,3	4,4	7,4

When all uncertainties are combined a large difference can be seen in electricity output. But even in the most negative scenario it will cover half of the current electricity demand within the province while the most positive scenario would even result in a surplus.

A.6 Financial exploration

At both the provincial and municipality level governments are looking for ways to enhance the PV deployment. A subsidy comparable to the national subsidy program SDE would be unfeasible due to its high costs. A limited budget would only be able to cover a small portion of the request for PV subsidy. Therefore it would be interesting to see whether there are other ways to stimulate PV deployment without these large subsidies.

Currently the price level of a PV system can vary from 3 to 4,5 €/Wp including installation (Appendix V). When 3 €/Wp is taken and a lifetime of 25 years a system as in table A.9 would produce 67260 kWh in its lifetime. The price per kWh would thus be 10294/67260 = 0,15 €/kWh. This is more costly than the cost of electricity (0,07 euro/kWh, table A.6) but less costly when the energy tax and value added tax are also taken into account (total of 0,21 €/kWh). The energy tax depends on the amount of electricity consumed (table A.7). A household consumes around 3500kWh/year and therefore stays within the first group. Small companies in the service sector might also use less than 10.000 kWh and while they don't have to pay the value added tax their price of 0,18 €/kWh is still above the price from a PV system. For large electricity consumers (>10.000 kWh) the price drops to 0,11€/kWh making it impossible to earn back the investment of a PV system.

These simple calculations do not involve changes in electricity prices, regulations and the actual costs of investment. Within a period of 25 years all these can change and it is therefore uncertain how well a PV system can really compete with electricity from the grid.

Table A.6 Price of electricity for small (<10.000 kWh) consumers[14]

Components in electricity price	Cost (€/kWh)
Cost of energy	0,07
Energy tax	0,11
Value added tax (B.T.W.)	0,03
Total	0,21

Table A.7 Energy tax (Ministry of finance, 2010)

Electricity consumption (kWh/year)	Tax per kWh (€)
< 10.000	0,1114
10.000 - 50.000	0,0406
50.000 - 10.000.000	0,0108
> 10.000.000 (business)	0,0005
> 10.000.000 (non-business)	0,0010

[14] - The mentioned price of 0,07 euro/kWh is an average of the price of Nuon, Eneco and Greenchoice.
- These prices do not include the costs for the connection and transport which are fixed and are only dependent on the capacity of the connection to the grid.

Electricity is normally paid on a monthly basis to electricity companies. When a PV system is installed this changes to an upfront investment with minimal costs of maintenance during its lifetime. This investment could be spread by loan or a lease which will add extra costs but still be attractive when it stays below the 0,21 euro/kWh. For users who can't install a solar system on their own roof an external roof could be equipped with a PV system while the energy is virtually used by the consumers without entering the formal economy. This construction is being applied in a pilot project of Zonvogel, a PV cooperative (Zonvogel, 2010). The advantages and disadvantages of both possibilities are shown in table A.8 below.

Table A.8. comparison of usage of own roof and external roof

		Own roof		External roof
Costs of installation	-	High, due to the small installation costs of system, installation and B.O.S. are high.	+	Very large installations can be installed efficiently.
Cost of organisation	+	Low, only consumer is involved and possibly a financial party and government for guarantee.	-	An organisation needs to be formed for management.
Complexity	+	Only interaction between consumer, supplier and installer.	-	Agreements with roof owner, grid and/or electricity company and an organisation is needed to manage the installation and administration with the consumers.
Regulations	+	It is allowed to subtract the produced energy from the electricity bill up to 1000kWh above the usage.	-	The feasibility depends on the ability to deliver the energy to the user for without entering the formal economy. The only known project where that is possible is the pilot of Zonvogel.[15]
Flexibility	-	The solar system is installed on own roof. When consumer moves to another house he has to take the system with him or sell it to the new owner. Consumers that rent a house or don't have a suitable roof won't be able to benefit.	+	Depending on the organisational form consumers can join and leave whenever they want. The solar system can stay on the roof during its economical lifetime.

[15] Without this ability of balancing (salderen) the generated electricity will be fed to the grid with a compensation that is only a fraction of the electricity price of small consumers. This way installing PV systems on external roofs becomes economically unfeasible.

To spread the investment of the solar system over multiple years the following structures will be analysed.

- Direct investment. To show the influence of the rise in energy costs and the price of the PV system an analysis is made where no interest has to be paid.
- Loan. A loan could be granted by a financial party where 5% interest rate is taken or at specific municipalities that cooperate with the sVn[16] to provide a loan with 2% interest.
- Loan with guarantee. The province of Utrecht has a guarantee fund for investments in sustainable energy sources. When a solar system qualifies for this guarantee fund the financial party that grants a loan has a lower risk and might accept a lower interest rate. In these calculations 3% is assumed. A house owner with a mortgage and interest rate deduction would also pay about 3% depending on their income and mortgage rate.
- Lease. In a lease construction the yearly paid fee is fixed during the lease period. Multiple interest rates are used in the calculations.

Variables

In the table below the variables that are used in the analysis are shown.

Table A.9 – Variables

Variable	Value	Unit
Costs of solar system	3,00	Euro/Wp[17]
Electricity usage of a household	3500	kWh/year[18]
Electricity output solar system	0,85	kWh/Wp/year[19]
Size of system	4118	Wp
Cost of system	10294	Euro
Energy price from grid (consumer price)	0,21	Euro/kWh
Degradation of output PV system	0,85	%/year[20]
Rise in energy prices	4,0	%/year[21]
Interest rate loan without guarantee	5,0	%/year[22]
Interest rate loan with guarantee	3,0	%/year[23]
Interest rate loan by municipality	2,0	%/year[24]

[16] The Incentive Fund Housing Dutch Municipalities (Stimuleringsfonds Volkshuisvesting Nederlandse gemeenten, SVn) provides low interest loans to improve the quality and affordability of building and living thru municipalities.

[17] See appendix V for a small inventory of system prices.

[18] Source: CBS, 2006

[19] Source: IEA, 2010-II

[20] The performance of a solar system is usually guaranteed by the manufacturers. 0,85% degradation per year is taken into account which corresponds to a 20% decrease in about 22 years which is common for these guarantees.

[21] The last 7 years the electricity prices grew by 7% a year (CBS, 2011). It is expected that the electricity prices will keep rising and a relatively low 4% is used for the calculations.

[22] Source: Greenloans (2010)

[23] Source: Greenloans presentation at Bird & Bird, 2010.

[24] Source: Municipality of Amersfoort (2010)

Direct investment

In this model (figure A.7) the payback time is shown for five different PV system prices per Wp. It is plotted against the rise in energy prices to see its influence. The PV system is paid upfront without a loan or lease so there is no interest rate.

Even with a price of 3 €/Wp and no rise in energy prices the payback time is 17 years which is well below the technical lifetime of a solar system of around 25 years. When a modest rise in energy price of 4% is taken into account the payback time drops to 13 years.

When the costs of PV systems will drop further in the future the payback time will drop even further. When a price of 2 €/Wp is reached and energy prices rise with 4% on an annual basis the payback time breaks the 10 year border.

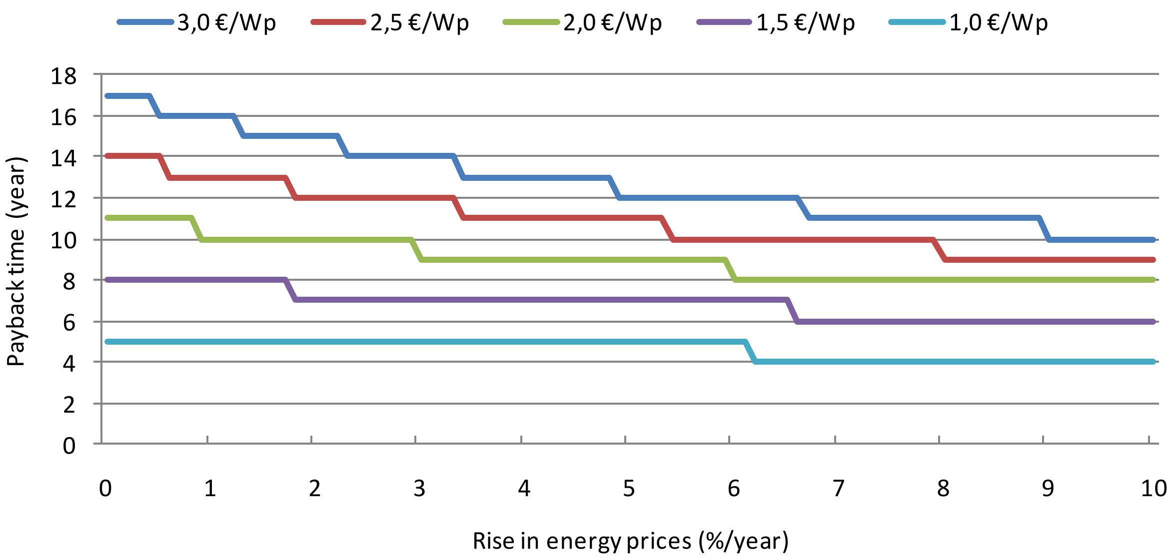

Figure A.7 – Direct investment payback time[25]

[25] The Lines are not continues because the model calculated the values on a yearly interval.

Loan and guarantee

In the figure below (A.8), the loan duration is shown for five interest rates including one with a price of 2 €/Wp instead of 3 €/Wp. On the vertical axis the yearly costs (interest and redemption) are compared to the energy bill that would normally be paid for the 3500kWh (with a yearly increase in costs of 4%) that is produced by the PV system.

When no yearly profit needs to be made and an interest rate of 5% is taken duration of the loan is 18,5 years. The loan duration decreases when interest rates drop to the level of loan with guarantee (3% interest) to 16 years and with a sVn loan (2% interest) to 15 years. These constructions can be very interesting for consumers since they don't have to pay extra for their electricity and after 15 to 18,5 years their PV system is paid off and the electricity that will still be generated for at least 6,5 to 10 years will be without further costs. It becomes even more attractive when the price of solar systems drops to 2 €/Wp and a loan with guarantee is granted. The duration of the loan without profit would then be 11 years.

Since the technical lifetime of a solar system is around 25 years the energy would be free when the loan duration is over. This benefit could also be included during the loan which extends the loan period but frees up a yearly extra income that could be given to the consumer or in case of the application on an external roof to the organization that uses that money to provide itself with the needed cash flow. With a 3% interest rate this adds up to around 250 €/household/year (3500 kWh). This could make it even more attractive for house owners since they will directly benefit from their switch to solar energy.

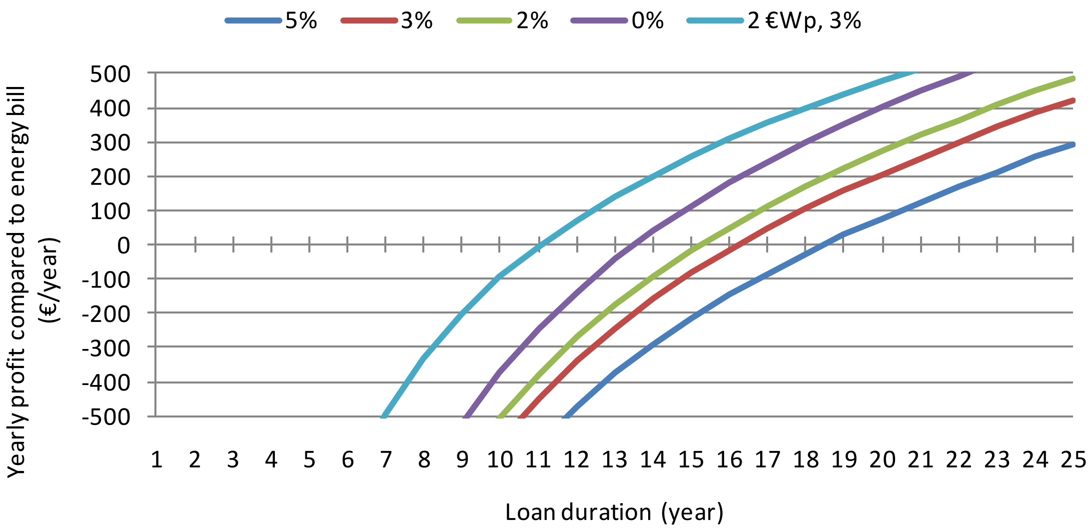

Figure A.8 – Loan duration time

Lease

In this lease construction the yearly fee is fixed and thus independent on the normal electricity price. In figure A.9 the lease duration is plotted against the yearly costs. The lines show the income for the lease construction provider in percent per year (like an interest rate). The current electricity costs of an average household: 3500 kWh * 0,22 = 770 euro (vertical line). The yearly increase in electricity costs from the grid is set to 4%. The sloped line at the right corner shows the yearly costs of electricity from year 8 onward. The costs for 2870 kWh (efficiency losses due to degradation of solar system)in year 24 are 2870 * 0,53 = 1521,10 euro.

With an income of 5% per year for the lease provider and a lease duration of 24 years the consumer would pay 900 euro's a year. With a 4% rise in electricity prices he would only start benefiting from year 7 onwards. When the interest rate drops to 3% the yearly costs will equal the current electricity bill for a lease duration of 25 years.

It becomes really beneficial for the consumer when the income of the lease provider drops to 2% or when in the future the solar system prices drop to 2 €/Wp and the interest rate is 3%. The duration would then be below the technical lifetime and a benefit can be given to the consumer compared to their current electricity bill. During the remaining years the annual costs will stay the same while the electricity price from the grid will probably keep on rising. This will make this model even more attractive.

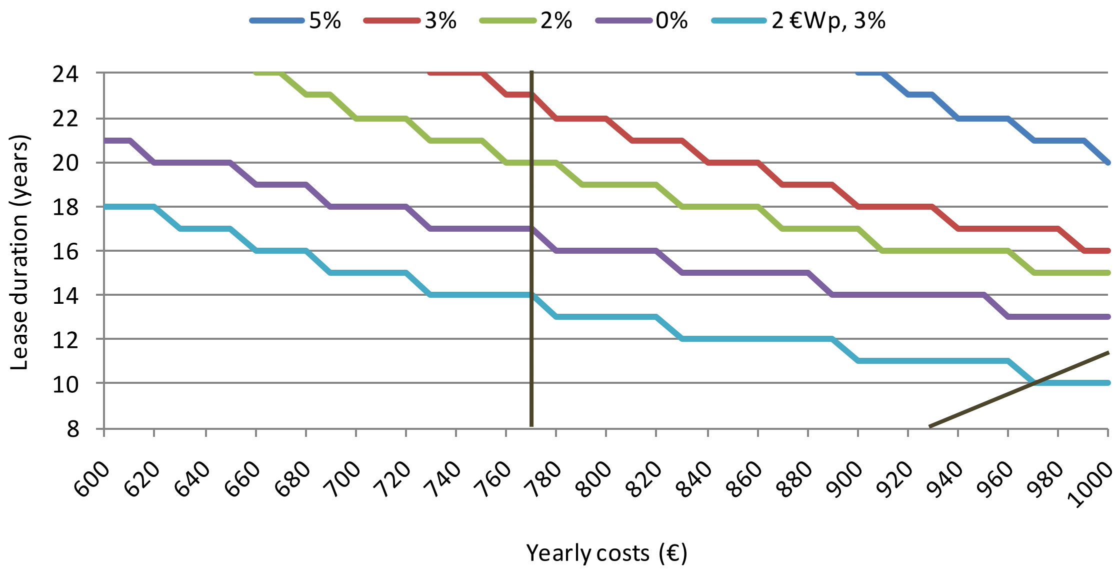

Figure A.9 – Lease duration[26]

[26] The Lines are not continues because the model calculated the values on a yearly interval.

A.7 Conclusion

The geographical potential analysis showed that the solar irradiation on the provincial surface is enormous in terms of energy that reaches the surface. But due to the high population density and the competing purposes for land surface PV should optimally be mounted on buildings where it does not compete with other uses.

Within the province 54 km^2 of surface is used for buildings resulting in 71 km^2 of roof space and 8,1 km^2 of facade suitable for PV. The roof and facade surface combined can cover between 50% and 150% of the current electricity need within the province. Future improvements in PV system efficiency and the ability to cover more of the available roof space can double this potential. With an optimal application this can result in an CO2 emission reduction of 40% in 2040 of the current CO2 emission caused by the provincial electricity and gas consumption.

Currently only 0,1% of the electricity that is used within the province of Utrecht comes from PV systems within the province. To be able to increase this share the financial exploration showed that the focus should be on small consumers who use less than 10.000 kWh per year due to their relatively high electricity price. With these high electricity prices the payback time of a solar system (13 to 17 years) is well within the technical lifetime of a PV system (25 years).

To overcome the barrier of the high upfront investment of a PV system multiple financial products were analysed.

The PV system could be financed with a loan. With a yearly increase in price of electricity from the grid of 4% and a 5% interest rate the loan duration would be 18,5 years. By lowering the interest rate to 3% with a (governmental) guarantee or 2% (sVn loan) the payback time drops to 16 and 15 years respectively. The duration of the loan will drop further to 11 years when the price of solar systems drops to 2 €/Wp and a loan with guarantee is granted.

A PV system could also be financed by a lease construction with a fixed yearly payment. This construction would be beneficial for the consumer when their yearly costs would be equal or lower than their current annual electricity bill. This is the case when the yearly profit of the lease provider is 2% or less and when the future PV system prices drop further.

The feasibility of installing PV within the province of Utrecht without subsidies depends on the possibility to get a low interest loan or a lease with a low overhead. When these can be granted by a foundation or government the consumer will be able to benefit from a solar system without the upfront investment and yearly costs that are equal or less than their current grid electricity costs. When PV system prices will drop further in the future these models will become more attractive.

A.8 Discussion

As discussed in the method on the sensitivity analysis, there are three main variables that have uncertainties. First: the GIS analysis performed by Arcadis. The analysis focussed on the municipality of Woerden and extrapolated part of that local data to the entire province of Utrecht. The uncertainty inherent in such an extrapolation also has its effect on the available roof space used in the calculation of the technological potential. To take away this uncertainty a detailed analysis of the entire province can be made but this will be costly and the added value can be debated.
Second: the ratio of available roof space versus usable roof space. This ratio is based on the estimate provided by the International Energy Agency. A more accurate ratio can be determined by analysing the buildings in the province of Utrecht. A detailed 3D map of the entire region in combination with simulations could even determine this ratio with a high certainty. This method is used on a small scale projects only. Using it for the entire province would be very costly.
Third: the current and future efficiency of solar systems. The estimate of the current efficiency could be determined in analysing the current sale of solar system components and taking the average. The estimate of the future efficiencies is calculated by the International Energy Agency and for such an extended period these numbers are very uncertain and difficult to improve in accurancy.

While the application of PV in glazing was not included in the calculated potentials, it can be interesting to analyse this separately. The application of PV in glazing can produce electricity, lower the demand for cooling in summer and can be applied even if there is no roof space available.

The financial feasibility exploration showed that for small electricity consumers (private consumers and small companies) the payback time is about half the technical lifetime of PV system. While the payback time is around 15 years, the average amount of time people live in one house is seven years. When a loan or lease is used, this period is even longer than 15 years. It might be interesting to conduct future research on how to deal with these differences. What needs to be done when people move to a different house but still have the lease or loan contract?

B. Technological Innovation System

B.1 Introduction

The sub research question that is central in part B is:

> ***How did the provincial PV Technological Innovation System develop and how can its performance be improved?***

This part of the thesis is organised as follows. In chapter B2 the theory on the TIS needed for the analysis is described. In chapter B3 the three step method is elaborated. The results are spread across B4, B5 and B6. The concluding remarks en discussion on the performed research are stated in B7 and B8.

B.2 Theory

B.2.1 Technological Transition

The goal of the province of Utrecht to be climate neutral in 2040 needs a long-term process of transforming the current energy system based on fossil fuels to a more efficient renewable energy system. This can be seen as a technological transition where new innovations diffuse in the existing energy system (figure B.1). This process can be divided in the following phases (Van Lente, Hekkert, Smits & Waveren, 2003): *Exploration* in which research leads to new technological variations and possible societal applications. *Take off* in which the new technology starts to influence the existing system. Competition starts and the new technology acquires a niche market. In the *embedding* phase the existing system is adjusted to fit the new technology. *Stabilization* finally occurs when the system is totally adjusted to the new technology and a new balance is formed.

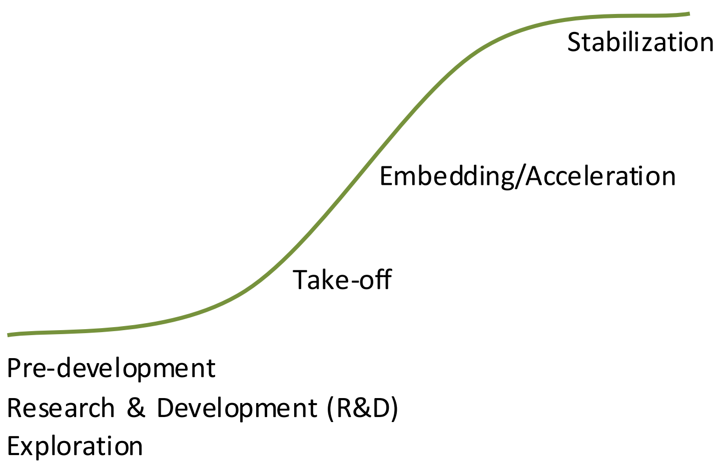

Figure B.1 The diffusion curve of innovation

B.2.2 Creative destruction

The current energy system is designed for the existing technologies to which the new technologies like PV are often not well adapted. This makes them inefficient and hard to apply (Rosenberg, 1976). Changing the energy system to fit in the new technologies will be a difficult process. In the exploration and take off phase it will be especially hard to break through the lock-in of the existing technologies. This breakthrough is called creative destruction (Schumpeter, 1934) in which innovative entrepreneurs take over the market from the established companies.

B.2.3 Technological Innovation System

To acquire insight in how the PV technology is going through these phases a theoretical framework is needed that maps the involved actors, institutions, networks and technological conditions. The Innovation System (IS) framework is able to do this. In 1987 Freeman was the first to describe an IS:

> *"...The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies "* (Freeman, 1987)

Based on this concept Lundvall (1992) proposed the National Innovation System (NIS) which was limited by the borders of a nation. Breschi and Malerba (1997) later added the Sectoral Innovation System (SIS) that focused on a sector. For this research however we need to look at only one technology (PV) for which the Technological Innovation System (TIS) was defined by Carlsson and Stanckiewicz (1991). The TIS focuses on all the structural elements (institutions, actors and networks) surrounding a specific technology with all its strengths, weaknesses and dynamics (Jacobssen and Johnson 2000).

System Functions

To gain insight in these dynamics the relevant activities within the TIS need to be mapped. Hekkert et al. (2007) introduced a method in which activities are analysed on their positive or negative influence on the development of the TIS. These influences are categorised in a number of System Functions that can be fulfilled within a TIS. Different sets of System Functions have been proposed but for analysing the development of sustainable energy sources a list of seven (Hekkert et al. 2007) have mainly been used in the research of Suurs and Hekkert (2005), Negro (2007), Negro et al. (2010). For this research the definitions of Negro et al. (2010) will be used. Below the description of every function an example is given on PV-specific activity within the province of Utrecht.

"Function 1: Entrepreneurial Activities

The existence of entrepreneurs in innovation systems is of prime importance. Without entrepreneurs innovation would not take place and the innovation system would not even exist. The role of the entrepreneur is to turn the potential of new knowledge development, networks and markets into concrete action to generate and take advantage of business opportunities." (Negro et al., 2010)

PV example: The realisation of 1,2MW of PV capacity in the residential area Nieuwland in Amersfoort.

"Function 2: Knowledge Development (learning)

Mechanisms of learning are at the heart of any innovation process. For instance, according to Lundvall: "the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning" (Lundvall 1992). Therefore, R&D and knowledge development are prerequisites within the innovation system. This function encompasses 'learning by searching' and 'learning by doing'." (Negro et al., 2010)

PV example: The University of Utrecht researching new ways of making the production of PV cells less costly.

"Function 3: Knowledge Diffusion through Networks

According to Carlsson and Stankiewicz (1991) the essential function of networks is the exchange of information. This is important in a strict R&D setting, but especially in a heterogeneous context where R&D meets government, competitors and market. Here policy decisions (standards, long term targets) should be consistent with the latest technological insights and, at the same time, R&D agendas are likely to be affected by changing norms and values. For example if there is a strong focus by society on renewable energy it is likely that a shift in R&D portfolios occurs towards a higher share of renewable energy projects. This way, network activity can be regarded as a precondition to 'learning by interacting'. When user producer networks are concerned, it can also be regarded as 'learning by using'." (Negro et al., 2010)

PV example: The conference held by the province of Utrecht on the application of distributed renewable energy resources including PV.

"Function 4: Guidance of the Search

The activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users fall under this system function. An example is the announcement of a policy goal to aim for a certain percentage of renewable energy in a future year. This grants a certain degree of legitimacy to the development of sustainable energy technologies and stimulates the mobilisation of resources for this development. Expectations are also included, as occasionally expectations can converge on a specific topic and generate a momentum for change in a specific direction." (Negro et al., 2010)

PV example: The goal of the province of Utrecht to become climate neutral by 2040.

"Function 5: Market Formation

A new technology often has difficulties to compete with incumbent technologies, as is often the case for sustainable technologies. Therefore it is important to create protected spaces for new technologies. One possibility is the formation of temporary niche markets for specific applications of the technology (Schot, Hoogma et al. 1994). This can be done by governments but also by other agents in the innovation system. Another possibility is to create a temporary competitive advantage by favourable tax regimes or minimal consumption quotas, activities in the sphere of public policy." (Negro et al., 2010)

PV example: The municipality of Amersfoort helping civic PV initiatives by providing them with professional support.

"Function 6: Resource Mobilisation

Resources, both financial and human, are necessary as a basic input to all the activities within the innovation system. For example, for PV, the abundant availability of silicon might be an underlying factor determining the success or failure of a project (van Sark, Brandsen et al. 2007)." (Negro et al., 2010)

PV example: The DEK subsidy by the province of Utrecht which was granted mainly for PV systems on farms.

"Function 7: Creation of legitimacy / counteract resistance to change

In order to develop well, a new technology has to become part of an incumbent regime, or has to even overthrow it. Parties with vested interests will often oppose this force of 'creative destruction'. In that case, advocacy coalitions can function as a catalyst to create legitimacy for the new technology and to counteract resistance to change." (Negro et al., 2010)

PV example: Entrepreneurs lobbying at the province of Utrecht for PV supportive policies.

Interaction between functions and motors

The System Functions influence each other. A fulfilment in one System Function can lead to a fulfilment in one or multiple other functions (Hekkert et al., 2007). *Knowledge Development* (F2+) can for example lead to *Guidance of the Search* (F4+). It is also possible that there is no Resource Mobilisation (F6-) which results in a lack of *Knowledge Development* (F2-). Suurs (2009) generalised certain sets of interactions called motors of innovation. These motors were formulated using multiple case studies and comparing the sets of interactions in each case study. Where motors emerged, they reorganised the structural configuration of the TIS. He found that some motors of innovation are more powerful than other. The System Building Motor and especially the Market Motor (see paragraph Typology of motors) were able to change the incumbent energy system. Thereby linking up to it and reforming parts of it. Policy makers and entrepreneurs should therefore strive for these motors to emerge. However these more advanced motors arise only when less powerful motors have built up the structure needed for the more advanced motors.

Typology of motors of innovation

Four motors are found by Suurs (2009). Together they form the entire diffusion process, from immature technology to main stream product.

The Science and Technology Push Motor

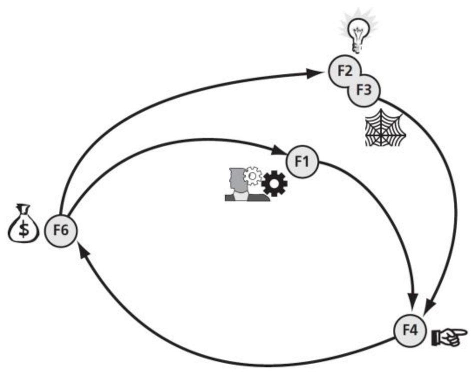

Figure B.2. The Science and Technology Push Motor (Suurs, 2009)

“The Science and Technology Push (STP) Motor is dominated by Knowledge Development [F2], Knowledge Diffusion [F3], Guidance of the Search [F4] and Resource Mobilisation [F6]. All the other system functions are either absent or relatively weak.

The dynamic of the STP Motor involves an event sequence consisting of positive expectations and/or research outcomes [F4] leading to the setting up of government-supported R&D programmes [F4] and, directly linked to it, the allocation of financial resources to the emerging technology [F6]. This results in a surge in science activities in the form of basic research and feasibility studies [F2], and also conferences, workshops and other meetings [F3]. In the next step, or in parallel, firms are approached by government actors and research institutes to participate, as technology developers and launching customers, in projects for the realisation of pilots and demonstrations [F1]. The willingness of these firms to participate in such risky projects depends particularly on the outcomes of the feasibility studies [F4]. With positive outcomes, firms may invest, thereby contributing to the expansion of the R&D programme.” (Suurs, 2009)

The Entrepreneurial Motor

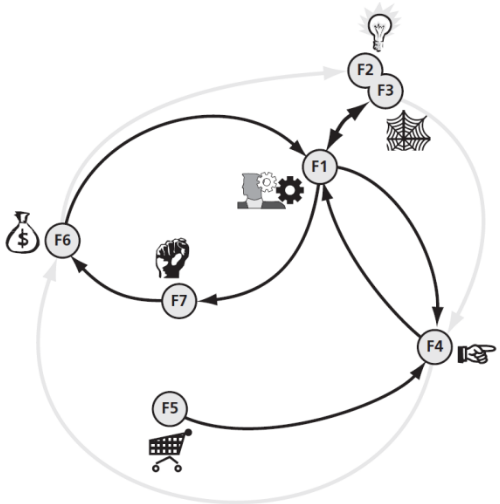

Figure B.3. The Entrepreneurial Motor (Suurs, 2009)

“The Entrepreneurial Motor is partly similar to the STP Motor. Its dynamics are also characterised by a strong fulfilment of Knowledge Development [F2], Knowledge Diffusion [F3], Guidance of the Search [F4] and Resource Mobilisation [F6]. What sets the Entrepreneurial Motor apart from the STP Motor is the particularly important role of Support from Advocacy Coalitions [F7] and Entrepreneurial Activities [F1].

The event sequence that characterises this motor commences with firms, utilities and/or local governments entering the TIS and initiating innovative projects [F1], usually adoption experiments or demonstrations, because they see opportunities for commercial or societal gain in the future [F4]. Given the pre-commercial status of the emerging technology, the actors lobby in order to obtain resources to cover part of their costs and to compensate the financial risks they take [F7]. If the lobby activities are successful, then the resources are granted in the form of project- specific subsidies [F6]. Depending on the funding, the projects are started [F1]. The outcome, positive or negative, feeds back into the dynamic as it provides the incentive for other actors to initiate projects, or refrain from doing so [F4]. The Entrepreneurial Motor may be strengthened through the presence of niche markets [F5]. ” (Suurs, 2009)

The System Building Motor

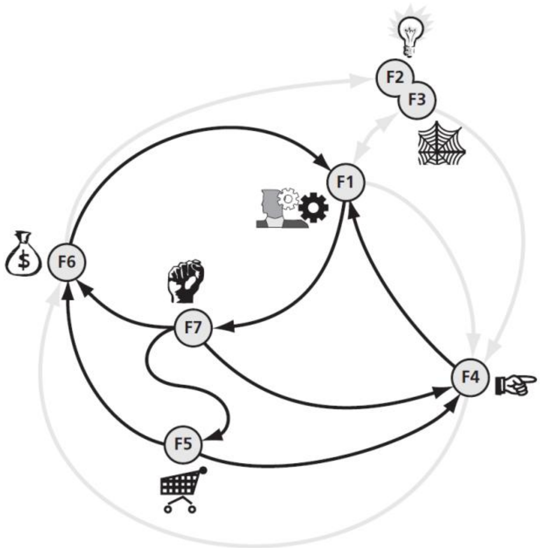

Figure B.4. The System Building Motor (Suurs, 2009)

"In the System Building Motor the set of dominant system functions is similar to those of the

Entrepreneurial Motor but it includes a more important role of Market Formation [F5]. The main difference lies in the connection between Support from Advocacy Coalitions [F7], on the one hand, and Market Formation [F5] and Guidance of the Search [F4] on the other.

These connections are established through entrepreneurs that organise themselves increasingly in networks and manage to draw in new actors [F1], including local governments, intermediaries and interest groups. From this powerful basis, they lobby the government [F7], not for project specific support, but for policies to mobilise resources or develop regulations beneficial to the emerging technological field as a whole [F4, F6]. Most importantly, their aim is to enforce the creation of a mass market [F5] for the emerging technology." (Suurs, 2009)

The Market Motor

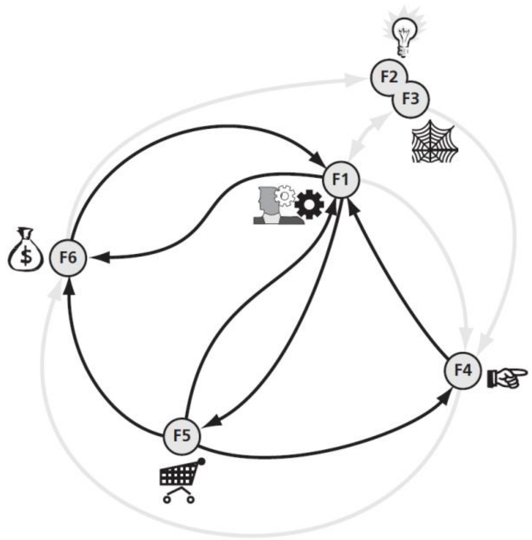

Figure B.5. The Market Motor (Suurs, 2009)

“The Market Motor is characterised by a strong contribution to Entrepreneurial Activities [F1], Knowledge Development [F2], Knowledge Diffusion [F3], Guidance of the Search [F4], Resource Mobilisation [F6] and Market Formation [F5]. All system functions are strongly fulfilled except for the Support from Advocacy Coalitions [F7]. The latter is not as important for the dynamics of this motor because Market Formation [F5] is no longer a political issue; a market environment has been created as the result of formal regulations. Instead, Market Formation [F5] is taken up as part of regular business activities, i.e., marketing activities connected to Entrepreneurial Activities [F1].

The event sequence which constitutes the Market Motor starts with the setting up of institutional structures that directly facilitate a commercial demand for an emerging technology [F5]. Once such structures are in place, this leads to high expectations [F4] and increasing availability of resources [F6]. This leads to the opening up of possibilities for new entrants to adopt the emerging technology [F1]. The newly entered firms are likely to make large investments, for example in infrastructure [F6], and they may develop marketing strategies [F5], thereby increasing demand for the emerging technology further.”

For a further elaboration on the motors and the succession of motors, see Motors of Sustainable Innovation (Suurs, 2009).

Succession Model

Besides the motors of innovation Suurs also developed the Succession Model for the evaluation of TISs in dynamics terms. He argues that the best way to support a formative TIS is to create the conditions for the motors to emerge. Once a motor is developing it should be supported by policy makers and practitioners. All of the four motors have particular drivers and barriers. If both the drivers are supported and the barriers overcome the motor might transform in a more advanced one.

“With this in mind, the Succession Model is used as a basis for formulating strategic lessons directed at policy makers and other practitioners that aspire to understand and influence the development of emerging energy technologies. These recommendations specify which interventions may be taken to support particular motors, and thereby to further the development of a TIS from one stage of development to another." (Suurs, 2009)

For an extensive list of strategic lessons, see Suurs (2009). In this thesis the relevant strategic lessons are mentioned in chapter C.4.3.

B.3 Method

The methodology that is used to put the TIS theory into practice is divided into three steps. A historical overview of the PV TIS in the province of Utrecht is made, using a method developed by Negro (2007 and 2010). In the second step the focus shift towards the current state of the TIS. For this step another method developed by the innovation science group at the Utrecht University (Hekkert et al., 2008) is applied. The combination of both the historical overview and the current state made it possible to identify the motors of innovations. In the last step these motors are identified and recommendations are formulated for stimulating the current TIS.

B.3.1 Historical analysis

This method is deducted from the method used by Negro (2007 and 2010). In the first study Negro analysed the TIS development of biomass in the Netherlands and Germany. The second study looked at the PV TIS within the Netherlands. This research will focus on the regional PV TIS of the province of Utrecht in which more attention is paid to (small scale) regional events[27]. The following steps will be followed to get a clear insight in the development of the regional PV TIS.

Identification of events

As a foundation the events of the national PV TIS database of Negro et al. (2010) will be used. Since the focus of this research is on the regional level some events that were relevant at the national level might not be relevant and will be excluded. Regional events will be added by analysing (local) newspapers, (governmental) reports, journals, websites and interviews with actors that were active in the regional PV TIS.

Database classification

The database is structured with the date of the event, reference to its source, description, category (see table B.1) and TIS track (new housing estate or existing buildings).

Allocation to function

The categories are allocated to a System Function (see table B.1). These categories and allocation were developed by Negro (2007) and might be changed if the analysis of the regional development shows that other categories or linkages to the System Functions are found necessary. Some events may have positive influence on a System Function and other negative. This is indicated with a +1 or -1. The balance yields insight in speeding up or slowing down the diffusion of PV.

[27] An event is taken into account when it had an influence on the performance of the regional PV TIS.

Graphical representation

Per System Function the positive and negative events are plotted in a graph. This gives a rough inside in the overall fulfilments of System Functions.

Historical storyline

The events linked to the System Functions and it scores are transformed into a narrative on how the TIS developed over time.

Table B.1 – Classification Scheme for measuring System Functions (Negro, 2007)

System Function	Event categories	Sign
Function 1: Entrepreneurial Activities	Project started	+1
	Project stopped	-1
Function 2: Knowledge Development (learning)	Desktop/Assessment/Feasibility study on the technology	+1
Function 3: Knowledge Diffusion through Networks	Workshop, Conferences	+1
Function 4: Guidance of the Search	Positive expectations of the technology; Government regulations	+1
	Negative expectations of the technology; Government regulations	-1
Function 5: Market Formation	Specific favourable tax regimes and environmental standards	+1
	Expressed lack of favourable tax regimes and environmental standards	-1
Function 6: Resource Mobilisation	Subsidies, investments for the technology	+1
	Expressed lack of subsidies, investments	-1
Function 7: Creation of legitimacy / counteract resistance to change	Lobby activities for the technology; Support of technology by government, industry	+1
	Lobby activities against the technology; Expressed lack of support by government, industry	-1

B.3.2 Current state

The innovation science group of the Utrecht University developed a tool (Hekkert et al. 2008) to evaluate the current state of the technological transitions defined by the Energy Transition platform of the Dutch ministry of economic affairs, agriculture and innovation (EL&I). To know how to accelerate certain transitions, insights was needed in the current drivers and barriers of the innovation system. One of the transitions that were analysed was PV technology at the beginning of 2008. For this thesis the same tool is used but focussed on the regional, provincial level instead of national.

The basis of the tool is the structured interview with experts. In this case an experts is someone that is active in the PV sector within the province. Four such interviews were held. One with a market and municipal expert (Peter van Vliet of Zonvogel), two with experts on the provincial government (Hans Rijnten and Jaklien Vlasblom, both officials at the province of Utrecht) and one with an expert on knowledge development (Wilfried van Sark, professor at the University of Utrecht). Extra information was acquired from literature review and unstructured interviews.

The structured interview consists of the following three stages in which multiple questions (see appendix II, in Dutch) are asked to cover the basic information and could be completed with extra information from the expert.

Stage of development

In the first step of the interview the general position of the transition is determined on the diffusion curve, see figure B.6 below. The first phase is the exploratory or pre-development phase. This extends to the presence of a prototype. In the take off phase the demand for the technology starts and there is a limited amount of commercial available products. The acceleration phase is characterised by the maturing of the market and a wider demand. In the last phase of stabilization of the technology becomes part of the established structure. By comparing the position given by the experts to the transition within the province it can be compared to the worldwide position and the national position researched in 2008 by the innovation study group.

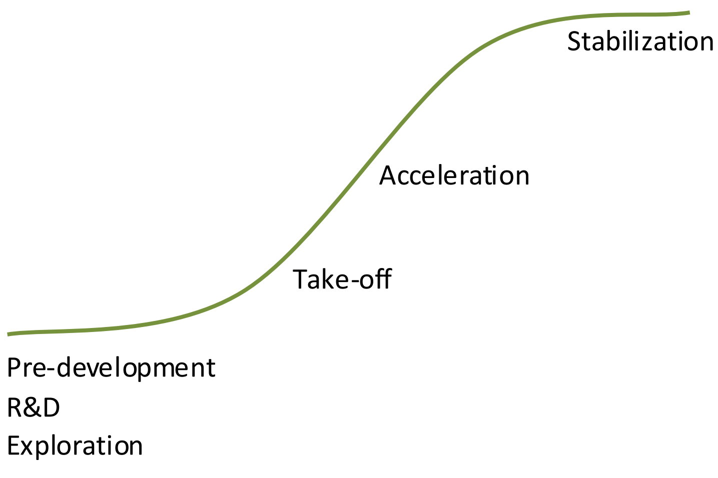

Figure B.6 The diffusion curve of innovation

Structure of innovation system

Deficiencies in the transition can often be seen in the structure of the innovation system (figure B.7). By asking the experts how well certain system parts and their corresponding actors perform, an insight is gained: what parts perform well and which parts need improvement. The performance can be graded on a 5 point scale from very weak to very strong.

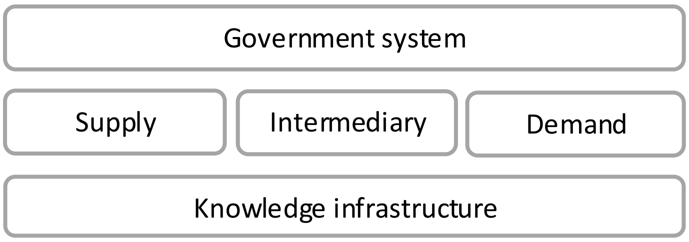

Figure B.7 The structure of the Innovation System

Function fulfilment

All the function of the innovation system (See B.2.3 - System Functions) are graded by the experts after a short explanation of what the systems functions are and what the specific function includes. The grading is done by asking a number of questions and finally rating the function from very weak to very strong. The experts also addressed the question whether or not the function is obstructive or not.

Functioning of innovation system

In this section the expert data are analysed and the function fulfilment compared in a spider diagram (figure B.8). This diagram shows the relative fulfilment and which might need extra attention.

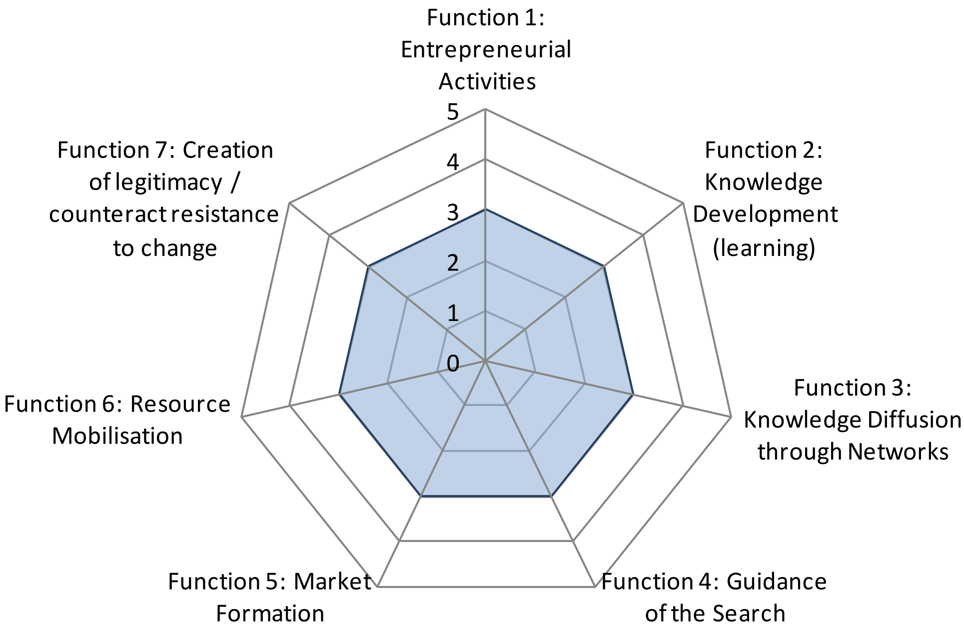

Figure B.8 Functioning of the innovation system functions

B.3.3 Motors of innovation

Identification of motors

The periods described in B.4 will be linked to the motors of innovation described in the theory. By comparing the function activity within a certain period with the characteristic function fulfilments found in the motors a linkage can be made to that motor. For the last period both the description of B.4.4 and the expert interviews of B.5 will show which motor is currently active.

Recommendations for practitioners

By combining the analysis of the current active motor and the theory of the Succession Model recommendation will be formulated in moving the motor forward preferable to a more powerful one. The recommendations will be linked with active parties that can influence the development of the PV TIS. These parties will be grouped in two kind of actors (Suurs, 2009):

- Enactors are dependent on the success of the technology and closely involved with its development.
- Selectors are engaged at a distance, for example because they have the possibility to choose between multiple options.

B.4 Historical overview

The development of the innovation system is divided into four periods. The boundaries of each period are characterized by a profound change in the TIS. Every period starts with an overview of the national developments followed by the regional events. The symbols F1-F7 refer to the System Functions described in paragraph B.2.3. Statistical data on the function activity can be found in Appendix III.

B.4.1 Period 1 - 1975 till 1995 - Research and Development

National developments (Negro et al., 2010)

The key event that triggered the start of the PV innovation system is the oil crisis in the seventies. National policy makers became aware that the Dutch economy is too dependent on fossil fuels and that a diversification strategy was necessary. This signal was picked up by the research community who started doing research on PV. Subsidy for this research was granted by the national government who over time became more interested in PV.

The Dutch solar trade association Holland Solar was founded in 1983 becoming main sparring partner for the national government.

While the research continued with funding from the national government a new policy instrument (SES) to stimulate market formation was set into place in 1988 which was renewed in 1991. It compensated 40% of the purchase costs of a PV system.

In 1990 the national government published the White Paper on Energy Savings which formulated the first goal of replacing 2PJ of fossil fuel with PV by 2010. A year later the first Environmental Action Plan (MAP1) stated multiple measures to achieve a CO2 reduction of 10% by the year 2000.

The Energy research Centre of the Netherlands (ECN) started cooperating with a large number of national and international parties both from the research world and the industrial sector. In 1994 the ECN and the company R&S produced an industrial PV module with an efficiency of 16%. By this time the Dutch PV research community had acquired an important position in the global PV research.

At the beginning of this period research groups were formed at universities and institutions in the Netherlands (F2, DE, 87/2). The Utrecht University sets up a group that focuses Si PV technology (F2, Negro, 2010). In 1980 their focus was on amorphous Si thin film and they see potential for the application of PV in the Netherlands (F2, F4+, Negro, 2010). Turkenburg, a professor at the university tries to mobilize the national government to support PV (F7+, Negro, 2010).

In 1983 the branch organization Holland Solar was founded in Utrecht (F7+, DE,87/1). Working groups were formed to overcome barriers for the application of solar technology.

In 1984 the Utrecht based company Ecofys was founded by Kornelis Blok and Ad van Wijk who were at that time both working at the Utrecht University (F1+, NRC Handelsblad, 2009). This research and consultancy company focussed on sustainable energy (including PV) and energy saving.

Research at the Utrecht University continued and in 1986 a study argued that grid connected PV-systems can be economically viable after the year 2000 (F3, Negro, 2010). The research on amorphous-Si thin film continued at the UU in cooperation with the TU Delft and NAPS (a French company) (F2, DE, 89/5). Another positive view came from Holland solar who expected an increased demand stand-alone applications (F4+, DE 86/5).

In 1990 the Province of Utrecht installed PV powered street lighting (F1+, DE 90/6). Two years later the Utrecht University started researching organic solar cells together with the universities of Wageningen and Delft (F2+, DE 95/1). ODE worked together with Ecofys, ECN and others to install and monitor grid-connected PV systems on 10 to 12 private owned houses (F1+, DE 92/5).

Research at Ecofys was done on environmental effects of PV-applications (F2+, DE 92,1). Sinke and van der Sark of the Utrecht University mapped the current development in roof integrations, storage of electricity and inverters (F2+, DE 93,2). Holland Solar reported on the size of the market which in 1993 existed of 14 PV suppliers, producers and dealers in a rapidly growing market (F4+, DE 93,2).

In 1995 the Utrecht University, ODE and the Consumentenbod started testing PV-products (F2+, DE 95,5), partly financed by VROM (F6+, DE 95,5).

B.4.2 Period 2 - 1996 till 2003 - Build op of innovation system

National developments (Negro et al., 2010)

While the SES subsidy is terminated in 1995 research programs supported by the national government through SenterNovem continue and are more market oriented.

Shell Solar Energy is founded in 1997 and opens a new production line for PV panels with a starting capacity of 2,5 MWp/year. In 2002 Shell Solar Energy closes this plant and opens a new plant in Germany using all the knowledge generated in the Netherlands.

In the second half of the nineties PV forms the largest expenditure post in the field of development of renewable energy in the Nehterlands. The main subsidy that supports PV is the EPR which was introduced in 1998 and where house owners can obtain 1,59 Euro/Wp installed. This subsidy triggers entrepreneurs to become more active.

Energy distribution companies and NGO's become active in the introduction of PV and large scale PV projects are being realized.

At the beginning of the 21st century a large political shift takes place in the parliament. The coalition agreement states that 500 million Euros need to be saved every year on energy and environmental subsidies. This results in the announcement of stopping the EPR subsidy in 2003 resulting in a 'gold rush' to obtain the subsidy before it terminates.

The green energy market is liberalized in 2001. From that moment PV has to compete with cheaper renewable energy options. While it was expected that this would limit the diffusion of PV its installed capacity still grew (See Figure II.9).

In 1996 the national government introduced a tax on energy called the regulating energy tax (Regulerende Energiebelasting, REB) to reduce the energy use of companies and households. Green energy stayed untaxed. As a result several small PV systems were installed between 1996 and 1998 by REMU including a bungalow park (F1+, DE 96,5) and a district in Veenendaal (F1+ DE 97,2).

The building of the residential area Nieuwland in Amersfoort was started in 1998 where a capacity of 1,3MW of solar energy was installed, divided over 12.000 m2 of solar panels (See infobox Niewland below). In 1999 a consortium of Stork, Ecofys, Rabobank and De Lage Landen launched a lease construction for profiting from the fiscal advantages of solar energy (F5+, DE 99,4).

In 2001 Holland Solar published a newsletter named Zonneklaar (F7+, DE, 01/1) and Econcern opened a website devoted to PV (F7+, DE 01/1).

In 2002 a new company Beldezon located in Utrecht announced a new PV product: The total installation and administration of PV-modules for municipalities (F1+, DE 03/4). At the end of 2002 the energy company REMU was sold to energy company Eneco (Goudsche Courant, 2002). From 2004 onwards it became completely integrated into Eneco.

At the end of 2003 the national government announced that both the EPR and REB programs will be terminated (See Appendix VI). To benefit from these two programs a lot of PV systems were installed before 2004. In Veenendaal the housing cooperation Patrimonium installed 1,1 MWp on flats together with Eneco (F1+ DE 03/6).

Infobox Nieuwland 1MW PV Project (Bouwmeester & Ijken, 1999)

World largest pilot project for high integration of PV in a neighborhood.

Capacity:	1,3 MWp
Focus on:	Heating, hot water and electricity
Initiator:	REMU (since 2004 integrated in Eneco) and Novem (currently Agentschap NL)
Commissioned by:	Ministry of Economic Affairs
Number of residences:	500 + some utility buildings
Surface covered:	12.000 m2

B.4.3 Period 3 - 2004 till 2007 - Collapse of market

National developments (Negro et al., 2010)

With the sudden stop of the EPR subsidy in 2003 the newly installed capacity in the next 3 years would be very low (Figure II.9). This collapse of market resulted in the loss of many jobs and knowledge in the PV industry.

In 2004 the MEP subsidy is introduced but its focus is on renewable energy in general and the subsidy is too low to make PV financially viable. As a reaction an advocacy coalition is formed by Holland Solar to lobby for programs that contribute to the future of PV technology and the level of expertise in the Netherlands. In response the national government develops a new set of energy research and technology programs with PV as one of the priority areas.

At research institutions and universities research is continued by financial support of mainly the EU.

Two new PV panel producing companies are founded, Sollar Solar and Scheuten Solar. Both are dependent on export due to the low demand for panels in the Netherlands.

In 2006 the national government again suddenly stops the current subsidy, MEP.

In replacement of the REB and the EPR the Milieukwaliteit Elektriciteitsproductie (MEP) caused the national (see figure II.9) and regional PV market to collapse since PV was not economically feasible yet without a strong subsidy program.

At the beginning of 2004 the energy market was liberalized and with the integration of REMU into Eneco the focus shifted from Utrecht to the national level.

In 2004 the Utrecht University calculated that PV can supply 23 times the current electricity demand in the Netherlands and the economical potential for renewable energy in 2050 is larger than the current demand for electricity (F2+, DE 2004).

In 2005 an office building in Vleuten with a PV system of 67MWh/year was graded the most economically building in regards of its energy use (F1+, Stromen, 2005).

Multiple companies, institutions and universities including ECN and the Utrecht University set up a pilot-construction for thin film PV called the Helianthos process with financial support of the national government (F1+, F2+, F4+, DE 2005).

The municipality of IJsselstein launched a subsidy for PV in 2006 (Seem infobox below, F6+, Municipality of IJsselstein, 2010). In Utrecht a solar energy square was opened for educational purpose (F5+, Technisch Weekblad, 2006).

The national government ends the MEP subsidy because, according to the minister, the goals for 2010 will be reached with the given subsidies.

B.4.4 Period 4 - 2008 till 2010 - Renewed attention

National developments (Negro et al., 2010)

In 2007 the new cabinet forms an agreement to transform energy supply to a more sustainable and efficient one. This results in the set up of a platform on sustainable energy that focuses on formulating recommendations for new policy on sustainable energy including PV.

This initiative gives a new impulse to the PV innovation system. A research institute (FESTpv) and a new company (APA) are founded. Both focus on developing cheaper solar cells.

In 2008, 2009 and 2010 a new subsidy (SDE) is granted that stimulates the market formation. For every kWh that is produced by renewable energy sources including PV a premium is given. The overall budget was limited and for PV the subsidies were oversubscribed within a week in all three years. Only a limited amount of systems with subsidy are installed due to a lack of capable installers and no obligation to install the system within a certain amount of time when subsidy is granted.

At the beginning of this period a group of research centres including the Utrecht University and solar related companies lobbied for financial impulse at national government (F7+, Trouw, 2007). As a result the national government started a new subsidy program called SDE in 2008. The province of Utrecht launched its DEK subsidy program (F6+, See Appendix VI) which was assigned mainly to farmers for PV projects. The province also tried to enhance the sustainability awareness by providing schools with PV modules and small wind turbines (F7+, AD/Amersfoortse Courant, 2008).

In 2008 the municipality building of Culemborg received the energy label A thanks to its high energy efficiency and the PV modules installed on the roof (F1+, AD/Utrechts Nieuwsblad, 2008). In 2009 the municipality of Amersfoort planned to have 800 m2 of PV installed on their building (F1+ AD/ Amersfoortse Courant, 2009).

In 2009 the municipality of Utrecht announced its program Utrecht creates new energy (Utrecht maakt nieuwe energie). Part of the program was to make Utrecht West energy neutral where solar energy was one of the measures to be taken (F4+, AD/Utrechts Nieuwsblad, 2009). The municipality of Veenendaal started a subsidy program for PV (See infobox below) that was fully booked within half a year.

The Utrecht based company Econcern, which was the largest company focussed on sustainability in the Netherlands was declared bankrupt (F1-, NRC Handelsblad, 2009). It was split up and sold to companies worldwide including the Dutch based energy company Eneco.

In 2010 both the municipality of Amersfoort and Leusden cooperated with the Incentive Fund Housing Dutch Municipalities (Stimuleringsfonds Volkshuisvesting Nederlandse gemeenten, SVn) to offer low interest loans (See infobox X.X) (F6+). The political party de Groenen in the municipality of Utrecht was also positive towards PV (F7+, Utrechts Nieuwsblad, 2010).

The representative of the province of Utrecht opened the first of five pilot roofs for the Sustainable roof program of the province. It was meant to extend the knowledge on sustainable technologies (including PV) that can be applied on roofs (F7+, Province Utrecht, 2010).

In the municipality of Amersfoort a PV specialist was hired to assist multiple citizen initiatives in realising PV projects in their neighbourhoods (F7+, Municipality of Amersfoort ,2010). In the city of Utrecht an electrical solar powered transport vehicle delivered its 10.000 shipment (F1+, AD/Utrechts Nieuwsblad, 2010). It received subsidy for its PV system.

The Groenlinks party of the province of Utrecht published a report public that showed the potential for solar systems (PV and boilers). In 2020 7,3% of the CO_2 emission could be reduced by applying these systems (F7+, AD/Utrechts Nieuwsblad, 2010).

B.5 Current State

B.5.1 Stage of development

In the province of Utrecht the PV innovation system is almost in the take-off phase. The PV products are well developed for specific market segments. For individual consumers small systems can be bought that can be installed without the help of an electrician. Companies with large flat roofs can install PV that can be rolled out over the roof. While these products are readily available the high initial investment is still a large barrier. New financing structures are finding its way to the PV market but in an early development phase. According to Negro et al. (2008) the Netherlands were in the exploration phase in 2008. Three years have passed with a growth in new installed capacity (See figure B.10 in chapter Background Installed capacity) so one can assume the current national position will have also shifted towards take-off. The worldwide position will probably shifted further along the curve towards acceleration in comparison with the position in 2008 (Negro et al. 2008).

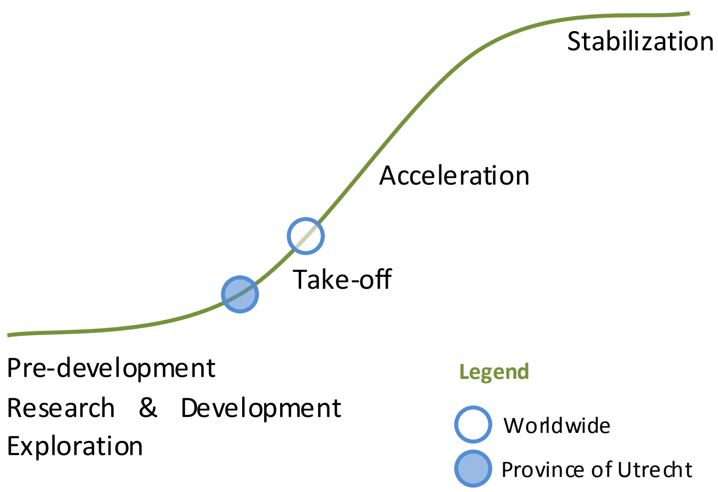

Figure B.10 The position of the province of Utrecht and the world on the innovation curve

B.5.2 Structure of innovation system

The structure of the innovation system shows the strength of the different parts involved (figure B.11). In the paragraphs below a description is given for every party.

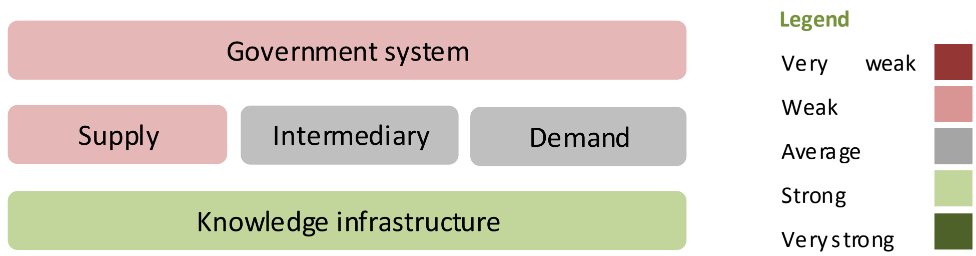

Figure B.11 the strength of the Innovation System

Government system – Weak / Average

Province of Utrecht and municipalities.

The PV market is still weak and dependant on support by the government system. In Germany the national government had put in to place a strong support mechanism with its feed-inn tariff hence its high share of renewable energy and PV (figure II.11 and II.12 in chapter II Background). In the Netherlands the national government has a much smaller support mechanism (currently the SDE), therefore a more central role can and should be taken by regional governments. Both the province of Utrecht and many of its municipalities are ambitious and want to become climate neutral by 2030 or 2040. This ambition is recently formulated and programs like the Sustainable Roof Program (Duurzame Dakenplan) which focuses on sharing information and demonstrating sustainable roof technologies (including PV) have just started and the results are still unknown.

Supply – Weak / Average

Manufacturers and suppliers of PV systems and components, installers, architects, developers and construction companies.

In the province of Utrecht there is a limited amount of companies, that mainly consists of electricians who install PV systems. The remaining part of the supply chain is not active in the province of Utrecht. The PV companies in Utrecht and the Netherlands are focused on neighbouring countries which have bigger, less fluctuating markets. Because of this there is a low rate of innovation focused on the national and provincial demand for PV. While the products are well developed, financial constructions to lower the barrier of investment are not developed or in the development phase.

Intermediary – Average

Consultancies, industry associations, customer associations, financial institutions, education and training centres.

The province of Utrecht has a few strong intermediary parties with a focus on PV such as Triodos (bank), Ecofys (consultancy), DHV (consultancy), Holland Solar (industry association for PV and solar thermal) and many small consultancy firms. While the market is still small, the consultancies have build up their knowledge in other countries and the few projects in the Netherlands. Holland Solar is becoming more active, and more companies join their association.

Demand – Average

Building owners (individuals, housing associations, businesses, industry, real estate companies, municipalities).

While the actual level of purchases of PV products is low, building owners are very interested in PV. Civil initiatives in the municipality of Amersfoort are trying to bundle their power to get a sound business plan. Housing associations are in dialogue with its tenants and municipalities to find out what possibilities there are in retrofitting or installing PV on new housing projects. The demand for the national SDE subsidy also showed that a lot of consumers and businesses are interested when an acceptable return on investment is possible.

Knowledge infrastructure – Strong

Universities and knowledge institutions.

The Utrecht University has a long history of PV related research dating back to the 80's. Recently the Hogeschool Utrecht joined in with a demonstration project (linked to the provincial Sustainable Roofs Program) and making PV technology part of its education program. The Utrecht University is cooperating, nationally and internationally, with many universities and research institutions but their focus is mainly on product improvement and less on practical implementation issues.

B.5.3 Function fulfilment

In this paragraph the seven functions of the innovation system are rated to get an overall picture of the current development within the province of Utrecht.

Function 1: Entrepreneurial Activities – Average

Considering the small size of the market a lot of entrepreneurs are active within the province. Most of them, electricians and consultancies, offer PV products as a part of their portfolio, though their main income comes from other activities. These companies are flexible and can profit from the market demand when it is there (mainly linked to national subsidies). The downside of these spread-out activities is the limited incentive to build up knowhow and innovation in the field of PV within these companies. Entrepreneurs active as producers, architects and contractors with a strong PV portfolio could strengthen the PV supply with more innovative solutions.

Function 2: Knowledge Development (learning) – Average / Strong

The knowledge quantity and quality is high compared to the national and international level. The Utrecht University has a strong position and is funded by AgentschapNL, EU, The Netherlands Organisation for Scientific Research (NWO), The Foundation for Fundamental Research on Matter (FOM) and Foundation for Technology (STW). The Hogeschool Utrecht is improving its position by adding sustainability and sustainable energy resources like PV to the curriculum of many of its education programs. The focus of most of the research is on less costly and efficient solar cells and smart grid integration and less on user knowledge.

Function 3: Knowledge Diffusion through Networks – Weak / Average

The knowledge generated by the universities and other parties is shared with other knowledge institutes worldwide. A low amount of patents is claimed and there is no clear vision to get the knowledge into the market. To cover this gap the Utrecht Centre for Earth and Environment (UCAD) of the Utrecht University was recently founded to enhance the communication on sustainable topics between the university and the government, the market and consumers.

Cooperation between market parties is weak within the province. The many small companies are mostly working on their own and share little information with each other.

The province and its municipalities are working together on sustainable issues and have regular meetings to share knowledge. The province also plans to put into place a knowledge platform where everyone can share their knowledge on sustainable (PV) issues to enhance the speed of implementations.

Function 4: Guidance of the Search – Strong

The province of Utrecht recently set its goal to be climate neutral in 2040 (province of Utrecht, 2009). Many municipalities have taken the same goal or even put their target on 2030. To reach this goal it is agreed that, together with a higher energy efficiency, PV should be part of the renewable energy resources that are needed to reach this goal. This is a strong incentive for other parties to join in.

On the national level the vision is fluctuating. This is visible in the starting and suddenly ending subsidy programs. The laws and regulations also hinder the further implementation of PV by not allowing tax free electricity from privately owned PV systems on external roofs.

The consumer is enthusiastic about the self supplying possibilities of PV but finds the systems too expensive and aesthetically not appealing.

Function 5: Market Formation – Weak and obstructive

The PV market in the Netherlands is seen as a small niche market and within the province the same applies. It is fragmented and mainly attracts small players with a low level of experience. Most of the PV systems are installed on private houses and a few companies who received SDE or another subsidy install them on their roofs.

Function 6: Resource Mobilisation – Weak / Average and obstructive

The funds from the national subsidy program SDE are insufficient to build a PV market. The province and its municipalities are not able to subsidise extended amounts of PV systems. The few projects that they support are used for demonstration projects. The financial market does not offer loans fit for small PV systems.

The provincial guarantee fund might be used to stimulate companies to install PV systems. The guarantee is given on the loan so the bank is able to charge a lower interest rate. With a low interest rate the project might be feasible due to its long payback time.

Besides financial resources, human resources are also limited. Due to the small market the little knowhow that is built up during PV projects is lost. Companies move when elsewhere market opportunities for PV are better or they change to other sectors. When the PV market will expand this lack of knowhow will probably be limiting.

Function 7: Creation of legitimacy / counteract resistance to change – Weak / Average

Investing in PV is not seen as a legitimate investment. The green image and the self supplying model are seen as positive but the payback period is considered too long. The uncertainty in electricity prices and governmental regulations makes it hard to make a business model with calculations for multiple years.

The lobbying power of the PV sector is limited. Mainly small parties are lobbying separately, not joining up to formulate a combined clear statement.

Resistance is coming from the existing energy system including the energy firms. The national government is also not willing to change the regulations on self supplying to improve the position of PV in the energy system.

B.5.4 Functioning of the innovation system

The innovation system of PV in the province of Utrecht is in an early take-off phase according to the experts interviewed. For the innovation system to move onwards on the diffusion curve the most urgent improvements need to be made on the supply side and the governmental system. The knowledge infrastructure is good and the intermediary and demand parties perform average.

From a function point of view the experts graded three functions below average: function 5 market formation, function 6 resource mobilization and function 7 creation of legitimacy / counteract resistance to change are low (see figure B.12. below). Functions 5 and 6 are also regarded to be obstructive for the further development of the innovation system. In part C of this thesis these underperforming functions will be further analysed and possible solutions proposed.

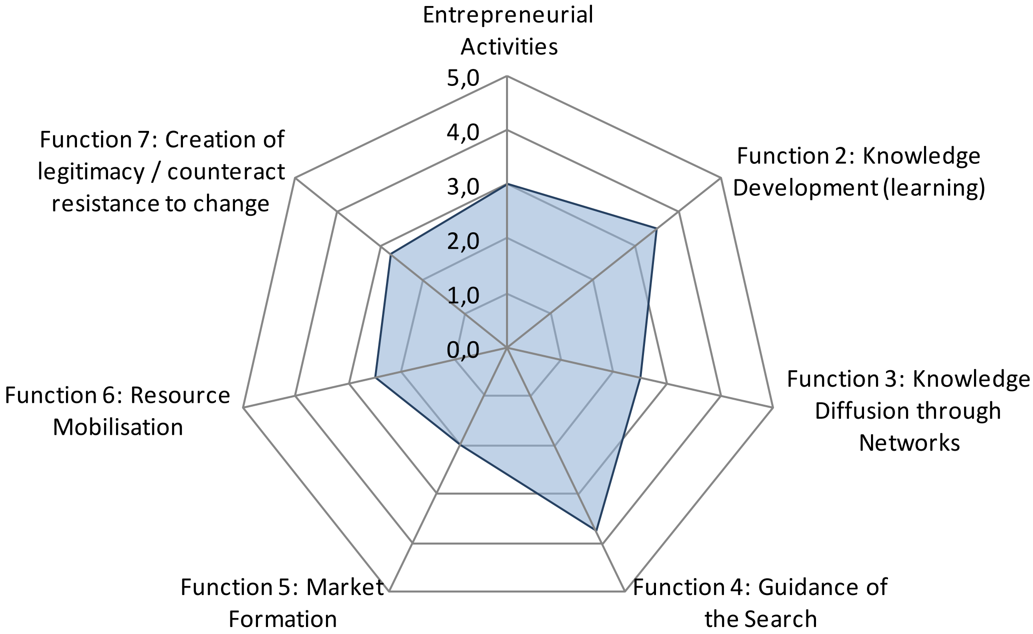

Figure B.12 Functioning of the innovation system functions

B.6 Motor of innovation

B.6.1 Identification of motors

The first period defined in B.4.1 stretched from 1975 till 1995 and was characterised by research and development. Within the province of Utrecht the Utrecht University was active by developing knowledge (F2) and expressed positive expectations on the PV technology (F4). This fulfilment of the guidance of search was also performed by the national governance. This start-up of the TIS within the province of Utrecht can be linked to the Science and Technology Push motor where knowledge development (F2) and guidance of search (F4) lead to national governmental funded (F6) research programs. Entrepreneurial activity in this period was limited which also corresponds to the characteristics of the Science and Technology Push motor.

From 1996 till 2003 the second period (B.4.2) showed a further build up of the innovation system. The difference with the first period is the high entrepreneurial activity (F1). Several systems were installed and REMU realised the 1MW Nieuwland project. The most fitting motor therefore is the Entrepreneurial motor. The niche market formed in this period could mainly exists due to the national governmental EPR and REB stimulating programs.

The third period dating from 2004 till 2007 (B.4.3) showed a decline due to the sudden ending of the national stimulating programs. Within the province no large PV systems were installed in this period. These periods of decline were also found by Suurs (2009) when stimulating policies were cancelled or a technology switch was made.

In the current period from 2008 onwards central (SDE) and provincial (DEK) governmental stimulating programs are opened (F4) after lobby (F7) by research centres and solar related companies. The market that had slowed down shows new progress (figure II.9). The municipalities are becoming more active and follow the province in its goal to become climate neutral in 2040 or even set their goal to 2030 (F4).The most fitting motor for this period seems to be the entrepreneurial one. The period of decline was too short to put the development back to the Science and Technology Push motor. The continued development of the PV TIS in the rest of the world probably also helped in continuing the motor that was active in the period before the decline.

In table B.2 below an overview is given on the motors that were active within the province in the different periods.

Table B.2 Motors of innovation active within the province of Utrecht

1975-1995	1996-2003	2004-2007	2008 onwards
Sc. Tech. Push	Entrepreneurial	Decline	Entrepreneurial

B.6.2 Recommendations for practitioners

Currently a lot of actors are involved in the TIS PV development within the province of Utrecht. The most important enactors are:

- PV technology suppliers
- PV system installers
- PV industry association
- Universities and research institutes

The most important selectors:

- Government at national, provincial and municipal level
- Banks
- Energy producers / companies
- NGOs
- Contractors
- Potential customers (business and private)
- University and research institutes

To empower the TIS in its current entrepreneurial phase and to make it possible to move forward to the more powerful System Building Motor and Market motor, each of these two groups of actors should emphasise the following tasks:

Societal needs

To sustain the motor the group of enactors active within the province of Utrecht should expand. This can be done by increasing the number of practical and commercially oriented projects. The demonstration projects within the sustainable roof program by the province of Utrecht are a good example to stimulate these developments.

An important task for enactors is to identify the societal needs for the application of PV. For example covering the gap between the current monthly electricity costs and the initial investments cost of PV by offering smart lease or loan constructions. The enactors should also lobby for support by the government. If the national government gives no support or resistant even, the enactors may find it more effective to draw support from local governments and energy companies.

Selectors and especially the governments should shape policy environments which provide continuous and reliable support for enactors. The national subsidy programs that were held in place were given for short periods and stopped within short notice. This unreliable support limits the possibilities for enactors to invest because of the high uncertainty in cash flows. The current government is reshaping the current subsidy (SDE) again so enactors again have to wait what will happen. On a provincial and municipal level the governments should formulate clear support mechanisms for a long time period. The current guarantee fund of the province and the municipal loans can fill the gap of the national government.

Coordination and building advocacy coalition

The current state analysis showed a weak knowledge diffusion (F3) and creation of legitimacy (F7). The TIS is still weak and suffers from a lack of coordination and direction. In an early phase this is not a problem but as the field expands it becomes critical to form coalitions and establish networks. Especially enactors should link up with each other and form knowledge platforms, policy networks. In cooperation with governments or NGOs public-private partnerships can also be formed. These networks should give direction of the market and technological development. The sustainable roof program of the province of Utrecht is an example of such a cooperation. This public-private partnership can influence other enactors and selectors to join in to get a stronger knowledge diffusion.

Market formation

The limiting market size hampers the development of the Entrepreneurial Motor. It is up to both the enactors and selectors to find niche markets where the current technology can be applied. The municipality in Amersfoort has hired an expert to try and link the PV suppliers to civil initiatives that want to install PV systems on their own or an external roof. These civil initiatives usually consist of people that are willing to pay a premium for their PV system compared to the electricity from the grid. It might even be that by the economies of scale and a smart leasing/loaning construction they won't have to pay a premium. These niches should be targeted for the market to expand.

By following these guidelines the Entrepreneurial motor is empowered and might over time develop into a stronger System Building Motor.

B.7 Conclusion

The historical overview showed that the development of the PV TIS dates back to the seventies of last century and followed four characteristic periods.

In this first period from 1975 till 1995 the prime focus was research. This research was carried out with subsidy from the central government. Within the province the Utrecht University researched technology improvements and the future market potentials for PV technology. The Utrecht based company Ecofys and industry association Holland Solar were founded in this period. The first entrepreneurial activities are also undertaken by installing street lights and small installations on private houses. The active motor of innovation in this period is the Science and Technology Push motor with a lot of research and only limited entrepreneurial activity.

From 1996 till 2003 the national subsidies for PV installations trigger more entrepreneurial activity. The research programmes set out by the national government also become more market oriented. On the regional level the energy distribution company REMU starts installing PV installations. Beside the smaller installations on private houses and a bungalow park, 1,3MW of PV capacity is installed in the new residential area Nieuwland in Amersfoort. In this second period the Entrepreneurial motor is active where the entrepreneurial activity is central and a market starts to form.

In the third period from 2004 till 2007 the national government stops the PV subsidy abruptly and replaces it with a general sustainable energy subsidy (which is also terminated abruptly in 2006) that makes PV a financially unattractive option resulting in a market collapse. On the provincial level of Utrecht research at the university continues but there is little entrepreneurial activity due to the lack of fit national subsidy. This period can be seen as a period of decline in which a sudden lack in market supportive measures is found.

In the last period from 2008 till 2010 the national government reintroduces a subsidy that has PV as one of its targets. In the three following years the subsidy is oversubscribed within a week. This triggers the revival of the PV market. Within the province municipalities and the provincial government set high goals in becoming climate neutral by 2030 or 2040 and regard PV as a renewable energy resource that is needed to reach these goals. Demonstration projects are set up by the province of Utrecht and many municipalities undertake projects to stimulate the application of PV. This is picked up by entrepreneurs resulting in the continuing of the entrepreneurial motor of the third period.

The interviews with experts showed that the PV TIS within the province of Utrecht is in an early take-off phase. According to these experts the weakest part of the TIS are the supply side and the governmental system while the knowledge infrastructure was graded good.

The last part of the interview with experts analysis showed that weak functions were market formation, resource mobilization and creation of legitimacy / counteract resistance to change are low. The first two are also regarded to be obstructive for the further development of the TIS.

When focussing on the currently active Entrepreneurial motor three main objectives can be formulated which correspond to the weak function fulfilment showed by the interviews with experts.

The first objective should be to expand the group of enactors active within the province. This group has to identify the specific societal needs and offer targeted PV products and services. These groups should be supported by selectors such as the government with continued and reliable support.

As a second objective the enactors should cooperate more to enhance the creation of legitimacy and knowledge diffusion. The lack of coordination and direction should be overcome by forming knowledge platforms and policy networks both within the private sector as public-private partnerships. The sustainable roof program by the province of Utrecht in which demonstration projects for sustainable roof technologies are held is a good example of a public-private partnership that enhances the cooperation and coordination.

The third objective is the market formation. The currently limited market size hampers the development of the PV TIS. Both enactors and selectors should focus on finding niche markets where the currently available PV technology can be applied. Two good example are the ZonVast project of Greenchoice and the municipality of Amersfoort working together with civil initiatives to install PV systems.

In general both enactors and selectors should focus on activities and functions that will lead to more and other System Functions. This way the entrepreneurial motor is empowered and might over time develop into a stronger System Building motor.

B.8 Discussion

The historical event analysis that is used for analysing a TIS is normally applied on a national level. Since this thesis focuses on the regional level of the province of Utrecht both the historical analysis and the analysis of the current state are made on the regional instead of the national level. In the historical overview there were only a limited number of regional events and therefore the interactions were also limited. The large national events (like the national subsidy policies) were very influential on the regional performance of the TIS. Still it can be noted that, especially in the last period where regional governments became more active, the regional performance of the TIS might differ from the national one. A clear regional goal, such as a climate neutral province in 2040 and active civic initiatives might trigger a better regional performance.

In this thesis four interviews with experts were held for the current state analysis. It would have been interesting to interview entrepreneurs and executives of the industry association Holland Solar. Due to the many topics handled in this thesis there was too little time to execute these interviews as well. Still the opinions of the experts interviewed did not differ very much. Personal conversations with entrepreneurs on multiple conferences, showed me that their opinions were in line with the ones extracted from the structured interviews.

C.Policy advice

C.1 Introduction

The gained insights from the research of Machiel van der Bijl and Jaco Blommerde are combined in this policy advice for the regional governments at the provincial level and the municipality level.

The research of Jaco Blommerde showed the importance of building up the solar innovation system by better linking the supply to the specific forms of demand, creating stronger coalitions between practitioners and mainly enhancing the solar market formation. The research of Machiel showed that a cooperative consumer model has the potential to form such a solar market and do so in a social and cost-effective way.

First the needed market formation is discussed in C2 focussing on individual consumers and cooperative consumers. Both the benefits and drawbacks are discussed. In paragraph C3 the role of the regional governments is described in enhancing the market formation and its wider role in stimulating the overall innovation system of solar.

C.2 Market formation

Currently only 0,1% of the electricity consumed within the province of Utrecht is provided by solar energy. To increase this amount more solar systems need to be installed. With the current prices of solar systems and the price level of electricity the payback time for solar systems for small consumers (less then 10.000kWh/year) is between 12 and 17 years. This payback time is roughly doubled for larger consumers due to their lower costs of electricity from the grid. The technical lifetime of a solar system is around 25 years. This means that small consumers will be able to earn their investment back while large consumers will not. stimulating the market formation should therefore be focussed on small consumers.

The main barrier for these small consumers is the high upfront investment of a solar system compared to the monthly bill of electricity from the grid. There are also consumers that will not be able to install a solar system because they do not have a suitable. The following two market models are focussed on overcoming the investment barrier and giving consumers without a suitable roof the possibility to install a solar system elsewhere.

C.2.1 Individual consumers

As stated above, the payback time of a solar system for small consumers is lower than the technical lifetime of the solar system. This means that there is some financial space before the solar system becomes cost neutral. This space could be used to pay for interest of a loan or the costs of a lease construction to take away the high upfront investment.

A loan or lease construction should not be too expensive. When for example an interest rate of 5% is used with a loan duration of 20 years the total sum paid for the loan is 2,5x the loaned amount. When this interest rate is lowered to 2% it is only 1,5x the loaned amount. There are a few options to lower the costs of a loan or lease construction:

- A foundation could lend money against a low interest rate to consumers. This could also be done indirectly with an intermediary party (see example below of Greenchoice)
- (Regional) governments can award loans with low interests by using the sVn loan construction or a revolving fund.

- (Regional) governments can award guarantees for loans in the financial market. These guarantees are less costly for the government and the interfering in the financial market is limited compared to a loan granted directly by the government.

By using one of these options for a lease or a loan construction a small consumer is able to produce its own energy with a solar system without the high upfront investment. An initiative that uses a lease model has recently been launched by Greenchoice (Greenchoice, 2011) in cooperation with foundation DOEN and Zonnefabriek. A consumer with a suitable roof can request Greenchoice to install a solar system without a start-up fee or monthly costs. The consumer only pays for the electricity generated by the solar system that is used. This price is 0,23 euro/kwh which is only 1 to 2 cents above the current electricity price. After 20 years the consumer becomes the owner of the solar system without extra costs. Initiatives like these will lower the barrier to get a solar system as a private roof owner.

C.2.2 Cooperative consumers

In a local solar cooperative, local residents collectively purchase and manage a solar power system that is placed on a nearby large roof. This has a number of benefits compared to placing solar systems on individual roofs. First, it can make the solar system less costly due to the relatively lower installation and maintenance costs. Second, it makes solar systems available to the large number of households that do not own a suitable roof or do not own a roof at all. Third, it makes a solar power system more affordable by cutting its high upfront costs in smaller pieces. In a solar cooperative, households can start with as little as one panel without the relatively high installation and maintenance costs that accrue to small solar systems.

A local solar cooperative needs funds to purchase and maintain a large solar power system, to run its internal affairs and possibly to pay rent for the roof space. These are provided by the cooperative members through an initial investment and annual contributions. The electricity production of each member's participation in the collective solar power system is balanced with his respective electricity consumption. This means that for each kWh of solar electricity that is produced, a member has to pay for one less kWh of electricity on his electricity bill. Therefore each kWh of solar electricity saves the expense on one kWh of grid electricity either excluding the energy tax (± €0,11) or including the energy tax (± €0,21), depending on the national policy regarding energy tax.

The members must live nearby each other and nearby the roof on which their collective solar power system is placed. This is important because it makes the local solar cooperative a social venture that can have a positive influence on the social cohesion in a neighbourhood. Opinions of local residents that participate in the initiatives in Amersfoort suggest that this is indeed the case and that the participants value this aspect. The social character of the local solar cooperative could also play a major role in involving more people through positive referencing if the first cooperatives are successfully established.

Please note that the solar cooperative is not ready to be implemented yet. There are three important problems that need to be solved and some conditions that need to be met. The first problem is that a procedure for participants who want to step out of the cooperative has to be designed. This procedure must allow local residents freedom to join and quit the cooperative. At the same time a certain number of participants are needed to prevent bankruptcy of the cooperative. The second problem is that the cooperative needs to be able to govern itself for 25 years. This self-government needs to be reliable despite the fact that it consists of volunteering participants who come and go just like the other participants do. The third problem is that the cooperative needs to have a plan for the contingency that the economic lifetime of its solar panels proves to be shorter than the lifetime that is assumed in the business case. In that case it is more profitable to replace the existing solar panels with the newer more technological advanced panels. However, this means that the cooperative needs to have money to make the new investment. The contingency plan for this circumstance should describe in which case the original solar panels will be economically obsolete and what the consequences are for the participants if the cooperative replaces the obsolete solar panels with new panels.

The most important necessary condition is that the national government forgoes the energy tax on the solar energy that is produced by a solar cooperative, on the basis of fact that the panels that produce the electricity are owned by the people who consume the electricity. It is also called 'balancing'. The argument is that by forgoing the energy tax on electricity from panels that are placed on the roof of the owner and by still levying this tax when the panels are placed on another roof than the owner's, an inequality before the law is created. This is currently being discussed by the ministries of Finance and of Economic Affairs, Agriculture and Innovation and parliamentarians Diederick Samson and René Leegte. Once balancing is allowed for solar cooperatives, the pay-back time of the investment falls below the 20 years in the model that is used to set up local solar cooperatives in Amersfoort. This is well within the life-time of the solar panels.

Experience with the civic solar initiatives in Amersfoort suggests that there are enough local residents who are willing to participate in pilot cooperatives, in which solutions for the above mentioned problems could be found. That way, if balancing will be allowed, the solar cooperative is ready to be used as a policy-tool to stimulate the use of solar power systems.

C.3 Role of regional governments

As stated in the introduction to improve the innovation system of solar energy it is needed to enhance the linkage between the supply to the specific forms of demand, creating stronger coalitions between practitioners and enhancing the solar market formation. Both at the municipality level as well at the provincial level there are multiple actions that can support these tasks.

At the provincial level the government should focus on bringing parties together and thereby enhancing the diffusion of knowledge. The formulated goal of a climate neutral province of Utrecht in 2040 sends out a strong signal and could serve as an umbrella to get different parties on the same track. Projects like the one of Greenchoice, Stichting DOEN and Zonnefabriek should be stimulated and other combinations should be made since these are able to move the innovation system forward.

For the individual and cooperative consumer model the province of Utrecht could extend its guarantee fund for sustainable energy projects to include solar systems by extending its maximum duration to 15 or 20 years. It might also be interesting to research whether these guarantees could be given to the supplier of a solar system instead of the consumer. The supplier could for example use a guarantee for 20 small scale solar systems for consumers and ask for a monthly fee in return. For the cooperative consumer model the cooperative could ask for a guarantee of the province to lower its costs for a loan. By using a loan the consumers that take part in the cooperative will be able to pay a monthly/yearly fee instead of a onetime fee at the start.

The municipalities are closer to the final consumer and are therefore more fit to undertake actions towards and with the consumer. For the individual consumer model a municipality can grant a low interest loan for solar systems as is done in the municipality of Amersfoort. Usually loans are granted for 10 years (sVn loan) while the payback time of the solar system is higher (around 14 years). It is therefore advised to extend this period to 15 years. Cooperation with suppliers and installers should also be undertaken so they can also stimulate and help the consumer in buying a solar system including such a loan.

Conclusion

Note: The discussions are covered at the end of parts A and B.

In this chapter answers to the research questions are provided. First the sub questions are answered, followed by the answer on the main research question.

A1. What is the technological potential of PV in the province of Utrecht?

Due to the high population density and the competing purposes for land surface PV should optimally be mounted on buildings where it does not compete with other uses. Within the province 71 km^2 of roof space and 8,1 km^2 of facade is suitable for PV. The roof and facade surface combined can cover between 50% and 150% of the current electricity need within the province. Future improvements in PV system efficiency and the ability to cover more of the available roof space can double this potential. With an optimal application this can result in a CO_2 emission reduction of 40% in 2040 compared to the current CO_2 emission caused by the provincial electricity and gas consumption.

A2. To what extend is installing PV within the province of Utrecht financially feasible without subsidies?

For small consumers who use less than 10.000kWh the payback time of a solar system is 13 to 17 years which is well within the technical lifetime of a PV system of 25 years. Still a large initial investment has to be made to buy the PV system. To overcome this barrier a loan or lease construction can be applied. The feasibility of installing PV within the province of Utrecht without subsidies depends on the possibility to get such a loan/lease with low interest/costs. When these can be granted by a foundation or government the consumer will be able to benefit from a solar system without the upfront investment and yearly costs that are equal or less than their current grid electricity costs.

B. How did the provincial PV Technological Innovation System develop and how can its performance be improved?

The historical overview showed that the development of the PV TIS dates back to the seventies of the previous century and followed four characteristic periods which were strongly influenced by the national developments. From 1975 till 1995 the focus was on research with limited activities by entrepreneurs and an active national government granting subsidies for research. In the second period, from 1996 till 2003, the national subsidies also focussed on market development and on a national and regional level entrepreneurs became more active in a market build-up. In the third period, from 2004 till 2007, national subsidies are fluctuating and limited, resulting in almost no new installed PV capacity and little activity by entrepreneurs. The university of Utrecht still continues its research. In the last period, from 2008 till 2010, both the province and its municipalities became more active in supporting PV. The national government also reintroduced PV subsidies resulting in more entrepreneurial activity.

Interviews with experts showed that the PV TIS within the province of Utrecht is in an early take-off phase. According to these experts the weakest part of the TIS are the supply side and the governmental system while the knowledge infrastructure was graded good. They graded as weak the market formation, resource mobilization and creation of legitimacy weak. The weakness of the supply side and the governmental system are regarded to be obstructive for the further development of the TIS.

To improve the performance of the TIS there are three main objectives. The first objective should be to expand the group of actors active within the province. This group has to identify the specific societal needs and offer targeted PV products and services. These groups should be supported by the governments with continued and reliable support. As a second objective the actors should cooperate more to enhance the creation of legitimacy and knowledge diffusion. The lack of coordination and direction should be overcome by forming knowledge platforms and policy networks both within the private sector as in public-private partnerships. The sustainable roof program by the province of Utrecht in which demonstration projects for sustainable roof technologies are held is a good example of a public-private partnership that enhances the cooperation and coordination. The third objective is the market formation. The currently limited market size hampers the development of the PV TIS. Actors should focus on finding niche markets where the currently available PV technology can be applied. Two good example are the ZonVast project of Greenchoice and the municipality of Amersfoort working together with civil initiatives to install PV systems.

In general the focus should be on activities and functions that will lead to more and other System Functions. This way the current entrepreneurial motor is empowered and might over time develop into a stronger System Building motor.

C. What should the regional governments do to accelerate the diffusion of PV within the province of Utrecht?

The regional governments can stimulate the production of solar electricity best by enhancing the market formation and bringing together different parties that are or should be active in the solar market.

The market formation should be targeted on small consumers who pay a relatively high price for electricity from the grid. These small consumers can be targeted individually or in a cooperative form. On an individual basis it is important to take away the high upfront investment barrier. This could be done with a loan or lease construction. For the cooperative form municipalities should support civic initiatives providing knowledge on how to set up a solar cooperative.

The answers to the sub questions together form the answer to the main research question:

How can the diffusion of PV in the Province of Utrecht be accelerated?

To transform the large technological potential into actual installed PV capacity there are currently three points of focus: First, the m*arket formation* should be enhanced, by targeting the small consumer both on an individual basis with low interest/costs loan or lease and a cooperative basis with knowledge support from municipalities. By doing this the *linkage between supply and demand* is also improved. As a last focus *coalitions should be built* to overcome the lack of coordination and direction. In an early phase this is not a problem but as the market expands it becomes critical to form coalitions and establish networks.

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Appendices

Appendix I – Estimation of installed PV capacity province of Utrecht

In the calculations below a rough estimation is given on the installed PV capacity within the province of Utrecht based on the granted SDE in 2009.

SDE granted within the province / SDE granted total * installed capacity in the Netherlands = Estimated PV capacity province of Utrecht

Table AI.1

Input Variables	Quantity	Unit
CO_2 emission	0,566	kg CO2/kWh
Output PV	0,7	kWh/Wp
CO_2 emission province of Utrecht	9345	kton
Electricity usage average household NL	3500	kWh
Households NL	7312579	
Households in the Province of Utrecht	537377	
Installed PV Capacity NL	68	MWp
Electricity production	46	GWh

Table AI.2

SDE Subsidy granted by Agentschap NL	Netherlands (MWp)	Province of Utrecht (MWp)
Private	6,08	0,27
Companies	25,48	0,88
Total	31,55	1,14

Table AI.3

PV within Province		
Percentage of total SDE granted within the province	3,62%	
Estimated PV capacity province of Utrecht	2,5	MWp
Estimated electricity production	1,7	GWh
Estimated number of households powered by PV	476	
Estimated percentage of household powered by PV	*0,09%*	
Estimated avoided CO_2 emission	0,94	kton CO2
Estimated percentage of total CO_2 emission within province	*0,01%*	

Another rough calculation is based on the ratio of people living in within the province of Utrecht and in the entire Netherlands. The installed capacity in this calculation is twice as high as the calculation based on the SDE. This is probably too high because most of the installations are installed in areas with a low population density like Friesland and Groningen where large roofs are more common.

Inhabitants province of Utrecht / Inhabitants Netherlands * Installed capacity in the Netherlands = Estimated PV capacity province of Utrecht

Table AI.4 Estimation of PV capacity based on ratio of inhabitants

Variable	Quantity	Unit
Inhabitants Netherlands	16515000	people
Inhabitants province of Utrecht	1220000	people
Percentage of people living in the province	7,39%	
Estimated PV capacity province of Utrecht	5	MWp

Appendix II – Questionnaire interview

Note: these interviews were held in Dutch.

Deel 1/9 Diffusiecurve

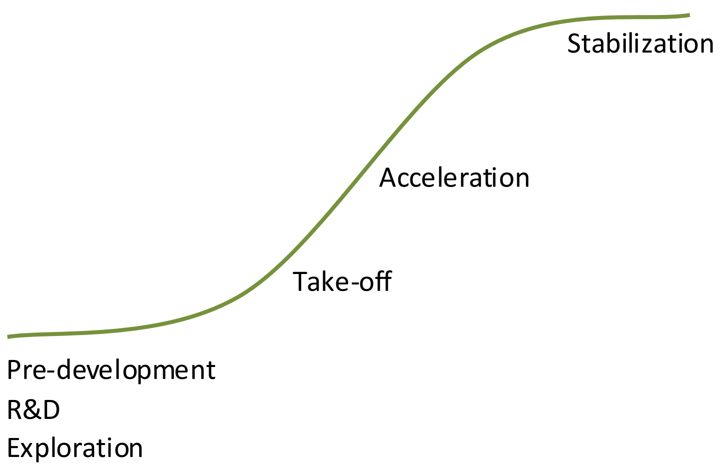
De evaluatie begint met het positioneren van het transitiepad op een hypothetische diffusiecurve. Deze heeft over het algemeen een S-vorm.

De eerste fase is de exploratieve of pre-development fase. Deze loopt tot het aanwezig zijn van een prototype.

Daarna volgt de take off fase. Hierin begint er een kleine vraag naar de technologie te ontstaan en worden een aantal apparaten commercieel verkocht.

Vervolgens is er sprake van een diffusiefase of versnellingsfase. Hierin neemt de diffusie van de technologie sterk toe. Het aantal aanbieders neemt over het algemeen af door toenemende concurrentie.

De laatste fase is die van stabilisatie. De groei is eruit en de technologie is echt onderdeel van de gevestigde structuur.



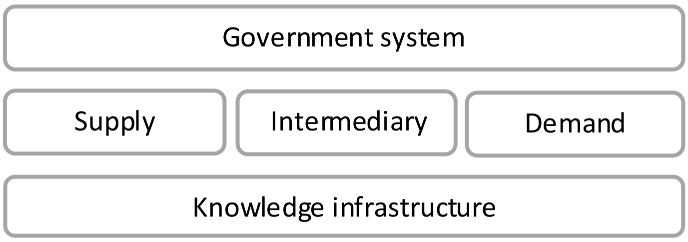
- Waar op bovenstaande diffusiecurve schat u de ontwikkeling van PV in de provincie Utrecht in? (open)

Deel 2/9 - Algemene onderdelen markt PV

In onderstaande afbeelding zijn de onderdelen van de PV-markt weergegeven. De vragen op deze pagina gaan over dit systeem en hoe u inschat dat elke onderdeel functioneert.

Voor elk blok in afbeelding:

- Welke actoren/instituties zijn hier actief? (open)
- Welke van de door u genoemde actoren ziet u als sleutelactoren? (Wie heeft een dominante invloed op de ontwikkeling van PV?) (open)



- Functioneren overheidssysteem (5-puntsschaal zeer zwak tot zeer sterk)
- Functioneren aanbod (5-puntsschaal zeer zwak tot zeer sterk)
- Functioneren vraag (5-puntsschaal zeer zwak tot zeer sterk)
- Functioneren kennisinfrastructuur (5-puntsschaal zeer zwak tot zeer sterk)
- Functioneren intermediairs (5-puntsschaal zeer zwak tot zeer sterk)
- Eventuele onderbouwing voor bovenstaande keuzes (open)

Deel 3/9 Functies - Functie 1: Ondernemersactiviteit

Voor het verkrijgen van inzicht in het functioneren van de markt, dienen de relevante activiteiten in kaart te worden gebracht. Deze relevantie activiteiten worden ook wel de systeemfuncties genoemd:

1 Ondernemersactiviteit

2 Kennisontwikkeling

3 Kennisdiffusie in netwerken

4 Richting geven aan het zoekproces

5 Creëren van markten

6 Mobiliseren van middelen

7 Creëren van legitimiteit.

De laatste 7 pagina's van deze vragenlijst gaan ieder over een van deze functies. Ze beginnen met ongeveer 6 vragen waarna er een algemene beoordeling over de functie kan worden gegeven. Aan het eind van elke pagina kan nog ingevuld worden of deze door u als belemmerend wordt ingeschat.

Functie 1: Ondernemersactiviteit

Ondernemers zijn essentieel voor het functioneren van het innovatiesysteem. De ondernemers creëren en exploiteren new business mogelijkheden, gebruik makend van nieuwe kennis, netwerken en markten. De ondernemersactiviteit is een van de belangrijkste indicatoren voor het functioneren van het innovatiesysteem.

- Zijn er voldoende ondernemers actief? (open)
- Wat is de kwaliteit van het ondernemerschap? (open)
- Wat voor typen ondernemers zijn er? (open)
- Welk deel van de activiteiten van de ondernemers vindt per typen plaats? (open)
- In welke mate wordt er geëxperimenteerd door ondernemers? (open)
- Wat is de variëteit in het aantal technologische opties? (open)
- Is er sprake van toetredende ondernemers of juist ondernemers die de sector verlaten? (open)
- Geef algemene score functie 1 ondernemersactiviteit (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 4/9 - Functie 2: Kennisontwikkeling

Kennisontwikkeling staat centraal in ieder innovatieproces. Ondernemers gebruiken deze kennis om new business op te zetten.

Mogelijke bronnen van nieuwe kennis zijn fundamenteel onderzoek (learning by searching), praktisch onderzoek (R&D, learning by doing) en imitatie waarbij enkel bestaande kennis gebruikt kan worden of een combinatie wordt gemaakt van zowel bestaande als nieuwe kennis.

- Hoe is de kennisbasis in termen van kwaliteit en kwantiteit? Kwantiteit: zijn er veel projecten, onderzoekers, patenten, artikelen Kwaliteit: leidende internationale positie, trekker van programma's, veel geciteerde patenten. (open)
- Wie zijn hier vooral in actief?/ Door wie wordt de kennisontwikkeling gefinancierd? (open)
- Hoe verhoudt de kennisbasis zich tot het buitenland en buiten de provincie? (open)
- Krijgt technologie ook aandacht in nationale/provinciale programma's? (open)
- Is de kennis vooral fundamenteel of meer toegepast? (open)
- Wordt er voldoende gebruikerskennis gegenereerd? Op welke wijze? (open)
- Wat zijn de voornaamste problemen/vraagstukken waarvoor kennisontwikkeling nodig is? (open)

- Geef algemene score functie 2 kennisontwikkeling (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 5/9 - Functie 3: Kennisverspreiding

De informatie-uitwisseling is niet alleen belangrijk voor R&D maar voor alle partijen in het innovatiesysteem zoals de overheid, de industrie, kennisinstellingen, belangenorganisaties en de markt. Door de overdracht van deze informatie kan de overheid haar besluiten baseren op de nieuwste technologische inzichten. De R&D op haar beurt zal beïnvloed worden door de veranderende regelgeving en andere politieke besluiten. Tevens is deze uitwisseling belangrijk voor het bepalen van standaarden.

- Zijn er sterke samenwerkingsrelaties aanwezig? Tussen wie? (open)
- Is de kennisontwikkeling vraaggestuurd? (open)
- Worden er voldoende gelegenheden georganiseerd waarbij kennis kan worden uitgewisseld? (open)
- Is er sprake van zodanige concurrentie dat geheimhouding van kennis een rol speelt? (open)
- Sluit de kennisontwikkeling aan bij behoeften van de markt? (open)
- Worden er licenties uitgegeven? (open)
- Geef algemene score functie 3 kennisverspreiding (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 6/9 - Functie 4: Richting geven aan het zoek- en ontwikkelingsproces

Wanneer er verschillende technologische opties bestaan, dient de overheid, industrie en/of markt een selectie te maken waarop de schaarse middelen gefocust worden. Wanneer dit niet gebeurt blijven er te weinig middelen over om alle opties te ontwikkelen. Wanneer de kennisontwikkeling (functie 2) wordt beschouwd als het creëren van technologische opties dan kan deze functie gezien worden als de selectie hiervan.

- Is er een duidelijk gearticuleerde visie dat wordt gedeeld door partijen? (open)
- Is er een duidelijke overheidsdoelstelling die activerend werkt? (open)
- Worden doelstellingen ondersteund door programma's / beleid? (open)
- Wordt traject zichtbaar gesteund door champions? (open)
- Wat zijn de technologische verwachtingen voor PV? (open)
- Hoe werkt dit door in het veranderingsproces? (open)
- Past de gearticuleerde visie binnen de bestaande wet- en regelgeving? (open)

- Zijn er negatieve verwachtingen rondom PV? Door wie worden die gearticuleerd? (open)
- Geef algemene score functie 4 richting geven aan het zoek- en ontwikkelingsproces (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 7/9 - Functie 5: Marktformatie

Nieuwe technologie kan over het algemeen moeilijk concurreren met technologieën die al tijden gemeengoed zijn. Ze zijn vaak inefficiënt en sluiten slecht aan op de bestaande toepassingen. Om de nieuwe technologie toch een kans te geven kunnen er tijdelijke nichemarkten gecreëerd worden voor specifieke toepassingen van de technologie.

- Hoe ziet momenteel de markt eruit? (open)
- Wie zijn gebruikers? (huidige en potentiële afnemers) (open)
- Grootte van de markt? (niche tot grootschalig) (open)
- Wie neemt vooral af? (publieke / private partijen) (open)
- Zijn er institutionele stimuli/belemmeringen voor markt formatie? (open)
- Is er sprake van de creatie van nieuwe markten of het openbreken van bestaande markten? (open)
- Geef algemene score functie 5 marktformatie (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 8/9 - Functie 6: Beschikbaar stellen van middelen

Financiële, personele en materiële middelen kunnen gezien worden als input voor alle activiteiten binnen het innovatiesysteem. Het is van belang dat deze voldoende aanwezig zijn om te kunnen innoveren.

- Zijn er voldoende financiële middelen beschikbaar voor de ontwikkeling van de markt voor PV? (open)
- Waar wordt dat vooral voor gebruikt? Onderzoek vs bouwen installaties. (open)
- Is er voldoende risicokapitaal? (open)
- Zijn er voldoende overheidsmiddelen beschikbaar? Welke? Waarvoor? (open)
- Kunnen bedrijven voldoende middelen vrijmaken? (open)
- Is er gebrek aan goed opgeleide mensen binnen de markt? (open)
- Geef algemene score functie 6 beschikbaar stellen van middelen (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Deel 9/9 - Functie 7: Legitimiteit/doorbreken weerstand door lobby

Wanneer een nieuwe technologie zich op een bestaande markt begeeft of deze tracht te veranderen (creative destruction) zullen de bestaande partijen weerstand bieden. Om deze weerstand te overkomen dienen de nieuwe partijen zich te groeperen. Deze groep kan dan lobbyen voor voordelen van de nieuwe technologie en bekendheid scheppen.

- Wordt investeren in PV gezien als een legitieme investeringsbeslissing? (open)
- Is er veel weerstand tegen verandering? Hoe uit zich dat? (open)
- Wie verzet zich tegen verandering? (open)
- Wat is de lobbykracht van actoren in de markt om eventuele weerstand te doorbreken? (open)
- Wordt er veel gezamenlijk opgetreden/vindt er coalitievorming plaats? (open)
- Geef algemene score functie 7 legitimiteit/doorbreken weerstand door lobby (5-puntsschaal zeer zwak tot zeer sterk)
- Is deze mate van functioneren belemmerend voor de verdere ontwikkeling van PV binnen de provincie Utrecht? (open)

Appendix III – Function activity

Statistics

In the table AIII.1 below the activity per period is shown for all the functions.

Table AIII.1 – Function activity in the different periods

	Period 1	Period 2	Period 3	Period 4	Total	% of total
F1+	12	8	2	7	29	22%
F1-	1	0	1	1	3	2%
F2	20	3	2	3	28	21%
F3	5	0	1	1	7	5%
F4+	9	1	1	1	12	9%
F4-	4	0	0	0	4	3%
F5+	6	1	2	0	9	7%
F5-	0	0	0	0	0	0%
F6+	5	0	1	8	14	11%
F6-	0	0	0	1	1	1%
F7+	8	9	2	7	26	20%
F7-	0	0	0	0	0	0%
Total	70	22	12	29	133	
% of total	53%	17%	9%	22%		

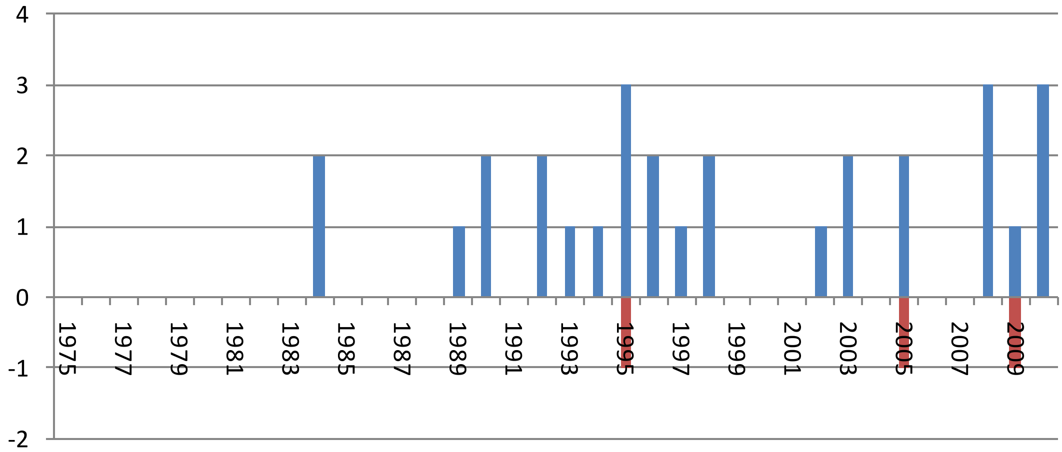


Figure AIII.1 – Activity function 1: Entrepreneurial Activities

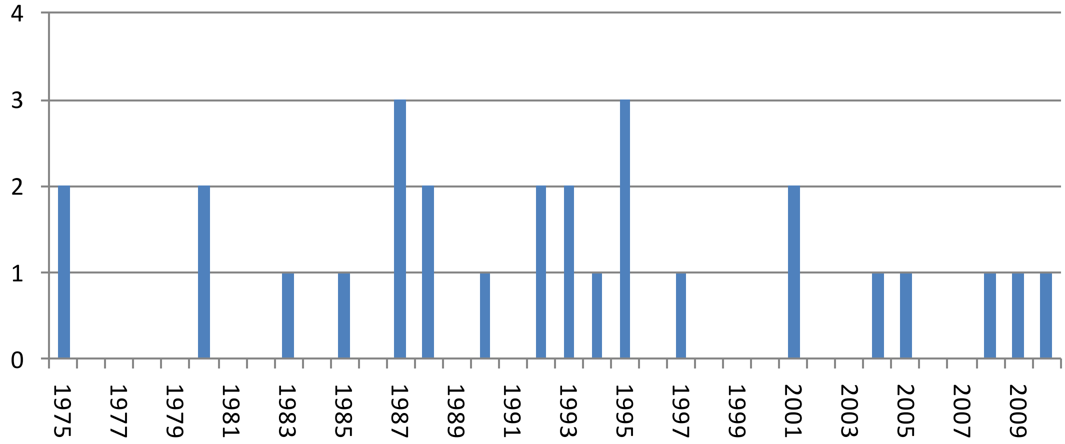


Figure AIII.2 – Activity function 2: Knowledge Development (learning)

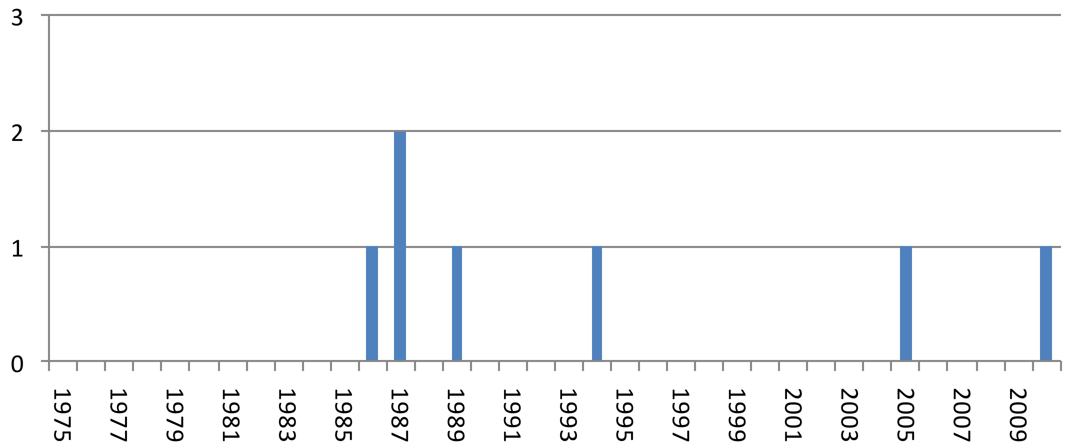


Figure AIII.3 – Activity function 3: Knowledge Diffusion through Networks

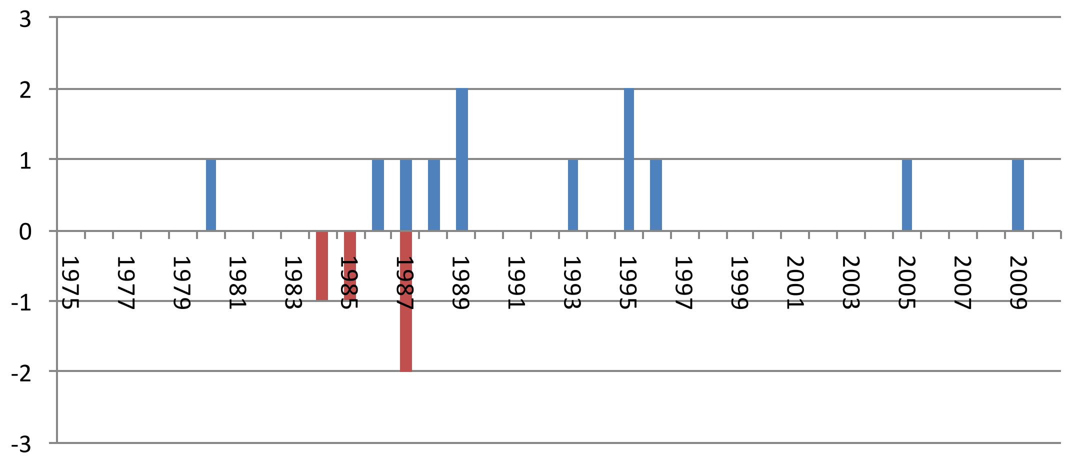


Figure AIII.4 – Activity function 4: Guidance of the Search

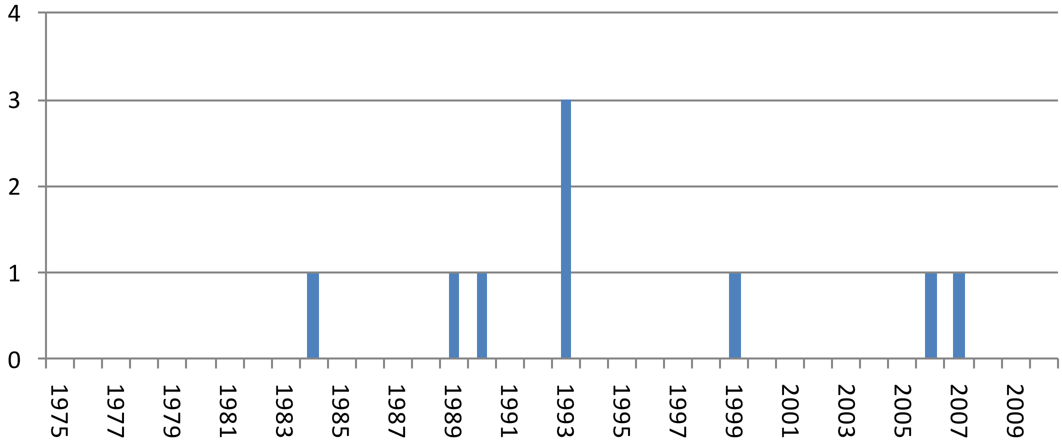


Figure AIII.5 – Activity function 5: Market Formation

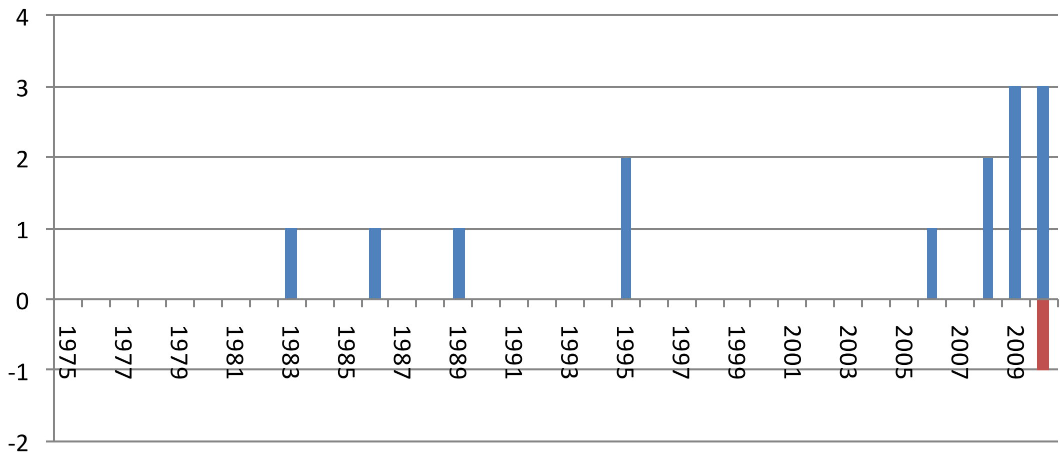


Figure AIII.6 – Activity function 6: Resource Mobilisation

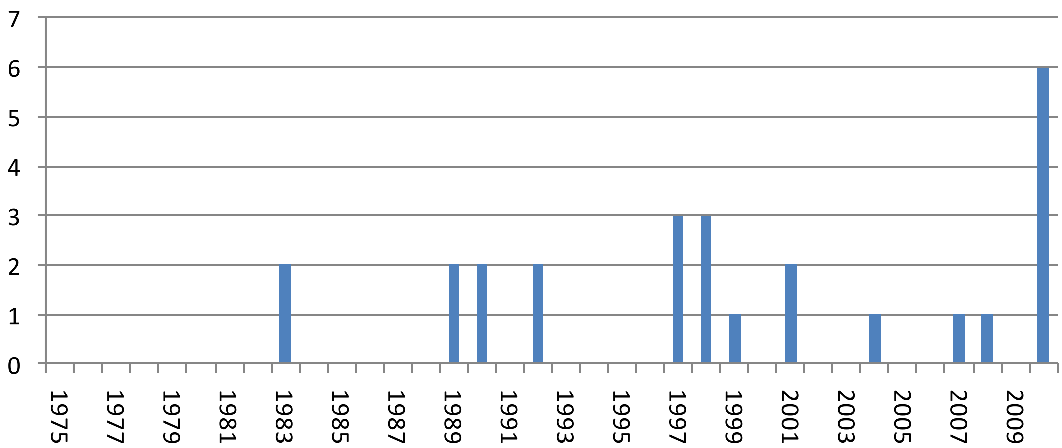


Figure AIII.7 – Activity function 7: Creation of legitimacy / counteract resistance to change

Appendix IV – International PV Scenarios

Table IV.1 International PV scenarios and the average multiplication factor

Scenario	2010	2020	2030	2040*	2050
Greenpeace ([r]evolution scenario) (GW)	18	355	1036	2520	2968
Greenpeace (advanced scenario) (GW)	21	439	1330	3489	4318
IEA ACT Map (GW)	22	80	139	439	600
IEA Blue Map (GW)	27	130	230	805	1150
IEA PV Technology Roadmap (GW)	27	210	870	2448	3155
Average (GW)	16	173	515	1617	2032
Multiplication factor (compared to 2010)		11	31	98	124

** average of 2030 and 2050*

Appendix V - Inventory of PV system prices

A short research on the internet was performed to look for market prices. The suppliers listed below had all or some prices online. Most suppliers do not list prices and are therefore not included.

Table V.1 Prices of PV systems

Suppliers	System Size (Wp)	Price (€)	Installation (€)	Total (€/Wp) Excluding installation	Including installation
Metdezon	3960	9999	1998	2,53	3,03
Wijwillenzon	2960	6439	1100	2,18	2,55
The Sunshine Company			-	2,20	-
Zonnestroom.eu	1890	5500	-	2,91	-
Duurzame-energiesystemen.nl	3700	10175	-	2,75	-

Appendix VI Governmental PV policies

Table VI.1 National governmental policies (Negro et al., 2010)

Period	Name of policy	Aim
1996-2003	REB	To reduce the energy use of companies and households. It comprised a tax on the use of grey energy.
2001-2003	EPR	To stimulate households to apply insulation and solar systems.
2003-2006	MEP	Stimulate the production of clean and renewable energy, including onshore wind (wind power) and cogeneration, biomass and photovoltaic solar energy.
2008- still running	SDE	Stimulate the production of clean and renewable energy, including onshore wind (wind power) and cogeneration, biomass and photovoltaic solar energy.
1996-2003	VAMIL	To accelerate depreciation of investment which were included on the energy list.
1996- still running	EIA	To offset investments in technologies against taxable profit which were included on the energy list.
1996-2004	BSE	To stimulate the use of sustainable energy and environmental energy technologies by providing subsidy for research and development projects in the field of renewable energy.
1996-still running	Green Funds	To stimulate private investments in environmentally friendly projects like PV by means of a tax exemption of this interest. The current government wants to end this stimulation.

Table VI.2 PV related regulations of the Province of Utrecht

Period	Name of policy	Aim
2003-2004	*Energiefonds*	PV not excluded but selection on efficiency (€/CO2 avoided) so other measures were subsidized.
2006 – ?	*Stimulatiefonds*	Focus on sustainable energy and energy saving. PV not included due to relative high costs. Focus on lighting and geothermal heat pumps.
2007 – 2009	*DEK1*	Focus on sustainability, energy and climate. Payback time was set to 20 years. PV could be installed with a payback time of less than 20 years. The subsidy was granted to farmers, the municipality of Amersfoort and two housing

		cooperatives that installed PV.
2008 – 2010	*Energiek Utrecht*	Targeted at enhancing the local economy and especially the construction sector. PV not explicitly targeted.
2009 -2010	*DEK2*	Follow up on DEK1 but energy production is excluded since energy saving is more efficient in €/CO2 avoided.
1 October 2010	*Meer met minder Utrecht (2)*	Linked to the national 'Meer met minder' program which focuses on stimulating house owners in making their house more energy efficient. PV not excluded but other measures are more cost effective.

Infobox B.4 PV related regulations at municipalities

- Amersfoort, Leusden and Woerden

  Both Amersfoort and Leusden currently offer low interest loans (2% a year) together with the SVn (Dutch housing stimulation foundation) (SVn, 2010). These can be used to invest in PV. In 2010 the council of Woerden also proposed to join the low interest loan program with the SVn (Woerden, 2010)
- IJsselstein

  From 2006 onwards IJsselstein subsidizes PV with a current subsidy of 2 €/Wp (Municipality of IJsselstein, 2010).
- Veenendaal

  From 2009 till the beginning 2010 the subsidy 'Energie besparen en Zonnepanelen' was available. A citizen could get up to 375 euro/m2 panel (Municipality of Veenendaal, 2010)