

Building integrated pv installations in the Netherlands -examples and operational experiences

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Abstract

Building integrated pv started receiving attention in the Netherlands around 1990. Attention has ever since been focusing on the integration of pv into new dwellings. Efforts have resulted in cost reductions, performance improvements, the development of new integration products and the creation of a network with utilities, property developers, architects, building companies and local authorities.

PV system costs have been reduced by one third, to 5 Euro in 2000. System performance has gone up slightly during the reporting period, further reducing the costs per unit energy produced. Inverter costs have gone down from 1.5 Euro/Wp in 1991 to 0.5 Euro/Wp in 2000. Concerning integration into buildings and the building process, the Netherlands pv programme has been concentrating on developing products for low-cost integration into sloped roofs of new buildings. Watertight profile systems have been developed, tested, and applied in projects on a growing scale. The costs for building integration have come down due to improvements in integration systems, the electric system and in installation procedures. Projects have also been carried out on an increasing scale to learn about the integration of pv into the building process.

In total, a capacity of more than 8 MW was installed by the end of the year 1999, with projects ranging from individual dwellings and offices to solar cities such as the Nieuw Sloten project in Amsterdam (250 kWp) and Nieuwland in Amersfoort (1MW).

Now, at the turn of the century, plans are being derived to give pv the 'boost' to become commercially viable within the next 7 to 10 years. For this, an ambitious goal is being formulated by government together with the pv industry, utilities, the building sector and others involved in pv in the Netherlands.

Already in the mid nineties, the long-term energy programme of the ministry of Economic Affairs set the target at an installed pv capacity of 250 MWp by the year 2010. In order to achieve a commercially viable market within the next 7 to 10 year, however, a goal of 500 MWp installed pv capacity would be required. Recent research shows that such a target is ambitious, but achievable if supported by dedicated government programmes, investments by industry and contributions of the building and utility sector.

1. INTRODUCTION

1.1 The Solar Age

It is generally expected that in the next century, photovoltaics will be able to contribute substantially to the mainstream power production, even though pv now is up to five times more expensive than grid power.

In densely populated areas, such as major parts of Europe, Japan and the US, large scale realisation of systems will only be possible through distributed pv systems in the urban environment since no land is available for the installation of ground-based systems. Rooftop programs in Japan (70,000+), US (1,000,000) and Europe (1,000,000) illustrate the world-wide attention in building integrated pv.

PV installations can be installed on surfaces of buildings and along roads or railways, allowing the possibility to combine energy production with other functions of the building or non-building structure. Compared to large scale ground based pv power plants, cost savings through these combined functions can be substantial, e.g. in expensive facade systems where cladding costs may equal the costs of the pv modules.

Additionally, no high-value land is required, and no separate support structure is necessary. Electricity is generated at the point of use. This avoids transmission and distribution losses and reduces the utility company's capital and maintenance costs.

Following the advantages of building integration, more and more countries view distributed pv as a power source with a large potential for the future and are correspondingly starting to construct and operate building integrated pv systems on a large scale.

One of such countries is The Netherlands, where building integrated pv started receiving attention in the early nineties. Now, at the turn of the century, the pv programme aims at a total installed capacity of 250 MW within the next seven years. These plans are largely based on the results of three

key efforts of the last five years in the Netherlands: the pv learning programme, the pv-tender pv-GO! and the pv Covenant.

1.2 The pv Learning Programme

The first pv programme in the Netherlands was carried out in the period 1990 – 1995 provided the R&D infrastructure and experiences with PV in the Netherlands (Kimman *et al.*, 1995). In 1995, a new five-years national pv program was adopted, with a financial effort starting with 6.9 MEuro in 1996 and growing to approximately 18.7 MEuro in 2000 (see fig. 1). The Netherlands Agency for Energy and the Environment (Novem) is responsible for the implementation of this program. Financing of the programme comes from the Netherlands Ministry of Economic Affairs.

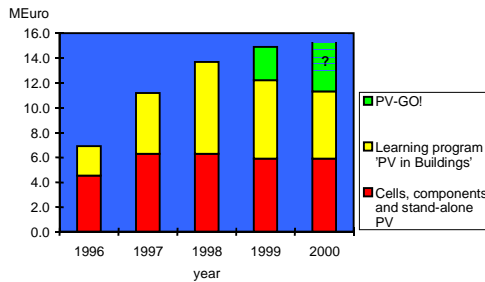


Fig. 1. Breakdown of the 1996-2000 budget of the Netherlands pv programme

The main goal of the 1996-2000 Novem program is *to create the conditions to let pv play the foreseen role in the national energy supply of the 21st century*. The 1996-2000 pv program concentrates on a number of issues dealing with these conditions:

- the creation of acceptance by society;
- essential progress in solar cell and pv system R&D;
- the creation of a market for stand alone pv systems;
- gaining experience with distributed pv in the built environment.

With respect to acceptance by society, communications plays a vital role. With respect to R&D, industrial production of high efficiency multi-crystalline silicon and the selection of next generation solar cells are the important issues.

For the grid connected pv systems, a plan was adopted to reach 250 MWp of installed solar capacity in 2010, in a three-phased implementation plan, aiming at a first target of 7 MWp in 2000. This equals approximately 3000 pv-covered roofs of residential buildings, arranged in 5 to 10 large-scale pv projects around the country, located in new residential areas. Annually, approximately 100,000 houses are built in the Netherlands, following a government directed programme. This volume offers abundant opportunities for the introduction of distributed pv.

The first phase of this implementation plan is the so-called 'pv Learning Programme', which aim is to realise pv pilot projects to reach specific learning goals. Scaling-up of projects and cost reductions are important features of the pv Learning Programme, as is shown in fig. 2.

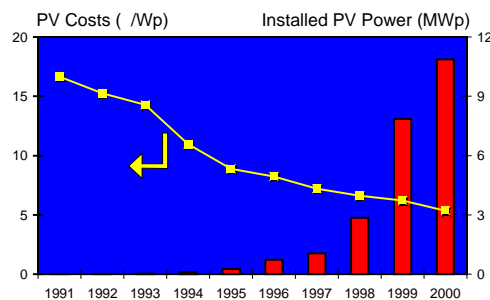


Fig.2. Achieved costs (left axis) and cumulative installed power (right axis) for pv projects in the Netherlands (1996- 2000)

1.3 'Learning while growing'

A large-scale switch to pv on buildings in the Netherlands will mean radical changes. These will start in the planning phase. New houses will need adequate roof and facade areas facing the sun. Property developers must be willing to apply new technologies. Architects must have the knowledge to incorporate photovoltaic elements into their designs in an aesthetically pleasing and energy-efficient manner. PV manufacturers must learn to produce pv systems which meet regular building standards and can be applied by contractors in a straightforward way. Electric utilities must adopt new standards, ensuring the electric safety of the pv system itself as well as a sound interconnection to the local electric grid. If utilities are to be the owner of pv power systems, they have to learn to co-operate with property developers and contractors in the realisation of these systems. They must also learn how to operate and manage a decentralised power production facility, located on 'substructures', owned by private individuals or housing companies.

Last but not least, support for pv is needed from the general public, since systems are to be installed in their neighbourhoods. Very often, private individuals will be involved in the management and operation of the pv system. In some cases, the house owners will also be the owner or lessee of the solar roof.

It is important to take up the introduction of building integrated photovoltaics step by step. In 1995, Novem adopted the 0-1-10-100 approach. The "0" stands for research facilities for testing roof integration, the electric properties of pv systems and relevant components and the safety of grid connected systems. "1" stands for one-off trials of particular technical concepts in individual buildings; "10" refers to practical experiments on the level of a row or street of houses concentrating on the implementation of technical concepts in conventional construction processes. Finally, "100" stands for expansion of the integration into the neighbourhood level. As the size of the pilot projects increases, attention shifts from technical to non-technical aspects.

1.4 pv-GO!

In 1999, a new programme was launched by Novem: pv-GO! After 9 years of R&D, a new step was made towards large scale, professional use of pv. PV-GO! is a three-monthly tender for specific grid connected pv applications with sufficient marketing potential. PV-GO! contributes up to a maximum of 25% of the system costs. Offers are ranked according to the required subsidy per Watt-peak. There is no emphasis on R&D aspects (as in the Learning Programme). In this respect, pv-GO! marks the transition from R&D to a market-oriented subsidy scheme.

In January 2000, a first tender was issued specifically for small scale residential systems (fig. 3, also see section 'AC-modules'). The budget of the first call was 2.7 MEuro, which would be sufficient for approximately 2MW additional installed pv capacity. It is expected that more tenders will be issued during 2000 and beyond.

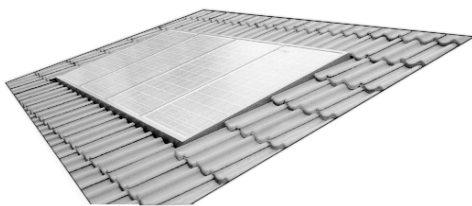


Fig. 3. Typical small scale residential system featuring 400 Wp (AC-)modules.

1.5 The pv Covenant

An important additional measure for the introduction of pv in the Netherlands is the pv Covenant. This is an agreement between Novem, the Ministry of Economic Affairs, a number of utilities and property developers, building material manufacturers, pv industry and research institutes. In the covenant, parties commit themselves to contribute to the realisation of 7.7 MWp by the year 2000, according to the so-called pv Introduction Plan underlying the pv Covenant. This scheme includes not only projections for the installed pv capacity, but also indications for the cost levels of pv. Table 1 shows the initial targets as listed in the pv Introduction Plan.

Table 1: overview of the pv introduction plan according to the pv Covenant.

year	Total Installed pv capacity (MW)	Turn-key system costs (Euro/Wp)
1995	0.4	8.89
1996	0.9	8.16
1997	1.7	7.45
1998	2.9	6.82
1999	4.9	6.23
2000	7.7	5.36
2005	51	3.64
2007	100	2.95
2010	252	1.95
2015	680	1.59
2020	1410	0.73

The pv Covenant was entered in 1997, with new parties having undersigned the agreement in 1998 and 1999 and lasts until 2000. A new covenant will most likely be signed in the course of 2000 for the period 2000 – 2007.

2. HISTORICAL OVERVIEW

2.1 pv power installed

During the period 1996-2000, pv systems were installed according to the 1-10-100 schedule of the Learning Programme. It is expected that the target of the pv Covenant (7.7 MWp) will be reached by the end of 2000. As throughout the world, pv capacity installed annually has been growing steadily, though not according to the projections of the pv Covenant: see figure 4.

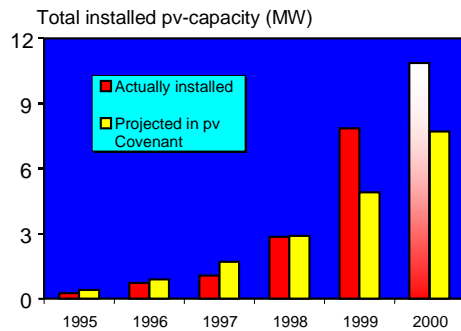


Fig. 4. Overview of cumulative installed pv power in the Netherlands: according to the pv Covenant and actually installed.

Main reason for the ‘slow start’ was the preparation time of a number of larger projects (see next section), which turned out to be longer than originally foreseen. At the end of 2000, however, the goals as stated in the pv Covenant will be reached easily, making pv industry in the Netherlands confident about the success of market introductions of pv during the next period.

2.2 Projects

2.2.1 Woubrugge

The zero-energy house in Woubrugge was the first project in the Learning Programme featuring a fully integrated pv roof (fig. 5). The pv system was installed in 1993 on the roof of a large single family house. The building is energy autonomous, i.e., the pv and solar thermal installation cover the annual energy consumption. The grid is used as storage system in times of abundance.



Fig. 5. The zero-energy house Woubrugge, first project in the Netherlands with pv as watertight roof cover.

The pv mounting structure was derived from greenhouse technology, though some adaptations were made. Frameless pv modules, held in moulded aluminium supports form the watertight layer of the roof. The project ‘Woubrugge’ marked the starting point of the use of this technique for building integration, thus acting as a project on the scale ‘1’ within the Learning Programme. Lessons from the project were used to further modify and improve the roof integration concept, for use in larger projects such as Barendrecht and Nieuw Sloten.

2.2.2 De Kleine Aarde

In 1995, a 7.8 kWp light transmitting pv system was realised as a glass roof integrated system at the National Environmental Education Centre De Kleine Aarde (fig. 6). The project was supported by Novem and Thermie.

The aim of the project was to demonstrate the possibilities of (glass)roof integrated pv as a feature of glass covered spaces (corridors and atria). Integrating pv into a glass roof can reduce the solar transmittance, decreasing the heat load of the corridor while simultaneously producing electricity for the adjacent offices and public spaces.



Fig. 6. De Kleine Aarde. PV producing power and playing with the sun.

The building is equipped with an energy-efficient artificial light system tuned in to the output of the integrated pv system. Special attention was given to the architectural aspects of the installation and the arrangement of the photovoltaic system in the building.

The project De Kleine Aarde clearly showed the architectural and aesthetical value of pv in glass roofs. It is one of the showpiece projects both in the Netherlands and throughout Europe, attracting many visitors and attention through publications.

The monitoring of the project revealed the following conclusions (Bader and Böttger, 1998):

- (1) The integration of pv in the glass roof reduced the overheating in the corridor by 57%, thus creating additional benefits from the pv system.
- (2) Both calculations and measurements showed that pv in the glass roof has only a marginal effect on the daylight admittance to the adjacent office spaces.

2.2.3 Leeuwenhorst

A third project on the scale ‘1’ was the Leeuwenhorst Congress Centre (LCC) in Noordwijkerhout (fig. 7). Contrary to the previous projects, where technical systems were tested on a real scale in a pilot project, the LCC project’s objective was to demonstrate the commercial viability of pv in

combination with low-energy design. The new hall of the Congress Centre features high-efficient lighting and heating systems, optimised thermal insulation and a pv sunshade as eye-catching feature. The pv system not only produces power for the building, but also serves as an architectural element playing with the sun. An increasingly important value of pv for office buildings.

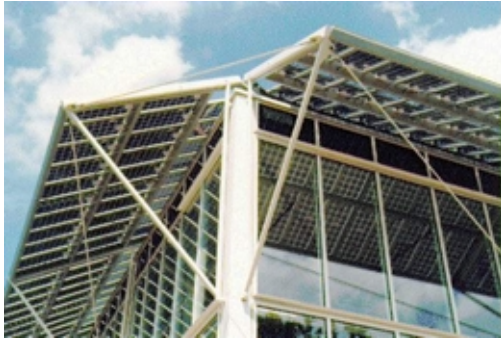


Fig. 7. LCC, demonstrating the pv for commercial building owners

2.2.4 Barendrecht

A typical example of a project on the scale of ‘10’ in the Learning Programme was the pv project in the city of Barendrecht (fig. 8). In a city extension, the property developer Slokker constructed a group of 36 dwellings with a number of sustainable features. Twelve houses are equipped with a roof integrated pv system of 1,5 kWp each. This project, completed in 1995, was the first project in the Netherlands where pv houses were sold on the regular commercial market. The owner of the house is the owner of the pv system. He has paid a premium for the pv system on the building of approximately 5,000 Euro.



Fig. 8. Barendrecht. The first project in the Netherlands featuring building integrated pv on a commercial basis.

The main objective of the project was to identify the constraints to the development of pv buildings for the regular housing market. How can property developers include pv in their buildings? Do pv systems fulfil all quality requirements of the building sector? How can pv be included in the regular building process?

This project also provided an excellent opportunity to investigate the willingness of the public to purchase houses with pv. Main conclusion of this investigation was that pv was one of the least important issues when deciding to buy a house in the Barendrecht project. On the other hand, 80% of the owners of the houses would buy the same house again, including pv, if they would be searching for a new dwelling. This leads to the conclusion that pv is at least not seen as a negative feature of the house (Van Mierlo and Van Roekel, 1996).

The Barendrecht project paved the way for the larger pv housing projects in the Netherlands, where pv is integrated into regular property development and sold to the building owner.

2.2.5 AC modules

In 1994, a new type of pv system was introduced in the Netherlands: the AC-module. Based on the experiences in larger projects, a comparison was made between a conventional system and a layout with much smaller inverters integrated into individual pv modules. From this comparison it was concluded, that efficiencies and costs could be equal to larger systems, but that small, modular units

could open up a new market for pv. Based on these feasibility studies, two manufacturers in the Netherlands developed the so-called AC-module.

An AC-module is a single module, with a typical size of about 100 – 200 Wp, equipped with a small inverter, assembled onto the module in the factory. The result is a fully integrated product, ready to install and easily connected to the local grid. Due to its characteristics, this concept is particularly suited for small modular pv-systems.

A test facility for AC-modules was created on the roof of the Ecofys building in Utrecht, testing 32 modules, equipped with four different module integrated inverters (Sunmaster 130S, OK4E, Edisun Solcolino, Dorfmueller 100) (Marsman *et al.*, 1998). General performance and temperature effects were measured. In addition, AC-modules were tested with support from EU-Thermie in systems in the Netherlands, Portugal and Italy (Molenbroek *et al.*, 1999).

In a second stage, larger projects consisting AC-modules were installed in the Netherlands, e.g. the Andersen Consulting building in Amstelveen (272 roof integrated AC-modules) and the A9 sound barrier near Amsterdam (2160 AC-modules integrated into the sound barrier).

From these projects the following conclusions were drawn (Marsman *et al.*, 1998):

- (1) The development of the AC-module started specifically for small systems owned by private owners/households AC-modules (fig. 9). Caution should be paid when applying AC-modules in larger systems (> 10 modules), due to the fact that currently the inverter still is the main cause of system errors. In larger systems the AC-module inverters will be dispersed throughout the system, often integrated with the module into badly reachable locations. Keeping track of the performance, identifying the faulty devices and replacing them proves to be a problem in such systems. Keeping track of the performance of up to 10 modules owned by a dedicated owner is often no problem.
- (2) High yields and efficiencies are reported. The projects monitored by Ecofys (the roof of Ecofys, the school in Amersfoort and the Arthur Andersen building in Amstelveen) conclusively show system efficiencies of 11.4% and performance ratios between 0.82 and 0.85 (De Graaf and Van der Weiden, 1995; Molenbroek *et al.*, 1999). Main reason for the high performance ratios is the lack of mismatch and DC losses between different modules.
- (3) The majority of AC-modules tested show reliable operation so far, though only continued monitoring can reveal the long term reliability during the module lifetime.



Fig. 9. Two AC-modules on the roof of a private residence. A new market for pv.

2.2.6 Nieuw Sloten

In 1996 a first project on the scale ‘100’ was realised, the 250 kWp Nieuw Sloten project in an Amsterdam new city district, with pv integrated on 71 houses (one-family houses and an apartment building, fig. 10). The project was initiated by the utility EBA (now part of NUON, one of the main utilities in the Netherlands) with assistance from Ecofys and with financial support of Novem and Thermie. The pv system is architecturally integrated in six inclined roofs and one facade. Four pv roofs with various orientations (east, south, west) are connected to one central inverter (SMA 150 kW) sized at about 70% of the maximum pv power.

The facade forms one subsystem (SMA 5 kW inverter). Finally, the pv strings in the roofs of the two penthouses on top of the apartment building are connected to eight inverters (Sunmaster 1800).

Nieuw Sloten was the first city district in the world where building integrated pv was demonstrated on such a large scale. The innovative integration aspects - mechanical as well as electrical - and the wide variety of system design characteristics within this project make it a unique research object. The monitoring results can be used for future pv system design optimisation which is needed for further cost reduction. Moreover the project offers data to assess the implications for the local distribution grid of large scale grid connected pv in the built environment.



Fig. 10. Wide-angle shot of the Nieuw Sloten project. In the front the roof facing west, in the background the apartment building with pv facade and the two penthouses. To the left the shaded east roof can hardly be distinguished.

The most important findings of the monitoring programme were (Kil *et al.*, 1999):

- (1) The system's performance ratio lies above the average for grid-connected systems.
- (2) Mismatch as a consequence of coupling of arrays with various orientations to a single inverter has led to a loss of energy yield below 1% on a yearly basis. This is in accordance with computer simulations that were carried out in the design phase of the project and leads to the lowest electricity production costs given the chosen system geometry.
- (3) No losses due to inverter undersizing have occurred. In case of the SMA 150 kW-subsystem the absence of losses is the consequence of coupling of various orientations. Further reduction of the nominal power of the inverter would have been possible leading to a further reduction of system costs.
- (4) The yearly energy yield of the pv system covers the electricity demand of approx. 85 households out of the total of 400 houses in the district, which means a penetration rate of 25%. The direct use of the generated pv power in the district has been 100% almost all the time. From this it is concluded that the maximum possible degree of penetration of pv in Nieuw Sloten is much higher, even with the actual distribution grid, without having to be modified.
- (5) a further reduction of the electricity production costs may be realised in similar projects by avoiding shading due to chimneys (3%) and by avoiding east and west oriented pv roofs (4%).

2.2.7 Nieuwland

Initiated by the Regional Energy Company of Utrecht (REMU), a 1 MWp grid connected pv system was constructed in the city of Amersfoort (fig. 11). The system is integrated on the roofs of approximately 500 houses grouped together in Nieuwland, Amersfoort's new housing area. Each house is equipped with its own inverter, following a standardised electrical design. The houses in the project are sub-divided into 9 subsections, each the responsibility of an individual property developer teamed up with the architect, contractor, etc., of his choice. PV systems are supplied turn-key by four different manufacturers.



Fig. 11. The pv project Nieuwland during installation

One of the key objectives of Nieuwland was to investigate how to develop projects like these with a complex organisational structure in which many parties are involved. Co-operation must be straightforward and standardised, in order to reduce costs and increase acceptance of the builders. One of the features developed for the project therefore was a standardised, efficient, quality control scheme including type tests, inspections, checklists and a protocol for guaranteed results of the pv systems

(GRS-pv). Under the GRS-pv approach, the system suppliers guarantees a minimum annual performance of the pv system. If the performance is not met the system owner is financially compensated.

End 1999 approximately 90% of all buildings are completed, monitoring has started on a number of systems. From the realisation phase, a number of lessons can be learned (Schoen *et al.*, 1997).

(1) Implementation of pv into the building projects is complex due to the fact that the architect has many design considerations that have to be taken into account. In Nieuwland, this lead to the following results:

- non-integrated, flat-roof based pv systems in two sections. Roof integrated pv-systems did not fit into the overall program of requirements set for these houses.
- two sections required a complete re-design of the houses. The property developers in these sections fully supported (financially) this re-design, showing their dedication to find attractive solutions for the integration of pv into houses.
- only in two sections the design of the houses was straightforward, without conflicts with the design requirements for the pv. In both cases, the architect was well experienced in building integrated pv. In all other sections, non-pv architects were involved.

(2) It took quite some time for the pv-suppliers (and other parties involved) to become acquainted with procedures for quality control as implemented in the project. It seemed that they did not always know what was expected from them, and that the quality control program developed by Ecofys for REMU did not have highest priority on their schedule. It was a difficult task to get the pv-installers to fill out inspection lists correctly. It may be assumed that the on-site installers are more familiar with hardware than with paperwork. Further improvements of quality control schemes, in collaboration with pv industry, and training of installers, could help overcoming these difficulties.

The Nieuwland project is a joint effort of REMU, Ecofys and the Italian utility ENEL, and is financially supported by the Netherlands Agency for Energy and the Environment (Novem) and the Thermie programme.

2.3 Operational experience and achievements

The Netherlands pv programme has focussed on two items which are closely linked: cost reductions and integration into buildings and the building process. As can be seen from figure 2, costs have fallen during the learning programme from 17 Euro in 1991 to 5 Euro in 2000. These cost reductions are in line with those reported in other countries.

It should be noted that system performance has gone up slightly during the reporting period, as shown in figure 12, further reducing the costs per unit energy produced.

Approximately 50% of the cost reductions are related to module manufacturing and cell efficiency. The other 50% result from cost reductions in the balance-of-system (BOS). Inverter costs have gone down from 1.5 Euro/Wp in 1991 to 0.5 Euro/Wp in 2000.

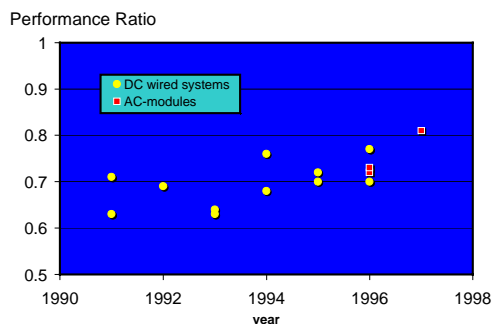


Fig. 12. Overview of achieved performance ratios of pv systems in the Netherlands

Concerning integration into buildings and the building process, the Netherlands pv programme concentrated on developing products for low-cost integration into sloped roofs of new buildings. Watertight profile systems were developed, tested, and applied in projects on a growing scale. The costs for building integration have come down due to improvements in integration systems, the electric system and in installation procedures.

Projects were also carried out on an increasing scale to learn about the integration of pv into the building process. How can we successfully and efficiently co-operate with builders when constructing (and operating) building integrated pv systems? In particular the larger projects have revealed that the

co-operation with builders is a complex effort, requiring a long introduction period and intensive collaboration between pv industry, builders and utilities.

3. THE FUTURE

During the first ten years of pv in the Netherlands, attention has been focusing on the integration of pv into new dwellings. Efforts have resulted in cost reductions, performance improvements, the development of new integration products and the creation of a network with utilities, property developers, architects, building companies and local authorities. Further cost reductions are essential, however, to remain attractive for the energy market. Also, a transition from large scale pv projects in new urban developments to other markets can be envisaged. Such transition is based on general changes in the building sector, but also on the opportunities for developing other markets for pv, such as office building or the consumer market.

3.1 Large scale projects

Based on the experience of Nieuw Sloten and Nieuwland, further attention for pv in large scale urban developments can be expected. A first project, the City of the Sun, has already been announced. Objectives of this new settlement, 50 km north of Amsterdam, will be the realisation of a emission-free city, including up to 5 MW pv. This project will be a next step in increasing the scale of pv projects.

PV is also being investigated for other large scale urban developments, though there might be a transition from integration in residential buildings to integration in large-area offices, community buildings and infrastructure such as sound barriers (fig. 13).



Fig. 13. PV as integral part of the infrastructure – low cost integration with potential for the new future.

A second transition might be towards the integration of pv into larger restructuring programmes within existing cities. This trend follows the general refocusing of energy efficiency improvements and integration of renewables from new dwellings to the vast majority of existing buildings. For this, new integration concepts and co-operation models between pv industry and market parties involved in restructuring (housing corporations, city authorities, banks) will be required.

3.2 pv for office buildings

Unlike Germany and Switzerland, the attention for pv as architectural feature of high-end office buildings has been low in the Netherlands. A number of projects, such as the Leeuwenhorst Congress Centre, have certainly attracted a number of office building developers, facade manufacturers and building owners to pv. A further increase of this market may be expected, even on a short term, but only if products of sufficient quality and aesthetic appearance become available on the pv market. In addition, attractive financing concepts for the commercial sector are required. A R&D-oriented subsidy programme, such as the Novem Learning Programme, will not be attractive enough for the majority of office building owners. New financing schemes are necessary to speed up this market.

3.3 New markets

3.3.1 AC-module systems – the consumer market

Following the success of the development of AC-modules, two marketing campaigns for small AC-module systems have already been initiated. Within the Solaris campaign, initiated by Greenpeace, individual AC-module units are offered to private consumers at a price level of 4.5 Euro/Wp (excluding installation). From market research, a near-term market potential of approximately 20.000 individuals highly motivated to purchase such a pv system can be expected. So far, more than 15,000 applicants have registered.

A second initiative is the SunPower concept, developed by pv industry and a number of utilities. Standardised AC-module packages of 400 Wp are offered to property developers to be integrated in new housing projects at a price level of less than 4.5 Euro/Wp. It is the intention to offer the SunPower concept also to individual owners of existing houses.

Both marketing campaigns indicate that pv industry believes that there is a growing market for small residential systems. A further development of this market towards the introduction of AC-modules at DIY-shops, supermarkets and other outlets can be expected. For this market, low-cost, standardised units are required. Also, the interconnection of these units with the low-voltage network must be straightforward and without utility intervention.

3.3.2 PV in the Green Energy market

A number of utilities is starting to recognise the potential of renewables in attracting customers to their services, in particular in a restructuring energy market as the Netherlands. Utilities offer green energy to their customers at a premium of approximately 0.04 Euro per kWh. Between 1% and 3% of all green energy is produced by pv (this varies between utilities), which seems small but could provide sufficient budget for the installation of up to 200 MW in the next ten years (Koot and Middelkoop, 2000).

In addition, utilities are installing pv systems for clients willing to enter a long-term green energy contract. The system is financed initially by the utility and paid back by the client through the long-term green energy contract. It is noteworthy that most of these systems are installed as low-cost, centralised systems on community buildings or as free-standing systems.

The growth of this market will lead to an increasing attention for large-scale systems, mounted on larger office and community buildings, or even ground mounted. This transition would follow similar developments in Switzerland and Germany. In these countries, new financing models such as the rate-based incentives and the solar stock exchange have resulted in increased attention for low-cost mounting on flat roofs of large area buildings and for ground mounting systems.

3.4 Key BIPV R&D efforts: zero BOS, zero loss

Costs of pv have gone down substantially during the last decade, to levels where markets for pv are beginning to emerge. Short term R&D for these markets should concentrate on developing the products and services that are tuned to the customers on these markets.

On the long term, however, further R&D efforts are required in order to achieve cost competitiveness with traditional energy sources. Various research projects have reported that the scaling up of pv production to 500 MW/production unit could result in pv module costs of less than 1 Euro/Wp (Bruton *et al.*, 1996; Langman and Van der Sman, 1999).

According to the analysis of Langman and Van der Sman (1999), PV system costs related to such scaled up module production could be on the level of 1.7 Euro/Wp, resulting in energy production costs of 0.14 Euro/kWh (excluding VAT), which could be competitive with the costs of traditional electricity if taking eco-taxes into account.

The basic assumption of this study, however, is that the BOS costs reductions are comparable to module cost reductions. For inverters and other pv-specific components (such as support structures) this is a valid assumption. For installation costs, however, this will not be easily achievable.

BIPV R&D efforts should therefore concentrate on two items:

(1) substantial cost reductions of inverters and support structures by making them suitable for mass production. Products should be universally applicable. Production methods should be upscalable. In addition, installation costs need to be reduced to levels where the installation of a building integrated pv system is not more expensive than the handling and mounting of the building material replacing the pv's. In short, long-term R&D should aim for *zero-BOS*, where costs related to the non-pv component of the system are equal to materials and labour savings.

(2) the performance of grid-connected pv systems shows a growing trend, as is shown in figure 12. Nevertheless, between the cell and the grid still more than 25% of the solar energy is lost, due to mismatch, module, cabling, inverter and grid connection losses. There are good opportunities in reducing these losses by developing innovative system designs, towards the challenging concept of *zero-loss*.

3.5 A new pv Covenant

Based on the success of the first pv Covenant, and based on the perspectives of the various market segments, a new pv Covenant is currently in preparation. Main objective of this covenant will be to give pv the 'boost' to become commercially viable within the next 7 to 10 years. For this, an ambitious goal will be formulated by government together with the pv industry, utilities, the building sector and others involved in pv in the Netherlands.

The long-term energy programme of the ministry of Economic Affairs has set the targets at an installed pv capacity of 250 MWp by the year 2010. In order to achieve a commercially viable market within the next 7 to 10 years, however, a goal of 500 MWp installed pv capacity would be required.

Recent research shows that such a target is ambitious, but achievable if supported by dedicated government programmes, investments by industry and contributions of the building and utility sector. These commitments should be collected in a new pv Covenant, which would thus create the basis for a commercially viable pv market within the next 10 years. Negotiations are currently ongoing, it is expected that the new pv Covenant will be signed by the end of the year 2000.

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