Nieuwland 1 MegaWatt PV Project, Amersfoort

1. Introduction

In the Waterkwartier district in the Nieuwland expansion area of the city of Amersfoort, the worlds' largest urban PV project (1999) has been realized. The project consists of over 500 houses and several other buildings such as schools and a sports facility with PV solar modules integrated in the façade and the roofs. The total PV power is 1.35 MWp, about 12,300 m^2.

The main investor of the project was the energy company REMU (now ENECO). The objectives of the Nieuwland 1 MegaWatt PV project were: to illustrate the impact of using solar power at district level, to reduce costs by applying solar power on a large level, to learn about various forms of ownership and management, to acquire experience regarding (electricity) grid and architectural aspects and finally to learn about other aspects connected to the urban scale of the project.

Figure 1: View from the south of the sports hall roof, also showing the school houses and the first row of housing (Photograph R. Schropp)

2. Stakeholders and added values

Utility

The energy company REMU (mainly active in the province of Utrecht), who initiated the project, later merged into the larger ENECO. The 1MW PV project followed on from six smaller projects undertaken by REMU in the same housing district between 1992 and 1998 paving the way for this large scale project. REMU also cooperated with the municipal Energy Company Amsterdam, which was preparing a 250 kWp project in the New Sloten district.

Table 1: overview of predecessor projects by REMU in the same housing district

50 rental homes for the housing company SCW	110	kWp
370 rental houses for the housing company HBG Vastgoed		
19 privately owned houses	55	kWp
2 primary schools	20	kWp
24 privately owned houses	9	kWp
2 energy balance houses	18	kWp

Consumers

One of the goals of the project was to investigate the effects of various forms of ownership and management. Therefore, the solar systems were installed on various different types of houses including one family houses, apartment buildings, schools and sports halls.

The houses are in private ownership or rented from a housing corporation. The PV solar energy system on the roof can be owned by Eneco or owned by the house owner. The tenants of the houses who have made their roof available for Eneco get, as compensation, 20% of the generated solar electricity (based on calculation) for free. The house owners who have bought the PV solar roof installed on their house, have bought the PV system for 25% of the system costs. Consequently they get all the solar electricity generated.

The energy company is responsible for maintenance of the systems for a period of 10 years. After the summer of 2008, ENECO and the residents will make new arrangements for the next 10 years.

Architects

The district was divided into development areas and each developer had their own architect. Only a few of the architects had previous experience with PV. For each subproject, a separate contract was made for turnkey delivery of the PV system.

Table 2: Architects and the PV area per subproject

Subproject	**solar modules (m^2)**
Sport centre (Weerstra Architecten, Drachten)	506
Kinder garden (C. Moller, Cita Architecten, Utrecht)	82
10 School houses (Van den Berg Architecten, Utrecht)	280
Jersey, 99 PV houses (Loof& van Stigt Architecten, Amsterdam)	3.480
Panta Rhei, 38 PV houses (Architectenbureau van Straalen, Zeist)	766
Solar portals (Architectenbureau van Straalen, Zeist)	94
Watergentiaan, 32 houses (Galis Architectenbureau BNA, Delft)	755
Cascade, 32 houses (Duinker, Van der Torre, Amsterdam)	672
Pitrus, Mattenbies, Rietgors, 119 houses (Klaus en Kaan Architecten, Rotterdam)	2.462
Kroos district, 125 houses (De Jong, Hoogveld de Kat, Utrecht)	2.832
45 Water houses (Atelier Z, Rotterdam)	370
56 Dyke houses (Bear Architects)	244
total m^2	**12.543**

3. Project organization

In 1992, when the development of the Waterkwartier district started, the municipality of Amersfoort had ambitious environmental targets. This ambition was communicated to the property developers of the district. In order to facilitate further action, the municipality engaged the environmental research and consulting firm BOOM as environment supervisor. Additionally, the municipality provided a budget of € 1,8 million to support achievement of the environmental targets.

The energy company REMU wanted to gain experience with large scale application of PV and were especially interested in the effects of a high concentration of PV sources on the public grid. REMU also believed that PV houses, although having a non-standard roof and being more expensive than conventional houses, could be sold on the market. Another reason for REMU to start this project was a commitment to support the development of solar technology. At that time, the Dutch government required the energy companies to develop their own energy and environmental saving programs. Other energy companies had chosen to focus on wind energy or energy production from waste. REMU focused on solar energy.

For this project, REMU applied for and received a subsidy under the EU Thermie programme and cooperated with the Italian utility ENEL, which had experience with large scale solar projects.

Novem (now SenterNovem, the Dutch renewable energy agency in the Ministry of Economic Affairs) also supported the project under its PV programme NOZ-PV. Novem was especially interested in technical improvements and decreasing the costs of solar systems. The main goal for Novem was to experience and solve possible barriers and problems in urban planning, architecture and grid integration for such a very large scale application of solar systems. Also the technical and social implications of this large scale application of PV were of interest to Novem. According to the NOZ-PV vision, the next step in the development of solar energy sources would be a complete solar city.

The costs of the 1 MW project were estimated to be € 8,6 million. The energy company REMU (Now Eneco) was the main investor in the project and carried full responsibility for the project. The project was supported by Novem under the NOZ-PV program and the European Commission under the Thermie-program.

4. Urban planning and architectural integration

The environmental supervisor BOOM was responsible for creating the ground conditions for the implementation of solar energy on such a large scale. The most significant contribution was a change in the spatial orientation of the houses from that which had already been defined in the Urban Plan. Originally, the houses were to be oriented in an East - West direction, which would limit the solar energy yield. After intervention from BOOM the urban plan of the Waterkwartier was changed to have more streets oriented in the North-South direction.

BOOM also developed the methodology that structured the effort of achieving the environmental and sustainability goals defined by the municipality. This methodology defines quality categories for each environmental aspect: energy, water, materials, transport, traffic, waste and landscape. The city council defined a target ranking from D to A in which D stands for the normal situation (as required by law), C for correct normal use, B for minimising the damage to the environment and A for the most sophisticated, autonomous situation.

The A variant is the best option for the environment. Levels B and C mean a large and a small step forward respectively. This method, as developed by BOOM, has been used in many projects before and after Nieuwland/Amersfoort, such as the GWL-terrain in Amsterdam, and later on in the Environmental Quality Plan of the City of the Sun in the city of Heerhugowaard. The method enabled the involved parties, who had no experience with solar energy, to understand the necessity of specific architectural solutions.

Figure 2: A view of Nieuwland by Google maps, the 1 MW project is in the upper-left quadrant

Taking the 'solar factor' into account from an early stage allowed the urban development of the district to be structured in line with a target level of 20 m^2 PV per household. The land was parcelled out in such a way as to render as many roof surfaces as possible suitable for the installation of solar panels, with a minimum of 500 to reach the level of 1 MWp.

The requirements regarding the PV houses were developed by REMU in cooperation with Ecofys. The idea was to use well proven concepts for the building technical integration of solar modules. Guidelines were developed regarding orientation, inclination and ventilation. The resulting architectural designs show a great variety of PV buildings, oriented between SE and SW, with tilt angles for the solar modules between 20˚ and 90˚.

Solar modules have been used instead of roofing tiles, as well as for cladding and as sunshades. The water tightness of the PV roofs was guaranteed by a watertight layer under the solar modules. PV roofs were mounted on the standard roof construction. PV arrays were placed on buildings with sloping roofs and with flat roofs.

The project includes over 550 houses, an elementary school, a kindergarten and a sports complex. Also, there is one application with solar portals connecting two rows of one family houses.

Subproject: Cascade, © Photographer: Jan van IJken

Subproject: Kroosbuurt, © Photographer: Jan van IJken

Subproject: Kindergarten Plons,
© Photographer: Jan van IJken

Subproject: Pitrus - Mattenbies - Rietgors,
© Photographer: Tjerk Reijenga

	
Subproject: Solar portal, © Photographer: Jan van IJken	*Subproject: Sport complex, © Photographer: Jan van Ijken*
	
Subproject: Jersey, © Photographer: Jan van IJken	*Subproject: Dyke or noise wall houses, © Photographer: Astrid Schneider, Berlin*
	
Subproject: prefab PV roofs, Photo: © NOVEM	*Subproject: School Houses, © Photographer: Jan van IJken*

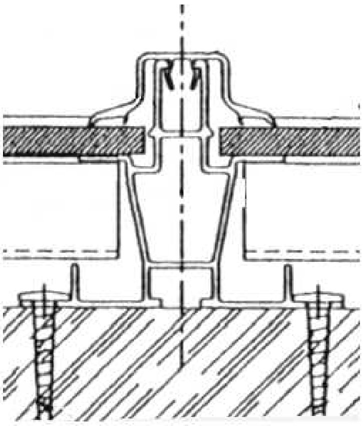
Figure 3: Photos of different subsystems

5. The PV arrays

The solar modules used in Nieuwland were supplied by Shell Solar, BP Solarex and RBB. For special purposes, like the sun shade systems on the apartment buildings, the Shadovoltaics system was used. Translucent modules for the solar portals and the sports complex were supplied by Pilkington Solar.

The modules were supplied in batches, according to the results of the manufacturer's flash tests. Modules with similar performance in the flash tests were grouped together when forming the strings. The system price was based on the flash-test power. The average turnkey price was € 6,9 per Wp.

The solar modules were integrated in a simple profile construction, consisting of: an asymmetric H-profile with a water gutter on the back side. This profile was fastened on one long side of the module. The following module was pushed into the lower part of the H-profile. On this side, there was some moving space for the panels, in order to allow for any movement in the roof construction.



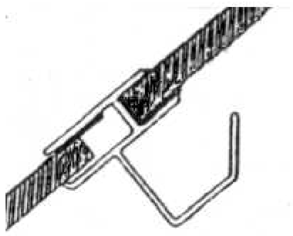


Figure 4: Building technical integration of solar modules

In the vertical direction, modules were fastened within the two parts of a BOAL profile (BOAL is a Dutch producer of aluminium profiles). The mounting system is shown in figure 4 above. The same integration system has been used in the Nieuw Sloten project in Amsterdam. The tilt angles of roofs with the BOAL system are between 20 and 90 degrees.

On 10 'School houses' and 23 other terraced houses the RBB PV700 mounting system was used in combination with the RBB modules. These modules have the same dimensions as 4 standard roofing tiles together.

6. Electric design and grid connection

The Nieuwland project is designed on the basis of one house - one system. The sizes of individual systems varies between 0,8 - 4,4 kWp. Each house has its own inverter and a feed-in kWh-meter. The main suppliers of inverters were Mastervolt and ASP.

Figure 5 below illustrates the electric configuration of individual systems. The inverters are placed in the attic. There are two separate kWh-meters, one for the PV generation and one for the consumption.

The electricity generated by the solar systems is supplied into the public grid. During the preparation for the project, REMU made some analyses of potential capacity problems in the PV-district. In order to avoid potential capacity problems, especially during the summer months when most of the tenants are on vacation, REMU provided some adaptation in the local public grid. These were: heavier distribution cables and larger transformers (1 x 630 kVA and 2 x 400 kVA instead of 1 x 400 kVA and 2 x 250 kVA) in the low voltage grid.

Up to 2008, no serious problems have occurred with regard to the grid connection.

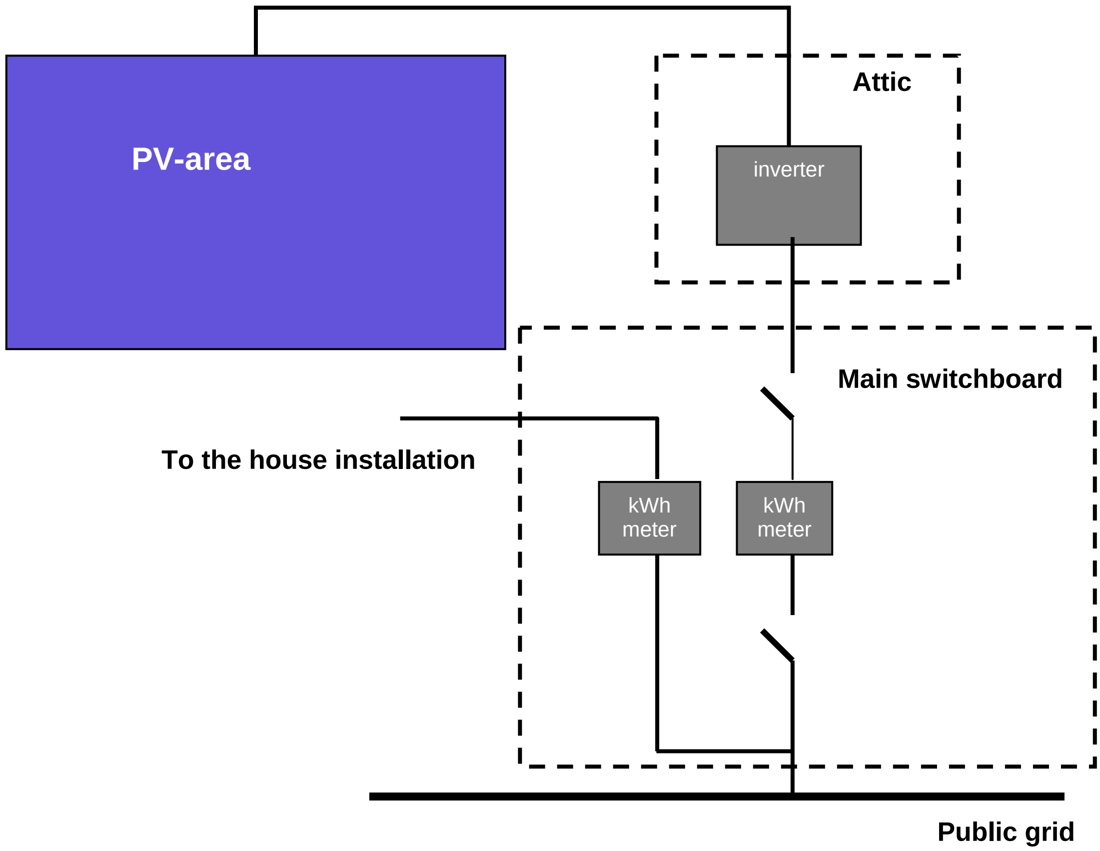


Figure 5: Electric design of individual PV-systems

7. Monitoring

Monitoring was provided by Ecofys and by the University of Utrecht. Each house is provided with a measuring instrument (Eclipse) on which the tenants can track the performance of their solar system. The Eclipse units can be connected to a PC to supply data which can be used to produce long term overviews of the system performance. Distance monitoring is also possible through a data logger and modem. Two monitoring reports regarding this project have been produced, one by Ecofys for the year 2005 and one by the University of Utrecht for the year 2007.

The conclusions of the technical monitoring were:

- The majority of the systems, about 80%, perform well.
- Some systems perform below expectations. The technical problems are related to shorter strings due to the chimneys within the PV area, malfunctioning invertors and shadowing by the neighbouring walls.

- The majority of the failures are not solved, often due to simple barriers such as the tenants not knowing who to call when they noticed a problem.
- Some monitoring units are not working.

Energy calculations were made by Ecofys for each PV system in 2005. The expected yield (kWh generated / kWp / year) was calculated for each individual system. The expectation was 750 - 800 kWh/kWp for optimally situated PV systems, based on Dutch climatic conditions. The average yield measured was lower than expected at 710 kWh/kWp. This was partially a consequence of the design freedom which was given to architects resulting in a high proportion of systems with PV modules not ideally placed.

The results of the analysis of one area are presented in figure 6 below.

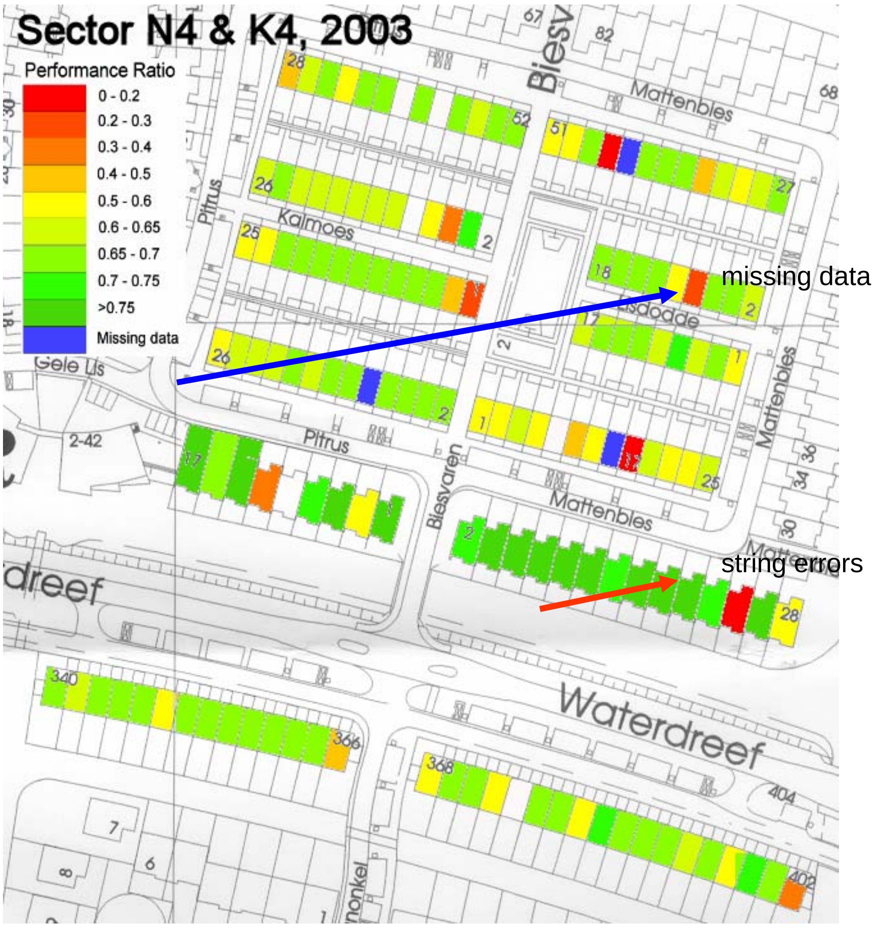


Figure 6: monitoring results in two subprojects

The estimated annual yield for the whole project (1,323 kWp installed power) was 944.000 kWh per year. In 1998, the average electricity demand per household was 3280 kWh per year. This means that the installed PV capacity should have provided electricity for 288 households in 1998.

8. Social Monitoring

The experiences of the participants in the project were studied and a report on social monitoring was produced by the University of Rotterdam: 'Rapport sociale monitoring 1 MW project Nieuwland, Amersfoort 1999 – 2002', Ger de Vries and Sacha Silvestar (Novem report No 146.950-008.1.)

The goal of this research was to register, analyse and evaluate the knowledge, attitude and behaviour of all participants in the project. The monitoring looked at: non-technical issues, the realisation process, the motives and experience of participants and the value for future projects.

The questions the research aimed to answer were:

- What do the participants know about PV and how important is this knowledge?
- What do the participants think of PV?
- What do the tenants know about their own situation: the electrical capacity and the electricity production of their PV system and their electricity demand?
- How did the implementation process go: what went well, what went badly?
- What are the practical experiences of the tenants: what went well, what went badly?
- Did the tenants specifically choose PV houses or was it for other reasons that they chose these houses?

A questionnaire was distributed among 448 tenants of solar houses and 59 direct neighbours. From 507 questionnaires distributed, 176 were returned filled in (participation of almost 35%).

<u>Push factors</u>

The tenants were asked their reason for moving to Nieuwland. The most frequent answers were:

- Previous house too small,
- Disturbing neighbourhood,
- Enlargement of the family – first child or more children
- Wishing to own a house (previously living in a rented house).

<u>Pull factors</u>

The most frequently reported reasons for moving to Nieuwland were:

- By the owners: to buy a new and larger house, attractive price, nice house and attractive surroundings.
- By the tenants: new and roomy house, attractive price, solar system for own electricity generation.
- By the neighbours: new and roomy house, services.

Attitude and behaviour regarding environmental issues and electricity usage

- 52% of the tenants and 27% of the owners considered the environmental measures important.
- 44% of the tenants and 21% of the owners answered that the solar system was the reason to choose this house.
- 66% of the respondents think that PV is not an important environmental measure.
- Almost a half of the respondents have no energy saving lamps in house.
- 86% of the owners and 39% of the tenants own a dishwasher. 66% of the tenants own a drier and 10% have a waterbed.

Information about PV

- 66% of the respondents considered that they had received sufficient information about the functioning of their PV systems.
- 68% of the respondents considered that they had received insufficient information regarding the costs of PV systems, especially the costs in the long term.
- 11% of the respondents were not aware that their house is connected to a PV installation.

Advantages and disadvantages of PV systems

- The respondents listed the following advantages of their solar systems: increasing the market value of their house, production of green electricity, less usage of pollutant energy, unusual (original) roofing.
- The following issues were named as the main disadvantages of PV roofing: no possibilities for roof extensions, uncertain costs in the long term, leakages and long periods of reparation at the beginning of the project.

Attitude regarding PV

- 85% of the respondents expect that PV will be installed more often on houses in the future.
- Majority of the respondents do not think that with PV one can show that he/she is environmentally conscious.
- Majority of the respondents do not think that solar electricity makes them less dependent on the central electricity supply.

Attitude regarding the visual aspects of PV

- About half of the respondents like it when PV is installed in a not too visible way. The roof applications are more liked than the applications on claddings.
- Majority of the respondents do not think that PV in their district is too showily implemented.
- Majority of the respondents are neutral regarding the niceness of PV houses.

PV in relation to other forms of green electricity

- Majority of the respondents think that solar electricity is a better solution than green electricity from the energy company.
- Majority of the respondents prefers PV to a large wind turbine in the district.

Feedback regarding the performance of the PV systems

- In the beginning of the technical monitoring, many respondents were confronted with malfunctioning monitoring instruments.
- About half of the respondents keep control of their electricity demand.
- Majority of the respondents do not know much electricity their PV system produces.
- Less than 10% of the respondents have connected their Eclipse monitoring unit to a PC.

Ownership and responsibility

- Majority of the respondents think that if they could choose again, they would choose to hire their roof to the energy company against 5 ct/kWh for placing a PV system.
- 14% of the respondents would not like to have PV system on their roof again.

Satisfaction

- More then 70% of the respondents are happy with the performance of their PV system.
- Majority of the respondents are not satisfied with other environmental measures in their houses like deal-wood window frames and water based paint. Also, they think there were

other better environmental measures, like better insulation and heat recovery systems, that could have been installed instead of PV
- Overall satisfaction with the houses and the district is very high.
- Regarding the financing of solar energy, the respondents suggested the following measures: subsidies, fiscal advantages, and obligations to install PV.

Willingness to invest in PV

Figure 2 below shows the responses of the respondents regarding their willingness to invest in PV in the future. 20% of the tenants are not willing to pay extra for a PV system; 25% of them are willing to pay up to € 10 per month extra and 25% are willing to pay up to € 25 per month extra.

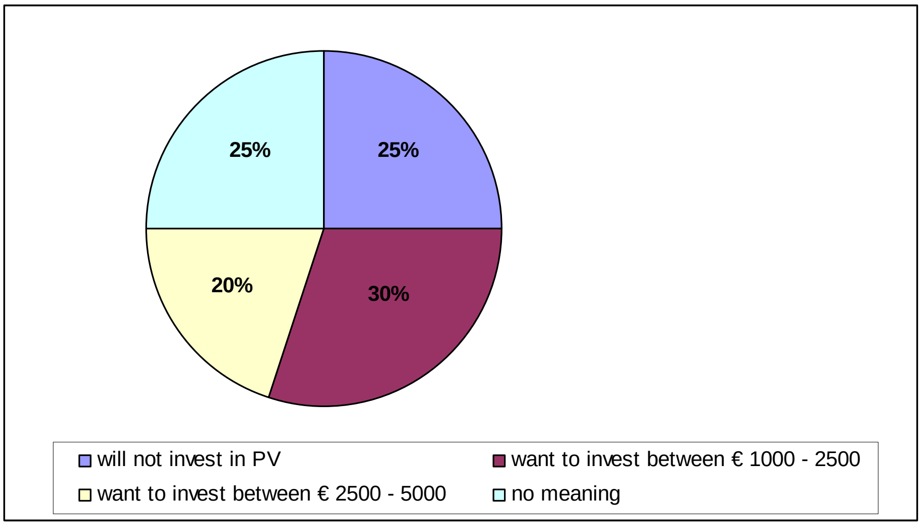


Figure 7: Willingness to invest in PV in the future

8. Maintenance

REMU (Now ENECO) was fully responsible for the maintenance of the PV systems for a period of 10 years.

Initially an experimental Performance Guarantee & Maintenance System was set up. For the first two or three years this worked well, with a consultancy company responsible for monitoring the performance of all PV houses. During the first years of operation, there were many problems with leakages. Also, some inverters malfunctioned. All of the problems that occurred in this period were solved.

However after some years this guarantee and maintenance system did not work out anymore. There were too many possible causes for lower performance or malfunctioning, such as shadowing by trees or leakage of roofs. Also some of the companies who had provided equipment did not exist anymore and it would have been difficult to claim under the guarantees initially provided.

In general the maintenance system is no longer ensuring good performance of all the PV systems. The energy company REMU (now ENECO) is now responsible for most of the maintenance. However when REMU merged into ENECO, the company got less involved in PV. ENECO collected the problems but only performed maintenance activities once a year. Maintenance had to be done both regarding the roof integration, where there were a few problems, and regarding the technical quality and performance of the PV. Between 2003 and 2007 maintenance was done on a minimum level; and the performance of the PV systems went down quite a bit.

9. Lessons learned

According to the statistics of ENECO, there were more than 35.000 visitors in Nieuwland over the last ten years. Many people and companies have learnt major lessons from this unique project.

Within the PV-upscale project, there were interviews with the architects and the tenants of Nieuwland. In this chapter the outcomes of these interviews are presented.

Architectural and building technical

The general impression of visitors is that Nieuwland is a very successful project with attractive and varied PV architecture.

The architects have drawn the following conclusions from this project:

- The application of solar energy opposes pressure on the spatial design of the district. It means that the streets must be oriented from east to west, except in the case of flat-roof buildings.
- PV roofing puts significant requirements on the architectural design of the PV-houses. The architect involved must take all these requirements into consideration when designing PV-houses.
- A simple replacement of roofing tiles by PV-modules is not possible. Extra measures are necessary (watertight layer or water tight profiles, adapted roofing construction).
- The introduction of a watertight layer has consequences for the logistics of the building process. After the layer was put in place, building workers walked across the layer, damaging it in many places.
- Each new project means that (some) new parties will be involved. It is very likely that these parties will have no knowledge and/or no experience with PV. It is important to inform these people about PV, especially about the aspects important for their part of the project.
- Some of the project developers wanted a traditional appearance for the PV houses. The architects found it very difficult to combine the high-tech appearance of solar modules with traditional housing.
- Architects seek more colours, varied dimensions and structures for solar modules. Also matching accessories are needed such as fastening constructions and edge and corner pieces. They expect that more choice will stimulate creativity and increase the number of applications.
- There was too much pressure to realize the target PV capacity and no space for other measures which were potentially more financially attractive and environmentally effective.

The major lesson learnt was firstly that there was no problem to integrate PV in the urban process. Even at a rather late stage the urban plan could be modified, though of course it is more optimal to take the solar factor into account from the very beginning. Secondly architects had no problem in designing and working with PV. The only important condition was that sufficient information was available to them. In this project this was achieved by a ‘helpdesk’, the architects and developers could call during the housing development.

The PV company Shell Solar learned especially in this project not to embrace the idea of combining the needed water tightness of a house roof with the integration of a PV solar roof anymore. In the Nieuwland project, again, too many problems arose with leakages etc.

Electrical

Except for the malfunctioning of some inverters at the very beginning of the project and cable connection failures, no major electrical problems have occurred. In particular there was no negative impact on the quality of the grid.

ENECO learned most from this project. The major lessons for ENECO concern the ownership and maintenance of so many dispersed PV systems. This was much more difficult than initially expected. Though a final conclusion cannot be drawn here, it is apparent that the connected problems must be solved, as sub-optimal or unclear ownership and poor maintenance have caused major problems during the lifetime of the project.

Tenants

The tenants were asked to summarize the strengths and weaknesses of their PV-houses. They named the following strengths: lower electricity costs, higher value of the house, contribution to green energy generation and environmental savings. On the other side, they named the following weaknesses:

◊ Long reparation period at the beginning of the project (leakages and inverter problems).

◊ Uncertainties regarding the costs and responsibilities in the long term. If ENECO offers me to take over the PV-system, but what will be my responsibilities? What are the maintenance costs and what are the benefits?

◊ There are no possibilities for roof extensions on PV-roofs.

◊ On some roofs there is no clear border in ownership between the neighbours and/or between the house owner and ENECO.

◊ Some monitoring units (Eclipse) are not working. The tenants are not sure if that also means that their system is not working. They did not get a handbook for Eclipse. Also, they could not ask ENECO about these issues since there was no contact person available at ENECO.

The original tenants had a basic understanding of PV due to excellent communication by REMU and the Municipality between1997 and 2000. However follow-up owners often were not aware of existing contracts and not well informed about PV. Now, 10 years after the opening of this impressive urban PV project, breakdowns or poor performance of the PV systems are often not noticed, except for roof leakages.

In the coming year it is expected that ENECO will try to interest the tenants in a continuation of the project, when they will offer to improve the maintenance and service. It is unclear if they will be successful as the confidence by tenants in ENECO might be too low, also due to problems such as leakage.

General

The Nieuwland 1 MW PV project was a ‘first of its kind’ in the world: never before had a BIPV project been implemented at such a scale. From an architectural point of view, the project was a big success. However, the after-care of the PV systems has been more time consuming than anticipated and it looks like the growing pains are not over yet.

It turns out that yearly monitoring and inspection rounds (the current practice for this project) has not been sufficient to keep system outages down to an acceptable level. Between 2003 and 2007 maintenance was done on a minimum level; and the performance went down quite a bit.

ENECO has offered the inhabitants tools to check the performance of their PV system, either through a display in their homes (the ‘Eclipse’ data-logger) or through the ‘Sundial’ internet service which can keep track of the performance of their system. So now most PV houses do have a monitoring system. However, this has not resulted in any significant error reporting by inhabitants. This may be partly due to ‘lack of ownership’ and not feeling responsible (they did not make the investment) and lack of substantial financial repercussion (no high feed-in tariffs). However simple problems like not knowing who to call or simply not being called back were in fact the main reasons reported.

One can say that it is not technical problems which are causing the major problems in one of the most famous PV projects in the world; rather it is poor communication with the tenants of the PV houses, especially after the first satisfying two years.

Sources of further information

“Performance evaluation of the 1 MegaWatt Building Integrated PV project in Nieuwland, Amersfoort, the Netherlands (January 2001 - February 2006)”, Corry de Keizer, Utrecht University, 2007.

“Rapport sociale monitoring 1 MW project Nieuwland, Amersfoort 1999 – 2002”, Ger de Vries and Sacha Silvestar, University of Rotterdam, 2003.

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