Brief Building Report – PV PERGOLA, Rijswijk, Netherlands

Shell has realized lately a modern and impressive facility for the central office staff of Exploration and Production: The Shell International EP Business and Technology Centre. The centre is located in the newly remodeled and refurbished Rijswijk Shell Campus and offers a modern office complex, meeting the need of this new century. Staff will benefit from working in pleasant, purpose-built offices, supported by a modern climate control system, making among others use of environmentally sound energy facilities and measures. As a part of this total redevelopment of the Shell campus 4000 m^2 of office floor area has been realized in the so-called L3-building; on the roof of this building the PV Pergola has been realized. This PV Pergola is the first pv system to be realized on a regular Shell building (excluding Shell Solar buildings).

The Netherlands PV NORD partner (nr. 11) SIEP (Shell International Exploration and Production) b.v. carries out the activities of Work Package 12 of the PV-NORD project: the so-called 'PV Pergola'. The objectives of WP12 is the successful design, installation and operation of a PV system in a large pergola on the roof of one of the refurbished buildings in the new Shell Campus.

General information

BUILDING	**PV PERGOLA (PV NORD Work Package 12)**
Site Location	Rijswijk, the Netherlands
Type of Project	Upgrading and remodelling of the SIEP office buildings as part of the Shell Rijswijk Campus
Building size	4000 m^2 of office floor area (in L3-building only) as part of a total redevelopment of the Shell campus
Building Owner	SIEP B.V.
Short Description	The overall objectives of WP12 is the successful design, installation and monitoring of a 65 kWp PV system as a 'Pergola' on the roof of one of the refurbished buildings in the new Shell Campus in Rijswijk, the Netherlands.

Author	Emil ter Horst, Horisun	Architect	Van den Broek en Bakema
Company	Horisun	Builder	Oskomera and Shell Solar
Address	D.B. Goerionstraat 42 3573 XP UTRECHT the Netherlands	Designer	Van den Broek en Bakema, detailed by Shell Solar and Oskomera
Telephone	+31.30.2760.380	BiPV system provider	Oskomera: PV integrated in a glass covering-over: the "PV Pergola"
Email	Eth@horisun.nl	PV provider	Shell Solar

Building Design and Layout

Rijswijk is a small town (40.000 people) just under the smoke of The Hague, with principal motorways to The Hague, Rotterdam and Amsterdam. It is close to the airport of Rotterdam and Amsterdam, and it has a wide choice in national public transport (and the SIEP Business and Technology Centre is at walking distance from the railway station.
The Plaspoelpolder is an expanding business location for ambitious new companies. Several major building projects are in progress to improve the availability of premier office accommodation in the area. In this challenging environment the redevelopment of the Shell Rijswijk Campus takes place. The new remodeled complex provides a bright and attractive "Main Street", running the full length of the complex. The refurbishment establishes a global home for Shell's E&P activities. There are many visits to the E&P Business and Technology Centre by partner and host government representatives.
The remodeling of the building area has offered the opportunity to integrate PV in the roof of the L3-building, the V3-restaurant and in the roof of the (purple) Mainstreet.
On the roof of the mentioned three buildings, but mainly on the L3-building a pergola has been realized in which a 'technical room' (for lifts, climate control system etc.) is accommodated. On top of this pergola a almost 750 m2 (65 kWp) PV system (the "PV Pergola") has been realized in 2003 and is in operation and monitored since then.

Artist impressions

Drawings

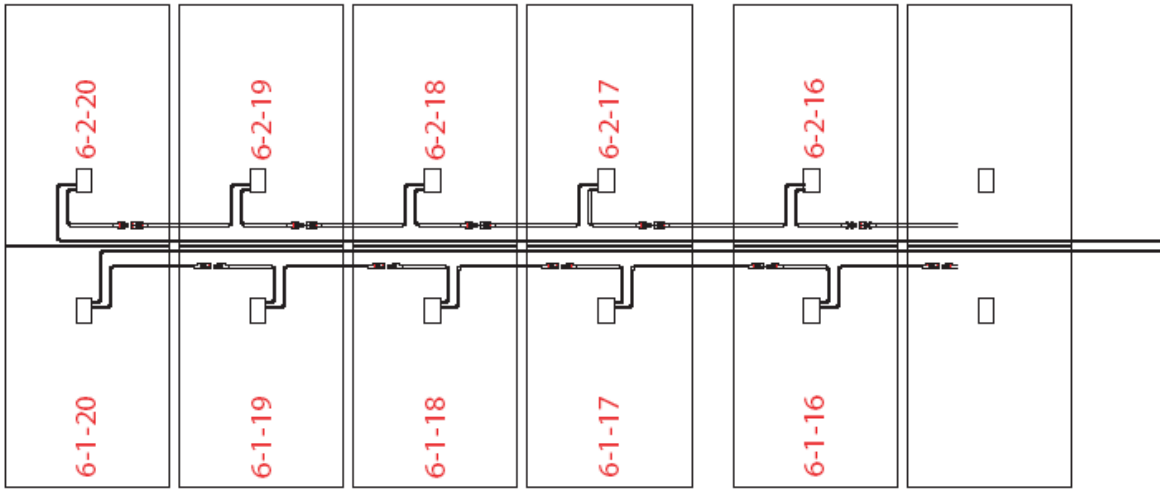


Figure 1 Electrical lay-out of a part of the PV Pergola

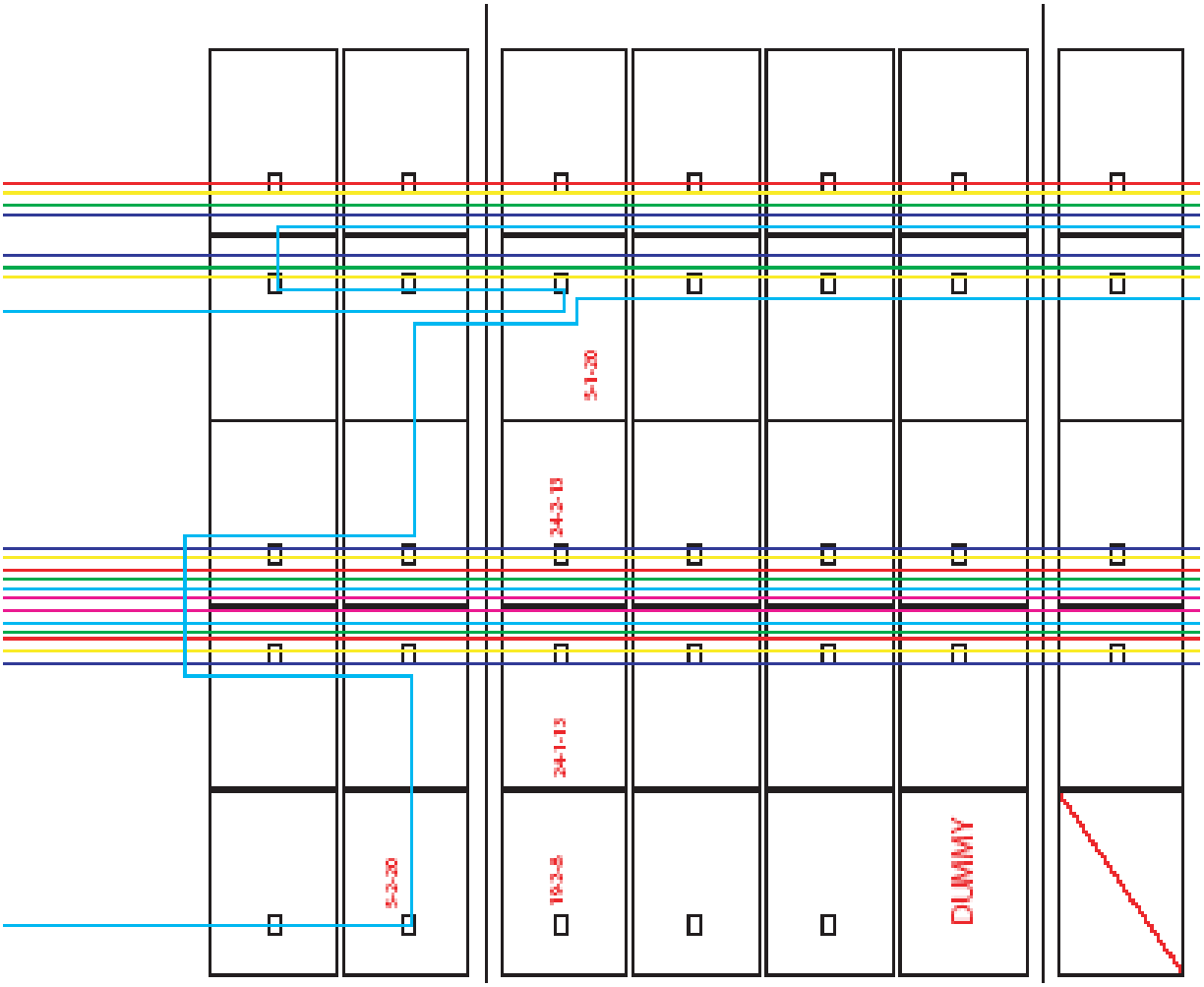


Figure 2 Illustrative part of the floor plan of the PV Pergola

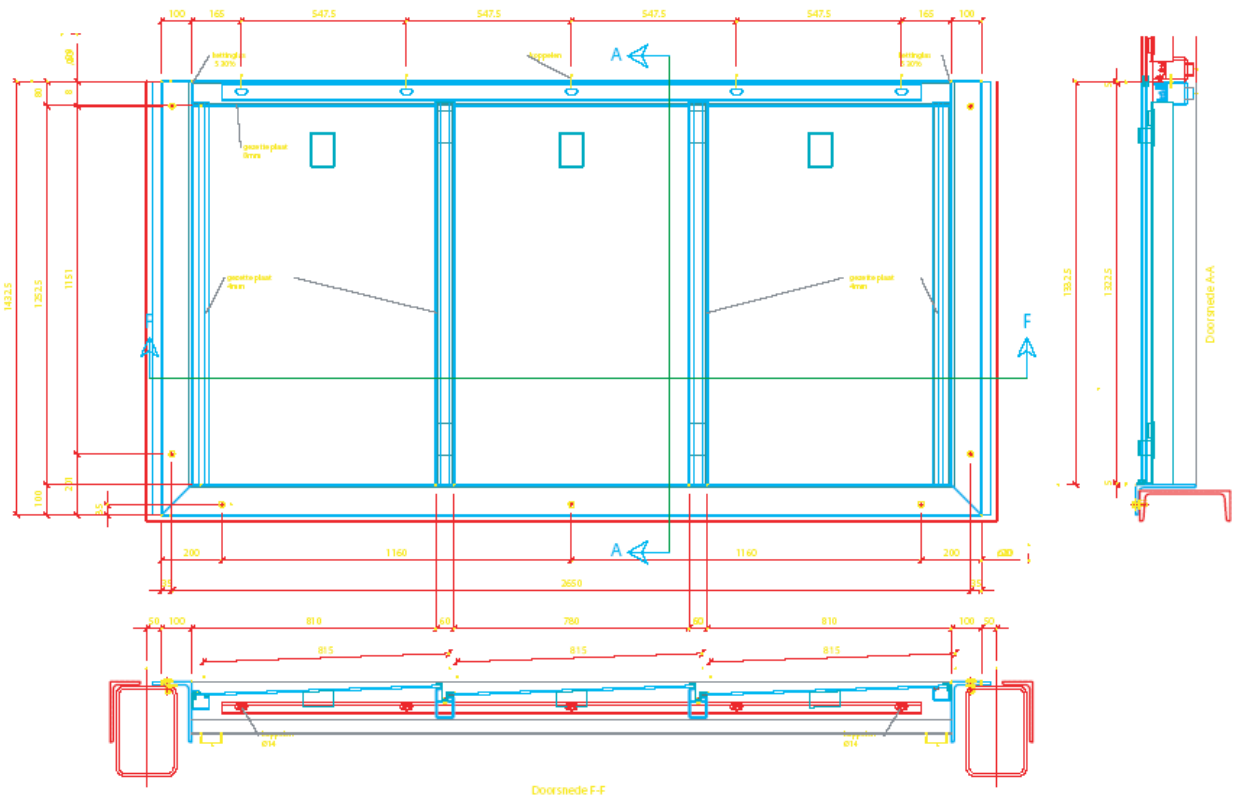


Figure 1 Physical lay-out of a part of the PV Pergola

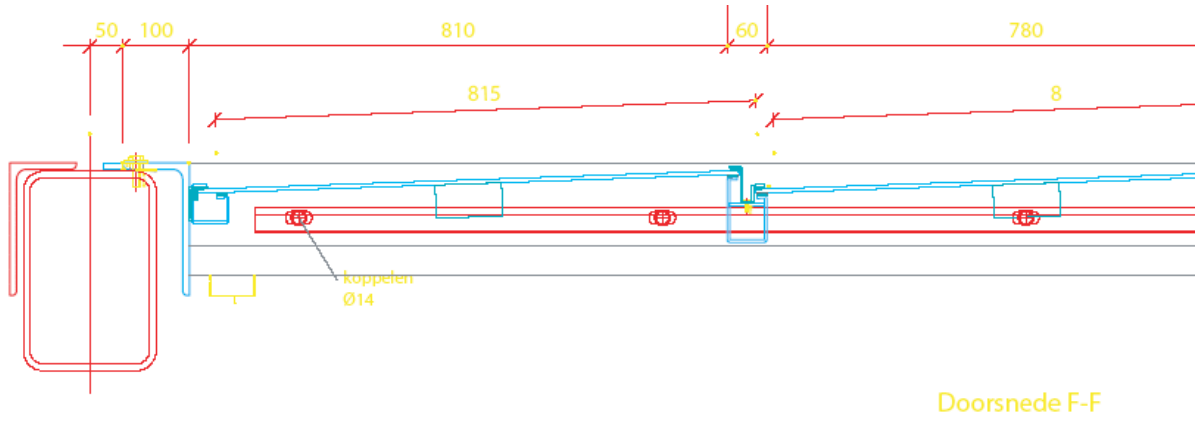


Figure 2 Construction principle of horizontally installed pv modules

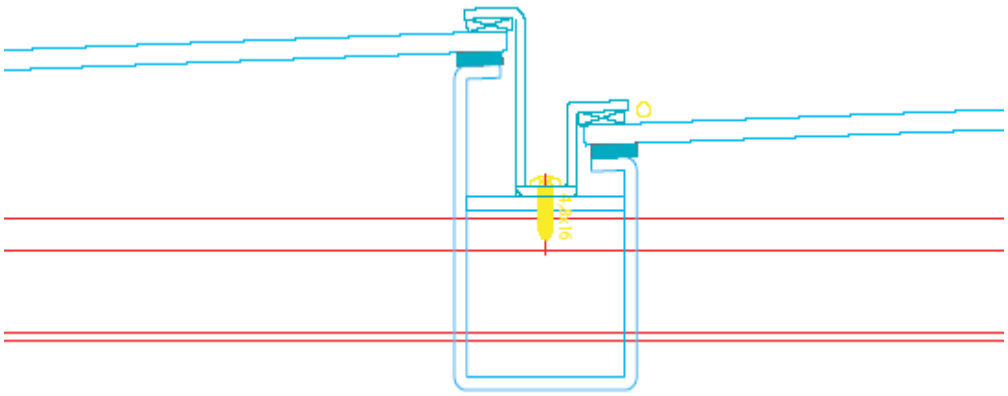


Figure 3 Detail of the construction related to the water drain-off

BiPV Principles

General Description

On top of the pergola on the roof of the office building a surface of 70 x 13 = 900m2 is available for PV. Here the 742 m2 "PV Pergola", consisting of 716 frameless PV modules has been realized in September 2004 and is in operation and monitored since December 2004. The lay-out of the PV modules is horizontal, covering the roof of the pergola but with a 'walking corridor' in the middle (see picture). There are 48 electrical strings of modules connected to 24 inverters, see also figure 1.

Building Integration

Due to the optimization of the building design, the final design of the PV Pergola has changed compared with the very first ideas, and the PV surface is now almost horizontal. Calculations show that horizontal PV systems have the highest yield per area ground surface of a building if only the roof can be used. This is confirmed by measurements in 2004. It was possible to engineer a simple but attractive solution for the integration of PV modules in this almost horizontal surface. In figure 2 the floor plan of the PV Pergola is given. . In figure 3 and 4 the integration of the modules is illustrated. Two types of modules, 318 standard Shell Solar S105 glass/white Tedlar modules (105Wp) and 398 custom made Saint Gobain/Shell Solar glass/glass modules (80Wp), have been used. Both types are frameless and have exactly the same size. The glass/glass modules are applied where it is possible to see the modules from below (see-through effect); elsewhere (above the roof on the 'technical room' the cheaper standard modules are used. The construction detail in figure 5 shows how the drain off of water has been solved. The Stainless Steel profiles also are used as cable gutter.
The horizontal modules were expected to get dirty during time; this contamination of the glass of the modules is solved by integrating a corridor for cleaning in the PV Pergola, see picture.
During 2004 and 2005 the energy performance and the necessity to clean the modules will be studied, see the preliminary results in last paragraph of this report.

Visual Appearance

The visual appearance of the PV Pergola from the ground floor is difficult to illustrate by pictures, as the PV Pergola has little color and therefore is visually rather absent on a picture. It can be best illustrated by the second artist impression. The PV modules are not to be seen from the street at all. From inside the building, from both the 'Mainstreet' and from under the PV Pergola self, the appearance is very exciting and attracting due to the light falling through the PV panels between the solar cells. The picture at the very right on the next page illustrates this effect.
From the top of the pergola the PV Pergola impresses by its size and by the almost horizontal appearance making the system looking even larger. The above picture illustrates this effect.

Pictures (September 2003)

Overview (PV Pergola in the middle)

Under construction outside

Under construction inside

PV Pergola mounted and ready for use.

Technical and Econocical Data

Technical Data

Total power: 65.230 Wp

- 318 Shell Solar S105 glass/white Tedlar modules (105Wp)
- 398 Saint Gobain/Shell Solar glass/glass modules (80Wp)
- Inverters: SMA Sunny Boy 21 x 2500W and 3 x 1700W
- Mounted horizontally as a 'Pergola' on the roof (design: Van den Broek en Bakema)
- PV modules and cells: Shell Solar
- PV Construction: Oskomera
- Mounting and DC installation: Oskomera
- AC installation: GTI

Expected production: 40.000-45.000 kWh per annum (based on calculations).

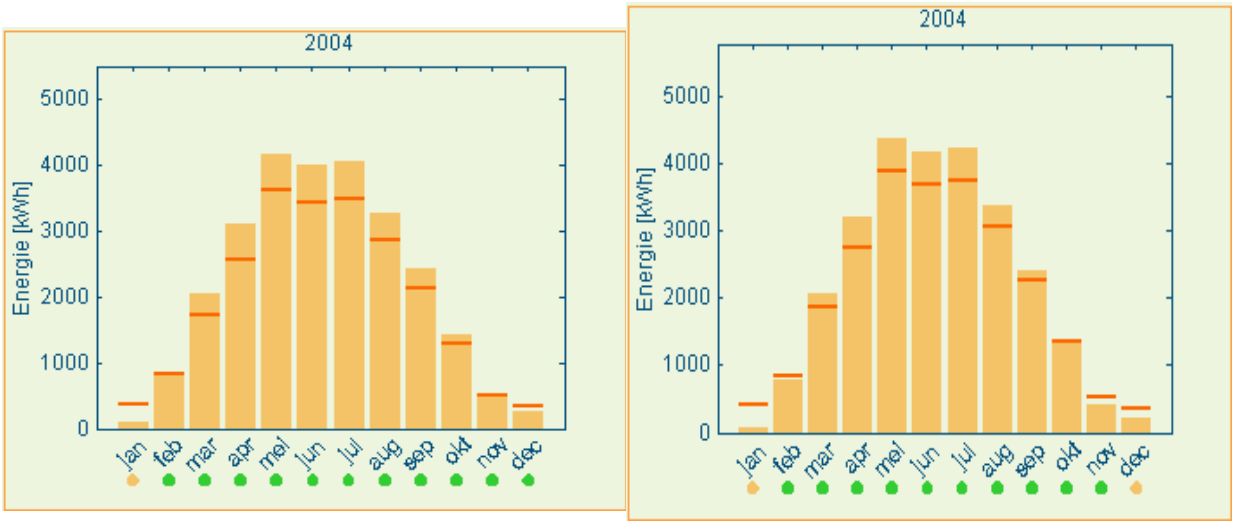
Monitoring

Data-monitoring has started on the 29th of December 2003 and functioned accurately during the whole of 2004 (see for more detail other reports). Data-monitoring is carried out with SMA's Sunny Boy Control Plus on:

- input DC voltage of all inverters;
- input DC current of all inverters;
- output AC power of all inverters;
- irradiation by a reference cell;
- 2 module temperatures;
- 1 ambient temperature.

Total PV Production in 2004 (MWh)	52.3 MWh[1]
Total Area/no of modules (m²/#)	742 m2 **(Roof only)**
Iverters	
Total no	24
System	SMA "Sunny Boy"
Monitoring system	
General	Building Energy Management System
PV System	SMA "Sunny Boy Control +"

We can see from the data and the figures below that the PV Pergola produced in 2004 about 14% better than calculated. The dashed line indicates the calculated production based on meteo-data and the nominal power. The data of the PV-Pergola have been given and analyzed monthly on the internet (http://zonnewijzer.beldezon.nl) and are also sent to the JRC in Ispra.



Total production in 2004 in kWp per month for sub system 1 of 31,8 kWp of glass/glass modules (398 modules of 80 Wp), and sub system 2 of 33,4 kWp of glass/Tedlar modules (318 modules of 105 Wp).

[1] Extrapolated from data from January until 24th of December, 2004

Economy

In the PV Pergola project the cost per m2 was 687 euro.
The cost per kWp was 7.849 euro.
About 40 kWp has been realized in the framework of the PV-NORD project, and therefore will be subsidized by the EC with about 35% of financial support. Another 25 kWp was realized and financed by Shell I.E.P. without any other financial support.
As the operation and maintenance of the PV Pergola is a part of the Energy Management of the building as a whole, almost no extra costs are connected to it. The economical lifetime expectancy (depreciation) of the PV Pergola is taken as follows: PV as a electrical component 20 year, inverters: 5 to 10 year; PV modules as a building component: equal to glass.
All energy produced by the PV Pergola is used by Shell on the Shell Campus. Thus no feed-in tariff contract had to be made with the electricity company ENECO on this matter. In fact therefore the PV Pergola can be seen as a energy saving measure for the Shell Campus.
The PV Pergola will be cleaned and checked only once per year at the outside (less than 0.5 day of work per year for almost 800 m2). Maybe the cleaning is not needed in future (from 2006 onwards).

Work Progress

The table below summarizes the work progress for the PV Pergola as part of the PV-NORD project. The project year 2002 was used for the final design of the PV Pergola, calculation of the energy performance, the first preparations of the realization and the negotiation with contractors. In 2002 it became clear that the preliminary design of the PV Pergola was not suited and had to be replaced by the much better horizontal design as has been built.
In the first half of 2003 the design was further detailed and building integration problems were solved, while the negotiations with contractors were finalized. End of June 2003 the installation of the PV Pergola was started and finished shortly after the holidays in September 2003. In December 2003 the data-monitoring system was installed and the PV Pergola was connected to the grid.
2004 was an very interesting year of operation and data-monitoring.

The building construction

Status (end of 2004):	Ready
Start of construction:	April 2001
The building construction finished:	Spring 2004
Residents moving in:	Floor by floor since Autumn 2003
Comments:	Part of a larger reconstruction project

The solar cell modules

Status:	Ready
Deliverance (acceptance):	29th of December 2003
Mounted:	30th of September 2003
Comments:	Almost horizontal frameless modules

Monitoring and ICT system

Status:	In operation
Deliverance (acceptance):	29th of December 2003
Installation:	December 2003
Initial tests:	December 2003
In use:	29th of December 2003
Comments:	Complete year of complete data available

Outcome and Lessons Learned

A first specific objective of the PV Pergola sub-project as part of the PV-NORD project is the successful integration of the PV system in a large glass covering-over (pergola) and a part of the roof of an office building in a northern EU country.
Though part of a large refurbishment project in the new Shell Campus, the PV project itself was never causing problems or delay. The design and negotiations were completed in the first half of 2003, the realization took place in only weeks in summer 2003, while the PV system had to wait several months to be connected to the grid and to undergo an acceptance test at the very end of 2003. This delay was caused by other factors than due to the PV Pergola. In fact an important lesson was that it was very easy to integrate this PV Pergola project into an extremely complex refurbishment project, because of the clear separation of the building-technical (e.g. water tightness) and electro-technical functions of the PV Pergola and those of the rest of the building. The design of PV in the pergola and roof was successful and the integration is from an architectural point of view very attractive.
A second specific objective was the innovative, cost-effective and fluent merge from the cheap and simple roof integration on a 'technical room' (for lifts, climate control, etc.) to the more sophisticated and attractive transparent PV pergola construction. It was possible to solve all possible conflicts, such as an esthetic detailing for cabling and connections and the detailing of water drainage in a short time. One lesson was that it was not possible to choose for a cheap solution in a high profile building like this. Instead a PV Pergola was designed with as less as possible interference with the main building process and with other advantages than PV only. The PV Pergola now adds a new and attractive space to the office building almost like a winter garden with half of it inside the building and the other half outside. Though the use of this space is not clearly chosen yet, smoking employees have discovered the winter garden already.

Preliminary Results and Comments

A third objective was to gain first experience with innovative PV constructions with a low tilt angle in northern Europe in general and in the Netherlands in particular. Horizontal PV systems become more and more important in the Built Environment. Experience with low tilt angle constructions are important to reach higher (future) penetrations of solar energy in the built-up environment.
The PV Pergola is the first large horizontal PV system in the Netherlands. Though it is too early to draw final conclusions, the first complete year of operation (2004) seem to lead to the following simple but important conclusions to be verified during the next years of operations.
Based on calculations, the production per square meter PV is 15% less than for a south oriented PV array, but data-monitoring showed a almost 15% higher production compared with these calculations. The PV Pergola project showed very clearly that it is possible to install 63% more PV and produce 38% more kWh per square meter roof area. Also several problems connected to wind load, water tightness, costs, esthetics of PV on flat roofs etc are solved more easily with horizontal than with tilted PV systems.
It is recommended to study horizontal PV and issues connected to this further, such as the degree of contamination, as well as innovative solutions such as the use of special films to avoid contamination. The first results of the PV Pergola project show that the contamination by rain and air pollution even in cities is very limited and even under almost horizontal situations under the condition that NO FRAMES are used. *One year after the erection of the PV Pergola: almost no contamination on the topside of almost horizontal frameless modules (about 2 degrees); but light contamination on the bottom side of glass/glass modules (probably due condensation during night)! Data-monitoring showed no difference in energy production after cleaning of the modules.* If framed modules would have been used the situation would be very different: in the lower part near the barrier of the lower frame the module then is contaminated easily at a tilt of 10 to 20 degrees or lower.

Last but not least, it can be concluded that the PV Pergola project overall has been very successful up to now. The total refurbishment of the Shell Campus will be finalized soon. In 2005 (after the PV-NORD project) it is expected that extra attention will still be given to the dissemination of results of the PV Pergola project, among others on the EPSEC-2005 in Barcelona.