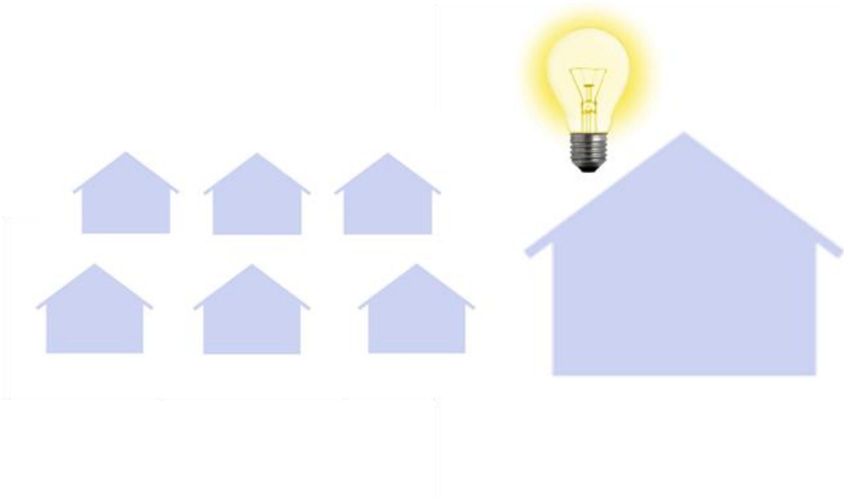
Photovoltaic local renewable utilities

diffusing photovoltaic systems in the Netherlands



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Preface

The making of this thesis spans a year. During this year the national government changed and along with it the renewable energy policy, AgentschapNL gathered a group of solar entrepreneurs in a meeting where the word subsidy was not used, a representative of the electricity company owning the nuclear power plant in Borssele attended one of the first national meetings of people working on cooperative local renewable energy projects, and another electricity company started a pilot giving people a photovoltaic system for which they can pay on a monthly basis. The buzz of photovoltaics reaching grid parity is definitely going around and the photovoltaics sector is changing as we speak. Possibly this thesis is witness to photovoltaics touching base in the Netherlands.

Machiel van der Bijl
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Abstract

Solar energy has a large technical potential that allows it to become one of the main sources of renewable energy in the long-term future. Currently, photovoltaics make up a minor part of the Dutch renewable energy mix and play a minor role in energy policies of the national government. However, the cost price of photovoltaic electricity has reached the same level as the price that small electricity consumers pay to their power utilities. This situation of grid parity creates a potential market for PV systems in the Netherlands that can become the consistent driver of photovoltaic diffusion that the PV innovation system needs. Policy that stimulates the formation of this market is therefore likely to be more effective in diffusing PV systems than current national government energy policy, which focuses on making PV systems cost-competitive with the grid, i.e. reaching grid parity. Facilitating the formation of photovoltaic local renewable utilities (PV-LRUs) can be such an effective PV diffusion policy, as it targets the other barriers to market formation that remain to be addressed now that grid parity is reached.

A PV-LRU is a self-supporting participatory photovoltaic energy project in which solar electricity is produced in the vicinity of the participants. The participants are both producer and consumer of the electricity that the PV-LRU produces. Their number is limited to the amount of people that can be in the vicinity of and supported by the projects collective photovoltaic system. The overall costs of setting up and running the PV-LRU can be financed by the participants themselves, possibly in combination with a low-interest loan. The overall costs could be paid back within the guaranteed technical lifetime of the solar panels with the savings on the energy bills of the participants.

Drawing a parallel with the earlier diffusion of cost-competitive off-grid PV systems in emerging off-grid markets, there are four non-price barriers to the formation of a market for PV systems. The PV-LRU overcomes these four non-price barriers. First, it makes PV systems available to the majority of households that do not own a suitable roof for PV, by installing a collective PV system on a large nearby roof instead of installing multiple PV systems on the smaller roofs of the participating households. Second, it makes PV systems affordable to the households that cannot pay the large up-front investment that PV requires, by allowing the purchase of as little as one panel while still ensuring this panel is placed in an optimally configured PV system. Third, it makes PV systems attractive by relieving households from the efforts of acquiring and managing the PV system and from the need to overlook the entire PV panel technical lifetime of at least 25 year. And fourth, its local character allows for positive referencing which could legitimize the use of PV systems to governments and late adopters by influencing public opinion on solar power.

By realizing the potential market for PV systems, the PV-LRU makes solar power an attractive option for local governments to realize part of their climate and renewable energy goals with. The PV-LRU requires relatively little government funds, as it can be financed by local residents and/or the financial market. It requires relatively little changes in town planning, as the PV systems are placed on existing roofs and produce little nuisance to the city environment. It requires relatively little administrative capacity from the local government, as this can be supplied by market parties. And it could require relatively little effort to reach its target group, households, as it allows for and

stimulates social interaction between local residents, thus autonomously spreading information about the government policy to other households and influencing public opinion on solar power.

To create a PV-LRU, a public-private partnership needs to be made, involving local residents, local governments, large roof owners, financers, electricity grid managers and electricity companies. Also, the law proscribing the energy tax that is levied on electricity for households needs to be changed to allow for balancing before the electricity meter, i.e. forgo paying the energy tax over the solar electricity from panels on a third party roof. Currently, there is inequality of justice between PV systems placed on one's own roof and on a third-party roof. Only when balancing before the electricity meter is allowed, can people place their solar panels on third-party roofs without having to pay energy tax on the produced solar electricity. This would dramatically improve the economic viability of PV-LRUs.

The feasibility of PV-LRUs depends on the readiness of local residents to participate, the ability of the different actors involved to co-operate, the stance of the national government with regard to balancing and the changes in the grid electricity price versus the PV electricity price. There are a number of problems that need to be solved and unknowns that have to be investigated before the PV-LRU is a fully developed concept. For now, it can be concluded that the PV-LRU is an interesting concept with a large potential to diffuse PV systems in the Netherlands.

Contents

1. Introduction

1.1. Problem description

Societies need to switch to renewable energy sources in order to ensure their power supply (Albrecht 2007) and to lessen the environmental burden that fossil fuels impose. Solar energy has a large technical potential that allows it to become one of the main sources of renewable energy in the long-term future (Boston Consulting Group 2010). To realize this potential while benefitting the Dutch economy, the Netherlands have to start forming a national solar energy market that uses the situation of so-called grid parity with consumer prices including the energy tax. Grid parity means that the electricity price of the new energy technology has become the same as the price of electricity from the grid.

Currently, photovoltaics (PV) make up a minor part of the Dutch renewable energy mix (0,04%, Centraal Bureau voor de Statistiek 2009). Policy makers and potential users of PV panels are generally convinced that photovoltaics are too expensive to be competitive with other energy technologies. This can be derived from the national discourse on solar energy, which is focused on the national government's subsidies for the diffusion of photovoltaics. These subsidies increase the revenue from solar electricity that is fed into the grid or partial restitution of the purchase costs of PV systems, i.e. they aim to make photovoltaics more price-competitive.

This thesis argues that PV systems have become price-competitive for small electricity consumers that produce for their own use. This means that PV diffusion is no longer hampered by price. There is also plenty of demand for solar panels: the Stimuleringsregeling Duurzame Energie (SDE)[1], which was the subsidy scheme for both small and large PV-systems in 2008-2010, has been heavily overbooked for every round(SenterNovem). Yet, the growth of installed PV capacity does not match these developments. This thesis explores a decentralized way of deploying solar systems in society that could address the alleged slow diffusion of photovoltaics in the Netherlands. It identifies non-price barriers to PV diffusion and offers a new strategy that addresses these barriers instead of the barrier of price-competitiveness. In doing that, this thesis follows up on the emergence of local photovoltaic initiatives in the Netherlands. This makes this research highly relevant for both researchers and practitioners who are working on the diffusion of photovoltaics.

1.2. Objective of this study

This thesis investigates how local co-operative solar energy projects, also called photovoltaic local renewable utilities (PV-LRUs, can drive the diffusion of photovoltaics in the Netherlands. Its main research question is:

[1] Translated: 'Arrangement for stimulating renewable energy'.

How can photovoltaic local renewable utilities stimulate the diffusion of photovoltaic technology in the Netherlands?

To answer the main research question, information on the current situation regarding photovoltaics in the Netherlands is needed to support the notion that there are diffusion barriers. Also, the barriers need to be identified. Furthermore, the concept of PV-LRUs needs to be defined. And finally, it needs to be described how these PV-LRUs can be created. Therefore, the following secondary research questions are answered:

1. **What are the characteristics of a photovoltaic local renewable utility?**
The PV-LRU is a new concept in the Netherlands. This does not mean that there has been no information on cooperative local renewable energy projects: there are a number of local co-operative solar initiatives in the Netherlands that more or less fit to the definition of a PV-LRU; and there is some literature on the decentralized organization of renewable energy generation. However, this information shows that there are different ways to organize local renewable energy projects. By defining the PV-LRU the scope of this thesis is determined while also providing more clarity on what makes local renewable energy projects exceptional. The answer to this question will point out why PV-LRUs can be a driver of PV diffusion.
2. **Which actors need to be involved and in what way, and what resources are needed, to create a PV-LRU?**
To know what a PV-LRU is and why it can be a driver of PV diffusion is not enough to explain how it actually can be that driver. It must also be known how a PV-LRU can be created and who can contribute in which way in order to facilitate this creation.
3. **What are the barriers to the diffusion of photovoltaics in the Netherlands?**
To predict the effect of PV-LRUs on the diffusion of photovoltaics, one needs to know what factors affect the diffusion of PV in the Netherlands and how PV-LRUs may influence these factors.
4. **What is the current situation in the Netherlands regarding photovoltaics?**
To predict the effect of PV-LRUs, a base situation needs to be known from which the predictions can be made. The answer to this question includes information on current PV capacity in the Netherlands and on what national government policies aim to stimulate photovoltaics diffusion.

1.3. Reading guide

This thesis consists of three different parts that are relevant for different readers. Chapter 2 contains the creative part of this thesis. It is used to answer sub-questions 1 and 2 and is relevant for everybody who wants to read and understand the main message of this thesis. The chapters 3 and 4 constitute the research part of the thesis. They form the basis upon which sub-questions 3 and 4 are answered, respectively. Chapter 3 is useful for all readers as it gives the context of the research problem. Chapter 4 is relevant for scholars on innovation diffusion literature and for people who want to know the studies that influenced the line of reasoning in this thesis. It describes the concept and workings of the PV-LRU and gives a vision on the role of the PV-LRU as a driver of PV diffusion. Chapter 5 concludes this thesis and ties all the chapters together in a main line of reasoning. Also, the discussion points out some flaws that inevitably are part of this work. This is important for people who want to use this thesis correctly for their own work.

1.4. Abbreviations and terminology

Balancing	The discounting of one's produced electricity with one's consumed electricity. There are two types of balancing, determined by the location of the PV system in relation to its owner. The first is balancing *after the meter*, in which case the PV system is placed on the property of its owner; the second is balancing *before the meter*, in which case the PV panel is placed on the property of somebody different than the system owner. More about balancing can be read in the internship report in Appendix: Internship report.
PV	Acronym for photovoltaic(s).
Photovoltaic	Adjective meaning 'solar electric', e.g. a 'photovoltaic panel' is a solar panel.
PV-LRU	Acronym for photovoltaic local renewable utility.
RES	Acronym for renewable energy source(s).
TIS	Acronym for technical innovation system.

2. The photovoltaic local renewable utility

This chapter describes the local renewable utility (LRU) as a concept that is likely to increase the diffusion of photovoltaics in the Netherlands. The LRU is inspired on the cooperative renewable energy initiatives described in the report *Nieuwe Nuts* (Wortmann, Kruseman 2008). The aim of this chapter is to give a clear description of the concept of these renewable energy initiatives in order to analyze its value for the diffusion of photovoltaics using arguments based on scientific theory.

In the first section, a definition of the LRU will be given and the implications and limitations of this concept will be discussed. Then, the specifics of the photovoltaic LRU (PV-LRU) are described. In the second section, a general business case of a PV-LRU is presented. Here it is described how a PV-LRU pays itself back and what key variables determine this. Then four basic scenarios and a sensitivity analysis are made to assess how the key variables influence the viability of the business case. In the third section, the PV-LRU is analyzed as an innovation and it is explained why this innovation can be expected to diffuse successfully. In the fourth section, the compatibility of the PV-LRU with government policies is discussed. This triptych on the merits of the PV-LRU is then followed by section five, in which the concept's possible weaknesses are anticipated.

2.1. The photovoltaic local renewable utility defined

The current electricity system is centralized, with power plants generating hundreds of megawatts and high-voltage grids distributing the power. This is because fossil fuel power plants generally become more economical the larger they are. Renewable energy technologies allow for a more decentralized electricity system. Wind, solar, tidal and wave energy are dispersed over large areas and are harvested with many smaller units instead of one large power plant. Capacities for wind turbines are between 1 and 7 megawatts, for a photovoltaic solar system several kilowatts. Although larger arrays of wind turbines or solar panels have an output of tens to hundreds of megawatts, they still have a modular build-up and consist of many small outputs pooled together. Renewable energy technologies thus make the choice for a centralized electricity system an arbitrary one.

In a decentralized electricity system the division of labor between producers and consumers also becomes arbitrary, because renewable power can relatively easily be produced by its own consumers. An example is the German village Jühnde, where since 2005 local biomass is used to produce electricity and heat for most of the circa 200 households (Wortmann, Kruseman 2008). The consumers need to be organized in order to participate in or own the undertaking. The manifest 'Nieuwe Nuts'[2], written for the Stichting Innovatie Glastuinbouw, a Dutch foundation for innovation in greenhouse farming, describes these local power generation projects as the next generation utilities. The manifest *Seeing the Light* by David Morris describes customer-owned electric utilities as the next development in our energy system (Morris 2001). In line with these sources, a local cooperative renewable energy project can be called a *local renewable utility*. The definition:

[2] Translation: 'New Utilities'.

A local renewable utility is a self-supporting participatory energy generation project in which renewable energy is produced in the vicinity of the participants.

There are three consequences to this definition. First, since the participants are participating in a self-supporting energy generation project, every participant is also a consumer of the energy that the local renewable utility produces. This distinguishes the local renewable utility from a traditional power company, where only a part or none of the participants are also a consumer of the produced energy (Morris 2001). Second, not all consumers of the energy produced by a local renewable utility need to be participants, as excess produced energy can be sold off to second parties. See Figure 1 for a schematic representation of this. Third, the number of participants is limited to the amount of people that can be in the vicinity of and supported by the renewable energy generation project.

In this thesis, the focus lies on the photovoltaic LRU, or PV-LRU. In the future, it might not make a difference for the feasibility of an LRU which renewable energy technologies it uses, but for now setting up an LRU using photovoltaics is a unique case. This is because the different renewable energy technologies all have different innovation systems with different actors and dynamics. The PV-LRU has the following distinctive properties:

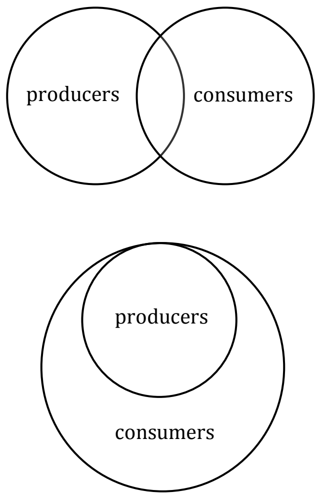

Figure 1 The relationship between producers and consumers of electricity in a centralized electricity system (top) and a local renewable utility (bottom).

- Easily applicable in urban environment, because solar panels are little obstructive to the city appearance, make no noise and emit no substances that could be detrimental to health;
- Small minimum system size, because the PV systems can range in output from kilowatts to megawatts without any effects on the efficiency of the system. However, the minimum allowable size of a PV system in a PV-LRU ultimately depends on the bulk discount on system components and the minimum number of participants that are needed to make the business case work. How big the minimum allowable size will be, is unknown, but the estimate is 30 kW_p.
- The ownership in a cooperative PV system can be divided over the participants both administratively and physically (minimum of one panel per participant). This makes it easier to adapt the tax regime to allow for balancing (see "Abbreviations and terminology"), as one of the main arguments of the Dutch tax authorities to not allow balancing is that the renewable energy generating unit cannot be physically assigned to one owner. This is the case for wind turbines, as each participant owns a share of the wind turbine but the wind turbine cannot be divided up into smaller energy generating parts.

Please note that this chapter focuses *local* cooperative renewable energy projects, as opposed to projects that are not confined to a neighborhood. In principle, the participant of a cooperative solar system does not have to live near the solar power system to use its power. There are two reasons to focus on the local variety. First, in its local form the cooperative renewable energy project makes maximum use of the benefits of a decentralized electricity system, which are an important reason for the desirability of the projects. The electricity is not only generated in many different places, increasing the resilience of the electricity system against calamities, but it is also transported over the shortest possible distance, thus minimizing the capacity that is needed from the grid and saving the costs of grid capacity expansion. Second, the local form of the cooperative renewable energy project benefits from social interactions within a neighborhood community. By both hearing about and seeing the benefits of a PV system, people reconsider negative perceptions of a PV system and are more likely to purchase a PV system themselves (Miller 2009).

2.2. The PV-LRU as business case

The definition of the PV-LRU in the previous section describes what it does but leaves open how it can be done. Here a basic business case will be presented to make the

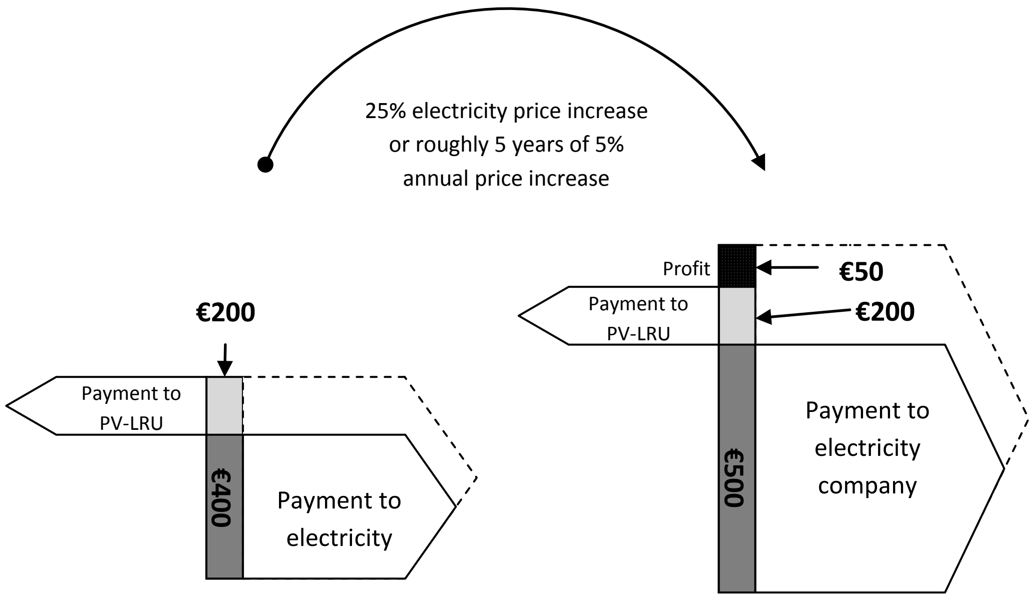

Figure 2 Reallocation of household expenses on electricity through a PV-LRU. The columns picture the total household expenses on electricity that originally were all paid to the electricity company (dark plus light grey area). By participating in a PV-LRU, the household reduces its payment to the electricity company (dark grey area). When the business case neither looses nor gains money (left diagram, the prevented payment (light grey area) now goes to the PV-LRU. The result is no increase in electricity costs while still partly switching to solar electricity. When the electricity price rizes (right diagram) both light and dark grey area increase in proportion. Only the payment to the PV-LRU stays the same. The difference between the prevented expenses and the payment to the PV-LRU is profit (striped area).

principle behind a PV-LRU clear while at the same time showing how PV systems can be competitive with commercial grid electricity. This case is not made by the author nor is it the only possible one: it has been derived from a business case that was made for Zonvogel, the access to which has been granted to the author. Zonvogel and other entrepreneurs who are working on realizing local photovoltaic projects without the use of subsidies do not publicly publish their business cases. Possibly this is because of the economic potential that the market for cost-competitive PV systems promises to have. The business case is therefore a basic version of the actual one. Nevertheless, the information below has scientific value, if only because it serves as an illustration to the diffusion of PV systems.

Suppose there are 100 participants in a city neighborhood who each are willing to participate in a corporation for €1.000,-. This gives the corporation €100.000,- to spend. Suppose this is spent on an installation of 27 kW_p, costing €81.000,- initial investment and €800,- annual operation and maintenance (O&M) costs and yielding over the project lifetime of 25 years an estimated 530 MWh, assuming a yield of 0,85 kWh/(W_p*year) at the start of the project that declines with 0,7 %/year. At the start of the project the remaining €19.000,- will be put on a savings account with 3% interest which will be used to pay the annual costs for O&M. Further assumptions are that participants, who move away during the project lifetime, will sell their participation back to the corporation for its objective value at that time; that the corporation will instantly resell returned participations without making profit or loss; that the number of participants will not grow beyond 100; and that none of the participants produce more electricity than they consume.

The key variable is the revenue the corporation gets for the produced solar electricity, which is assumed to be equal to the money the participants do not have to spend on commercially produced grid electricity because they use the solar electricity. When this is below the average cost price of the corporation's PV system of 0,19 €/kWh, the corporation is making money and otherwise it is making a loss. See Figure 2 for a graphical representation. The revenue per kWh of solar electricity at the start of the project is assumed to be 0,21 €/kWh if balancing is allowed (see "Abbreviations and terminology") and 0,09 €/kWh if not. To make two more scenarios, an annual growth of the grid electricity price of 0% or 5% over 25 years is assumed.

Table 1 The possible results of a participation in a PV-LRU. The results are given in euros and exclude the participation of €1.000,- and the interest revenues from the corporation per participant. The project lifetime is 25 years and the cost price of the electricity from the PV-LRU is 0,19 €/kWh.

	annual growth grid electricity priced	balancing allowed?	
		no (0,09 €/kWh)	yes (0,21 €/kWh)
annual growth grid electricity price	0%	*-430*	*320*
	5%	*60*	*1500*

The results of these scenarios are displayed in Table 1 and show that no money is lost on the investment already from the next worst scenario. And although even the best scenario is no financial gold mine, it will do for people who value the 25 year energy price security or CO_2-emission reductions that this investment will give.

Because this business case spans a 25 year period, there are a lot of uncertainties, like the development of the electricity price or the value of CO_2-emission rights. The value of scenarios like in Table 1 is not to predict the future, but to assess risks. To complement the scenarios, a sensitivity analysis on the variables 'annual electricity price rise' and 'PV system cost price' has been performed (Figure 3). The analysis shows that the business case improves quickly with a decline in PV system costs or a higher growth rate of the electricity price. The interest rate influences the business case only weakly. The PV system costs have been historically declining and as there is room for more technological learning, they can be expected to keep declining. This will influence the business case positively. The main uncertainty for the business case is therefore the electricity price. Effects of price developments for CO_2-emission rights have not been incorporated in this business case, but can be expected to only have a positive influence.

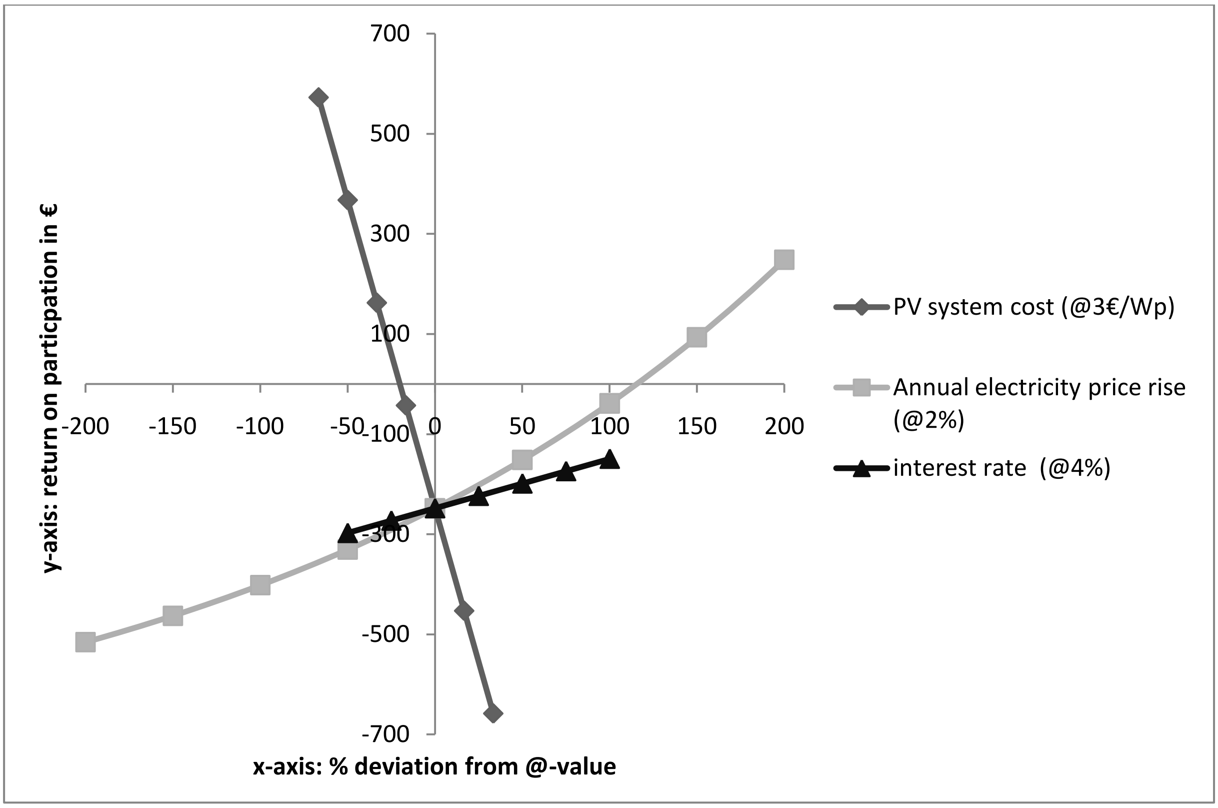

Figure 3 Total return on €1.000,- participation after 25 years. Sensitivity analysis of the three variables 'PV system cost', 'annual electricity price rise', and 'interest rate' on the money reserved for operation and maintenance. On the x-axis the percentage of deviation of the standard values, which are: 3€/W_p PV system price, 2% electricity price rise, 4% interest rate, and 0,09€/kWh electricity price at t_0. So '-100' means for the series 'Annual electricity price rise' that the electricity price rise is 2 minus 100% of 2, is 0%. Conservative standard values have been picked for the variables. The range of deviation for each variable is chosen on what is realistic. E.g. the interest rate is assumed not to drop below the 2%, which is a deviation of -50% from the standard value of 4%.

The revenues of the corporation from interest are equally distributed over the 100 participants in the business case and summed with the actual return on the participation. E.g., the participant can have an actual return of -€200,- but might get +€300,- from the corporation revenues, thus having a total return of +€100,-.

2.3. The PV-LRU as innovation

What makes a PV-LRU an innovation? In chapter 3 an innovation is described as an invention that is being used on a significant scale and as a product in which a new technology has found its application. These definitions came from Hekkert c.s. and Kruijsen respectively (see chapter 3) and both have the concept technology at its core. However, the definition of Kruijsen also takes new applications of existing technologies, i.e. new products, in account. A PV-LRU is not an innovation because it is a new technology: photovoltaics are not new. Although the PV-LRU can exist because of the incremental innovations in photovoltaics that made it cheaper, this does in my opinion not count as the application of a new technology. Rather, the PV-LRU is an innovation because it applies photovoltaics in a new product. This product is solar electricity from your own PV panels that are installed and maintained for you, placed on a roof that is provided for, and against a competitive price, no matter how long you choose to use these panels. By purchasing a participation in an LRU the customer is not provided with renewable energy as such, but rather with the means to produce energy from renewable energy sources that are accessible to the customer and to do so according to his or her own specifications. This is a different product than is offered by regular power companies, because there the electricity is sold rather than the means to produce and use it.

A PV-LRU is an innovation that is likely to diffuse because it complies with the characteristics that an innovation is supposed to have in order to diffuse. In chapter 3 it is concluded that an innovation needs to be competitive, attractive, affordable, available and legitimate in order to diffuse. I argue that the PV-LRU is all of this for the following reasons:

- **Competitive** Photovoltaics can produce electricity for a cost price of around 0,20 €/kWh. This is the same as Dutch households pay for their grid electricity. In other words, PV systems have reached grid parity with households. Therefore they are competitive. As photovoltaics are likely to become cheaper and the grid electricity price is not likely to decrease, the technology is likely to become only more competitive over time. Even if balancing is not allowed and revenues are far below cost price now (they would be the bare electricity price of around 0,09 €/kWh) the PV-LRU can deliver power for a competitive price if grid electricity price rises with 5%/year for the 25 years of the guaranteed lifetime of the PV panels, as is calculated in the previous section. This is not an unrealistic price rise, considering the historic trend of the electricity price;
- **Attractive** Purchasing and exploiting a PV system through a PV-LRU is relatively free of effort. The location, installation, maintenance and administration are taken care of by the corporation and its business partners. Also, the purchased PV system can be sold back to the corporation when the owner moves away, thus relieving the owner from the effort of selling the PV system with the house on the housing market or taking the system with him. The corporation can exploit the participation, be it possibly at a loss, until it is resold again. The PV-LRU thus makes owning and exploiting a PV system easy, allowing the benefit of energy security and the environmental benefits fully in the spotlights. This makes PV systems attractive;
- **Affordable** The PV-LRU solves the barrier of the high up-front costs of PV systems in two ways. First, it allows for participations as small as one panel. On itself, a one-panel system is not effective, but as part of the large PV system of the corporation it is. This might lower the participation threshold to about €500. Second, as a corporation it is easier to obtain low-interest loans, possibly with the help of guarantees by the local government and finance the PV systems. Then, the participation threshold lowers to the membership fee of the corporation,

allowing people to participate almost independent of the income or capital they have. This makes PV systems affordable;

- **Available** PV systems are readily available to households, but the roofs to place them on are not. The PV-LRU has the negotiation power and trustworthiness to make deals with owners of large roofs to use their roof space. The roof owners themselves are often not small energy consumers and consequently pay a lower tariff for their electricity than households do. So large roof owners do not yet have a commercial gain from a PV system on their roof. But they can already earn some money with their roof space by renting it to the PV-LRU. This makes the abundant roof space that is present in our build environment available to people who want to exploit a PV system, but who do not have a roof to place the system on themselves. This makes PV systems available;
- **Legitimate** The PV-LRU is not legitimate yet, both in the jurisdictional and the social sense: the act of balancing, which is an important aspect of the PV-LRU business case, has neither been denied nor confirmed as a legitimate practice by the tax authorities and is in discussion in the parliament (Rijksoverheid 2010a); and PV systems are still widely perceived as a non-competitive energy technology that needs subsidizing or a personal financial sacrifice to employ it. But the PV-LRU does gain legitimacy from the fact that the people who pay for it are the people who benefit from it. And these people vote, maybe hold government offices, and talk to other people. Ergo, the close connection of a PV-LRU with its users could make its users the very agents that augment its legitimacy, as they raise their voice in the political arena and spread an attractive image of PV systems to their social connections. This last point finds confirmation in two literature sources. First, Miller observed in his case studies that PV systems spread in 'islands': once a first PV system was successfully installed and exploited in a village, more followed readily. Miller concludes from this that referencing is a very important in changing people's perception of PV systems (Miller 2009). Second, a study amongst applicants for a PV subsidy in the province of Groningen, the Netherlands, tentatively observed that "although the social motives for adopting a PV system are not strong, the more other PV owners a person knows, the stronger these social motives become" (Jager 2006).

2.4. The PV-LRU as a policy instrument

The performance of a PV-LRU as a policy instrument would be a thesis on itself. In this thesis, I can only give a good reason why the PV-LRU would be a good policy instrument for stimulating the diffusion of PV systems. A good policy is effective and compatible with overlapping policies on overlapping topics and/or from other government levels. In terms of money spent per kW_p of solar panels diffused and amount of solar panels diffused per year, the PV-LRU could be more effective than subsidies. This is because PV-LRUs can utilize money from the market. Government funds could be used as guarantee to secure low-interest loans for the PV-LRUs instead of spending it directly on the PV-LRUs. This could make a budget available to PV-LRUs that is a multiple of the government funds. How this policy would compare with putting the government funds in a revolving fund I do not know. This depends amongst other factors the size and the life time of the loan that is guaranteed, development of interest rates and the speed with which the PV-LRUs can repay the loans. But as revolving funds from government money still not free money from the financial market, I expect the policy helping PV-LRUs to diffuse more panels per year than the revolving fund policy.

As to compatibility to other policies, the PV-LRUs need to be compatible with a) other climate policies, such as energy saving policies, and b) other types of PV policies. Energy saving measures go hand in hand with using solar panels. Firstly because the effect of solar panels is similar as that of energy saving measures: a lower energy bill. Secondly both measures can be implemented on the household level. Thirdly, implementation of one of the measures is likely to increase consciousness of the other measure. For example, people who install a PV system could become more conscious of their electricity use because they look at their electricity meter more often (to see how much electricity their solar panels produce) or because they need to know their use to size their PV system. Fourthly, if solar panels are to cover the entire electricity consumption of the household, lower electricity consumption allows for a smaller PV system, thus saving money. The case of Amersfoort is a good example of the connection between energy saving measures and PV systems: during their energy saving campaign, the municipality was frequently asked to support the installation of PV systems, too. As to point b: other policies that aim to stimulate the diffusion of photovoltaics are the feed-in tariff, direct subsidies for system purchase, low interest loans and revolving funds. All these policies would only improve the business case of the PV-LRU. Therefore, the PV-LRU is compatible with all of these policies.

2.5. The failing PV-LRU

The strong points of the PV-LRU have been described; the weak points are also important to consider. I can think of two ways a PV-LRU can fail: people do not like the concept or the executive committee fails.

The product of the PV-LRU could simply not sell. It is unknown how many people will actually be appealed by the concept and why they will be appealed. The product might also not sell to roof owners, who find the benefits of granting access to their roof smaller than alternatives such as waiting until photovoltaics are cheap enough to be exploited by the roof owners themselves. In the long term, the question is whether the PV-LRU would still be attractive if renewable energy has become cheap enough to be exploited by fully commercial power producers. This depends on the costs of transportation compared to the costs of local power generation and storage, on the existence and importance of a pan-European electricity grid, etcetera.

A fundamental attribute of the PV-LRU is that it enables participants to own the source of the energy they use. This has only meaning if this means that participants also have control of their energy source. And this is only the case when the participants have control of the money flows, capital stock and business relations of the corporation. To have this control, the corporation needs to have an executive committee. This committee should be formed of participants, i.e. be internal, if the participants are to have the most possible control of the corporation. There are two weaknesses of an internal executive committee: the level of competence and the accountability. The first weakness is caused by the fact that only a limited group of people can apply for a position in the executive committee, as this group is comprised of the limited amount of participants a PV-LRU per definition has. It could be that this group is too small to produce enough competent people to manage the corporation. The second weakness is the case when the committee is not hold accountable enough for the welfare of the corporation, which for example could happen when the committee is formed by volunteers. In that case, one has to rely on implicit social contracts to ensure that the committee manages the corporation well. This could not be enough when the corporation is large or when large money flows need to be managed. The executive committee needs then to become professional, which might mean that some committee members need to come from outside the corporation.

2.6. To conclude

In this chapter I have described the concept of the photovoltaic local renewable utility (PV-LRU) to define the core principle behind local cooperative solar energy projects. I have presented this concept as a part of the energy transition towards renewable energy sources and with that towards a decentralized energy system. The PV-LRU has been defined as a self-supporting participatory solar energy generation project in which solar energy is produced in the vicinity of the participants. This means that a participant is both the producer and the consumer of the solar electricity and that the electricity is produced in the vicinity of its users.

I have argued that the PV-LRU can play a central role in the diffusion of PV-systems in the Netherlands for three reasons. First, the PV-LRU is an innovation that targets a market that can exist without subsidies: the market of households. And it does so because using normal PV panels, the electricity of which has reached grid parity for small electricity consumers. The PV-LRU can pay for itself with the saved expenditures on grid electricity of its participants and is therefore independent from subsidies. The PV-LRU is something new to this market because it applies photovoltaics in a new product, which is solar electricity from your own PV panels, while *all* of the overhead is taken care of. This is a different product than is offered by regular power companies or PV system providers, because the former sells the electricity itself rather than the means to produce and use it, and the latter takes care of only a part of the overhead that a PV system entails.

Second, a PV-LRU is an innovation that is likely to diffuse. It complies with four of the five characteristics described in this thesis that can increase the diffusion of an innovation, while it could induce the fifth. It is *competitive* because it can deliver electricity against a cost price that has reached grid parity for small electricity consumers. It is *attractive* because it makes purchasing and exploiting a PV system easy: placement, installation, maintenance and administration are taken care of; and the purchased PV system can be sold back to the corporation when the owner moves away, thus relieving the owner from the effort of selling the PV system together with the house on the housing market or of taking the system with him. It is *affordable* because it greatly reduces the high up-front costs of PV systems by allowing people to buy a virtual system the size of one panel and/or by providing financing. This gives people to possibility to participate even if they have a low income and/or little capital. The PV-LRU makes PV systems *available* by making the abundant roof space that is present in our build environment available to participants who do not have a roof to place the system on themselves. And it could make PV systems *legitimate* in the social and political world of the participants through positive referencing and political pressure.

Third, the PV-LRU could be a good climate and renewable energy policy. A good policy is effective and compatible with overlapping policies. Because PV-LRUs can utilize money from the market, they could be more effective than subsidies and revolving funds because these utilize the limited funds of the government. And as any renewable energy or climate policy stimulating the diffusion of PV, like a subsidy on PV panels, a feed-in tariff, a revolving fund or a low interest loan, would only increase the viability of the PV-LRU, it is at least compatible with policies that stimulate the use of PV systems. Unfortunately, I do not know whether the PV-LRU would be compatible or not with policies that stimulate other renewable energy technologies or energy saving measures.

After discussing the strengths of the PV-LRU, the weaknesses were anticipated. These are important to consider, because the concept has not been applied much yet and there are important knowledge gaps that need to be acknowledged in order to deal with the eventualities that will come about each time the concept is put into practice. First, the product of the PV-LRU could simply not sell. The current demand for PV-LRUs is unknown. It is also unknown how the demand for PV-LRUs will be affected once a number of them have been realized. Second, the management of the PV-LRU might fail. A fundamental attribute of the PV-LRU is that it enables participants to own the source of the energy they use. The ultimate manifestation of this would be an executive committee whose members are participants of the PV-LRU. Two potential problems are that a) there are not enough competent people among the participants to manage the corporation, and b) the committee member are not hold accountable enough for the welfare of the corporation. In both cases the committee could mismanage the PV-LRU with as result a decline in the number of participants and ultimately bankruptcy. The solution of attracting competent people from outside the corporation might be as of yet too expensive or might lead to alienation of the participants from the corporation, thus detracting from the close connection between electricity consumers and their electricity source the PV-LRU has to offer.

3. A market to diffuse photovoltaics

This chapter analyses the Dutch PV sector from the perspective of innovation diffusion theory. It shows that the creation of a market for PV systems can strengthen the Dutch photovoltaic innovation system and thus speed up the diffusion of PV systems. It shows how the PV-LRU is compatible with the Dutch innovation system of photovoltaics and with possible stakes of the national government to maintain a strong PV industry.

Innovation diffusion theory will be used to identify the best way to increase the diffusion of PV, because this theoretic framework is holistic. It not only uses the commonly used paradigm that the innovation that delivers its service most cost-effectively will out-compete rivaling technologies on the market and therefore will diffuse. It also looks at the legitimacy of the innovation and the measure of institutional adaptation that is needed to allow for an innovation to diffuse. This means that innovation diffusion theory not only takes into account the role of technology developers and governments as subsidy providers, but also looks at the role of entrepreneurs, institutions and of governments as effectors of institutional change. The holistic approach of innovation diffusion theory allows it to be easily connected to other scientific disciplines, such as sociology or network theory. This is important for understanding the interdisciplinary topic of energy transition, which is what the diffusion of PV is ultimately about.

The subject of PV technology diffusion will be presented from three different angles, each based on innovation diffusion technology. Hekkert c.s. take the network perspective and model the diffusion of an innovation as the result of a network of actors who influence the diffusion and development of an innovation while also influencing each other in doing so. Although this framework has been used to analyze the diffusion of a couple of renewable energy technologies (RETs, this thesis is, together with the thesis of my fellow student Blommerde, the second time it is applied to photovoltaics[3]. Of the view of Hekkert c.s. it can be said that it looks at a whole technology innovation system (TIS, while Miller focuses on a part of the system. Miller describes the role of entrepreneurs in diffusing an innovation in a new market. He describes a couple of very interesting and relevant case studies of the diffusion of PV systems in rural areas that are not connected to the grid. In these cases, entrepreneurs have to overcome significant additional barriers in order to sell PV systems that are already competitive with incumbent energy technologies. The third angle is presented by Kruijsen, who also looks at the role of entrepreneurs. But instead of looking at their capacity to best market barriers, she looks at their role as product developers and how they as such involve users in the Dutch PV TIS. Kruijsens work predates the work of Miller and Hekkert c.s. with at least 5 years, yet is still complementary to the work of the later authors. The use of her work in this thesis therefore adds a forgotten strand to innovation diffusion literature[4] that proved to be particularly useful for the diffusion of renewable energy technologies.

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[3] The first time is the article *Understanding innovation system build up: The rise and fall of the Dutch PV Innovation System*, by Negro et. al. (2010).

[4] In fact, her work seems not to be cited at all, while it has been published in *Business Strategy and the Environment,* Volume 7, pp. 250-255 in September 1998.

This chapter consists of two parts. The first part aims to find the barriers to PV diffusion in contemporary Netherlands. It starts with a description of the theories of the three mentioned authors and ends with a synthesis of these theories, in which will be concluded that the creation of a new PV market is needed to further diffuse photovoltaics and that the entrepreneur is the designated actor to create this new market. Based on this, I will list the barriers that entrepreneurs face to create a PV market. The second part of this chapter describes a potential PV market and describes what entrepreneurs need to do to about the barriers from the first part to create this market.

3.1. Barriers to photovoltaics diffusion

3.1.1. Innovation diffusion theory

An invention is a new technology, product or service that is not yet being used. An innovation is an invention that is being used on a significant scale (Hekkert, Ossebaard 2010). Photovoltaics are an invention[5] that has successfully been an innovation in niches such as space travel and off-grid rural electrification. It holds the promise of becoming an innovation in the power markets based on an electricity grid: its relative price is about to become competitive with grid power and there is ample entrepreneurial activity to launch photovoltaics on the grid power markets. Yet the rate of diffusion of photovoltaics in these markets is slower than can be expected on the basis of their cost price or the amount of R&D put into it.

The framework of the *innovation system* explains this slow diffusion by modeling technological change as a system change within society. As Hekkert puts it:

> *"The systemic character of technological change explains why technological change is often a very slow process and why it is so difficult to influence. After all, the rate and direction of technological change is not so much determined by the simple competition between different technologies, but predominantly by the competition between various existing innovation systems, both fully developed and emerging ones."*
>
> —Hekkert et al. 2007, p. 415

The simple competition between different technologies would be the diffusion of the cheapest technology that answers a demand in a market. The innovation systems would be conglomerates of factors determining the competitiveness of technologies in society. The following definitions make clear what these factors are. An innovation system is:

[5] The first photovoltaic cell was invented by Fuller and Pearson in 1954 (Twiddel, Weir 2006).

> *"...The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies".*
>
> —Hekkert et al. 2007, quoting Freeman 1987

Or similarly:

> *"a system made of elements (organizations and institutions) between which relationships exist that influence the development, the application and the diffusion of innovations".*
>
> —translated from Hekkert, Ossebaard 2010, quoting Boschma, Frenken and Lambooy (2002)[6]

So innovation systems consist of agents that are involved in the diffusion of technologies and who influence each other through networks. The above definitions give a somewhat vague description of the agents. Freemans 'institutions' include agents that are not institutions in the sense of contemporary innovation literature, e.g. entrepreneurs. Boschma e.a. include 'organizations' in institutions, but this still can be more specific. Jacobsson and Johanson describe the types of agents more accurately with "actors and their competence", the networks for knowledge transfer and the institutions, such as legislation, the capital market or the educational system (Jacobsson, Johnson 2000, pp. 629-630). So institutions are societal constructs that mark the borders of what actors can do with their competences and the two interact witch each other and amongst each other through networks (Hekkert, Ossebaard 2010, pp. 24-25). This still leaves open who the actors with their competences are. Hekkert makes the following list: companies, knowledge centers, financial organizations, governmental organizations and intermediaries (Hekkert, Ossebaard 2010, p.25).

Customized forms of the innovation system framework have been used to explain different aspects of innovation diffusion. There is the national innovation system, which is often used by policy makers to compare innovativeness of countries in order to improve their own national innovation system. It includes all the institutions and actors within one country that influence technology diffusion. Then there is the regional innovation system, which focuses on the effects of a regional concentration of innovators, such as in Silicon Valley, on the number of innovations that are made in that region. And third there is the technological innovation system (TIS), not following the trend of the scaling down in the first two types, but rather the trend of technology focus: as the national innovation system is concerned with all kinds of innovations and the regional innovation system tends to focus on a coherent set of technologies, the technological innovation system focuses on a single technology. This perspective is used to understand the success or demise of an innovation and for designing policy to increase—or decrease—the success of an innovation. The definition of a technological innovation system is:

[6] Translated from Dutch: 'een systeem dat bestaat uit elementen (organisaties en instituties) waartussen relaties bestaan die de ontwikkeling, de toepassing en de diffusie van innovaties beïnvloeden'.

> *"a network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilise technology".*
>
> —Hekkert, Negro 2009, quoting Carlsson and Stankiewicz

The power of the TIS is that it models innovation as both a collective process in which institutions play an important role, and an individual process in which entrepreneurs and firms play an important role (Hekkert et al. 2007, p. 415). That allows taking other factors besides cost price and R&D effort into account when analyzing the diffusion of an innovation. Also, its relatively low number of involved agents allows the system to be analyzed like a system in the natural scientific sense: the TIS has a purpose, namely influencing the diffusion of a technology, and it can be more or less functional in doing this (Hekkert, Negro 2009, p.585). The idea that a TIS can be more or less functional is an important idea. It suggests that it can be determined what makes a TIS functional and that a TIS can be engineered (with innovation policy) to become more functional. Based on this, lists of *system functions* have been defined, which should be fulfilled to make a TIS functional. The functions are fulfilled by the actors and institutions and influence each other through vicious or virtuous circles in the networks. There are different lists of functions in innovation literature and it has not been determined yet which list fits reality best. I will use the functions as defined by Hekkert c.s., as these are the most recently defined, building on and comprised of older lists. Moreover, a follow up study checked the performance of the function list in several case studies and concluded that none of the functions was superfluous (Hekkert, Negro 2009). This makes the list of Hekkert c.s. clear while still being extensive.

3.1.2. Hekkert c.s.

The system functions of Hekkert c.s. have been formulated with special attention for RETs. They are part the concept of the technological innovation system. This paragraph describes how Hekkert c.s. work with this concept. Hekkert identifies RETs as being particularly prone to diffusion barriers for three reasons. Firstly, they are often system-wide and radical innovations, meaning that both these innovations and the system with which they can be used in society need to be developed from scratch and simultaneously. As such they have to be implemented while they are not fully developed, in a society that is fully adjusted to the use of the competing technologies and in a business environment that has large stakes against them (Hekkert, Ossebaard 2010, pp.32-40). Secondly, the benefits of RETs often accrue to society as a whole, while the individual consumer faces extra costs in both money and time. In other words, RETs are generally not attractive to buy. Thirdly, RETs often do not get progressively adopted through the five different consumer groups that innovation diffusion theory distinguishes[7]. For RETs, the innovators and early adopters are formed by particularly engaged environmentalists who stand far apart from the early minority and later adopters. It is this gap between the consumer motivations of early adopters and early minority that RETs often are not able to get across (Hekkert, Ossebaard 2010, pp 40-44). Moreover, while RETs are slow to diffuse, they are very much needed to produce energy without causing climate change

[7] These consumer groups are derived by Everett Rogers from the S-shaped innovation adoption curve. They are called, order from early to late adoption: innovators, early adopters, early majority, late majority and laggards.

through fossilogenic CO_2-emissions. It is on the basis of this problem and with the aim of finding a solution that Hekkert researches the diffusion of RETs and how to speed up this process (Hekkert, Ossebaard 2010, pp7-9).

At the basis of a TIS are actors, divided between insiders and outsiders. The insiders take the initiative and develop a new technology and persist in doing so despite set-backs. The outsiders can provide external resources such as money and lobbying power and by deciding to do that, they select the innovations that are deemed promising. Hekkert therefore calls the outsiders 'selectors' and the insiders 'initiators' (translation from Hekkert, Ossebaard 2010, p.55). They play their role in varying ratios in the four phases the growth of a TIS typically knows: development, take-off, acceleration and stabilization, resulting in an S-shaped growth curve. In the development phase initiators are most important, generating many possible technologies. In the take-off phase, one technology has become generally accepted among the initiators and is now taking on the competition with its traditional counterpart. In this phase, the selectors play an important role by building up the innovation system of the technology. In the acceleration phase the innovation system has become strong enough to promote its technology and to make itself ever stronger. And in the stabilization phase, the technology has diffused throughout society and has become a traditional technology itself. Although these phases narrate a perfectly linear process in which innovations take off and become mainstream, they do not proceed in such an orderly fashion. Hekkert stresses that the phases proceed in a chaotic, non-linear manner, in which the innovation system grows and declines continuously (Hekkert, Ossebaard 2010, pp. 57-61).

It is on this interpretation of the TIS that Hekkert builds forth by elaborating on the two central concepts: the roles of actors and the development phases. The first concept he redefines by replacing the two roles of initiator and selector with seven functions (Hekkert et al. 2007). These functions are the roles that actors should be fulfilled in a TIS to make it successful, what here pertains to the rate in which the TIS develops and diffuses its technology. The seven functions are (Hekkert, Ossebaard 2010, Hekkert et al. 2007, Hekkert, Negro 2009):

1. *Entrepreneurial activities*
2. *Knowledge development*
3. *Knowledge diffusion through networks*
4. *Guidance of the search*
5. *Market formation*
6. *Resource mobilization*
7. *Creation of legitimacy*

With the interaction between the functions Hekkert describes the second concept, the development phases, using the concept of innovation motors as described by Roald Suurs (Hekkert, Ossebaard 2010, p. 76ff). Innovation motors are feedback loops of TIS-functions, starring as vicious or virtuous circles that change the innovation system from within. There are four innovation motors, each corresponding to a development phase of the TIS: the motor of knowledge, the motor of entrepreneurship, the system build-up motor and the market motor, corresponding to respectively the development, take-off, acceleration and stabilization phase. Each motor progressively adds one or more functions to the existing motors and with that adds a new feedback loop to the innovation system, bringing the innovation system in a new development stage (Hekkert, Ossebaard 2010, p.76-78).

3.1.3. Miller

Damian Miller's book *Selling Solar* was published in 2005. It is a case study of the diffusion of small solar electricity systems, happening during the 1990s and early 2000s in rural areas in India, Sri Lanka and Indonesia that were not connected to an electricity grid. The story of entrepreneurs setting up companies that sell competitive home photovoltaic systems for power and light is relevant for this thesis, because the case of contemporary photovoltaics diffusion in electrified, grid-connected areas is arguably very similar. First it will be discussed how the work of Miller is relevant for the Netherlands now. Then Millers' main conclusions will be presented.

To show the relevance of Millers case study, this case will be compared with the case study performed during the author's internship (see Appendix: Internship report. Millers case is the following (Miller 2009). During the 1990s, small photovoltaic systems became the cheapest option for supplying electricity for lighting and radio or television to households in rural areas that are not connected to the grid. A typical small PV-system consisted of 50 W_p worth of panels and a battery, operating at 12 volts. Traditionally, kerosene lamps were used to supply lighting and car batteries or generators were used to supply electricity. A PV system became a superior and cheaper option for these technologies because of three reasons. First, a PV system was scalable and could be sized to the energy consumption of the owner. Because of this the total costs of the system were less than that of a generator, despite the fact that the generator produced electricity for a lower price per kWh. The sheer overcapacity of the generator made it costlier than a tailored PV system. Second, PV systems could provide enough power to use electrical lights which were markedly better than kerosene lamps. The electrical lamps and the PV system together were cheaper than kerosene lamps. On top of this, electrical lighting was safer and of a higher quality than the light of kerosene lamps. Third, the PV-systems saved the trouble of taking a car battery to a charging point while still providing electricity reliably.

Despite the fact that PV systems were competitive and that entrepreneurs were working to enter the rural off-grid PV market, the systems diffused slowly or not at all. Miller explains this by identifying four properties of an innovation that determine whether it will spread. These diffusion factors are attractiveness, competitiveness, affordability and availability (Miller 2009, pp.28, 39). When one or more of these properties lack, innovation diffusion is hampered. He then takes the entrepreneur as the key agent for the diffusion of the technology: the entrepreneur seeks to enter the market that the innovation has opened up in order to sell this innovation. The innovation diffuses as it is being sold. The act of entrepreneurship is then defined as making sure all four aspects apply to the innovation that is to be diffused. In other words: according to Miller, the speed of innovation diffusion is determined by the capacity of entrepreneurs to make an innovation attractive, competitive, affordable and available.

As explained, the PV systems were already competitive. So the barriers to their diffusion had to be due to lack in attractiveness, affordability and availability. Miller identified the following barriers:

- Attractiveness: image of unreliability. Miller finds that although PV systems were attractive, the image of unreliability strongly influenced the decision of potential customers to actually purchase a PV system. The solar systems were perceived attractive because they offered a secure price, social status, the main reason why PV systems were unattractive to buy, was because potential customers thought the technology to be unreliable. The most important determinant of this perception was referencing, i.e. the opinion and experience of other people. Because many of the existing PV systems were installed through government or NGO stimulation programs that neglected after-sales service, these systems broke down, thus proliferating the image of unreliability.
- Affordability: high up-front costs. Consumers need to pay 75% of the lifetime costs of a PV system at the moment of purchase. This is about 20-30% of the annual income of a typical customer. Even though the system will pay for itself in four years compared to the kerosene lamps and car batteries, many potential customers cannot afford these high up-front costs (Miller 2009, p.61).
- Availability: non-existent market infrastructure. A network of retail shops with spare parts and trained personnel is needed to reach customers and to service the PV systems after they have been installed. Such a network did not exist in the areas the entrepreneurs were active.

On top of this, the entrepreneurs had difficulties raising funds to set up their business and address the above barriers. Government subsidy programs focused on making PV systems competitive. The other diffusion barriers were not recognized and consequently the work of entrepreneurs to solve these barriers was not financially supported. Investors generally did not regard solar energy in poor rural areas as a worthwhile investment and were reluctant to lend money.

The contemporary Netherlands have a similar case: although PV systems have become a competitive alternative for power from power companies, as will be explained in paragraph 3.2.2, the diffusion of PV systems remains retarded while government subsidies are spent on making photovoltaics competitive. Entrepreneurs seeking to enter the Dutch market for domestic PV systems face similar barriers as the entrepreneurs in India and Sri Lanka did. When applying Millers four diffusion factors to the Dutch case, the following barriers can be found:

- Competitiveness. The cost price of electricity from PV systems is likely to drop below domestic consumer prices soon, as explained in chapter 2. This makes power from PV systems an economic substitute for commercially produced power for domestic consumers.
- Attractiveness. A PV system provides power for an almost fixed price during its lifetime, which is typically 20-25 years[8], thus protecting domestic consumers for a possible rise in commercial electricity tariffs due to fossil fuel scarcity or taxes on CO_2-emissions. Also, a PV system increases social status, as environmental

[8] Warranties on solar panels typically guarantee 80% of initial power output after 20 years.

friendly behavior is considered desirable in our society. From my experience in Amersfoort, an important problem is that people do not know whether they will stay in their house long enough to let the PV system pay for itself. If one moves before your system has paid itself back, you either have to sell the system with the house or take the system with you. Both options have their risks: one does not know how much the new house owners are willing to pay for the PV system and one does not know whether the house one is moving has place for a PV-system.

- Affordability. The domestic consumers face high up-front costs that comprise a significant portion of their annual income. A system that covers all of the electricity consumption of a household would cost roughly 30% of its annual income[9]. This could deter a possibly large number of potential consumers from purchasing a PV system.
- Availability. There seems to be no problem with the availability of PV systems. There are ample suppliers and installers active on the Dutch market and anybody can buy a PV system and let it be installed without hassle. The Netherlands have an excellent infrastructure, making distribution and servicing of PV systems possible. There is however a problem with the availability of the roofs to put the PV system on. From an ad hoc poll at an information meeting about making a PV-LRU, roughly two-third of the visiting local residents did not own a roof with the right orientation or did not own a roof at all. This gives a tentative indication that the majority of the people who are interested in purchasing a PV system do not have a place to put it.
- Just like in India, Sri Lanka and Indonesia, entrepreneurs lack supportive government policies. Dutch Government subsidy programs focus on making PV systems competitive, too. Again, the other diffusion barriers are not recognized and consequently the work of entrepreneurs to solve these barriers is not financially supported. Indeed, the unstable subsidy regime of the past decade has bred complacency and insecurity among potential customers and investors, making it harder for entrepreneurs to find financing and to sell their PV systems. There is a positive development here: the government is discussing whether to make the institutional change to allow for balancing before the meter (see section Abbreviations and terminology) of power from PV systems owned by households, which would significantly increase revenues from solar electricity.

These were the barriers as seen from the perspective of the entrepreneur. Miller also describes the solutions that took these barriers away in his case studies. But before proceeding to that, there is another author on innovation theory, who takes the unique perspective of product development. This fills up a knowledge gap that Millers work leaves open. As said, in Millers framework, the entrepreneur stimulates the diffusion of an innovation by engineering the innovation or its context in such a way that the innovation becomes competitive, attractive, affordable and available. What Miller does not describe, is how exactly this engineering happens. Also, Miller separates the creation of the innovation and the diffusion of it, thereby neglecting the interaction between

[9] Assuming: an electricity consumption of 3.500kWh/yr; an average income of €41.900/yr (source: CBS, *Income distribution of households 2008,* for owner-occupiers); a photovoltaic system of 4kW$_p$; and a solar system price of 3-4€/W$_p$ including both purchase price and installation costs.

innovation development and innovation diffusion. The following author, Kruijsen, acknowledges this interaction by regarding innovation development as a form of product development.

3.1.4. Kruijsen

Kruijsen published her PhD-thesis *Photovoltaic Technology Diffusion* in 1999, over a decade before the writing of this thesis. Yet her main question was the same as the one of this thesis and Hekkert's: how to accelerate the diffusion of photovoltaics in the Netherlands. With her background in industrial design, she approached this problem from the perspective of product development. This distinguishes her from Hekkert, who uses the innovation system perspective, and from Miller, who focuses on the role of entrepreneurs in innovation diffusion. Yet she does not neglect the other perspectives and weaves the product development process together with the innovation diffusion system and the entrepreneurial act. Kruijsen first develops a theoretical model for analyzing technology diffusion, then tests this model by first applying it to the Dutch and Californian PV innovation systems and then putting it into the hands of a panel of Dutch PV experts. She then draws conclusions on both the usefulness of the theoretical model and on the analysis of the PV innovations systems with this model.

The fact that Kruijsens perspective on photovoltaic diffusion is different from Hekkert and Miller, yet still is a perspective on the same topic the two other authors reflect about, pervades into her terminology. It is therefore useful to understand how the different terminologies correspond. Kruijsens 'technology' is analogue to Hekkerts 'invention' and 'innovation'. Hekkerts 'invention' is what Kruijsen describes as an unapplied technology; an 'innovation' is then a technology applied in a product. The difference between Hekkert and Kruijsen is their unit of analysis: for the first it is the innovation, while for the second it is the technology that lies behind the innovation. Hekkerts 'innovation diffusion' implicitly pools together the transition of an invention to an innovation and the diffusion of this innovation. Kruijsens 'technology diffusion' is more explicit as it defines these two processes separately as respectively 'technology application' and 'technology dissemination'. In other words: 'technology dissemination' roughly corresponds with 'innovation diffusion' and 'technology application', also called 'product development', is the definition of the transition of an invention to an innovation as it is implied in Hekkerts model.

She models technology dissemination as a diffusion network that looks like a simple version of Hekkerts TIS. The diffusion network consists of actors fulfilling one or more of the following four functions as displayed in Table 2.

Table 2 The functions in a TIS according to Kruijsen, compared to Hekkert. Both authors model the diffusion of a technology with a network in which the actors fulfill different types of functions. The 1999 model by Kruijsen contains four functions, while Hekkerts more recent model has seven. Hekkert does not quote Kruijsen in his work, so the congruency of their models is probably caused by the fact that they both use the network paradigm of innovation diffusion theory.

Kruijsens functions	Hekkerts functions
(1) technology development	(2) knowledge development (3) knowledge diffusion
(2) product development	(1) entrepreneurial activities
(3) use	(5) market creation
(4) stimulation	(4) guidance of the search (6) resource mobilization (7) creation of legitimacy

She then models function (2) product development in more detail with a model of technology application. She models this as a product development process consisting of four processes and, most importantly, two external resources: user wants and technological options.

Finally, the innovation diffusion model and the product development model are connected with each other using a concept from the world of product development: object worlds. In Kruijsens words:

> *"The integration of [technology] dissemination and application is possible when the actors active at both levels are able to understand each other, thus enabling knowledge transfer. The actors at the level of the product development process and their interactions during the product development process can be analysed by describing the object worlds of these actors (...). Object worlds will also be used (...) to analyse the actors at the network level. This can be done because the interactions at the diffusion network level aimed at technology diffusion can be compared to the interactions at the product development level. Both the network interactions and the product development interactions are negotiations across the object worlds of the participants of these interactions."*
>
> —Kruijsen 1999, p.64.

There is no explicit description of what an object world is, but the author understands it to be the following:

> *An object world is the total of the meanings, issues and values a person attributes to a concept.*

The linking of object worlds happens through interaction. Before interaction can take place, both actors need to make mutually compatible interfaces. Kruijsen gives a concrete description of this in the case of connecting technology developers with product developers, but it applies to all interactions between the four different network functions:

> *"The technology developers should make themselves understandable for the product developers before any interaction in terms of knowledge transfer can take place. The actors do not have to speak the same 'language', they do not have to use the same jargon or terminology, but they should be able to understand the others in their environment."*
>
> —Kruijsen 1999 p. 66

The connection between the innovation system and the product development system is important because it is this connection that enables market creation. The product is the link between supply and demand, i.e. suppliers and users. The entrepreneurs from Millers case study are the actors that with their work make this connection between innovation system and product development and with that stimulate photovoltaics diffusion. In her interviews with actors from the Dutch photovoltaic innovation system, Kruijsen finds that "[a]ll interviewees strongly emphasised the need for market development." The author concludes that the innovation network focuses too much on technology development and too little on market development. She also concludes that user function is not connected strong enough with the three other network functions to develop a strong market.

Kruijsens empirical study yielded many more conclusions than the two stated above. Her work includes recommendations regarding market stimulation policy, product development and the role of a branch organization. These are mostly outdated, either because the recommended actions have actually happened in reality or because the current situation has changed too much. Kruijsen worked with a situation in which subsidies were still needed to create a market for photovoltaics and in which the purchase and installation of a PV system was not common practice. As described in this thesis, the current situation allows for market creation without subsidies and the purchase and installation of a PV system has become common practice.

3.1.5. Barrier overview

Since Chapin and Fuller developed the first solar cell in 1954 (Twiddel, Weir 2006), large efforts have been spent on making these cells more efficient and/or cheaper. Accordingly, the scientific and political discourse on the status of solar energy as a viable alternative to fossil energy has largely been about reducing the cost price of the renewable energy source. Miller and Kruijsen point out that technology developers, governments, investors, and potential customers are fixated on lowering the cost price of solar power to the extent that they forget to check whether prices have actually gone low enough. The goal of lowering the cost price of photovoltaics is to make the technology competitive with incumbent energy technologies. This thesis is based on the fact that, in all likelihood in the short term, the cost price of photovoltaic electricity will drop below the market price for grid electricity for Dutch households. This means that cost price will no longer be the main diffusion barrier for photovoltaics in the built environment for small consumers and that speeding up photovoltaics diffusion becomes a societal instead of technological problem.

From the perspective of the TIS of photovoltaics, the absence of a market is now the main diffusion barrier. This has been independently concluded by Kruijsen in 1999 and Hekkert c.s. in the second half of the 2000s. The Netherlands are strong in R&D and despite the absence of a local market, host a couple of PV cell producers. In other words: the diffusion motors of knowledge and of entrepreneurship are present. But the TIS needs to grow stronger if it is to become independent from subsidies. This entails the creation of a market. The market can be an important driver of innovation diffusion in addition to the national government. To form a market, there has to be supply and demand. The demand needs to be articulated to enable suppliers to fulfill this demand. And suppliers need to develop products and services with PV systems for which there is a demand. Kruijsen shows that the network function of product development is crucial to make the link between supply and demand in order to create a market.

Entrepreneurs are per definition working to connect supply with demand and often take the role as product developers. This means that they can play a central role in creating a market for PV systems owned by households. Consequently, entrepreneurs can play a central role in the diffusion of photovoltaics. So any barriers that make it difficult for entrepreneurs to succeed, are barriers to create a market, and therefore are barriers to the diffusion of photovoltaics. Using Millers case studies of the off-grid PV market in rural areas in India, Sri Lanka and Indonesia, I argue that entrepreneurs working to enter the Dutch PV market for households need to deal with the following barriers:

- PV systems are not very affordable because of their high up-front costs;
- A possibly substantial part of the potential users does not own a roof that is fit for a PV system or do not own a roof at all, for example when they are renting or when they live in an apartment;
- PV systems are unattractive because people might move to another house before the PV system on their current house has paid itself back;
- Government policy is and has been unfavorable for entrepreneurs because it focuses on making photovoltaics competitive, thereby ignoring the non-price barriers that entrepreneurs face and breeding complacency and insecurity amongst investors and customers with its intermittent subsidy schemes.

3.2. A new market for home PV systems

The published work of Hekkert c.s., Miller and Kruijsen give clues to what can be done to overcome the diffusion barriers that are described in section 3.1. Together with the experience from the case study on Amersfoort a coherent picture on which actors need to do what emerges. This picture will be described in the form of a discourse between the three authors and the author of this thesis.

3.2.1. The need for a market

Hekkert c.s. see innovation diffusion as a revolution against an established technology led by advocacy coalitions:

> *"In order to develop well, a new technology has to become part of an incumbent regime, or it even has to overthrow it. Parties with vested interests will often oppose to this force of 'creative destruction.' In that case, advocacy coalitions can function as a catalyst; they put a new technology on the agenda (...), lobby for resources (...) and favorable tax regimes (...), and by doing so create legitimacy for a new technological trajectory."*
>
> —Hekkert et al. 2007, p. 425

This perspective has interesting consequences for the diffusion of PV systems in the Netherlands. First, creating legitimacy is the ultimate solution for promoting innovation diffusion, superseding—but not obsolescing—technology development. As I understand, for an innovation to be legitimate means that it has become a commonly accepted alternative for the incumbent technology in society. In the case of PV systems, this would mean that the national government sees them as an important asset for the country its energy system and that customers see them as a reliable and useful alternative to other energy technologies. Second, legitimacy is created actively created and broken down. According to Hekkert c.s., this is done by advocacy coalitions. The author understands this to be changing groups of one or more actors that in principle can come from all the seven system functions. Often the advocacy coalitions consist of typical combinations of functions called innovation motors, as described in paragraph 3.1.2.

So according to the framework of Hekkert c.s., to increase the diffusion of photovoltaics, the technology must become more legitimate. And to create more legitimacy, more innovation motors must start running in the innovation system. A quick glance at the current situation suggests that both the motor of knowledge and the motor of entrepreneurship are running: both R&D and entrepreneurship are strong in the Netherlands. The next innovation motor in line, the motor of system build-up, follows from its predecessor by the addition of the market function to the innovation system. This is consistent with the emphasis both Kruijsen and Miller lay on the necessity of a market for PV to stimulate the diffusion of the technology. Therefore, I argue that the creation of a market for photovoltaics in the Netherlands is the best way to speed up the diffusion of photovoltaics.

3.2.2. The market of PV systems for households

The cost price of photovoltaics is on its break-even point with electricity prices including taxes paid by households. Turn-key prices of photovoltaic systems in 2009 were estimated to be 3-4,5 €/W_p, corresponding to generation costs of 0,33-0,50 €/kWh(Holland Solar 2009). This is widely expected to be declining. Small consumer prices have always been the highest, which is consistent with the assumption from economic theory on markets that larger users have more power to negotiate a sharper price. Another reason for domestic prices to be higher, is the taxes of 0,1121 €/kWh, against <0,0408 €/kWh for users above a 10.000 kWh/year use (Rijksoverheid 2010b, p.26). So the declining photovoltaic electricity price will reach parity with the grid electricity price for small consumers soon. This opens up a potential market that for the first time in the Netherlands is so large it can become main stream. In principle, domestic households can generate their own electricity that is not only cost-competitive with commercial grid electricity, but also out-competes commercial grid electricity in price stability. This makes PV systems attractive for three types of potential customers: households, public housing corporations and regional governments.

Households, with their average annual electricity use of 3500 kWh, typically fall within the category of small electricity consumers. They pay the highest energy tax and therefore will be amongst the first to benefit from self-generated solar electricity. A study by Jager queried a group of people that were interested in installing a photovoltaic system using a grant by the city of Groningen, the Netherlands, for their motivations in doing so (Jager 2006). The query posed nine motivations, which then the interviewees needed to rate with a score from 1 (unimportant) to 5 (very important). The four most important motivations were, ranked from important to unimportant, 'the contribution to a better natural environment', 'the grant on offer', 'the increased value of my home' and 'the central organization of the request for a grant'.

Expenditures on heating and lighting have been increasing, also relative to total expenditures of households (see Figure 4). Moreover, the lower the income of a household, the higher the portion it spends on heating and lighting. In the case that electricity prices continue to rise, the costs for the consumed energy will supersede the rental fees, starting with the lowest incomes. Households with the lowest incomes typically live in public housing. Public housing corporations have an interest in keeping their houses affordable for their customers and therefore have an interest in keeping the living costs for energy from rising as fast as they have been doing. This can be achieved with renewable energy technology, of which the electricity generation costs remain level during the lifetime of the renewable energy technology that is applied. In the case of photovoltaics, this is over 20 years. It is important for the public housing corporations that an LRU allows the total rents to be equal or lower than would be the case if the electricity came from commercial grid-operated companies.

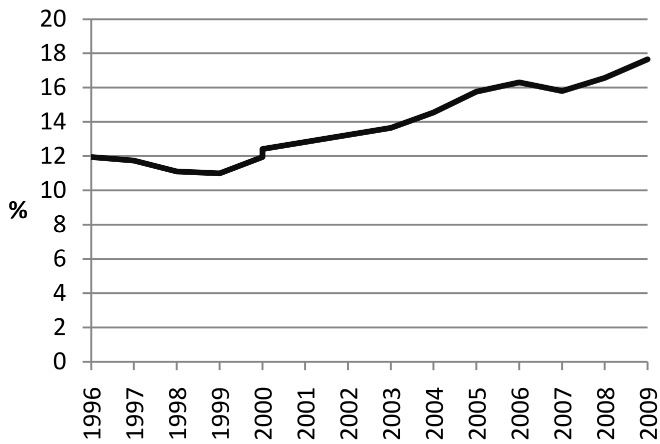

Figure 4 Household expenditures on warming and lighting as a proportion of total housing expenditures. The double data point for the year 2000 is an artifact caused by a change of an indicator definition: the results of the old and new definition are both plotted here. Source: *ref CBS 'Bestedingen; beknopte indeling naar huishoudkenmerken'.

Many municipalities and provinces have their own climate targets in which local renewable energy generation plays an important role in achieving local CO_2-emission reduction targets. Abundantly diffused PV systems pave the way to reach these targets while at the same time striving for affordable public housing and creating large support amongst stakeholders for implementing renewable energy technologies. PV systems are specifically fit for cities, as roof space is the most available space in these areas and as photovoltaics are relatively unobtrusive to their environment.

3.2.3. The entrepreneurs

The work of Kruijsen and Miller give the actors that need to be involved in creating this market. As in this market the PV systems are already competitive with the energy technologies that they are to replace, entrepreneurs are the actors by choice to diffuse photovoltaics. Entrepreneurs can tap the financial recourses that lay dormant in the potential customers and investors, and that are much larger than the financial resources of the government layers. Miller shows that the entrepreneurs have to make an innovation competitive, attractive, affordable and available in order to diffuse it. PV systems are already competitive. So these entrepreneurs have to do the following to open up the market for PV systems:

- Make the PV systems more attractive: take away the necessity to own the panels for their full 25 year-plus life span in order to benefit from them;
- Make the PV systems more affordable: find a solution that releases the customers from the burden of the high up-front costs;
- Make the PV systems more available: find a way to allow people to own and exploit a PV system on roofs or property of a third party;
- Based on Hekkert c.s. creating legitimacy can be added:
    - Show investors and households that PV systems can indeed be economically exploited in an easy, sound and reliable way;
    - Get the national government to renounce the energy taxes on solar electricity that is produced by home-owned panels on third-party property.

According to Kruijsen, product developers are the actors of choice to create a market. This is because they are the ones that can develop a product that complies with the above criteria. They can make the connection between the available photovoltaic technologies and the wishes and needs of the potential customers. In doing so, they do exactly what Millers entrepreneurs would do. In fact, Kruijsens product developers are the same actors as Millers entrepreneurs. So the entrepreneurs have to open up the market by developing a PV product that solves all the barriers and they will do so by connection customers needs with technology developers and producers. To do this, they need to make interfaces with technology developers and especially with customers, i.e. communicate with them in mutually understandable language, referring to mutual values and ideas. Kruijsen shows that the customers, or users, are the group that is the least connected to the rest of the innovation system. In fact, Hekkert c.s. only mention users implicitly by defining the market function in an innovation system. To the author’s opinion the users should be mentioned explicitly in the innovation diffusion process.

Table 3 The most important diffusion barriers that entrepreneurs face on the Dutch market for PV systems for households, based on the case study on the solar initiatives in the municipality of Amersfoort. If these barriers are overcome, a market is created that can exist without government subsidies and the diffusion of photovoltaics can be expected to increase. Based on the case study in the author's internship.

Diffusion barrier	Solution
risk of moving before pay-back time has been reached	lease contract or facilitate the resale of PV system
high up-front costs	lease contract or low interest loans
half of households does not own a fit roof	placement of PV system on third-party roof
energy tax is levied on power from PV system on third-party roof	law change

3.3. To conclude

Innovation diffusion theory has been used to explain how the rate of diffusion of photovoltaics in these markets can be slower than can be expected on the basis of their cost price or the amount of R&D put into it. Based on innovation diffusion literature and the description of the Dutch innovation system made in chapter 3, it was concluded that the scientific and political discourse are fixated on lowering the cost price of solar power to the extent that they forget to check whether prices have actually gone low enough. As the cost price of photovoltaic electricity at the break-even point with the market price for grid electricity for Dutch households, cost price will no longer be the main diffusion barrier for photovoltaics. The framework of the technical innovation system (TIS) explains this by modeling technological change as a system change within society in which both the collective processes within institutions and the individual process of entrepreneurship play a role.

I have used the TIS model of Hekkert c.s. as starting point. In this model, the initiators and selectors are modeled with seven system functions, which act together in typical patterns forming positive feedback loops stimulating innovation diffusion. These are called innovation motors. There are four innovation motors which correspondent with the four development phases of an innovation system: development, take-off, acceleration and stabilization. Each motor progressively adds one or more functions to the existing motors and with that adds a new feedback loop to the innovation system, bringing the innovation system in a new development stage. A rough analysis of the current situation was made, suggesting that both the motor of knowledge and the motor of entrepreneurship are running. Then, it was concluded that to strengthen the PV TIS and increase PV diffusion, the next innovation motor in line should be started. This is the motor of system build-up, which follows from its predecessor by the addition of the market function to the innovation system. It has been shown that this is consistent with the conclusions of two other literature sources that are independent of Hekkert c.s.

I have concluded that the fact that the cost price of photovoltaics is on its break-even point with electricity prices including taxes paid by households, opens up a potential main stream market for PV systems consisting of households, public housing corporations and regional governments. Based on Miller and Kruijsen, entrepreneurs can be defined as the key actors for creating this market and defined two roles these entrepreneurs need to fulfill. First, they have to be problem solvers. Miller shows that the entrepreneurs need to make an innovation competitive, attractive, affordable and available in order to stimulate its diffusion. Based on Hekkert c.s., the property of legitimacy has been added. As PV systems have become competitive, the entrepreneurs have to solve the following problems:

- Make the PV systems more attractive: take away the necessity to own the panels for their full 25 year-plus life span in order to benefit from them;
- Make the PV systems more affordable: find a solution that releases the customers from the burden of the high up-front costs;
- Make the PV systems more available: find a way to allow people to own and exploit a PV system on roofs or property of a third party;
- Give more legitimacy to photovoltaics;
    - Show investors and households that PV systems can indeed be economically exploited in an easy, sound and reliable way;
    - Get the national government to renounce the energy taxes on solar electricity produced by home-owned panels on third-party property.

Second, the entrepreneurs have to be product developers, connecting the technological possibilities to the user needs and demands. Kruijsen shows that entrepreneurs therefore need to be connected to both the developers and users of PV systems. She also shows that users are the function that is least connected to the rest of the innovation system. Hekkert c.s. only implicitly include users into the innovation system through the function of the market. If a market is to be created, the users need to be involved to successfully develop products with PV systems that sell, i.e. diffuse. To do this, the entrepreneurs need to communicate with the users in mutually understandable language, referring to mutual values and ideas.

4. The current situation in the Netherlands regarding photovoltaics

This chapter serves a threefold purpose: it gives an overview of the current situation in the Netherlands regarding renewable energy sources in general and photovoltaics in particular; it establishes solar energy as an indispensible part of an energy mix that serves both climate– and energy security targets; and it also shows that the use of photovoltaics should be stimulated to a higher degree than happened. First, characteristics of Dutch energy production and – consumption are given. They help to place other data in perspective and will show the role of photovoltaics in the current energy mix.

Second, the relevance of photovoltaics for the period up to 2020 is discussed: climate– and renewable energy goals of the Netherlands and the EU for the year 2020 are described and compared; the policies that are enacted to reach these goals are described insofar as they pertain to renewable energy sources and photovoltaics. Furthermore ; and a forecast study on the expected results of these policies in 2020 is used to provide a prediction on which goals will be met; this also servers and to show that photovoltaics might contribute more in emission reductions in the build environment.

Third, the relevance of photovoltaics for the period after 2020 is discussed. Long-term goals for climate and renewable energy and a back-casting study based on these goals predict that photovoltaics will become one of the main renewable energy sources and is indispensible for obtaining an electricity mix with more than 40% renewable sources in Europe. In addition, an overview of the potentials of solar–, wind– and biomass electricity in the Netherlands, shows that solar electricity has a large potential even theretherein this country.

Finally, the case of the diffusion of off-grid photovoltaics in un-electrified rural areas in the 1990s and early 2000s is used to show that in order to reach a large scale diffusion of photovoltaics in the Netherlands, barriers other than the price of solar electricity should be addressed already before the technology reaches grid parity.

4.1. Overview current situation renewable energy in the Netherlands

To provide a background for the climate and energy goals discussed in this chapter, statistics on electricity production and CO_2 emissions and –emission reductions are provided here. These statistics are a selection of the data provided by the Central Bureau of Statistics (CBS, the Netherlands and focus on renewable electricity technologies, especially solar electricity technology. For maximum reliability, only the definite data on CBS is used, thus excluding the preliminary data for 2009.

In 2008, 124 TWh of electricity was consumed[10](CBS 2010a, of which domestic renewable power sources provided 8,93 TWh or 7,46%[11](CBS 2010b). The largest part of this was generated with by wind energy and biomass. Solar energy produced 38 GWh of

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[10] The total electricity consumption *includes* the electricity that is used during the production of electricity.

[11] The percentage is calculated using the total electricity consumption *excluding* the electricity that is used during the production of electricity.

renewable electricity with 57 MW_p of installed capacity[12](CBS 2010d). The largest part, 34 GWh, 90%, was produced by on-grid installations that were not owned by power companies.

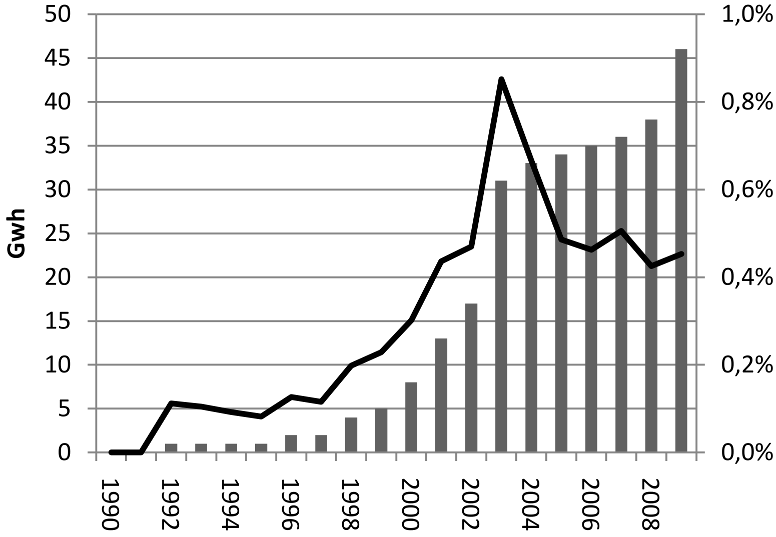

Figure 5 Solar electricity production compared to total renewable electricity production in the Netherlands over the years. The columns show the solar electricity production in GWh; the line shows the proportion of solar electricity production in the total renewable electricity production. Source: *ref CBS (2011) Renewable electricity; domestic production, imports and exports.

This means that 0,43% of the total renewable electricity production was from solar energy. Over the years, the amount of produced solar energy has increased., see Figure 5. However, its proportion to the total produced renewable electricity first increased and then decreased, meaning that photovoltaics at first had a higher growth and then a lower growth relative to other renewable energy sources.

Emissions of greenhouse gases amounted to 206,8 Mton CO_2-eq in 2008, which is 4,0% less than the emissions in base year 1990. The electricity companies emitted 38% of this (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, p.30,177). Electricity from renewable energy sources prevented the emission of 5,9 Mton CO2-eq, of which photovoltaics prevented the emission of 0,023 Mton CO_2-eq in 2008[13](CBS 2010c).

4.2. The relevance of photovoltaics up to 2020

4.2.1. Government goals for greenhouse gas emissions and renewable energy in 2020

The Dutch government has the following goals for greenhouse gas emission reduction and renewable energy use for 2020 (Ministry of General Affairs 2007, p.34): 30% greenhouse gas emission reduction compared to 1990-levels; improve energy efficiency by 20%; and 20% avoided use of fossil energy sources according to the substitution method[14]. An intermediary goal of 9% renewable energy according to the substitution method is set for 2010. Specifically for electricity from renewable energy sources a target

[12] The installed capacity is determined in December of each calendar year. When calculating the ration of produced electricity to the installed capacity, there is a negative bias, because the December value is higher than the annual average, because of continuous growth of capacity.
[13] The renewable electricity taken into account in this table comes from domestic renewable energy sources.
[14] The EU and the Dutch government measure renewable energy use with different methods: the 'final use'– and 'substitution' method respectively. Therefore, the EU target translates into a Dutch target of about 1 %-point higher and vice versa. See Energiecentrum Nederland; and Planbureau voor de Leefomgeving 2010, p.130 for more information.

figure of 55 TWh_e is set, which is 35% of the predicted electricity use in 2020. (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, pp.78-79).

The EU sets different climate and energy goals for the Netherlands. By 2020, the Netherlands are required to cut their greenhouse gas emission with 16% of the 2005 level (European Union 2009b, p. 147, i.e. 17% of the 1990 level. Also, renewable energy consumption is required to be 14% of the gross final consumption of energy by 2020[15] (European Union 2009c, p.46).

4.2.2. Dutch policies for emission reduction and renewable energy

Untill the first of January 2011, the following policies were in place: the Dutch Schoon & Zuinig[16] program, written by the Ministry of Housing, Spatial Planning and the Environment (VROM, formulates the policies to reach the climate– and energy goals (Ministry of VROM 2007). The policies treated here apply to renewable energy and households, as these policies affect the amount of photovoltaics installed. Firstly because they directly subsidize the production of solar electricity; secondly, because they indirectly subsidize the production of solar electricity through rewarding reduced fossil energy consumption by households. For more information on other active policies in the Schoon & Zuinig program, see Appendix B in Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010.

For stimulating renewable energy production, the Stimuleringsregeling Duurzame Energie[17] (SDE) subsidy is enacted. This feed-in subsidy gives a premium on electricity from renewable energy sources, that is equal to or smaller then the difference between the cost pricepricecost of the renewable electricity and the consumer price of general electricity, of which the first mentioned is estimated by Energie Centrum Nederland[18] (ECN) on a periodical basis and the second mentioned is determined by the electricity market. The minister of Economic Affairs determines the amount of subsidy money available and the order in which the subsidy applications are granted, i.e. by order of application or by tender. This and the price estimation by ECN is done separately for each category in the SDE (Tilburg et al. 2008, p.10). The categories with their allotted subsidy budgets can be found in Figure 7.

[15] Emissions in 2005 were 212,1 Mton CO_2-eq (Brandes, Vreuls 2007) and 215,4 Mton CO_2-eq in 1990 (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010).
[16] 'Clean & Efficient'.
[17] 'Stimulation of renewable energy'.
[18] 'Centre of Energy Netherlands'.

For stimulating energy efficiency in newly build– and existing households, an obligatory energy efficiency norm and the covenantconvenant 'Meer met Minder'[19] are enacted, respectively. Both policies aim to decrease the use of fossil energy sources in households, which is measured with the Energy Performance Coefficient (EPC). The lower the EPC, the less fossil energy a household will consume, assuming a standard lifestyle of the occupants of the house its occupants. In the covenant 'Meer met Minder', agreed upon by the government, energy companies, installation companies and construction companies, house owners are stimulated to voluntarily lower the EPC of their house (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, p.45). In practice this means that energy inefficient houses benefit from relatively cheap isolation measures, while energy efficient houses might install relatively expensive photovoltaic panels.

By lowering the allowed EPC, the government forces houses to cut their fossil fuel energy

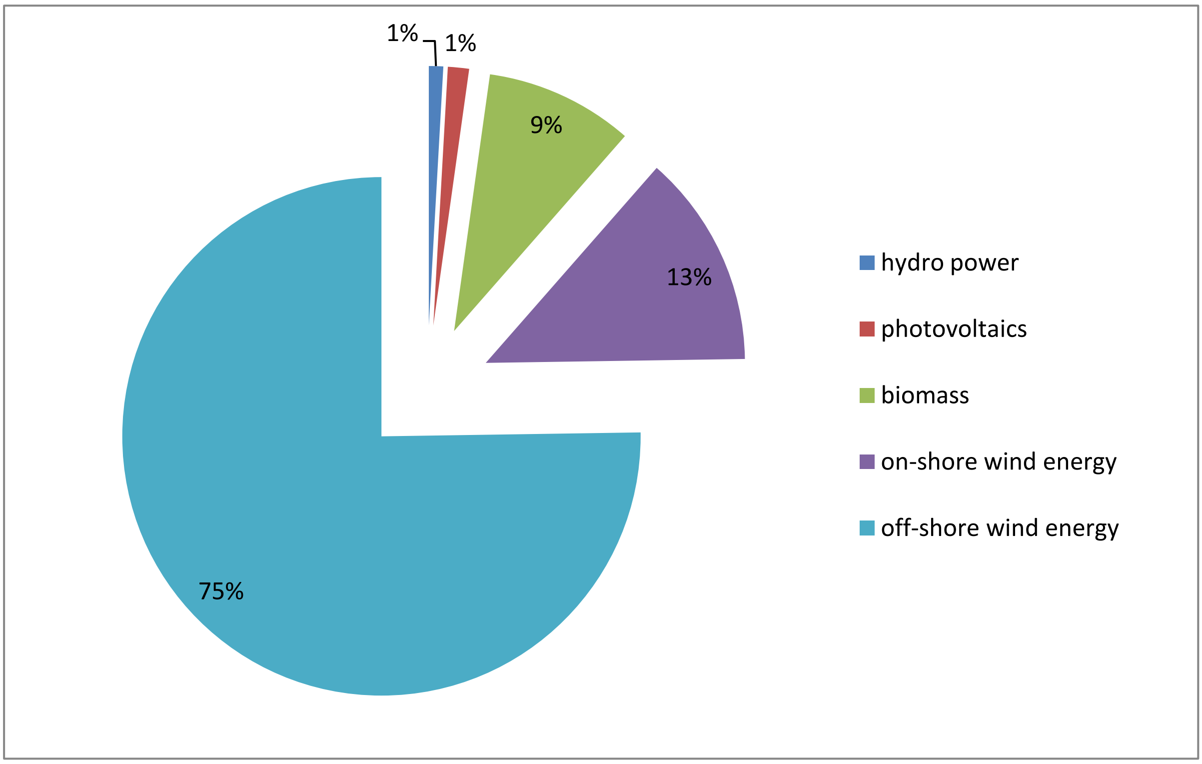

Figure 7 Allotment of SDE subsidies in 2010. The five main categories that fall under the SDE subsidy are displayed with their subsequent maximum available subsidies for 2010. The total available subsidy is 7.044,- mln€. Sources: www.senternovem.nl and Tamminga 2010.

consumption. For newly build houses the norm for EPC[20] will be ≤0,6; ≤0,4 and 0 in 2011, 2015 and 2020 respectively[21] (Den Dullk 2010)(Ministry of VROM). In practice, an EPC lower than 0,4 can only be obtained by using a renewable energy source in the house (Den Dullk 2010). This means that the placement of solar boilers or –panels on new houses will be necessary from 2015 onwards. A forecasting study on livelihood the living

[19] 'More with less'.
[20] The Energy Performance Coefficient (EPC) indicates how much energy a house is using compared to a reference house that represents the state of houses before energy saving measures became commonplace. The scale is from 0 to 1, zero meaning the house is energy neutral and 1 meaning the house uses the same amount of energy as the reference house.
[21] A house that uses no energy from fossil sources for heating, a 'passive house', has an EPC of 0,4.

environment in the Netherlands predicts that on average between 30.000 and 120.000 houses are will be build every year up to 2020. Assuming that each house will have 24m^2 of solar panels (Den Dullk 2010), this would entail the installation of 72 to 288 MW$_p$ of solar panels each year for the period 2015-2020. To give a rough estimate with no predictive value except that it gives a good indication of the scales of magnitude that will be involved: this annual installation of more than the 2008 installed capacity would lead to a production of 1,2 TWh of solar electricity by 2020[22], which would be 0,2-0,9% of the 130 TWh electricity consumption that is predicted by ECN in their evaluation of current climate– and renewable energy policies (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, p.65).

[NB: The reality of the Dutch national renewable energy and climate policies changed at the time this thesis was finished. Remaining time for editing allows only a short description of the new policy. The SDE subsidy as described below stopped at January 1st 2011. Starting at July 1st 2011, the new policy called the SDE+ is open for application (Rijksoverheid a). From a letter of the minister to the Lower House the following can be derived (Rijksoverheid b): The SDE+ allows renewable energy technologies that have a cost that is 15 €ct/kWh or less, as probably will be determined by the ECN, to apply for the subsidy. Applications will be accepted in four phases allowing the renewable energy technologies (RETs) with the lowest cost price to apply in phase one and the RETs with the highest allowed cost price of 15 €ct/kWh to apply in phase four. When each phase will start is not clear, but a period of 13 weeks per phase is indirectly mentioned as a norm. The money for this subsidy will be drawn from a raise on the energy tax and partly from a tax on coal and gas. The budget for 2011 will be 1,5 billion euro. Small photovoltaic systems of <15kW$_p$ are not eligible for the SDE+ subsidy. All in all this change in policy does not diminish the strength of argument that national policies are not beneficial for the photovoltaic sector in the Netherlands.]

4.2.3. Expected results in 2020

To determine if the current climate– and energy policies bring the goals for 2020 within reach, the ECN has, by orders of the Ministry of VROM, performed an intermediate policy assessment (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010). This forecasting study predicts climate– and energy parameters for 2020, based on three scenarios that assume respectively 1) no new policies, 2) a continuation of the current policies and 3) the continuation of current policies together with the implementation of intended policies, of the ‘Schoon en Zuinig’ program.

The report predicts that 44 Mton CO_2-eq of emissions will be reduced in the scenario with full policy implementation (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, p.136), i.e. the scenario with the most emission reductions. Of this, 32 Mton CO_2-eq would be reduced in sectors that fall under the European Trading System (ETS) for carbon emissions and would as such not contribute to the national

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[22] Assuming generation intensity of 100W$_p$/m^2 and capacity factor of 0,8 kWh/W$_p$/yr. Also assuming that panels will deliver in the same year that they are installed, that all the panels are installed instantaneously at the beginning of each year and that in 2020 no new panels will be installed.

target of 30%[23]. The other 12 Mton CO_2-eq would be reduced in non-ETS sectors, of which most in the traffic sector due to reduced fuel consumption (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, fig. 7.10).

In the maximum reduction scenario, not all reduction goals are met. The scenario predicts a reduction of 16-24% for ETS and non-ETS sectors together. But, the ETS sectors reductions are determined by the EU and thus not influenced by Dutch policy. The scenario predicts a less dan 50% chance the NL goal will be met; there is a larger than 50% chance the EU goal will be met (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, pp.125,132).

The present report cannot say whether the Netherlands will meet the EU target of 14%, final use method, or not. However, it does conclude that at least the current and intended Schoon & Zuinig program has to be enacted to have a chance in reaching the EU goals. The Dutch target of 20% renewable energy will not be met: the predictions are 2-3%, 6-7% and 13-16% renewable energy by 2020 for scenarios 1, 2 and 3 respectively (Energiecentrum Nederland, Planbureau voor de Leefomgeving 2010, p.131).

4.3. The relevance of photovoltaics after 2020

This thesis assumes that in the medium and long term, solar power could play an important role in the Dutch energy system; this section describes factors that warrant this assumption.

4.3.1. Long-term goals and scenarios for climate and renewable energy

Long-term goals for climate and renewable energy are more like intentions and differ in that respect from the more quantified goals for 2020. Although they do not offer certainty, they do offer a common vision, facilitating cooperation and consistency over time. As such they are of importance to future policies now.

The European Council "recognises that (…) developed countries as a group have to take the lead by reducing their emissions below 1990 levels (…) by 25 to 40% by 2020 and by 80-95% by 2050" (European Union 2009a, paragraph 12). The advisory nature of this text shows from the difference between the 2020 goal mentioned here and the actual target of 20%. Nevertheless, the advice has been taken as a norm: the Ministry of Vrom mentioned the long term goal of 80-95% greenhouse gas emission reduction in a speech of the minister (Ministry of VROM).

[23] This is because the maximum allowed CO_2 emission under the ETS is determined at European level to be 21% reduction to 2005, which would mean for the Netherlands a reduction of 75 Mton CO_2-eq in the sectors that fall under the EPS. When actual emissions in the Netherlands would be higher or lower than this target, the difference will be traded under the ETS.

The back-casting study Roadmap 2050, which was initiated by the European Climate Foundation (ECF), gives scenarios of how the 80-95% emission reduction goal would have shaped the energy sector of Europe by 2050. It has three scenarios, differing in the mix of carbon neutral energy sources. In all its scenarios, 95% decarbonization of the power sector was assumed (European Climate Foundation 2010, p.41). The Roadmap optimizes its scenarios around a number of parameters, amongst which technology costs, infrastructure costs, grid reliability and political feasibility. Therefore a wide range of renewable energy technologies is applied in all three scenarios. It can be concluded that in the scenarios with the largest share of renewables in the electricity mix, photovoltaics are indispensable. There are two points in the ECF report that lead to this conclusion. First, in the baseline, the 34% renewable electricity comes largely from hydro, biomass and wind: photovoltaics would have a share of 1%; In the scenarios with 60 and 80% renewables, the Roadmap predicts a much larger share of 12 and 19%, respectively (European Climate Foundation 2010, p.50). Second, solar and wind energy production are negatively correlated over a day and over a year. If both technologies are included in the electricity mix, production fluctuations of the two technologies are predicted to cancel each other out (European Climate Foundation 2010, p.61).

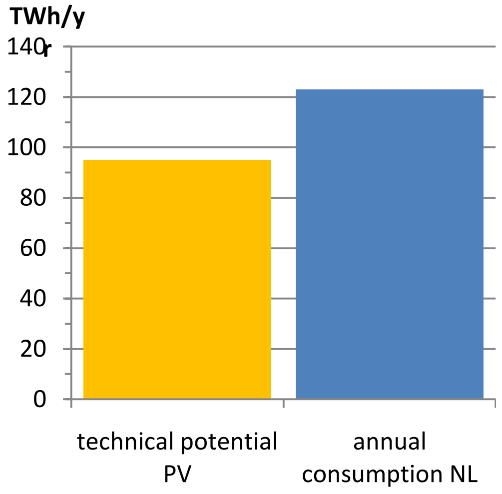

Figure 8 Potential for producing PV electricity in the Netherlands (Boston Consulting Group 2010) compared to the Dutch electricity consumption in 2008 (CBS 2010a). The potential is somewhere in between the technical and the economic potential.

4.3.2. Potential of solar, wind and biomass for electricity

The technical potential of solar is large and largely unexploited. Figure 8 shows the potential of PV electricity in the Netherlands compared with the total electricity consumption in 2008. (Boston Consulting Group 2010). The sources for these estimates are: a study by ECN for solar; two studies, by ECN and the European Environment Agency (EEA), for off-shore wind; an ECN report, an ECN expert opinion and a study by the engineering bureau Procede Biomass for biomass; and a benchmark based on population density for on-shore wind.

4.4. To conclude

Photovoltaics make up a very minor part of the Dutch renewable energy mix. The total Dutch electricity consumption in 2008 was 124 TWh, of which 7,46% was produced by domestic renewable energy sources. Renewable electricity came mainly from wind and biomass: only 0,43% of the Dutch renewable electricity production was from photovoltaics. Subsequently, photovoltaics prevented the emission of only 0,023 Mton CO_2-eq on total emissions of 206,9 Mton CO_2-eq.

The Dutch climate– and renewable energy targets for 2020 are more ambitious than the analogue targets set for the Netherlands by the European Union. The Netherlands strife for a 30% greenhouse gas emission reduction compared to 1990-levels and a production of renewable energy of about 19% of the gross final consumption of energy; the European Union requires the Netherlands to achieve a 17% greenhouse gas emission reduction and the production of 14% of renewable energy, according to the same definitions. Given the current and intended climate– and energy policies of the Netherlands, the emission goal of the Netherlands is less than 50% likely to be met; its European counterpart has a >50% chance of succeeding. Similarly, the Dutch renewable energy target will not be met, while it is unclear whether the European target will be met.

The European and Dutch climate– and renewable energy policies are enacted under the 'Schoon & Zuinig' program under the coordination of the Ministry of VROM. Of these policies, the SDE subsidy and the EPC norm apply to the diffusion of photovoltaics. The SDE subsidy is a feed-in tariff that fills the gap between the market price of electricity and the cost price of renewable electricity. Its budget amounted to 7.044,- mln€ in 2009, of which 1,3% was reserved for photovoltaics. The EPC is a norm for fossil energy use of households. Newly build houses are required to comply with a progressively strict EPC which is expected to make the placement of solar boilers and –panels a necessary addition to energy efficiency measures from 2015 onwards. The fossil fuel consumption of existing houses is reduced by voluntary participation of house-owners in the 'Meer met Minder' covenant. Here, the EPC serves as a reference for the energy efficiency of a household.

The long term climate target is unofficially agreed to be an 80% reduction of greenhouse gas emissions by 2050: both the European Council, the Dutch minister of VROM and the ECF back-casting study *Roadmap 2050* use this goal. The Roadmap 2050 scenarios assume that a 95% decarbonized electricity sector is required to reach this goal. In the scenarios where this is made possible largely by renewable energy sources, photovoltaics are indispensible. Also in the Netherlands, photovoltaics have a large potential that needs to be tapped to reach a high share of renewable energy production. Reaching a high share of renewable energy sources is pivotal for obtaining both climate– and energy security targets.

5. Conclusion

This chapter provides the main line of reasoning of this thesis. Here, the main and secondary research questions are answered. The secondary research questions will be answered first. Then, the main research question is answered with referrals to the answers on the secondary research questions. And finally, this thesis is critically reflected upon to ensure that the results are understood in proper context and to point out the knowledge gaps that remain.

5.1. Answers to the secondary research questions

5.1.1. The characteristics of a PV-LRU

In Chapter 2 the common characteristics of local cooperative renewable energy initiatives have been described, with an emphasis on the variety using photovoltaics. The local cooperative organization of energy production is a relevant option for our energy system because renewable energy sources are ubiquitous and renewable energy technologies are small compared to fossil fuel power plants. The resulting decentralized electricity system allows consumers to be also their own producers. Following the lead of literature on this topic, a local cooperative renewable energy initiative was named a local renewable utility (LRU) and an LRU using specifically photovoltaics a photovoltaic local renewable utility (PV-LRU). An LRU was defined as a self-supporting participatory energy generation project in which renewable energy is produced in the vicinity of the participants. From this the following characteristics of an LRU have been derived:

- Every participant is also a consumer of the energy that the LRU produces, as opposed to traditional power companies where just a part or none of the shareholders is also a consumer of the produced energy;
- Not all consumers of the energy produced by an LRU need to be participants;
- The number of participants is limited to the amount of people than can be in the vicinity of and supported by the energy producing units of the LRU, in this case the PV system or systems.

And the following characteristics apply specifically to a PV-LRU:

- Easily applicable in the urban environment;
- Very scalable, i.e. the PV system output can range from kilowatts to megawatts without any effects on the efficiency of the system;
- The ownership of the PV system can be divided over the participants physically as well as administratively, as opposed to what is the case with wind turbines. This possibly allows for the direct balancing of the produced electricity of a participation with the energy bill of the participant, i.e. to count one less kWh of electricity bought from the electricity company for each kWh of solar electricity from the participation that is fed into the grid. In this case, every kWh of solar electricity saves the expenses of the about €0,20 a kWh of grid electricity costs including taxes.

Because of the cooperative organization of a PV-LRU, its business case can break even without government subsidies. By organizing the installation and exploitation cooperatively, the negotiation position of the participants is improved. This makes it easier to secure suitable roof space, loans or government guarantees for low-interest loans. Also, it relieves the owners of PV systems from the efforts of buying, installing, maintaining and exploiting the PV system, the trouble of high up-front costs and the effort of having to sell or move the PV system if the participant moves away before her PV system has become obsolete. The PV-LRU requires the investment of social capital from its participants. I.e., participants need to cooperate and trust each other and govern their cooperation. As the business case gives social rather than commercial rates of return, participation is based on the merits of the security of energy price and supply and the fulfillment of the need to have an environmental conscious lifestyle, rather than on financial gains.

5.1.2. The actors and resources needed to create a PV-LRU

In the case study of the municipality of Amersfoort, as performed in the author's internship there (see Appendix: Internship report). In this study on the creation of PV-LRUs there, the involvement of the following actors has proved to be necessary or likely to become necessary for the creation of a PV-LRU:

- *Neighborhood residents* These are the potential participants of the PV-LRU. Early involvement in the creation of a PV-LRU makes sure it will be *their* PV-LRU, i.e. that it will be organized to their liking as much as possible and that they can govern the PV-LRU. Without the early involvement of the potential participants there will not be enough social capital to create a PV-LRU;
- *Roof owners* PV systems will first and foremost be installed on roofs. At least a part of the participants will need access to a suitable roof belonging to somebody else. It is efficient to put all the PV systems together in large systems on large roofs: this reduces the amount of negotiations and contracts that need to be made and the system is more likely to remain in place during its life time as it will not be removed to allow for dormers, for example. Therefore, owners of large roofs need to be involved;
- *The municipality* Involvement of the municipality gives the PV-LRU legitimacy, which helps in negotiations with official partners such as roof owners, banks and the government itself. Also, the municipality can stand surety for low-rent loans;
- *The financier* Part or all of the money that is needed to start a PV-LRU can be financed. This gives neighborhood residents the possibility to pay for their participation more in installments and less up-front. This allows people to participate with a lower minimum entrance fee or to participate for a larger share than they can pay for up-front;
- *The electricity grid manager* If the produced solar electricity is to be balanced against the electricity use of the participants, the electricity grid manager is needed to perform this administrative action. It is the electricity grid manager who possesses the data on both the use and the production of electricity of all the grid connected actors;
- *The electricity company* As an alternative to the electricity grid manager, the electricity company can balance the produced electricity with the participants' consumption.

The function of the actors described above sometimes entails the provision of a necessary resource. However, some resources can already be present and some resources need to be supplied by any, some or all of the actors. Therefore, the above list of actors does not mention all that is needed to create a PV-LRU. The resources that are needed are:

- *Financial capital* Money is needed to purchase the PV systems and pay for their installation and maintenance. Other costs are the costs for officially founding a corporation, the costs for setting up the necessary contracts between the involved actors, the compensation for the access to roof space and the costs of governing the corporation;
- *Social capital* In order for a PV-LRU to work, its participants must be able to trust each other and work together in so far, that they can agree on the form of their corporation and its official representation. Only then the PV-LRU can successfully negotiate with other official partners. It is also likely that the presence of social capital is important for attracting new participants, i.e. people will join the PV-LRU because they hear from their close relations that it works and that participation is desirable;
- *Expert knowledge* Expert knowledge on PV systems and on financial and legal matters is needed. Depending on the amount of financial and social capital present, the expert knowledge can be paid for by hiring an expert or can be supplied by the participants themselves;
- *Legitimacy* is the status of the PV-LRU as a trustworthy, sensible and viable undertaking. This resource is needed and supplied by all actors. For example, the involvement of official partners grants the PV-LRU more legitimacy in the eyes of potential participants and vice versa.

5.1.3. Barriers to photovoltaics diffusion in the Netherlands

In chapter 3 the framework of the technological innovation system, as developed by Hekkert c.s., was used to explain what factors could stimulate the diffusion of photovoltaics in the Netherlands. This framework was supplemented by the work of Miller and Kruijsen, on subsequently the role of entrepreneurship and the role of product development in the diffusion of photovoltaics.

The main barrier to the diffusion of photovoltaic diffusion is the absence of a market that is independent of government support. In the model of Hekkert c.s., the creation of a market is the next step to stimulate innovation diffusion, after the creation of knowledge and the rise of entrepreneurial activities. It was briefly observed that the ECN and the technical universities generate much knowledge on photovoltaics in the Netherlands; and that by housing several producers of PV cells the entrepreneurial activities are also present in the Netherlands. There is not, however, a strong market for PV systems as the government stimulation policies that create this market are changing frequently. Supplemented by the fact that the importance of a market for the diffusion of PV systems is also subscribed by Miller and Kruijsen, and that there are no indications that government stimulation policies will become more stable, this leads to the conclusion that the creation of a market that is independent of government policy is needed to increase the diffusion of PV systems in the Netherlands.

The cost price of photovoltaics is close to reaching grid parity with the electricity prices including taxes for households. This offers the opportunity to create a market for PV systems that could exist without subsidies. The market demand would come from three actors:

- *Households* could benefit from the price security and the fulfillment of the need to have a more environmentally conscious lifestyle;
- *Public housing corporations* typically have clients with a low income whose costs for heating and lighting take a proportionally large part of their total expenditures. The price security of PV systems allows them continue to offer affordable housing to their clients in the face of rising energy prices;
- *Municipalities* have in increasing number devised climate and/or renewable energy targets. They could fulfill part of these targets efficiently by facilitating the creation of a PV market that could continue on its own.

The demand of the potential customers above should be met with a product using photovoltaics that fits the wishes and needs of the customers. Kruijsen argued that the user group is insufficiently connected to actors in the rest of the photovoltaics innovation system, such as technology developers, to do this. She argues that this connection needs to be made by product developers. Miller concluded something similar in his case studies, only he named the product developers entrepreneurs and the product an innovation. Millers case studies involve the diffusion of competitive off-grid PV systems in rural areas of India, Sri Lanka and Indonesia that do not have electricity grids. Although these PV systems were competitive, i.e. they were cheaper and better than the incumbent off-grid electricity systems, they did not diffuse and entrepreneurs faced a number of barriers before they successfully sold the competitive PV systems. The situation in the Netherlands is the grid-connected version of Millers case studies: PV systems have become competitive with the incumbent power plants. Therefore, the diffusion of the PV systems is expected to meet with similar problems as in Millers case studies. Miller concluded that innovations in general and PV systems in specific had to comply with four properties to diffuse, the absence of three of which posed the barrier to PV system diffusion in his case studies:

- *Competitiveness* The PV system needs to be better or provide power for lower costs than its incumbent counterpart;
- *Attractiveness* In Millers case, potential customers often regarded PV systems as unreliable due to bad practice in transient government stimulation programs, making the PV systems unattractive. In the case of the Netherlands, PV systems are regarded as uncompetitive and premature. On top of this, to benefit economically from a PV system, the potential customer need to use the panels for their full 25 year-plus life span. As people often will have moved before this time is over, this makes PV systems unattractive;
- *Affordability* PV systems have high up-front costs which not all potential customers can or will afford, even if the pay-back time of the investment is low;
- *Availability* PV systems need to be available to potential customers. In Millers cases, the supply of the actual PV systems was problematic due to bad infrastructure in the regions. In the case of the Netherlands, the supply infrastructure is fine. However, many potential customers do not have access to roofs that are suitable for a PV system.

Based on Hekkert c.s. a fifth property can be added:

- *Legitimacy* Investors and households need to be shown that PV systems can be economically exploited in an easy, sound and reliable way. And the national government needs to renounce the energy taxes on solar electricity that is produced by home-owned panels on third-party property.

All these properties can be a barrier to the diffusion of PV systems if the systems do not comply with them. There are more barriers than the price barrier on which research and development and government policies have been fixated to the extent that they forgot to check whether prices had actually become low enough. So, to work on the diffusion of PV systems in the Netherlands, one needs to focus on the non-price barriers.

5.1.4. The current situation for photovoltaics in the Netherlands

In chapter 4 a short description of the Dutch electricity production system is given and the relevance of photovoltaics in the Netherlands first in the short term and thereafter in the long term is determined. For the short term the climate and renewable energy goals for 2020 are described as well as the government policies that are enacted to reach these goals. A report of the ECN explained if these goals can be expected to be met in 2020. To get an idea of the long-term importance of photovoltaics for the European and Dutch energy system, the soft EU climate and renewable energy goals for 2050, to which the Netherlands implicitly adhere, have been described. The back casting scenario study Roadmap 2050, in which the European Climate Foundation (ECF) depicts possibly pathways towards 95% decarbonization of the European electricity sector, is also taken into account.

This general compendium of statistics, facts, scenarios and policy goals leads to the conclusion that photovoltaics make up a very minor part of the Dutch renewable energy mix and that the Dutch climate and renewable energy policies are maybe enough to comply with European goals that are set for the Netherlands. Of the 124 TWh of electricity that the Netherlands consumed in 2008, 7,46% was provided by domestic renewable power sources. And of the domestic renewable energy production, 0,43% came from photovoltaics. The EU target for 2020 for the Netherlands is that 14% of the gross final energy consumption comes is provided by renewable energy sources. It is unknown whether the Netherlands will meet this target. The climate target of the EU requires the Netherlands to cut their GHG emissions with 16% compared to the 2005 level. The ECN predicted that there is a larger than 50% chance that this target is reached.

Solar power is with its technical potential of 95 TWh/year by far the largest of the renewable energy sources in the Netherlands. And the long term climate target used by both the EU and the Dutch minister of VROM is an 80% GHG emission reduction by 2050. The back casting study of the ECF *Roadmap 2050* assumes that to reach that, 95% of the electricity sector needs to become decarbonized. In the scenarios where this is achieved with renewable energy sources, solar energy is indispensible. It is therefore likely that solar energy is going to play an important role in our future energy system.

5.2. Answer to main research question

The main research question was: How can photovoltaic local renewable utilities stimulate the diffusion of photovoltaic technology in the Netherlands? In the secondary research questions the base situation of photovoltaics in the Netherlands has been assessed, the barriers to the diffusion of PV technology have been summed up and the PV-LRU has been described. Based on these questions, the main research question can now be answered as follows:

> *PV-LRUs can stimulate the diffusion of PV systems by opening up the market for home PV systems. These systems will soon be competitive and therefore can exist without government subsidies and create a substantial and constant demand for PV systems. PV-LRUs can open this market because they address its non-price barriers. The creation of the market can give a strong impulse to the dwindling technological innovation system of photovoltaics in the Netherlands and therefore stimulate PV diffusion.*

First, it will be explained why a market for PV systems will strengthen the technological innovation system (TIS). Then it will be described why PV-LRUs can open up a market. And finally it is argued that facilitating the creation of PV-LRUs could be an effective renewable energy policy.

5.2.1. The need for a PV market

There are three arguments that point out the need for a market in the Netherlands to stimulate the diffusion of photovoltaics. The first argument is that a market would strengthen the TIS of photovoltaics which would increase PV diffusion. The innovation system model of Hekkert c.s. links the concept of system functions with the four development stages of an innovation by introducing the concept of diffusion motors. The first two innovation motors which concern the creation of knowledge and the onset of entrepreneurial activities, respectively, are present in the TIS of photovoltaics. In order to strengthen the TIS more, the model of Hekkert c.s. proposes that it needs to be incremented with a market. The second argument is that the creation of a market leads to PV products that better suit user demands and thus diffuse more. Kruijsen concludes this after analyzing the PV-TIS from the perspective of product development. The third argument is that a self-supporting PV market could be a driving force behind the entire PV-TIS. It would stimulate product development, research and development and solar cell production. This stimulation has historically been done by the Dutch government. However, government support has become fixated on lowering the cost price of solar electricity by stimulating technology development. The policies stimulating demand for PV systems, on the other hand, have been transient and stimulated demand for PV systems in insignificant amounts and for short times. A self-supporting PV market could replace government policy in creating a steady and significant demand for PV systems.

5.2.2. The PV-LRU opens up the market for home PV systems

In chapter 3 it was showed that the declining photovoltaic electricity price will soon reach grid parity for households. This creates a potential self-supporting market for home PV systems. To open this market, the non-price barriers from Miller, as described on page 19 need to be overcome. The PV-LRU is an innovation, not because it is a new technology, but because it applies an existing technology in a new product. In chapter 2 it is shown how the PV-LRU addresses all of the non-price barriers that hamper the diffusion of PV systems.

In short, the PV-LRU makes PV systems:

- attractive by relieving users from overhead costs and risks;
- affordable by lowering up-front costs;
- available by making the required roof space available;
- legitimate by spreading a positive image of PV systems through referencing.

The case studies of Miller suggest that if these barriers are overcome, PV diffusion will increase because PV systems get sold. On top of this, the reactions of local residents to the concept of the PV-LRU, as experienced in the internship (see Appendix: Internship report, suggest that there is a demand for such a product. This is confirmed by a recent study in which local residents of the small towns Veendam and Stadskanaal, the Netherlands, were asked whether they would participate in co-operative solar initiatives. 35% of the respondents would immediately participate and another 27% would participate if a good number of other people had joined the initiative. To correct for a probable bias of residents with high environmental awareness amongst the respondents, the study assumes the actual percentages are only half of this. In that case, 7800 and 6000 households in the three northern provinces would immediately join or follow others to join respectively (Stokman, Wolf 2011). On top of this, 13% of the respondents would pay extra costs on top of their electricity bill of €150 to participate in a co-operative solar project.

5.2.3. The PV-LRU as an energy policy

The PV-LRU can in principle benefit from traditional renewable energy policies such as subsidizing the purchase of PV systems or instating a feed-in tariff. Anything relieving the costs of purchasing the PV systems or increasing the revenues from the produced solar power helps the PV-LRU business case. But there are new, potentially more effective, policies that stimulate the PV-LRU while tapping into the market potential for PV. These are especially fit for municipalities, as these operate at the same local level as PV-LRUs do. These policies do not spend government money directly on solar panels but use it to extract money from the market or to create social capital or expert knowledge. Therefore, they might produce more effect per euro spend. The policies are:

- Mobilize local residents to form a PV-LRU, i.e. create social capital;
- Grant free access to roof space on municipal buildings or semi-municipal buildings such as schools and sports facilities;
- Grant or stand secure for low-interest loans;
- Provide expert knowledge.

5.3. The necessity of stimulating PV diffusion

This thesis did not focus on the question whether the diffusion of PV now is necessary or desirable. The literature on climate change has reached consensus on the desirability of decarbonizing economies. The big question is how we want to transition to this decarbonized economy. This is as much a political question as a scientific one. The answer to this question open is left open, as that could fill a thesis on its own. It is therefore assumed that photovoltaics will start to play an important role in our energy system in the short term. Whether this is the case is not relevant for the scientific value of this thesis: at best, this thesis will prove to be highly relevant to society; in the worst case, this thesis turns out to be a thought experiment on the development of photovoltaics and prove to be only relevant for the scientific discourse on energy transitions.

Still, this thesis can present a basic argument to why the diffusion of PV systems now is desirable, based on the current situation for PV in the Netherlands. The argument is:

> *If we as society want to have a decarbonized energy system while largely using renewable energy sources, the use of solar energy is necessary. And if we want to strengthen the Dutch economy with this necessary implementation of solar energy we need to start implementing now in order to use the R&D that the Netherlands have accumulated.*

The potential of other renewable energy sources is not large enough to supply all the electricity that is likely to be used in the Netherlands. So if the most of our electricity is to come from renewable energy sources, solar energy has to be one of them. And if we wait with implementing photovoltaics ourselves, foreign entrepreneurs, solar cell producers and installers will do the job for us. This would be a missed chance for the Dutch solar cell producers and Dutch R&D institutes on photovoltaics to easily gain practical experience by applying their theoretical and technological knowledge and it would be a missed chance for Dutch entrepreneurs that install and maintain PV systems.

5.4. Discussion

There are four information gaps in this thesis, caused by the broad scope of the main research question and the unstructured way the research has been done. The broad scope was necessary because a whole new interdisciplinary topic needed to be described. The unstructured way of researching allowed for adjusting the research questions during the research. This was necessary because only after more was known about the topic, the relevant research questions became apparent. The information gaps are:

- *The size of the potential of the market for house PV systems.* This thesis assumes that the size of the market for house PV systems is significant. However, it is unknown how many households will actually be interested in the PV-LRU. A recent study by Frank Stok (Stokman, Wolf 2011) might shed some light on this. Also, this thesis does not discuss in detail the amount of suitable roof space that is potentially available to PV-LRUs. Starting points for answering this question are a recent study by order of the Province of Utrecht on the potential of sustainable technologies on roofs (Province of Utrecht, the Netherlands, Arcadis 2010) and the master thesis of Patrick Defaix (Defaix 2009);
- *The effectiveness of the PV-LRU as renewable energy and climate policy*. It is unknown how much it will cost to facilitate the creation of PV-LRUs and how much photovoltaic capacity could be installed as effect of this;
- *The necessity or desirability of diffusing PV systems.* As said in the beginning of this section, this is not investigated here. Scenario studies such as the Roadmap 2050(European Climate Foundation 2010), REPAP2020 (Rosende et al. 2010)

and the Roadmap PV of the International Energy Agency (IEA 2010) are a starting point for answering this question;

- *The state of the art of local renewable energy initiatives in the Netherlands and in other countries.* The empirical information in my thesis comes from the case study on Amersfoort, which was performed during the writing of this thesis. However, there are more local renewable initiatives around: my choice for this research topic was inspired on the initiatives in Jühnde, Germany and Lochem, the Netherlands. Unfortunately, there was no time to seek out and investigate other local renewable energy initiatives. This could give valuable information on best practices for government involvement, mobilizing local residents and financing the projects. Starting documents for answering this question are: Inventarisatie Zonnestroommarkt (Arcadis 2011), Seeing the light (Morris 2001) and Nieuwe Nuts (Wortmann, Kruseman 2008).

Furthermore, please note that the municipality of Amersfoort is hiring one of the founders of Zonvogel to facilitate the creation of PV-LRUs. This means that my case study gave much information on Zonvogel and much less information about the other entrepreneurs that are working to create PV-LRUs. There is therefore a chance that the general description of the PV-LRU turns out to be not so general. There was no time to go by the other entrepreneurs and compare their work to my description of a PV-LRU. Additionally, during the writing of the thesis the author has become employed by Zonvogel to work in Amersfoort.

The final point of discussion concerns the conclusion in this thesis on the state of the technological innovation system (TIS) of photovoltaics in the Netherlands. Hekkert c.s. describe a method to analyze a TIS by assigning each relevant event to one of the seven system functions. Every event adds or subtracts points to the indicator score of the system function, depending on whether the event stimulates or inhibits. The higher a system function scores, the stronger it is present in the TIS. This method was not used for two reasons. First, it would have required that less time was spent on researching the actual PV-LRU, which is at odds with the main goal of this thesis. The main goal of this thesis, investigating the concept of the PV-LRU, has scientific value regardless of whether the implementation of PV is actually desirable at present or whether the PV innovation system actually needs a market. Therefore, a systematic TIS analysis has not enough added value for this thesis. Second, literature research was less laborious and offered a good approximation. Useful sources were two articles written by Sinke (Sinke 2002, Sinke 2009), the TIS analysis of the Province of Utrecht in the thesis of Jaco Blommerde (unpublished) and the PhD thesis of Joanneke Kruijsen (Kruijsen 1999). From these sources the general picture arises that a strong market is the main thing lacking in the Dutch photovoltaic innovation system.

Appendix: Internship report

Introduction

In chapter two of my thesis, I concluded that photovoltaics make up a very small part of the Dutch energy mix and that the diffusion of photovoltaics need to increase if long term climate and renewable energy targets are to be met. In chapter 3 of my thesis, I discuss four thinkers on renewable energy technology diffusion to understand what can be done to speed up the diffusion of photovoltaics in the Netherlands. In this internship report, I do a case study on my internship at the municipality of Amersfoort, in which I worked on increasing photovoltaics diffusion using governance.

This internship was inspired by the development of the initiative in Lochem. This initiative had sprung forth from collaboration between an alderman of the municipality of Lochem and two local entrepreneurs. By February 2010, when my fellow student Jaco Blommerde and I visited the initiative, the support of the village residents was already raised and a business model was in the making. This inspired me and Jaco to do our theses on local solar initiatives as a mean to diffuse photovoltaics in the Netherlands. This also inspired our supervisors to see potential in basing PV-LRU's on the civic solar initiatives in Amersfoort.

Acquiring expert knowledge

In July 2010, the workgroup decided to supply the initiatives with expert knowledge to help them to become full-grown PV-LRU's. Because neither the City of Amersfoort nor the Province had the manpower and the expert knowledge available to do this, the workgroup hired a consultant. The consultant would spend 2 working days a week on supporting the initiatives, from September to December 2010, with likely an extension of this term afterwards. The consultant was to be paid with funds from both the city of Amersfoort and the province of Utrecht. Also, the consultant would be available in the future to work on similar solar energy projects for the province of Utrecht. After checking with the initiatives in Amersfoort if they would like to receive support for their endeavors in the form of a consultant, and receiving positive answers, the workgroup issued a job vacancy and started taking job interviews.

The workgroup interviewed in four interviews five applicants that were drawn from the networks of the workgroup. We selected on knowledge of the solar system market, motivation to work with renewable energy technologies, the ability to connect an array of different stakeholders, experience in organizing the financing for innovations that are on the brink of breaking through, and knowledge on the legal aspects of renewable energy production. The final choice fell on Peter van Vliet, founder of a network organization that relays news and information on sustainability to open-access internet sites, lobbies for sustainable policies at the national government, and also founder of another foundation that is working on economically exploiting photovoltaic systems without subsidies.

Van Vliet joined the workgroup Civic Solar Initiatives in the second half of September 2010. By this time, some things had changed with the initiatives since my survey in June. Initiative 1 was transferred from the workgroup to a special project to facilitate owners associations . (both 'civic solar' as 'owners associations' form part of Saving Energy in the Neighbourhood)This was because this initiative needed to rally the support from the owners association. Setting up a collective energy saving or renewable energy project with an owners association is a special case, as an owners association is more difficult a legal person than a foundation or cooperation. The energy saving project paid special attention to this and could therefore support initiative 1 better. Initiative 2 found its application for the SDE subsidy rejected. Initiative 4 had approached one of the schools in the neighborhood with a proposal for placing neighborhood-owned solar panels on the roof. The school personnel were positive; the caretaker of the school building had reserves and declined the proposal. Also, initiative 4 had come in contact with a market party that offered to buy power in bulk for the initiative in order to save money on the bill for grid electricity, henceforth called Company A. The saved money could then be invested in a collective photovoltaic system, then electricity of which would save even more money from the bill for grid electricity. This could then also be invested in even more solar panels and so on. The new developments within the initiatives became apparent while Van Vliet and the initiatives 2, 3 and 4 got acquainted with each other. Initiative 5 had no time for meetings then and proposed to meet when a business case could be presented to the local residents.

Supporting the initiatives

In September and October 2010, the first two months Van Vliet was hired and the workgroup started to actively cooperate with the initiatives, was about getting to the core of the initiatives, to what was already there. From the meetings between Van Vliet and the initiatives five things became apparent. First, the initiatives were not familiar with the concept of balancing one's electricity consumption with electricity produced from one's solar panels placed elsewhere (in short 'balancing'). Neither were they aware of the legal issue this concept caused. Third, three of the four initiatives did not have any calculation of a business case. Fourth, none of the initiatives had secured roofs for solar panels yet. Although this last point was already known at the start of my internship, it was emphasized now by it being important for the actual execution of the initiatives their plans. Fifth, the initiatives were ready to mobilize local residents. They had motivated initiators and/or strong social networks.

The workgroup started three general lines of action: securing roofs in each of the neighborhoods on which solar panels could be placed, making business cases for a PV-LRU and making balancing possible. Parts of the first two lines of action are different for each initiative while the third line of action is independent of initiative specifics. Before I describe the specific parts of the first two, I will describe their generic parts together with the work done on balancing, which is entirely independent of initiative specifics.

Securing roofs

The initiatives looked for roofs from a bottom-up perspective. People looked around in their neighborhood in search for large enough and south-oriented roofs. The workgroup, however, had access to municipal geographical and demographic data: the department of

Real Estate and Facilities[24] had information about upcoming renovation or demolition and ownership of all the public buildings such as schools, sports halls, swimming pools and municipal buildings; and the department of Geographical Information had information on parcel size and ownership of all the addresses in the city of Amersfoort and recent air photos of the entire city area. The municipal data allowed for a top-down search, covering a large number of roofs in one search.

I used the municipal data to first check the availability of the roofs the initiatives had chosen. It became apparent that most of these roofs were not available and alternatives should be looked for. I did this by making a top-10 selection of most interesting roofs for the neighborhood of each initiative, again using the municipal databases. At request, the Geographical Information department produced a database with the size, address, function (residential, office, industrial etc.) and owner of all the parcels larger than 500 m^2. The main assumption is that the larger the parcel size, the larger the roof of the building on that parcel. And as it is preferable for the sake of simplicity and economy to place the panels of a PV-LRU on one large roof, the largest parcels are the most interesting to look at. The Geographical Information database was queried for the largest parcels in a neighborhood that have a residential, communal, health care, office, education, sports or commercial function. Table 4 explains the inclusion and exclusion of certain functions in the search query. The parcels that came out of the search query were then checked on air photos for roof orientation and shadows.

Table 4 The included and excluded parcel functions of the municipal Geographical Information database of all the parcels larger than 500 m^2 in the city of Amersfoort. In the first column the function; in the second column the motivation for including or excluding the parcels with that function in the search for roofs that apt for placing the PV system of a PV-LRU.

Included functions	
Residential	By selecting this function, the housing corporations are included in the search. They own large parcels and could benefit from supplying their clients with power from a PV-LRU. This is because the recurring expenses for their clients are expected to rise significantly due to rising grid electricity prices, making it more difficult for housing corporations to service their not very affluent clients. As a PV-LRU provides power for a price that is the same as the current price for grid electricity for households, and that remains fixed for a decade or two, it could counter the rising of recurring living expenses in social housing. This makes housing corporations attractive partners for a PV-LRU. This function also includes owners associations of large residential blocks. Because these are somewhat difficult legal persons to grant loans to or make contracts with, I did not include them in my final selection of candidate roofs. However, as the city of Amersfoort is gaining a lot of experience in working with them in their energy saving campaign, owners associations are likely to become interesting partners for a PV-LRU in the coming years.
Communal	This function includes churches and community centers. These could

[24] In Dutch: Vastgoed en Voorzieningen.

	benefit from the reinforced relationship with the neighborhood which could follow from partnering in a PV-LRU. For now, I left the churches out of the search because the secular nature of the initiatives and my workgroup places the churches slightly further away from our contact network in neighborhoods. And because the looks of churches with a traditional architecture would probably be spoiled by the placement of PV panels on their roofs.
Health care	Health care buildings, such as hospitals or nursing homes, have typically large roofs. I expect health care institutes to be neutral towards partnering in a PV-LRU, as their perspective shows no strong arguments for or against it. To not prematurely exclude good candidate roofs, I included this category in the search query.
Office	Office buildings have typically large roofs and might house companies who might be interested in the image boost they could gain with the placement of solar panels on their roofs. However, as companies are commercial actors, they might be inclined to ask rent for the use of their roof space. This would negatively affect the business case of a PV-LRU.
Education	Schools are very attractive partners for a PV-LRU for several reasons. First, all buildings of primary and secondary school are ultimately owned by the municipality and therefore schools are easy to be persuaded by the municipality's positive attitude towards allowing PV panels on their roof. Second, schools might benefit from positive publicity and an enforced relationship with their 'customers' the local residents. Third, the placement of PV panels on their roof allows for educational programs about PV systems, which is rapidly becoming a highly relevant topic in society. For example, vocational schools could combine the placement of PV panels on their roofs with courses on installation and maintenance of PV systems. Fourth, primary and secondary schools are strong community centers in a neighborhood because they connect all the neighborhood children and their parents to each other. Schools are therefore good places to raise community support for setting up a PV-LRU. Fifth, schools often have large roofs.
Sports	Sports halls and swimming pools are often owned by the municipality, making them attractive partners for a PV-LRU for the same reason as schools. Also, they typically have large, flat roofs which are especially attractive for placing PV panels upon. And similarly to schools, they bring local residents together by common activity, placing them in the centre of the neighborhood social life, thus possibly promoting support for a PV-LRU.
Commercial	Shopping malls are often central, recognizable places in a neighborhood. This could make PV panels that are placed on roofs there also central to and recognizable for the local residents participating in a PV-LRU. However, just like offices, shops could as rent for the use of their roof space. This makes them only marginally attractive partners for a PV-LRU. I still include them in the search query to make it comprehensive enough.

Excluded functions	
Industrial	Industrial buildings often have large, flat roofs that are free of shadows from for example trees. Yet they are not very attractive partners for a PV-LRU. The building owners are, as commercial actors, likely to ask rent for their roof space. Also industrial areas are often placed separated from residential areas and therefore do not have any social connection with neighborhoods on the basis of which a PV-LRU could be founded.
Hotel	Hotels, hostels and other traveler accommodations are likely to ask rent for their roof space, are unlikely to have a social connection to their neighborhood as their clients are per definition travelers through and have a reasonable chance of being placed in forestry areas, in which case the shadows cast by trees are likely to render their roofs useless for PV panels.
Remaining	This administratively created category contains a jumble of building functions that do not fit in any other category and is therefore not likely to yield interesting roofs for PV-LRUs.
Mixed use	This category mostly contains parcels with two functions. To limit the search query to the most likely partners for PV-LRUs, this category is not included.

Enabling balancing of consumed and produced electricity
'Balancing', as it is called in short, is the act of subtracting the electricity a person has fed into the grid from the electricity that person has pulled out of the grid. This is done automatically when a person feeds her produced electricity into the grid through the same connection through which she pulls electricity out of the grid, i.e. when she has placed her solar panels on her own roof or land (Dutch National Government 2011, art.50 lid 2). The solar power system is then connected 'before the electricity meter', as it is called. This means that in practice someone saves the electricity tariff including taxes of a kWh pulled from the grid for each kWh of solar electricity he produces[25]. This is legitimate practice in the Netherlands.

However, balancing could be considered illegitimate when a person feeds his produced electricity into the grid through *another* connection than the one through which he pulls electricity from the grid, i.e. when he has placed his solar panels on the roof or land of a third party[26]. The solar power system is then connected 'behind the electricity meter'. In this case, the law Wet Belastingen op Milieugrondslag treats the produced solar electricity the same way as commercially produced electricity and requires taxes to be paid on the solar electricity.

This means that a person, who connects her PV panels to the grid through a different connection than her own, saves the electricity tariff *excluding* the environmental tax of a kWh pulled from the grid for each kWh of solar electricity she produces. The difference in

[25] Until he has produced as much as he has consumed in a certain time frame (typically a year).
[26] And also when a person has his solar panels on his own roof or land, but connected to the grid through another connection than the one through which he pulls electricity from the grid.

revenues between a household that owns and uses a solar panel with and without balancing thus equals the environmental tax that is levied upon grid electricity. In 2011, this was €0,13 per kWh[27] (Rijksoverheid 2010b, p.26)on a total price of around €0,22 per kWh. Balancing would thus increase the revenues of a PV installation by roughly half and would make a better business case.

When Van Vliet joined the workgroup in Amersfoort, he was already lobbying at the national government to legitimize balancing. He continued doing so, now also with the benefit of the initiatives in Amersfoort in his mind. A quick ad hoc poll at an information meeting with the local residents of the neighborhood of initiative 3 about setting up a PV-LRU revealed that roughly two-third of the visitors did not own a roof or owned a roof that was unfit for PV panels (Municipality of Amersfoort, the Netherlands). To let them participate in a PV-LRU, their panels needed to be installed on a third-party roof.

The exact doings of the lobby are strategic information, as the lobby still continues, and I will not describe them because that would conflict with my interests as an intern working on realizing PV-LRUs. Important for this thesis is what actors are involved in the act of balancing. The administrative act of balancing lies firstly with the electricity grid controllers. These companies collect data on the electricity that is drawn from and fed in the grid for each connection. They could balance consumption and production before sending the net consumption/production to the subsequent electricity companies. They then bill their customers based upon the provided consumption/production data. The electricity companies could also perform the administrative act of balancing. The making of the law Wet Belastingen op Milieugrondslag (in short 'Wbm', which determines when electricity produced at another place than it is consumed should be taxed, lies with the government. The Wbm law is then interpreted by the tax authorities, who could then proceed to tax a PV-LRU on the produced energy.

Initiative-specific actions
Given these general lines of action, the workgroup proceeded with each initiative separately. There has not been cooperation between the initiatives. Initial contact has been made between the most of the initiators in December. Initiative 5 remained inactive in anticipation of a detailed business case. The initiatives 2, 3 and 4 followed all different paths.

For initiative 2, the chosen location of the area around the central station was important. If not on the roof of the station hall, the initiators liked to place the panels on another roof nearby. Because of this, the workgroup focused on obtaining a roof in the station area and did not work with the top down search for roofs. The workgroup restarted the stranded negotiations on the roof of the central station hall and started negotiations with a second roof-owner in that area. The strength of the central station roof needed to be assessed first before negotiations could continue. The initiators started out to hire a couple of contractors to investigate the station roof and give a tender for a solar system, partly subsidized by the Province. At the end of December 2010 the initiators had received two tenders; the strength of the station roof had not been assessed yet. The workgroup took no further action and waited for the station roof strength assessment.

[27] €0,1114 per kWh environmental tax plus 19% VAT levied upon this tax.

Initiative 3 had in mind to place PV panels on the roof of a nearby vocational school. This plan did not proceed, as information from the municipal Department of Real Estate and Facilities revealed that by 2013-2014 the school would move out of the building. Negotiations about the use of the roof needed to wait until the building would be sold. The initiator and the workgroup then continued with the top-down list of buildings from the search query of the municipal Geographical Information database. By December 2010, three building owners were found to be interested in providing roof space for a PV-LRU: a vocational school, a health care centre with a general practice and a pharmacy and a housing corporation. At the same time, the initiator proposed to hold an information meeting to poll the enthusiasm for a PV-LRU amongst the local residents. The initiator had earlier received a municipal subsidy of €2500 for neighborhood activities promoting sustainability that would expire by the end of 2010. This money was used to hold information meetings at 8 and 10 December 2010 during which the general business case of the PV-LRU and the selection of candidate roofs were presented. Also, visitors who were sure they would like to participate in a PV-LRU could sign in for a preliminary enrolment. This gave them right of way over participation to the PV-LRU if it were to be founded and enrolled them in a lottery for a free participation in the future PV-LRU worth one PV panel.

After the first school, initiative 4 approached another school to ask for its roof space. The initiative managed to get a donation of 20 PV panels and asked the second school to allow these panels on its roof. In the meantime, the initiative negotiated with the earlier mentioned Company A to see if they could supply the neighborhood with affordable renewable energy by buying grid electricity in bulk and investing the thus attained discount in PV panels. The initiative wanted the workgroup to meet with Company A to give a second opinion on its business case. Company A also wanted to meet with the workgroup to talk about including their business case into the plans of the workgroup. The workgroup wanted to meet with Company A to support initiative 4 in their plans and to investigate opportunities that could help to realize a PV-LRU. In October 2010, the workgroup met with Company A. The meeting generated insufficient trust between the members of the meeting. It arrived at an impasse: the workgroup was not convinced that Company A could contribute to realizing a PV-LRU with their preliminary business case and asked for more details; Company A wanted the workgroup to partner up with them to further develop their business case and asked for information on the contracts needed for a PV-LRU and a declaration of intent from the municipality. The meeting ended in miscommunication on the follow up. Both parties thought the other party would work to comply with their request for information. Due to badly maintained minutes, this did not become apparent before the second meeting. In the end, none of the information requests were heeded. The 18th of November 2010, the second meeting was held, now including members of initiative 4. Initiative 4 also brought a fourth party: someone who was external to the initiative and who volunteered to consult the initiative. This meeting also ended in disagreement. Initiative 4 did not know what to do with the workgroup and Company A while Company A and the workgroup remained at a stale mate. In the end, the fourth party consultant and Company A decided to work out the company's business case together.

Research conclusions

The conclusions drawn in this section are tentative. They are based on the observations I made during my internship rather than statistical research or reproducible experiments. They are shaped by my knowledge of governance theory and my every-day experience with human interactions. As such they offer topics on civic solar initiatives that are interesting to research in more detail and more systematically. They are also meant to advice policy makers on the use of PV-LRUs as a governance policy instrument. I will use these conclusions for my thesis.

> *1. Local citizens and large roof owners seem to be interested in participating in a PV-LRU.*

There are three observations that support this conclusion. First, the five civic solar initiatives made themselves known to the municipality on their own initiative without them being asked to do so. This illustrates their interest in setting up a local solar energy project. Their interest in specifically the PV-LRU shows from the information meetings held with initiative 3. The meetings were visited by in total 75 people of which 55 signed in for the preliminary enrolment. This means that over 70% of the people who were presented with the idea of the PV-LRU were interested in participating. Of course, the question remains how many of the rest of the 3040 invited households of the neighborhood will become interested in participating in a PV-LRU.

> *2. Civic initiatives have difficulties with connecting to official partners on their own.*

At the time of the first evaluation in May 2010, none of the five initiatives had partnered up with official partners such as banks, roof-owners, local governments or energy companies. This was not due to lack of time or lack of trying. The most organized initiatives, initiatives 2 and 4, were at least a year old and had formed official foundations. Initiative 4 had approached the province of Utrecht, asking for financial support and goodwill. Initiative 2 had, since its foundation was created, been negotiating with the owner of the central train station building.

From my conversations with the initiators of initiatives 2 and 4, I observe that they relied heavily on the social and ethical appeasement of their initiatives when recruiting official partners for their initiatives. I hypothesize that official partners are more likely to have stakes of political and economic nature rather than of social nature, as these partners are political institutes or companies. This would mean that the initiators would need to stress the political and economical value instead of the social value of their initiatives in order to convince official parties to partner up with them. Put bluntly: civic solar initiatives are prone to stick to their idealistic basis too much when entering negotiations with economic and political parties and because of that fail to recruit them.

There is a nuance to this statement. I assume that all contemporary civic solar initiatives have an idealistic basis. Coming civic solar initiatives could very well have an economic basis. This is based on the following argument. There are two main motivations for households to purchase a grid connected PV system, which is the most common type in the Netherlands: economic and idealistic. As PV systems have only recently become economically attractive, people are likely to assume that PV systems have only idealistic benefits. If this is the case, most contemporary civic solar initiatives must have an idealistic basis.

3. Providing expert knowledge helps the initiatives more than providing subsidies would.

Subsidies would not enable the initiatives to make the coalitions that are necessary to become a PV-LRU. Subsidies can enable a number of activities that are only useful when they are backed-up with expert knowledge: they would enable the initiatives to organize information meetings, but not to fill these meetings with presentations that would inform local residents sufficiently to engage collectively in making a PV-LRU; they would enable the initiatives to found an official foundation or cooperative society, but not to engage in partnerships with official parties; they would allow for roof strength assessments and offers for the installation of PV systems, but not for an agreement with a roof-owner to use his roof space; and they would allow for the purchase of PV systems, but not for the balancing of the produced power with each individual participant. As the initiatives lacked expert knowledge, providing subsidies alone would not have helped them sufficiently to reach their goals.

This conclusion is not entirely hypothetical. My internship offers two examples, in which an initiative could not fully utilize a subsidy until the workgroup of the municipality provided additional expert knowledge.

- Initiative 2 had received provincial subsidies to set up an official foundation and to ask offers for PV systems from installers. To be organized in a foundation was not enough to come to an agreement with the owner of the central train station roof. And the offers for PV systems could not be assessed for their quality before the workgroup provided knowledge on what a typical offer for a PV system looked like. Only after the offers were assessed for their quality, could they be used as solid information for the negotiations with the station roof owner. These negotiations are still in progress, but it is likely that the offers will help the initiative to make a more solid case for the station roof owner.
- Initiative 3 had received the €2500 municipal subsidy for promoting sustainability in its neighborhood. Combined with the business case that the municipal workgroup and the initiator made, this money made information meetings possible that possibly laid the foundation for a PV-LRU.

5. The involvement of the municipality helps the initiatives more than providing subsidies would.

The municipality could give access to the roofs of municipal buildings or provide expert knowledge, low interest loans or funds for risk-covering guarantees, helping solar initiatives in a direct way. I hypothesize that each of these activities would help the initiatives more than subsidies would. This is because the above activities will make the municipality involved with the solar initiatives, while providing subsidies will not. I define 'involvement' here as working and thinking alongside other parties involved in a common goal, in this case the foundation of a PV-LRU, during a prolonged period of the project time. Subsidies would yield a punctuated, one-way interaction with a solar project, being the moment the subsidy is provided against certain requirements set by the subsidizer.

I think this difference in involvement is important because of two reasons. First, the involvement of the municipality will bring a combination of three resources that is unique for the municipality to a solar initiative: legitimacy, credibility and reliability. As an institute that promotes the common interests of its community, the municipality will ensure with its involvement in a PV-LRU that the solar initiative is beneficial for the common good. First, this will make the social goal of the PV-LRU legitimate, thereby also legitimizing the use of loans with social interest rates and social pay-back times. Second, this will make the social goal of the PV-LRU credible to local residents, i.e. it assures local residents that indeed the initiative is not set on making a profit despite the fact that it is aiming to run its business on an economically sustainable basis. Third, as an institute with an organizational and financial service record, the municipality could make an initiative a more reliable partner to do business with. This helps for securing resources such as loans or roof space from other official partners. By providing legitimacy, credibility and reliability, the municipality will enable solar initiatives to access to a variety of essential resources, including subsidies or other forms of financing. Second, involvement in a solar initiative probably costs the municipality less money than providing subsidies will for the same amount of PV systems diffused: low interest loans could form a revolving fund that would continue to stimulate PV system diffusion for a longer time than direct subsidies would; guarantee funds to cover risks could enable the financing of initiatives through low-rent bank loans that are substantially larger than the money needed for the guarantee funds; hiring experts or educating municipal officials could very well have more and longer effect on the diffusion of PV systems than spending the money directly on subsidies for PV systems[28].

Internship conclusion

The goal of my internship was to facilitate the civic solar energy initiatives in the creation of a local photovoltaic utility and to set up a city-wide photovoltaic project based on these civic initiatives. The three tasks that had been formulated to reach this goal have been partly completed.

The first task was to set up communications between the civic solar initiatives and the municipality and between the initiatives themselves. The connections between the municipality and the initiatives 2, 3 and 4 are strong: there is regular e-mail and

[28] Whether granting access to municipal roof space would help the diffusion of PV systems against a lower price than direct subsidies is uncertain. At the moment of granting access, there are no costs for the municipality. But it could cost the municipality income in the future if the value of roof space would increase or the price of grid electricity would become higher than that of solar electricity.

telephone contact; face-to-face meetings are easily set up, whether they are at the city hall or at the initiatives' headquarters; and information is readily exchanged. The connections amongst the initiatives are weak: there is little contact between the initiatives outside the contact through the municipality. The needs and resources of the initiatives have been mapped out in sufficient detail to facilitate them successfully. This makes the first task is about three-quarters completed.

The second task was to gather knowledge that was still missing in either the initiatives or the municipality to set-up PV-LRUs. This was knowledge on the official partners to recruit and the juridical and financial organization of a PV-LRU. This knowledge has been acquired with the hiring of Van Vliet and the cooperation with the municipal departments of Real Estate and Facilities and of Geographical Information. This makes that the second task is fully completed.

The third task was to give a policy advice on how the municipality of Amersfoort is to facilitate local solar energy initiatives. As an internship report, this chapter only shows that the governance approach of setting up PV-LRUs has potential and how the involvement of the municipality in this is important. This makes the third task as of yet largely uncompleted.

The main goal has been partly reached. The initiatives have been facilitated in their work to create a PV-LRU, although no PV-LRU was actually founded. Also the city-wide photovoltaic project has not been set up. This is only partly caused by not finishing the three above tasks. Along the way, it has become apparent that new tasks need to be completed to set up PV-LRUs. These are: recruiting local residents, acquiring roof space, formally organizing the initiatives and the support of the municipality, possibly acquiring financing, arranging the administration or even balancing of the produced energy, and installing the PV systems. There is potential to reach the main goal. Some mayor steps have been taken with initiative 3, finding roofs and finding enough potential participants amongst the local residents. As the options of the other initiatives to do the same are still open, it is likely that more progress towards setting up PV-LRUs will be made. The biggest uncertainties are the amount of local residents that will actually participate and the willingness of the local electricity grid controller to balance the produced solar electricity with the participants their electricity use.

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