Nieuw Sloten PV Houses, Amsterdam

1. Introduction

The Nieuw Sloten PV houses project was one of the first PV projects installed at an urban scale worldwide. In this project PV was installed on houses in a new housing area. The project was led by the local electricity utility, the Energy Company of Amsterdam (now NUON). It was an important demonstration of PV in urban areas and helped to pave the way for later projects.

The houses were completed in 1996 so there are now 12 years of experience from the project. This case study looks at the lessons learnt since the project was started. A separate pdf describes the development process and the organizational lessons learnt.

Nieuw Sloten is located in the south-west of the city of Amsterdam in the Netherlands and can be easily found on Google Maps with the coordinates: N52˚ 20' 39" / E4˚ 48' 19".

The goal of the project was to realize a fully integrated PV system in a new build residential area with approximately 100 dwellings. The PV system was integrated physically (solar modules instead of roofing tiles), electrically (connected to the public grid) and organizationally (the project was embedded into the area development process). A total of 250 kWp of PV was installed.

The PV system is owned and operated by the utility. The householders own the houses, but not the PV system. There is a legal separation of the house and the roof marked by the waterproof layer installed under the PV modules. The electricity generated is used within the district but is not linked directly to the house on which it is mounted.

In a densely populated area such as Amsterdam it is not always possible in urban planning to orientate houses towards the South. This was the first project in Europe with PV roofs oriented to the east and west. The east and west facing roofs have low roof inclinations for better insolation.

Photo 1 - View from the South of the apartment building with 2 penthouses with PV roofs

2. Stakeholders and added values

In order to achieve good organisational integration of the implementation of the PV system within the development of this new city area a new organisational approach was necessary. In the standard development process the utility company only gets involved during the last phase of the development of the new district. In this project the utility began collaboration with municipal organisations at a very early stage of the development of the district. This made it possible to create better conditions for the realisation of the PV system. For further information see the description of the development process, available as a separate PDF (see further information nr. 3).

The New Sloten project had also a much wider effect than just the technical implementation of a PV system. As a spin-off of this project the municipality of Amsterdam now invites the utility company to participate every time they start a new, innovative building project. The scheme below illustrates the development process for developing new districts in the Netherlands and the phase in which the New Sloten project was implemented.

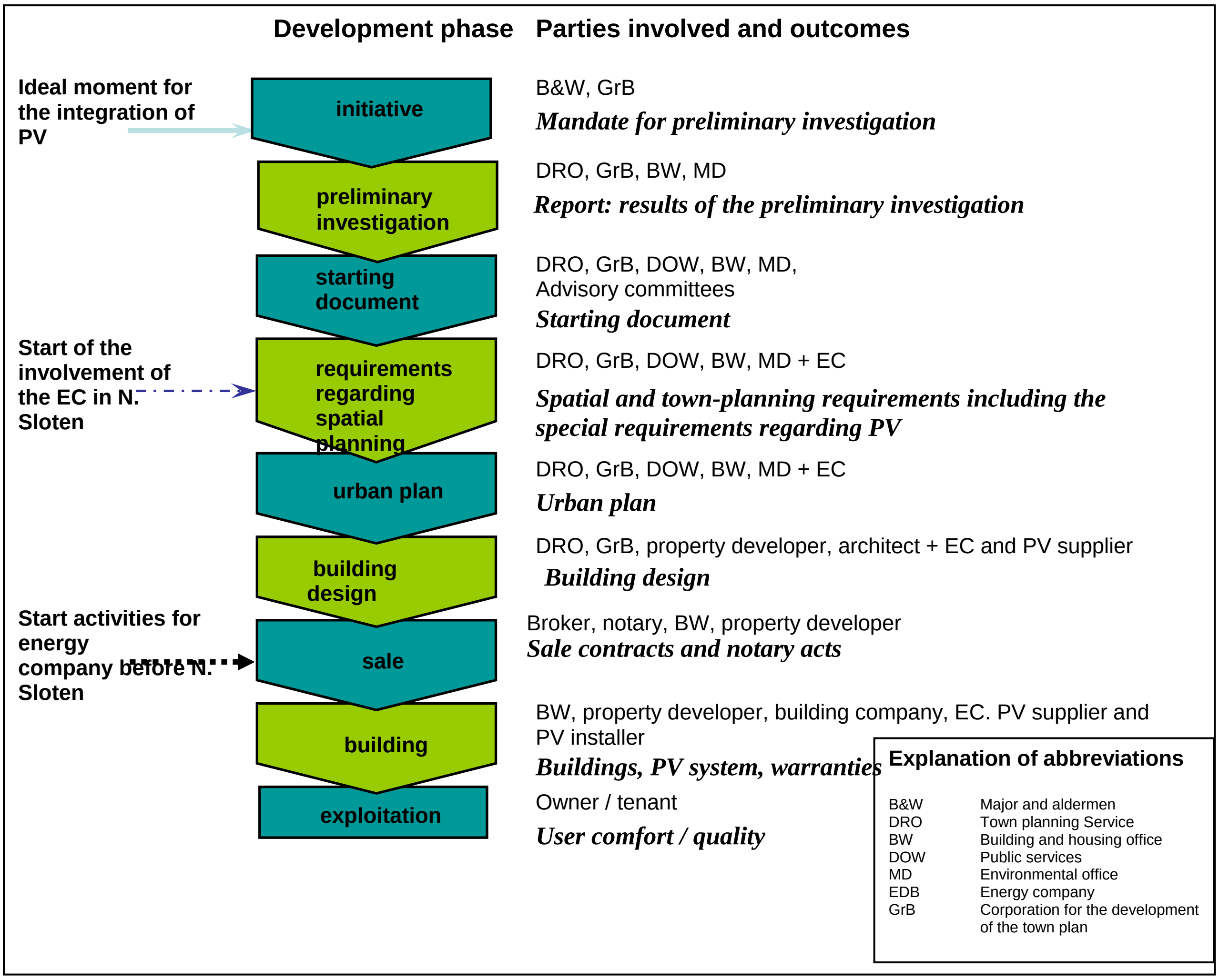


Figure 1: Integration of PV system into the development process of new city districts in the Netherlands.

The Energy Company Amsterdam initiated the PV project and led the project team as an environmental initiative. Other members of the PV project team were: Ecofys, the Newcastle PV Centre, and the environmental organisations Miljøkontrollen from Copenhagen, Sermasa from Madrid and ICIE from Genova. The environmental organizations aimed to learn from the project and use the knowledge when implementing similar projects in their countries. Figure 1 below illustrates the project organization.

Three companies had been bidding for this project. After a thorough analysis and negotiations, it was agreed that two companies, instead of one, would be contracted. The PV modules were supplied by BP Solar, who supplied half of the modules, and R&S Systems (now Shell Solar) supplied the other half of the modules and the rest of the components. R&S was also responsible for the system engineering and the delivery of the system on a turn key basis. One reason for the wide range of organizations involved was the need to show a European aspect to the project in order to obtain funding under the European Commission THERMIE programme.

The building company UBA from Uithoorn was the property developer. Architect office Duinker & van den Torre designed the PV houses.

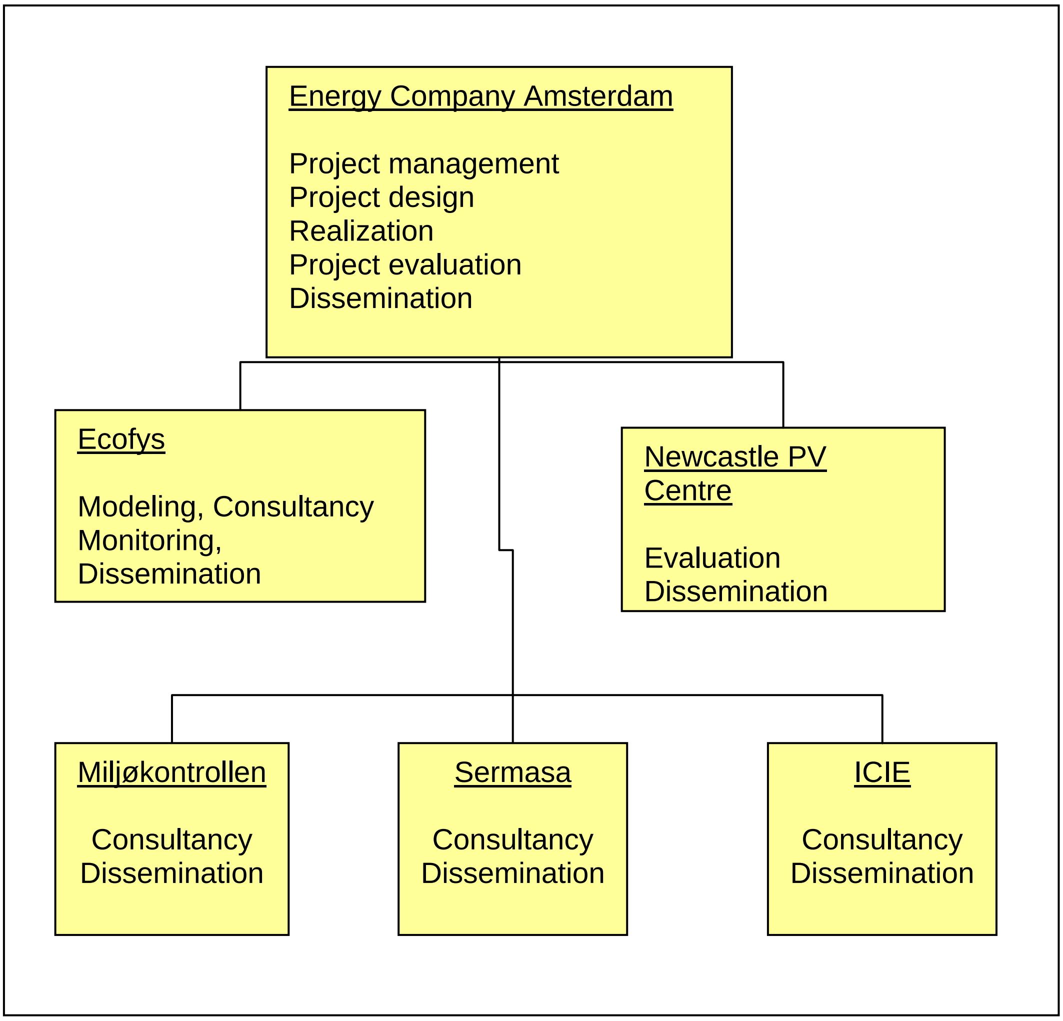


Figure 2: Project organization

With this project, the Energy Company of Amsterdam (now NUON) achieved a number of goals which have played an important role in later urban PV projects. In particular it is important to remember that at the beginning of the 1990's very few parties really believed that PV had a future. This project showed that:

- PV 'works', even in a northern country like the Netherlands
- PV can also be applied in 'standard' architecture
- Important lessons were learned regarding the physical integration of PV, project organization and market development.
- Market parties worldwide were encouraged in applying PV as a promising technology.

The project also had positive impacts on the stakeholders involved.

- The architects involved in the project learned how to use PV modules and applied the knowledge gained in later projects.
- Buyers of the PV houses liked the visual appearance of their houses and were proud to be an 'ambassador' of PV energy.
- The utility gained experience with PV in residential areas. This experience was used in the development of the plug-in PV products like Sunpower and in later large scale projects like Nieuwland, Vroonermeer and City of the Sun.
- A large number of consumers learned about solar electricity and were prepared to welcome in their houses visitors from all over the world and let them see the technical details of their PV roofs.

3. Costs and financing

The total cost of the PV system in Nieuw Sloten was € 2,5 million. Forty percent of the costs were subsidized by the Thermie program of the European Commission (EC) and nine percent by Novem (Dutch government). The remaining costs were covered by the municipality of Amsterdam, the project participants from Copenhagen, Madrid and Genoa and by contributions from the module suppliers Shell Solar and BP Solar. It is important to mention that at the time, the Utility Company of Amsterdam was owned by the municipality. That is the reason why the municipality invested and not the utility.

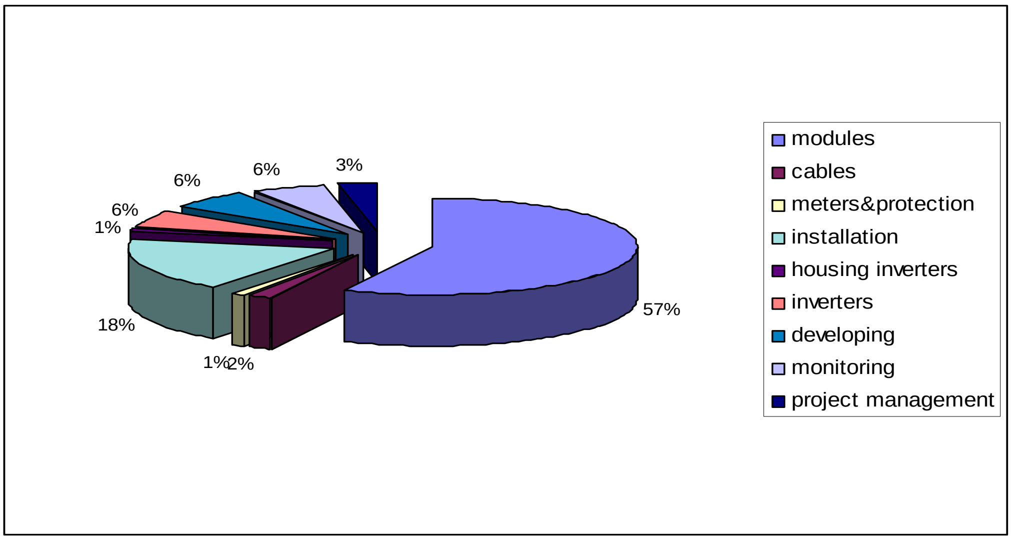


Figure 3: Total project costs and component costs

4. System concept

Before starting this project the Energy Company Amsterdam investigated a number of alternative options regarding the implementation of a 250 kWp PV system within their area. Aspects considered included: utilisation of the PV electricity, electrical configuration of the system, mechanical construction of PV roof covers and costs.

Initially, the possibility of using electricity generated by a PV system to supply DC loads was investigated. The only major DC consumer in the area was the tram. For this, the frequency of the trams and their electricity demands were analysed. The Sloten district is located at the west edge of Amsterdam. The tram arrives every 12 minutes and at these precise moments there is a demand for up to 1000 A at 700 V. There is no demand outside these peak intervals which means that only about 30% of the available electricity yield from the PV system could be utilized. Generally speaking, the tram grid could be a good solution for connecting the PV system if the system was placed in the centre of the city where the trams consumption is steadier.

Next the possibility of placing PV systems on office buildings was analysed. The daily demand of a newly built office building in Amsterdam was measured and compared with the expected yield of the large PV system. The conclusion was that the demand curve of office buildings ideally fitted the yield of the PV system. Unfortunately, the urban plan of New Sloten did not foresee any new office buildings in the district.

The only possibility to use the PV electricity was in a newly developed housing project. A feasibility study was conducted in which three different system concepts were analyzed:

a. 1 system per house: 100 individual systems
b. 1 system per block of houses: 6 systems
c. 1 system per district: a single 250 kWp system.

The analysis showed that option c: a single installation on the district level would be financially the most attractive one. In particular the costs of inverters, installation and maintenance were more expensive for options a. and b. For option c it was necessary to build an inverter room, but this extra investment was lower than the extra costs of a. and b.

Experience at New Sloten and at the 1 MW project in Amersfoort showed that private householders are concerned about maintenance costs of PV systems over the long term. It seemed that they would be prepared to have a PV-roof as their own responsibility only if the cost of maintaining the system was clear and maintenance contracts were available with certified installers.

5. Integration into the architecture and construction of the houses

The New Sloten housing development consists of around 100 dwellings. PV is installed on the roofs of 34 of the terraced houses (orientations west, south and east) arranged in a U shaped around some further flat roofed houses (without PV), see photo 2. To the north is an apartment building with 37 dwellings. PV is also mounted on the south façade, the main roof and two penthouse roofs on the apartment building.

Because the implementation of the PV system was embedded into the development process, the architect was able to take into account all measures necessary for the good functioning of the PV systems while providing visually attractive houses.

- The family houses were provided with extra windows along the roofs because the PV system meant that it would not be possible for the occupants to build dormers (roof extensions which are very usual in the Netherlands).
- The colour of the cladding material was chosen to match the colour of the PV modules.
- All chimneys were shorter than standard chimneys to avoid shadowing the PV arrays.
- The roof construction was adapted to carry the profiles for mounting of PV modules and to allow ventilation under the PV modules.

The PV array area fully covers the roof surface of the PV dwellings with a mono-pitch roof.

Photo 2: Wide angle photo of the Nieuw Sloten PV houses. In the foreground is the west facing roof, in the centre is the south facing roofs and in the background the apartment building with PV facade and two penthouses with angled roofs. To the left the east roof can hardly be distinguished.

In this project, solar modules replace the traditional roofing. The consequence is that the utility company, being the owner of the PV system, must guarantee the water tightness of the roof. For this, it was necessary that the utility provide a GIW guarantee (Garantie Instituut Woningbouw) for the PV-roofing. This requirement was integrated within the turn-key delivery of the PV installation.

On the wooden construction of the roof, in place of the roof tiles, BOAL (Dutch producer of Aluminium profiles) profiles were fastened in a vertical position. Also, the string cables to connect groups (strings) of modules were placed. After this, the modules were mounted between the profiles and connected to the string cables.

Photo 3: Mounting of the PV modules

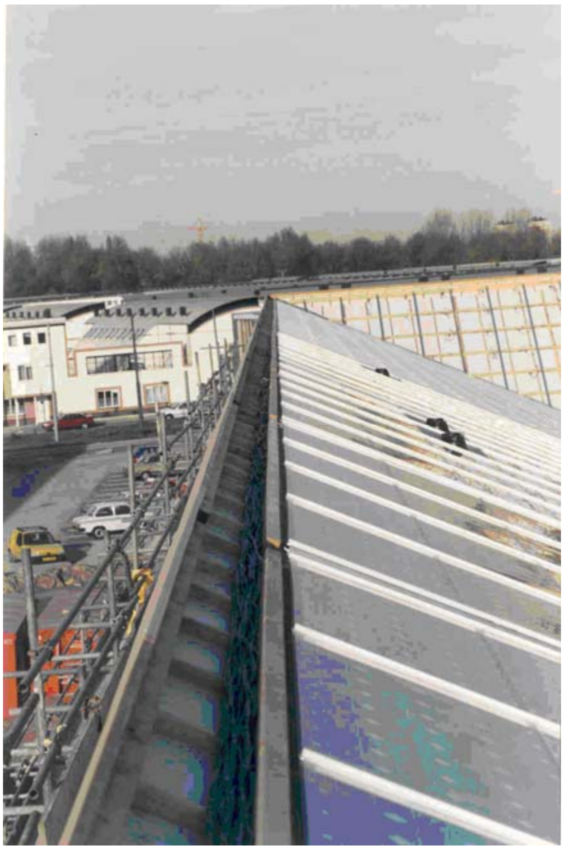


Photo 4: The string cables are collected in the cable duct along the ridge side of the roof.

Chimneys are integrated within a plate with the same dimensions as the solar modules. The chimneys (not yet mounted in the photo) were specially shortened to reduce shadowing on the modules.

Photo 5: Plates for the integration of chimneys and ventilation pipes

Photo 6: The edges of the roofs were finished with aluminium plates.

6. Modules

Two types of solar modules were used in this project: BP Solar and Shell Solar. The BP Solar modules were larger than the Shell solar modules, see the table below. The total amount of modules used was: 1586 BP modules with a total peak power of 113,6 kWp and 2821 Shell modules with a total peak power of 136,8 kWp.

For both types of modules a warranted minimum power was provided and checked. Module test results provided by the suppliers were used to group the PV modules into strings of similar performing modules in order to optimize the system yield. The modules were labelled with stickers in different colours. The results of the module tests were supplied to the energy company due to agreements with the module suppliers.

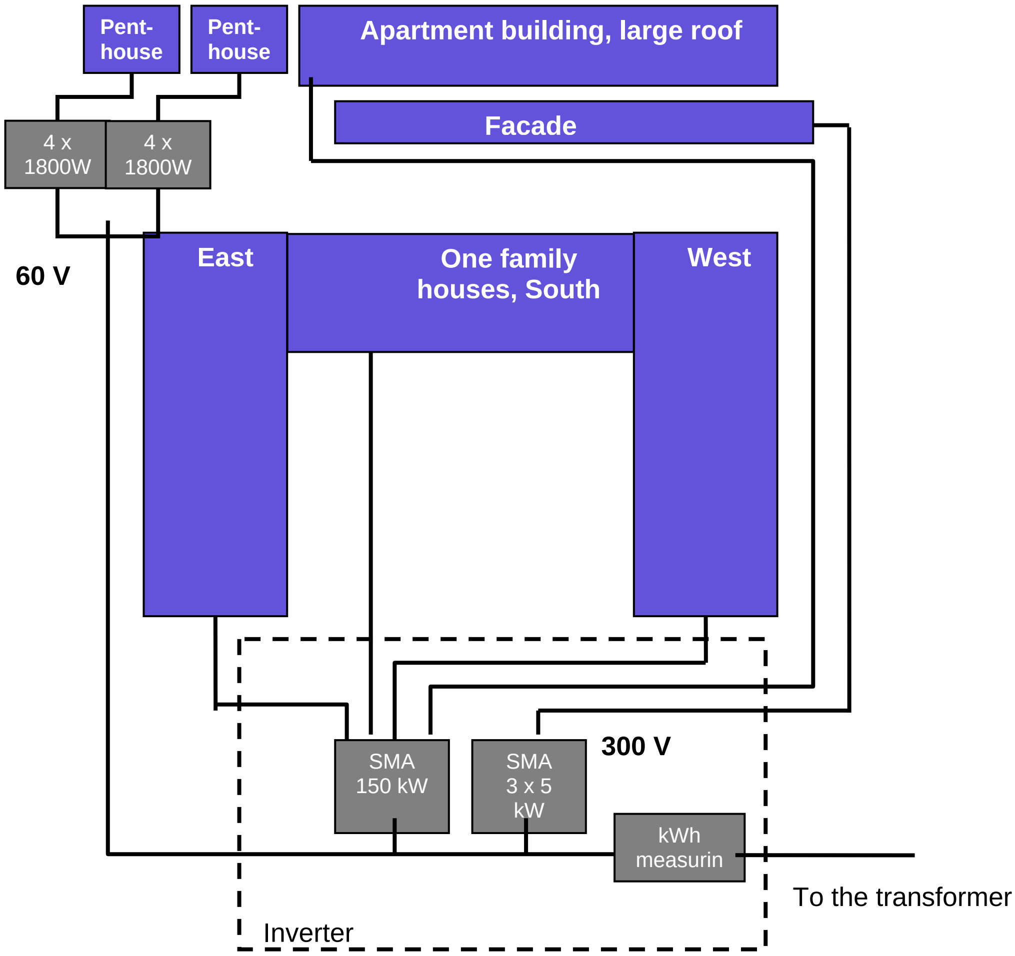
Table 1: Technical data of solar modules

Data solar modules		BP Solar PB275	Shell Solar RSM 50
Pmax	nominal peak power	75,00 W	50,00 W
Pmin	warranted minimum power	70,00 W	46,00 W

7. Electric design and grid connection

The PV system in New Sloten consists of four subsystems. The family houses and the large roof of the apartment building are connected to one large SMA inverter of 150 kW. The cladding of the apartment building is connected to a block of three SMA inverters of 5 kW each in master slave configuration. Each penthouse roof is connected to a series of 4 independent Sunmasters of 1800 W (on the roof). The SMA inverters are situated within the inverter room on the central plain of the district. The AC sides of all inverters are connected on the low voltage bus bar leading to the transformer room from where the current is distributed to the district.

Figure 4: Electrical scheme of the PV system in New Sloten, Amsterdam



The PV system is connected to the public grid at one point. Solar electricity is used within the district. The quality of the electricity matches the requirements regarding decentralised electricity production as defined by the Dutch energy federation Energiened.

The electricity generated is fed into the public grid at low voltage level. The fluctuation in the ratio between the PV system output and the demand in the local grid was considered before the system was installed. The worst case, maximum yield from the PV system and no demand from the district, was expected in the summer when the majority of tenants are on vacation. In that case, the public grid is able to distribute the solar electricity to consumers outside the PV district.

The electricity generated in this project is sold on the renewable energy market as a part of a renewable energy product called Natuurstroom. Natuurstroom is a mixture of solar, hydro and wind energy. The price of Natuurstroom is slightly higher than 'grey' electricity: the monthly costs are € 4,25 more than for 'grey' electricity, inclusive of VAT, at an yearly demand of 3500 kWh per household.

The voltage housekeeping in the area of Nieuw Sloten has been thoroughly analyzed in order to find out the relation between solar electricity generation and electricity demand in the district. The conclusion is that the demand in the district is much higher than the PV electricity. On a very few occasions, the demand was lower than the PV electricity generation. In that case, solar electricity was distributed to the neighbouring district. There were no distortions in the public grid caused by the PV system. This knowledge was later used while developing the City of the Sun.

8. Monitoring

The average energy production of the PV system in Nieuw Sloten was calculated to be in the range of 160 – 180 MWh/year The actual energy performance proved to be higher than predicted (76.5% performance ratio rather than the 72.5% performance ratio predicted). The calculations were based on the results of the flash tests of the modules.

Monitoring was provided by Ecofys during the period from August 1997 to July 1998.

Table 2: The electricity yield and standardized electricity yield per subsystem

subsystem	characteristics	Y (kWh/kWp)	Y_{klim} (kWh/kWp)
A: 214 kWp	All N, E & W dwellings & apartment building roofs through SMA 150 kW.	704,88	729,70
B: 21 kWp	Façade through 3x SMA 5kW	548,30	559,30
C: 8 kWp	Penthouse 1 through 4 Sunmaster's	755,21	785,70
D: 8 kWp	Penthouse 2 through 4 Sunmaster's	724,30	753,20
Total: 250 kWp		694,08	718,06

Table 3: Measured and calculated yearly irradiation per PV array

surface	elevation (˚)	orientation (˚)	measured (kWh/m^2)	calculated (kWh/m^2)
family houses	25	90	939	973
family houses	35	180	766	842
family houses	25	270	1015	1086
large roof apartment building	20	163	923	892
cladding apartment building	80	163	908	1027
roof penthouse	20	208	802	862
roof penthouse	20	208	960	1033

Figures 5 to 7 illustrate the PV electricity production in relation to electricity demand in the district. On sunny days there is a surplus of electricity which is fed into the public grid. In the figures Pwijk is the electricity demand in the district, Ppv is the electricity generation by the PV system, Pnetto is the difference between electricity supply and electricity demand.

Figure 5: Electricity generation, demand and the difference between the two from 1st to 10th of May 1997.

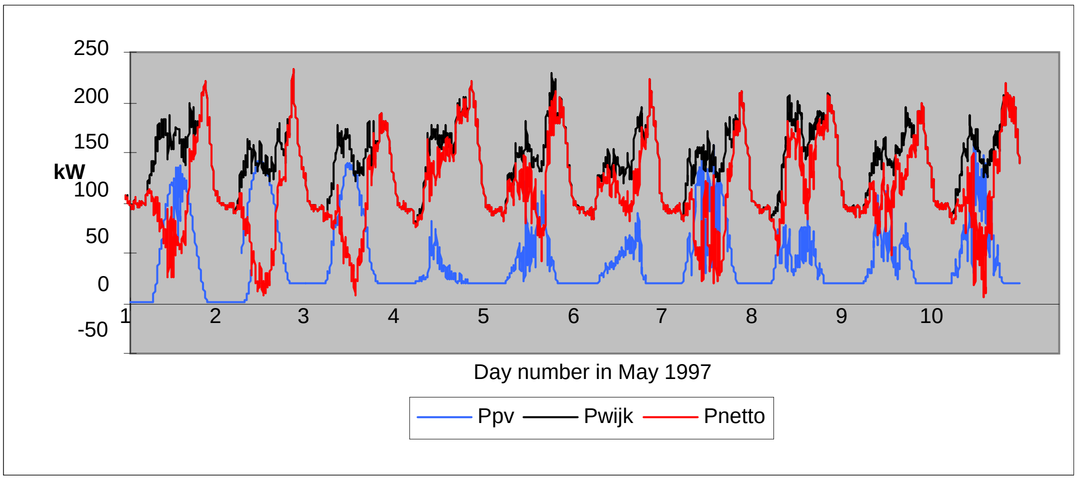


Figure 6: Electricity generation, demand and the difference between the two values on 1st May 1997

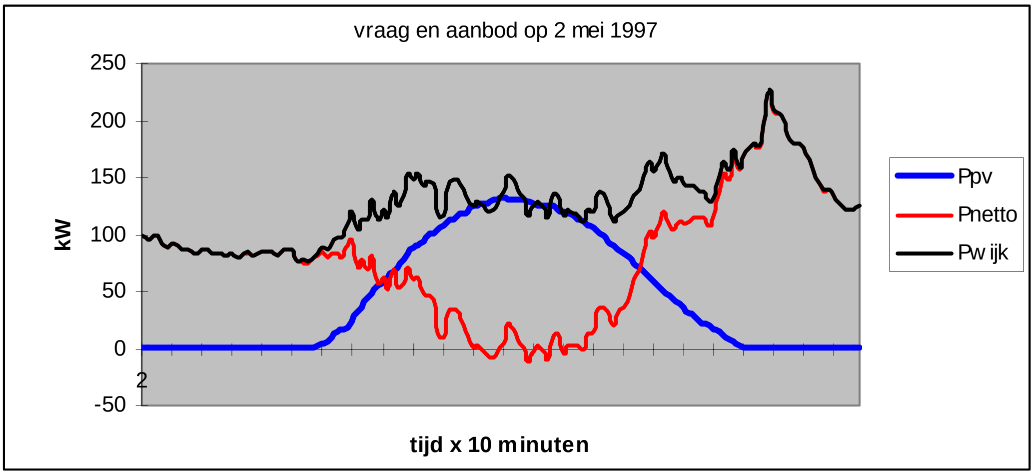
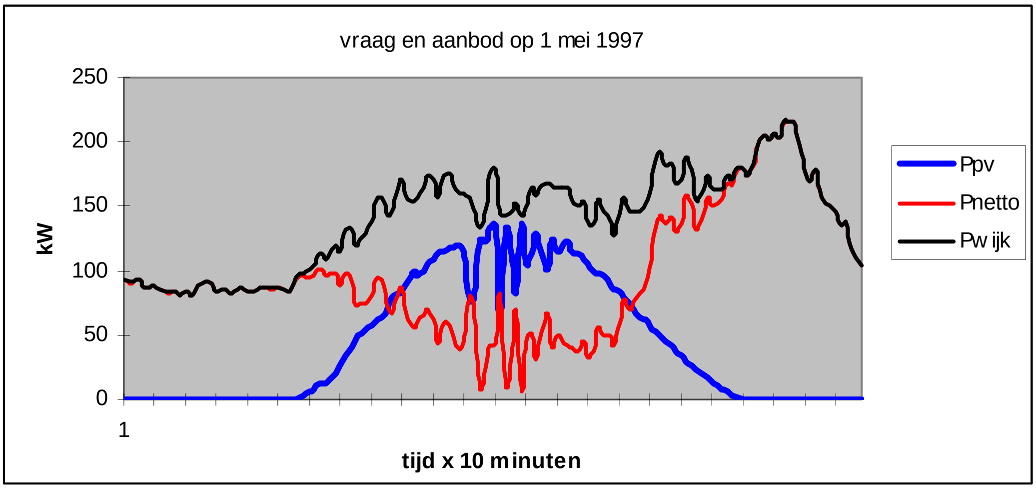


Figure 7: Electricity generation, demand and the difference between the two values on 2nd May 1997



The energy monitoring showed that:

- The performance of the East and West oriented PV arrays is significantly (about 20%) lower than for the South arrays. The total electricity generation is herewith lowered by about 4%.
- The mismatch because of the coupling of areas with different orientations to one inverter is about 1%. This corresponds with the computer simulations made during the preparation of the project.
- There was no difference in performance between the Shell and BP modules.
- Combining different oriented PV arrays with different kinds of modules to one central inverter led to lowering of electricity production by 1% to 5%. These losses are compensated by lower costs of this configuration.
- Energy losses due to high temperature of the PV array are between 3% and 5%.
- Shadowing due to the chimneys in the PV roofs led to energy losses of 3% to 4%.

9. Maintenance

The maintenance of the PV system in New Sloten is in the hands of the owner of the system: the energy company NUON. The system is monitored online. In order to ensure the safe operation of the installation and be able to follow it at a distance, three indicators are placed in all switchboards (DC- over voltage protection (varistors), DC- isolation control of the invertors, and a smoke alarm). There is one switchboard in the district for each PV array.

The only reparations up to now took place in the first two years of operation.

- The SMA 5000 inverter had to be replaced due to serious malfunctioning. This was covered by the inverter guarantee. Except for a few exchanged fuses, there were no other electrical problems in the PV system up to May 2008.

- There was a leakage problem with the roofs of the houses. The original concept was that the PV modules would form the watertight layer for the roofs. However this proved not to be reliable for shallow roof angles. This problem was solved quite rigorously: all modules were removed in order to place a water tight sheet on the wooden roof construction. After this, the modules were put back in the same way. The costs for this reparation were paid equally by the energy company, Shell Solar and Novem.

10. Lessons learned

Architecture and construction

Experience showed that some of the PV roofs in Nieuw Sloten were not watertight, even under non-extreme weather conditions. The BDA (Bureau Dak Advies: institute for roof research) looked for possible causes of the leakage's. It appeared that the conditions on the leaking roof were more extreme than the laboratory conditions under which a test roof was studied. In reality, there are roof lengths of 8 metres at a slope of 25°, whereas the test roof measured 2m^2 and under a slope of 45°. In addition, the roof construction consists of two parts, which means that there is a horizontal seam in the middle of the roof. The water which comes on the roof boarding enters the house through this seam.

Roofs in New Sloten which have a slope of 36° and have a maximum length of 6 metres stayed watertight, although on these roofs the very same construction of the PV roofing has been used as on the leaking roofs.

This problem led to the recommendation that watertight layers be installed under PV roofs. This has been applied to all PV roofs built in the Netherlands since then. Publicity around the problem led to greater caution by developers and a perception of risk. It is important to keep in mind that the water tight layer must be of very good quality because people walk across it during the mounting of the modules.

Ownership

The PV system belongs to the utility NUON, not to the house owners. This means that there is one system to operate and one body responsible for operation and maintenance rather than hundreds of individual householders each responsible for a small system. This has proved to be a success, especially because the private owners were afraid of taking responsibility for installations they knew nothing about.

Electrical

The fuses and measuring equipment for the string cables were placed in the connection box of each house block. For this, approximately 100 string cables from the entire block are collected in a cable duct on the ridge side of the PV roof, and are then led to the connection box via a vertical cable protection pipe in the corner house. In future projects, it should be seen whether it is possible to fuse and measure the strings on the roof in order to reduce the amount of cables which have to be run to the ground.

Covering technical risks

When drawing up contracts with the suppliers of PV systems, it must be specified how possible risks in the form of leakage’s and/or disruptions in the electrical supply will be dealt with.

Lack of knowledge about PV among participating parties

New Sloten taught us that, at the time this installation was realized, only specialised parties had sufficient knowledge of PV. In the future, more attention must be paid to training and information with respect to electricity generation from solar energy.

PV is not yet part of standard procedures

At one time, the project in New Sloten was almost brought down because changes with respect to the original design due to the PV were not passed on to the planning authority. This contrasted with other (‘ordinary’) changes (for example, those introduced by the property developer) which were passed on. In order to avoid similar situations in the future it is good to make PV a part of standard procedures in the development process of new city areas.

Insurer does not recognise PV roof

PV roofing can be insured either as glass or electronics. This is because the insurance companies have not yet introduced a separate PV category. As a result, the residents in New Sloten pay insurance for the house and NUON pays an extra insurance for the PV roof.

PV installer is not a roof specialist

The advantage of PV systems is that they can be used simultaneously as roofing and as electricity generator. This can be a disadvantage as regards the skilled installation. The installer of PV systems must be skilled in PV installation activities as well as in roofing. At the moment, there are no ‘dedicated’ PV installers in the Dutch market.

Goodwill is good, commitment is better

The system in New Sloten was realised based on goodwill of the municipality, the property developer and the residents of the PV houses. This goodwill made it possible for the utility company to realise this project. From the point of view of common interest, it is desirable that the commitment and costs are shared among all the parties involved: government, council, utility company and the house owner.

No trigger for the property developer
The municipality of Amsterdam is entitled to set limits on the prices of newly built houses in order to protect the market. This makes it less interesting for property developers to put PV houses on the market (at cost price). It should be possible for developers to include (a part of) the costs of a PV system in the price of a house. The other way to stimulate developers to make more PV houses would be for the municipality to proscribe a certain percentage of PV houses in new city areas.

Continuity of project management
In order to prevent misunderstandings and to keep up speed, it is necessary that there is a central manager of the project who has a complete overview of all agreements made. This can prevent problems when some members of the project team leave the organisation.

Sources of further information

1. “Monitoring PV system Nieuw Sloten”, May 1999, report available only in Dutch.
2. “Kiem van maatschappelijke verandering”, B.C. Van Mierlo, December 2002, Amsterdam.
3. “Development of the building integrated PV solar installation in Nieuw Sloten, Amsterdam”, Jadranka Cace and Emil ter Horst, June 2008, Horisun, Utrecht.

More info: NUON, Spaklerweg 20, NL-1096 BA Amsterdam or Jadranka Cace, RenCom.
jadranka@rencom.nl, Jan de Beyerhof 14, NL-1191 EP Ouderkerk a/d Amstel

Web sites: http://www.pvdatabase.org
http://www.bipvtool.com/index.php?case=The%20Netherlands
http://wikimapia.org/2636556/nl/Nieuw_Sloten_Zonnepaneel_Huizen

This Case Study was prepared by Horisun: Jadranka Cace (jadranka@rencom.nl) and Emil ter Horst (eth@horisun.nl).