BIPV Technical Solutions and Best Practices

Promotion of Building Integrated Photovoltaics

EVE | Ente Vasco de la Energía

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The Pure Project

PURE project has addressed the promotion of PV integration in the urban environment in five European countries: Spain, Portugal, Italy, Greece and Slovakia. The project has lasted for three years, from January 2006 to December 2008, and has made an special emphasis on the promotion of the 2002/91/EC directive on Energy Performance of Buildings (EPBD).

Energy Agencies, Universities and Technology Centres from selected countries, together with a German PV manufacturer, have taken advantage of best examples and designed a series of promotion activities focused on the agents responsible for the introduction of PV systems in the cities: public bodies, architect associations and building industry professionals.

Proposed objectives have been addressed through a new concept, the PV Demo Relay Node (PVDRN), a kind of facility housing several promotional activities, installed in each selected country and used as a permanent exhibition, a permanent contact point for technical and regulative aspects of PV and to hold conferences and seminars.

The project partners have focused their efforts in improving the following barriers to the development of building integrated PV and EPBD:

- Lack of basic information concerning technical and economical aspects of available solutions. There is a wide group of European countries in which some target groups, such as architects, designers or providers of building appliances, and some key actors (e.g. public bodies) do not have useful information of existing solutions for the integration of PV into the urban environment. The PV-DRNs have acted as the vehicles to carry this information from the technical agents to the key actors and end-users, and have contributed to compile all the available information about technical and economical solutions.
- Lack of awareness about the importance of integrating renewable energies into buildings, in order to save costs and to avoid GHG emissions. The project partners have organized a campaign for end-users in general, to reinforce the use of PV in the EU countries that have been traditionally delayed in terms of the incorporation of new technologies and advances to their society.

The following report represents one of the encouraging measures.

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1 Introduction

The dissemination of best practices and examples is an important step in the development of PV technology. Photovoltaics is a mature technology but there are still some applications that require several dissemination activities for further development, and there can be no doubt that the architectonical integration of PV elements into the urban environment (BIPV) is one of them. Additionally, BIPV requires an extra effort to encourage stakeholders to increase the number of BIPV systems, bring in new legislation, etc.

It is very important to explain the possible uses that can be made of the sun's energy just by integrating photovoltaic modules as design elements into buildings. Conventional façades, roofs or sun screening components can be replaced altogether by integrating solar modules. It is important to demonstrate that producing energy using the envelope of the building is an entirely natural way of protecting our environment and keeping the air clean.

This brochure is intended to act as a guide for architects, end-users, public bodies and the general public, in order to give a comprehensible overview of the different ways photovoltaic modules can be integrated into buildings, that is, different technical arrangements to replace existing construction elements by PV modules in roofs, façades and building elements.

A compilation of best examples for the different applications is also presented here. The classification has been made according to where the elements are integrated: into roofs, into façades, into the urban environment and finally at an urban scale. The most advanced examples come from Germany, which has the most advanced photovoltaic arrangements in Europe. Finally, a compilation of FAQs and a list of PV related websites are provided.

This brochure will be complemented by another one focusing on the legislation and potential benefits for BIPV. It forms part of the work carried out under the European project PURE, an ALTENER project in the Intelligent Energy Europe program which seeks to promote PV in buildings and in the urban environment in Europe, especially in the six participating countries, characterised by their vast PV potential but low PV implementation.

2 Technical solutions

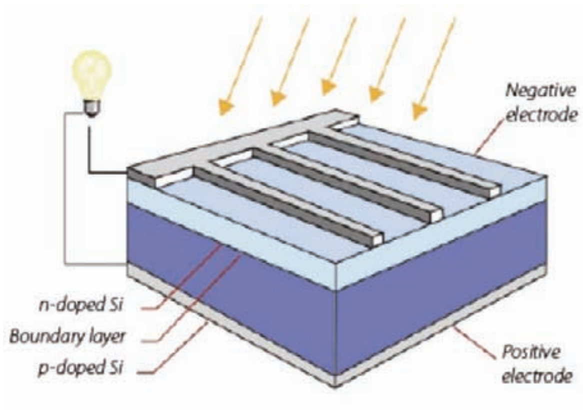
2.0. Basic information on producing energy from sunlight

In Europe, sunshine provides 600 - 2000 kilowatt hours of solar energy per square metre every year. There is therefore great potential for using photovoltaic systems to produce clean, environmentally-friendly energy.

The first chapter gives basic information on photovoltaic energy, to explain how energy is generated from sunlight. It also explains how a system is built up from a single solar cell to a module and ultimately, how all the components are fitted together in an electricity system.

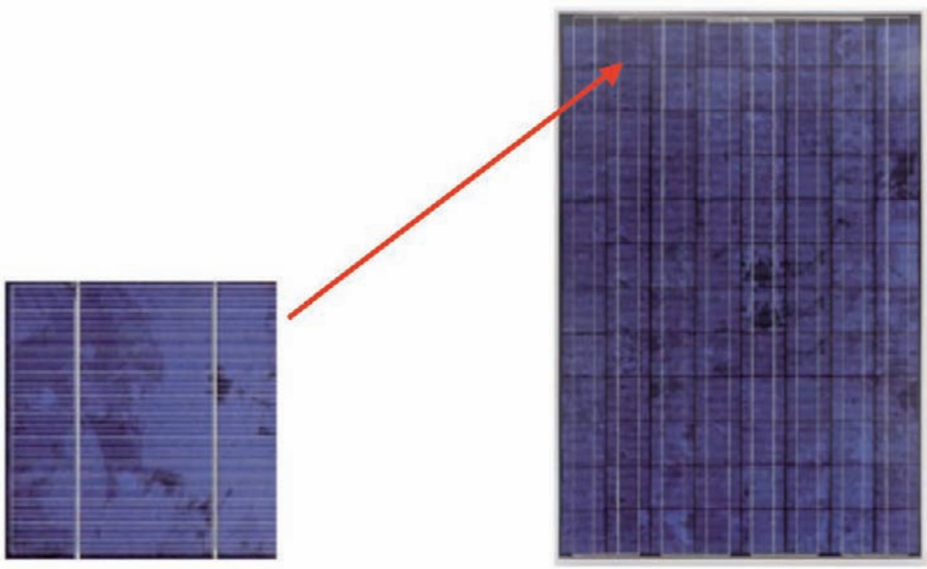
2.1 How does a solar cell work?

In order for electricity from silicon cells to be used, current must flow from the positive to the negative terminal (like a battery). This is why photovoltaic cells are composed of two layers, a positively and a negatively "doped" layer. Light shining on the cell generates a voltage between the two layers which appears at the terminals. A single cell only gene¬rates a small amount of electrical power; modules therefore contain a large number of interconnected photovoltaic cells.



2.2 From the cell to the solar module

Each cell has an approximate output of just 2.5 - 4 Wp, so they are connected together as described above to form modules which in turn are interconnected to form a complete photovoltaic generator. The solar modules are housed in a frame and fitted with a glass plate to protect them against external influences. Before being sent to the local supply grid, the direct current (DC) generated by the solar module has to be converted to alternating current (AC) by an inverter.



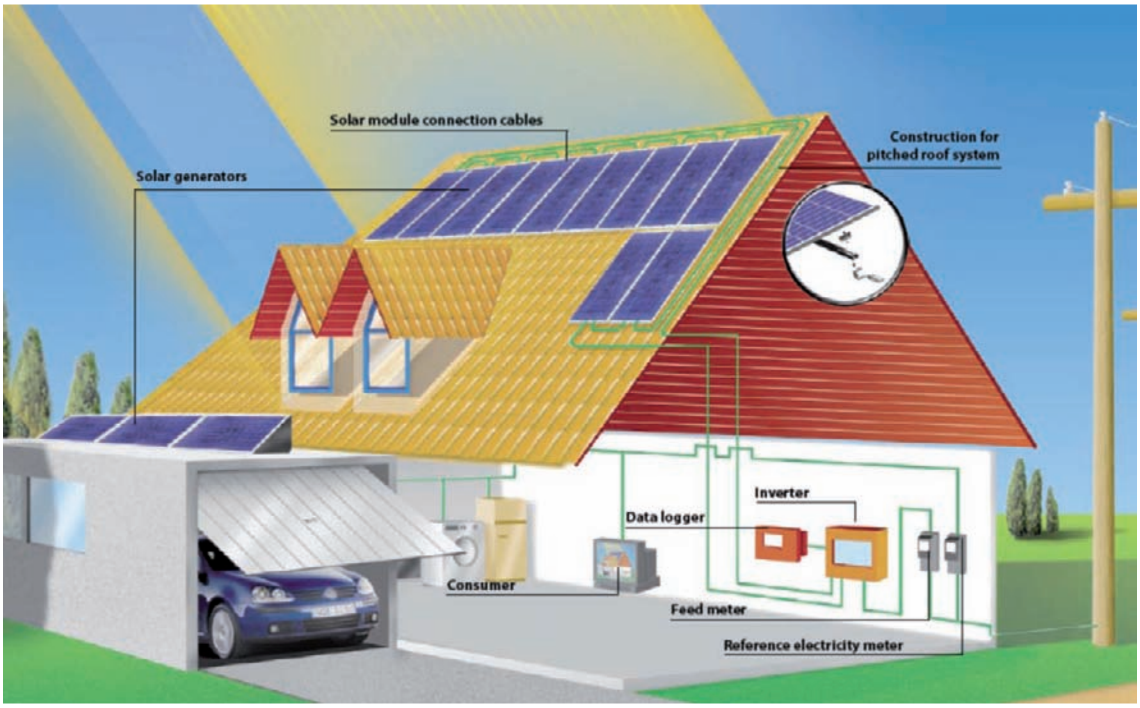
The components

The **solar generator** consists of a specified number of photovoltaic modules, depending on the model and the required system size.

The **module support structure** is directly secured to the rafters of the building so that no alteration of the existing roofing is required. Modules mounted on flat roofs are fitted on stands for optimum alignment. This does not damage the roof covering in any way. There is therefore an optimum solution for any kind of roof structure.

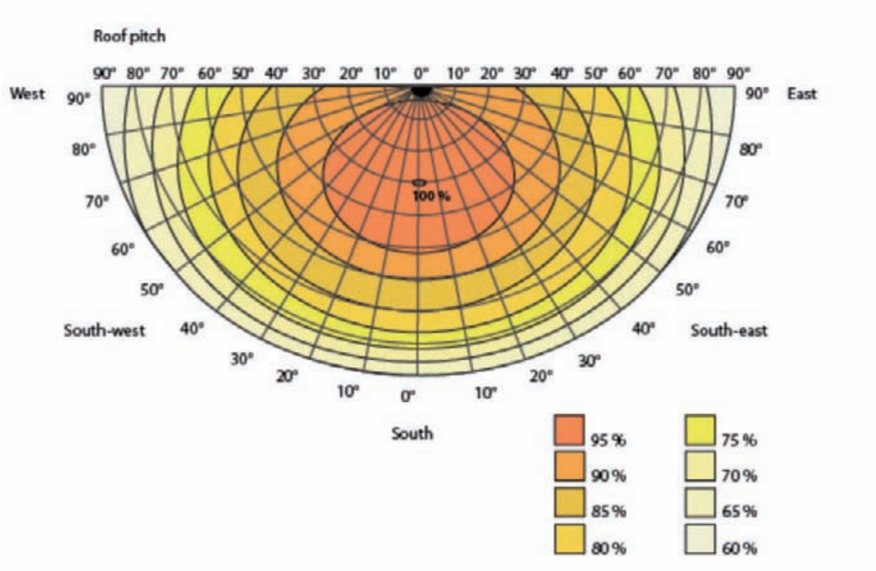
The **connection cables for the solar modules** have a weather-resistant and UV-resistant sheath and are fitted with pluggable connectors (Multi Contact). This not only simplifies installation but also prevents an inadvertent reversal of polarity in the connections.

The **inverter** converts the DC voltage produced by the solar cells into AC voltage which can be fed into the existing supply grid. Inverter operation is fully automatic: it comes on at dawn as soon as electrical energy is generated and switches off again at dusk. After the inverter the generated electricity passes through a feed meter which is used to determine payment.



Dependency of energy generated on system installation

The amount of electricity produced depends on the region, alignment and tilt angle. A yield of approx. 700-1000 kWh per year and installed kWp can be expected, with a space requirement of approx. 10 square metres. On 5 kWp systems the annual yield varies between 3,500 and 5,000 kWh, enough to meet the electricity requirements of a 4-person household (approx. 4,000 kWh).



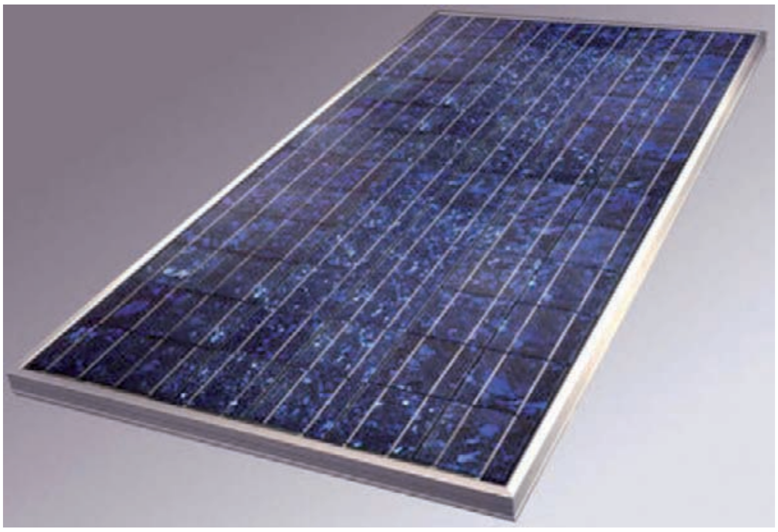
3 Types of modules and their production

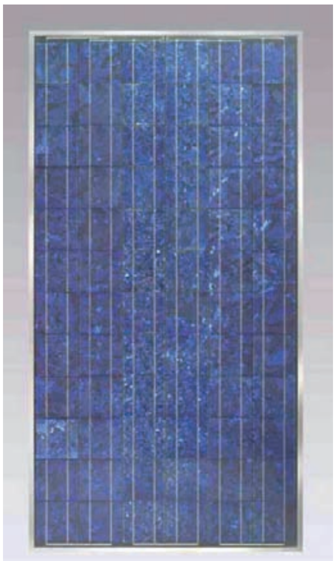
3.1. Types of modules

There are two types of modules:

3.1.1 Standard modules (glass/foil module)

"Standard" modules are made of a laminate. They are very common for adding modules on the roof or for very large generators installed in the countryside.

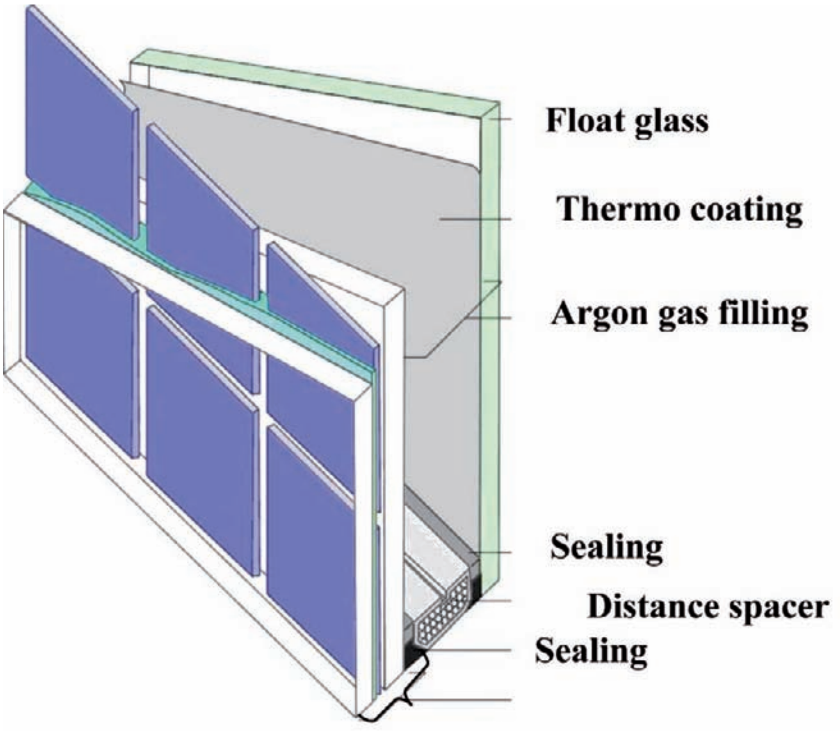




Standard modules with polycrysstalline solar cells

3.1.2. Semitransparent modules (crystalline glass-glass module)

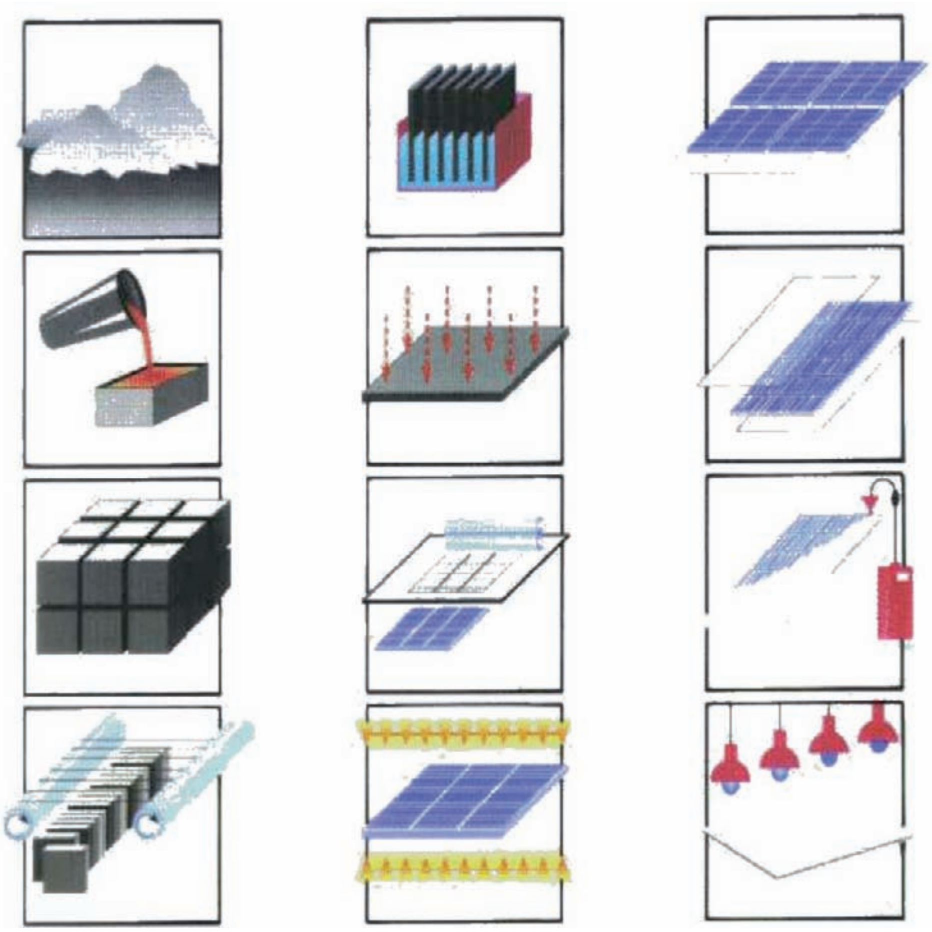
Structure of an insulated photovoltaic module for a photovoltaic system integrated into the building.



For architectural integration glass/glass modules are more popular, because of their design and the fact that they can be manufactured as insulated glass. The front position of an insulated glass-glass module is the basic "optisol" part. This consists of an extra white pane and a float glass. Between these two glass panels there is a special resin with the solar cells embedded. The additional part to produce an insulating effect consists of a distance support with a seal on either side and another pane with a thermo plus coating. The space between the basic part and the back glass is filled with argon gas.

3.2 Production

The graph below shows in simple terms how a photovoltaic module is usually produced.



1. Extraction of the ultrapure silicon. Manufacture of the raw solar cells (wafers).

2. Electrical connection to wafers. The wafer is now a solar cell, capable of producing energy.

3. Assembly of the solar cells into a module. To protect sensitive solar cells it is common to use glass. Finally the module will be tested using a “flasher”.

4 Integration of solar modules in buildings

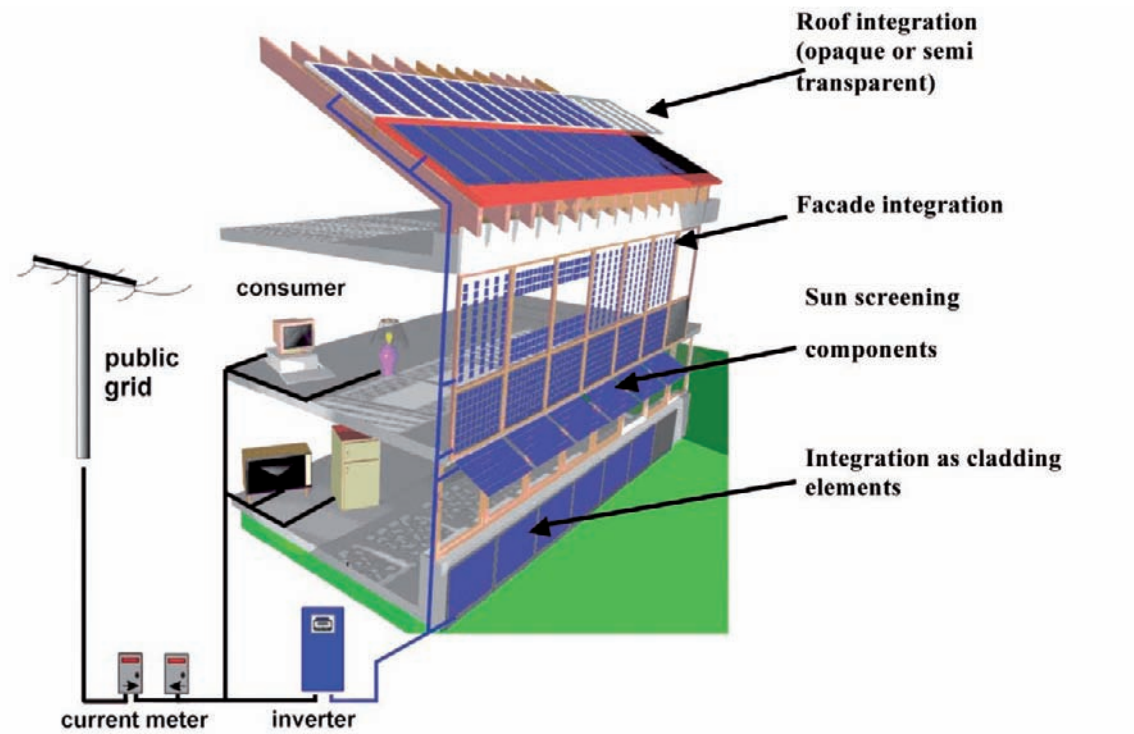
This chapter explains how modules are integrated into the building. Although there has been a major increase in interest in building-integrated photovoltaic, the rise in the number of buildings constructed with building-integrated photovoltaic is scarcely any larger than the rise in standard photovoltaic plants. The reason most often given for this discrepancy is the high cost of integrating photovoltaic into façades and roofs. However, this cannot be the only reason, given that façades are often built in marble and other high-cost materials. A primary cause may be uncertainty and a lack of knowledge of the new technology. Yet the effort involved in planning and configuring a building-integrated solar plant is no different to that required in building a "normal" glass façade/roof or a standard photovoltaic plant. It can almost be planned and built like a normal glass façade or roof and electrically connected like a conventional solar plant. However building-integrated solar plants offer a chance to make double use of the building shell: for climate protection and as an environmentally-friendly energy producer.

4.1 Forms of integration in buildings

There are many alternatives for integrating photovoltaic into buildings. Generally speaking there are three areas of the building where photovoltaic-modules can easily be integrated:

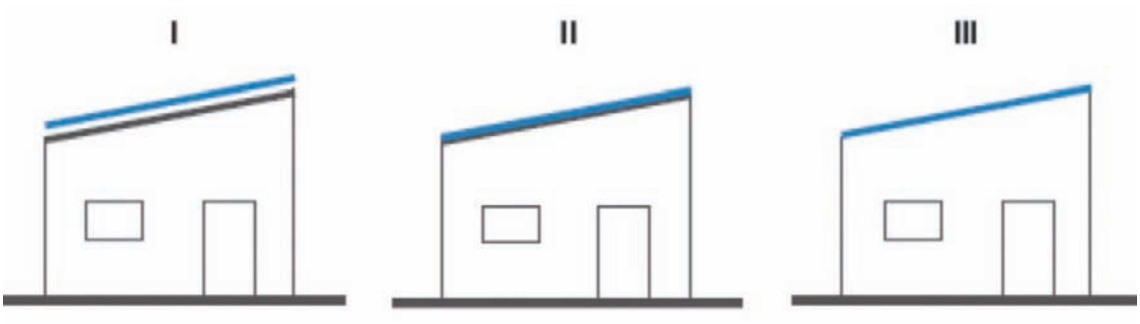
- the roof
- the façade
- the sun screening components

The diagram below shows these different alternatives:



4.1.1 The Roof

There are three different alternatives for installing solar-modules on a roof.

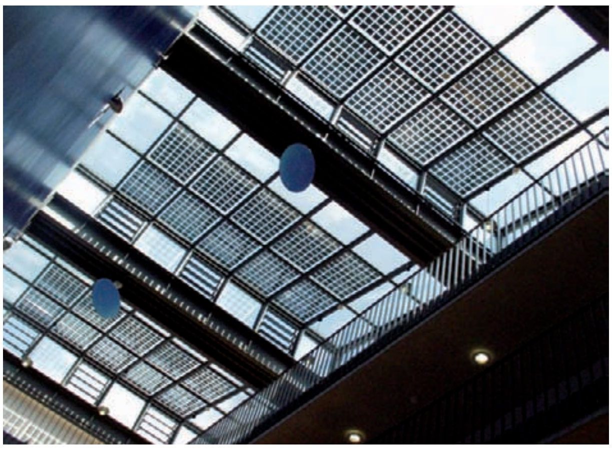


(Source: Landesgewerbeamt Baden Württemberg

I. The most common way is not to integrate them into the building but to add them to the surface of the roof.

II. Another possibility is to integrate them directly into the roof.

III. The third and most fully integrated solution involves making the PV-modules act as the roof itself.



4.1.2 The Façade

Environmentally friendly solutions have rarely looked this good in practice: the shapes and colours of façade elements can be manufactured in a number of different ways to adapt perfectly to the appearance of the façade. The design in which solar cells are embedded in cast resin between two glass panes means that solar elements can be significantly larger than conventional components. This is a major advantage in terms of design and installation. Solar cells from various global manufacturers can be fitted in the solar elements. The resulting diverse range of visual appearances of the photovoltaic modules allows the architect to exercise his creative freedom.

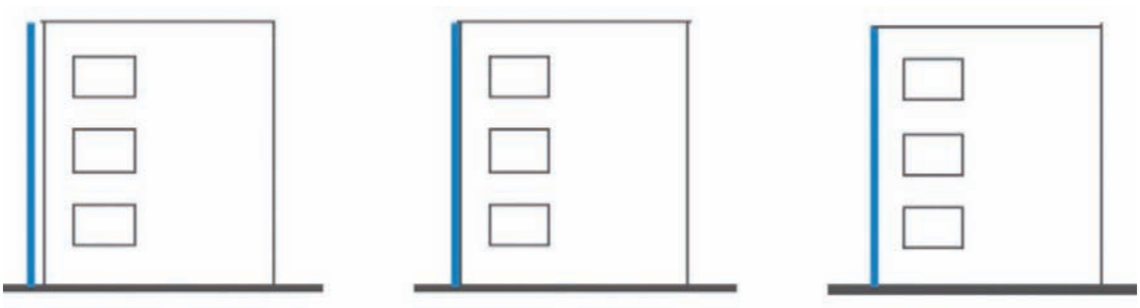
Modern façades have different functions, for example:

- Heat protection
- Insulation glass
- Sun protection
- Noise protection

Using a solar glass-glass module you can achieve all of these features with the added advantage of

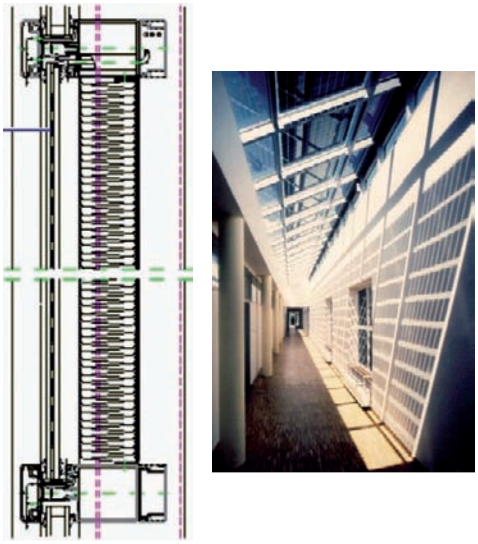
- Environmental friendly energy production!

Like roofs, there three options for integrating solar modules into façades:

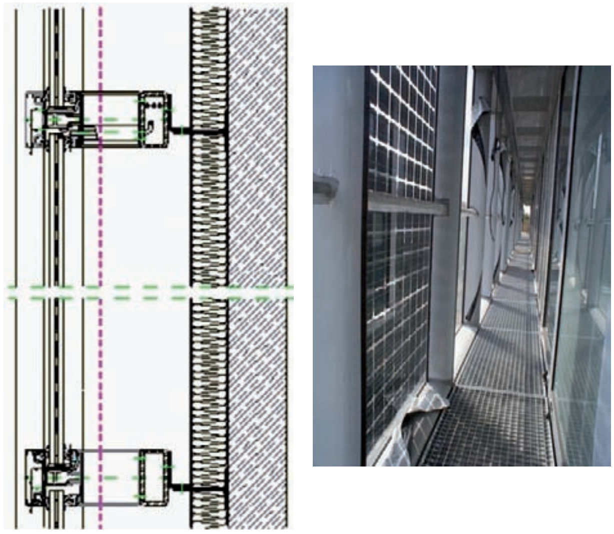


Source: Landesgewerbeamt Baden Württemberg

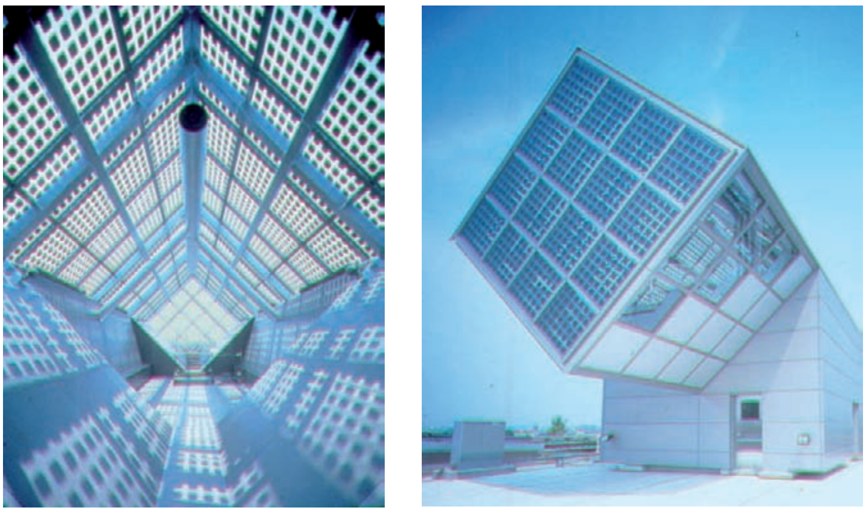
The solar cells can be integrated in a cold façade like a curtain wall façade or in warm façades.



Example for a warm façade.
Source: Scheuten Solar



Example for a cold façade. Source: Scheuten Solar



Nipponcenter in Japan. Source: Scheuten Solar

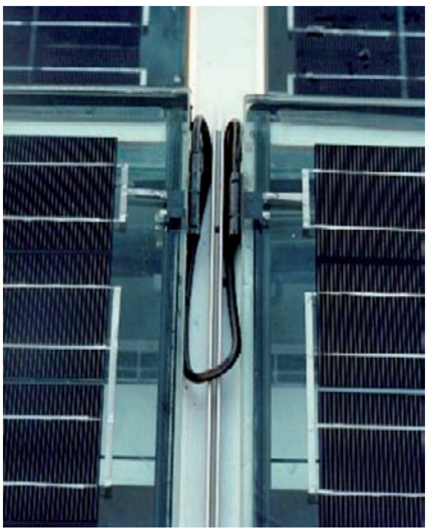
The pictures above show photovoltaic modules that are fully integrated into the roof and the façade. The modules replace the insulated façade or roof, saving the cost of these structures in a new building. The modules have a total rated capacity of 13.7 kWp and cover a surface area of 215 sq m.

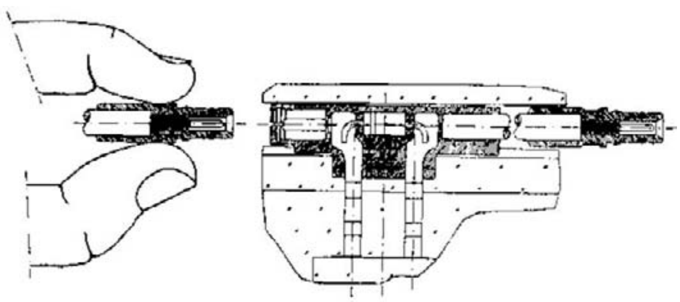
In the example below an existing façade was renovated and replaced with an ultra-modern energy producing system.

Ökotec building in Berlin.
Source: Scheuten Solar

The power connection

The picture below shows an example of two modules can be connected. The glass-glass modules have a very easy-to-handle electricity connecting system. With these types of electrical connection it is possible to hide the cables inside the substructure to achieve a uniform, aesthetically appealing result with no distracting cableways.

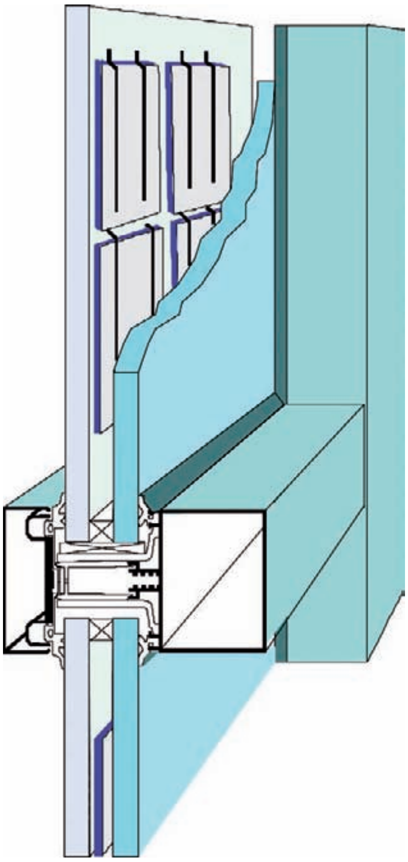




Source: Scheuten Solar

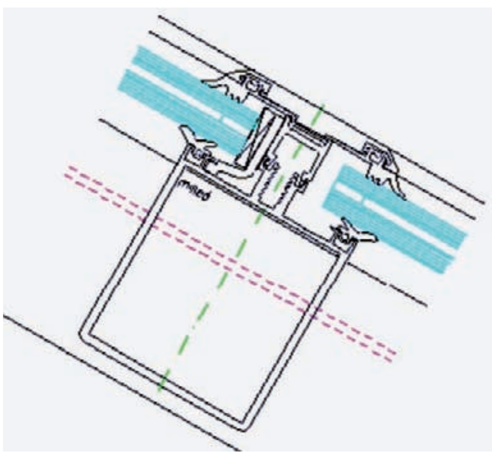
Examples of façade constructions

The modules can be integrated directly into the construction of the façade. Because they are made of glass, they can be handled like a normal glass pane.



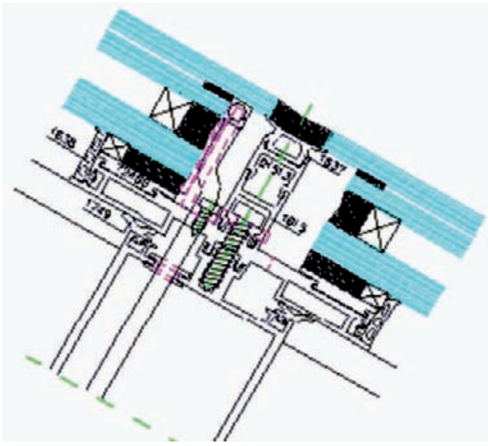
Solar modules integrated in the construction

There are different ways of integrating modules into the construction. For example you can use a façade with an ordinary construction.



Photovoltaic modules integrated in an ordinary construction

PV modules are even suitable for integrating into a structural glazing façade.



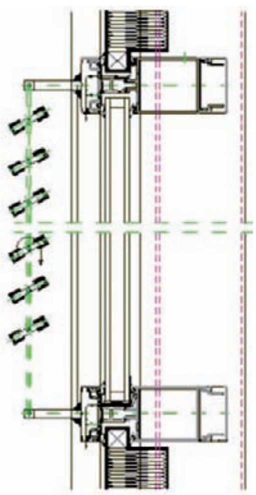
Photovoltaic modules integrated in structural glazing façade

Please note that for any type of construction you must take care over safety and adhere to the legislation for buildings of the country in which you are installing the generator. The rules that apply to building integrated photovoltaic are usually the same as for integrating glass panels.

4.1.3. Sun screening components

Using photovoltaic for sun screening has two benefits.

On the one hand you can save otherwise essential sun screens because the solar cells in the glass-glass module provide sufficient shade. You can choose the see-through rate depending on how much shade is needed. At the same time, the photovoltaic modules produce electricity, which means an interesting investment in the future. The nice thing about using PV modules as sun protection is that the best inclination for producing the most energy is the same angle that provides the most shade (see example below):



5 Best examples

We will now present some examples of different applications. Depending on where it is sited, PV installations in an urban environment are classified as roof-integrated (inclined or flat roofs, opaque or semi transparent) or façade-integrated (large windows, skylights, curtain walls, balustrades, sun screening components, integration as cladding elements, etc.). It can also be integrated into other urban features such as streetlights, noise barriers, pergolas and canopies, etc. The increased use of semi-transparent glass PV modules of a suitable shape and opacity level, offers a wide variety of possibilities for architects' designs.

The examples below show some of these solutions for integration exclusively into buildings, with additional data on the installation: power, type of modules, technology, site, special features, etc. In many cases, the example could be included in two or three different categories.

Good examples for integration of PV modules and elements into the roofs

Roof-integrated PV can be further subdivided depending on whether it is installed in flat or sloped roofs, straight or curved roofs, opaque or semi transparent roofs, tiles, etc.

The examples below show examples of some of these solutions for integration exclusively into buildings, with the source of the photograph.

Integration of PV into the tiles of a sloped roof

Project Name	Integration of PV in tiles
Location	Molina de Segura, Murcia - SPAIN
Latitude/Longitude	38°4'53.79"N 1°7'58.67"W
Year	2004
Source	SolSureste
PV power total	5,985 kWp
PV application	Integration of PV in tiles

Summary

Integration of PV into the tiles. The characteristics of these tiles, which are equivalent to conventional ones, make it possible to completely cover the roof with them. The tile is manufactured from artificial refurbished materials. There is no difference with conventional roofs. Mechanically, they are very light and easy to manage, saving time in the installation process. They are 100% recyclable and free from CFC. They are fire-resistant up to 800 degrees.

Annual energy production is forecast at around 8,000 kWh.

Crystalline silicon PV tiles integrated with a traditional roof.

Integration of PV into an inclined roof (replacing ceramic tiles)

Project Name	Islay Columba Centre
Location	Bowmore, Isle of Islay - UNITED KINGDOM
Latitude/Longitude	55°45'36"N 6°16'47"W
Year	2003-07-16 (Operation start date)
Source	SES Atlantis
PV power total	19.73 kWp
PV application	Integration: PV roof tiles

Summary

The PV system consists of a total of 1,644 SES Atlantis Sunslates. The array's nominal power output is 19.73kWp. The building is arranged along a North-South axis and therefore the roofs are facing due west and due east. This leads to a reduction in the annual energy output of around 15% but it was decided that both roofs would be covered in Sunslates to maximise the available roof area for PV.

Annual production: 8164 kWh Measured (2005)

Installation of Modules in inclined roof.

Project Name	'School Houses' Nieuwland
Location	Amersfoort, Utrecht - NETHERLANDS
Latitude/Longitude	52°12'4.3"N 5°22'29.6"E
Year	1998 (Operation start date)
Source	Shell Solar Energy
PV power total	26 kWp
PV application	Integration: PV roof tiles

Summary

The project consists of 10 'school houses' temporarily in use as a school building. The 10 houses with 28 m^2 of PV-panels each, have in total 285 m^2 PV-panels, or about 26 kWp. The PV panels used are “PV roof tiles”. The PV-roofs are oriented more-or-less south at a tilt angle of 23 degrees. The yearly solar power output from the 10 semi-detached houses with PV is expected to be 19700 kWh.

Detail of roofs

Integration of PV into an inclined roof (transparent roof)

Project Name	ZICER Building, University of East Anglia
Location	Norwich, Norfolk -UNITED KINGDOM
Latitude/Longitude	52°37’18”N 1°14’16”E
Year	2003-06-01 (Operation start date)
Source:	
PV power total	33.88 kWp
PV application	Integration Inclined roof, semi-transparent PV-modules Façade - transparent PV façade

Summary

The Zuckerman Institute for Connective Environmental Research (ZICER) building is home to the University of East Anglia’s School of Environmental Sciences which runs, among other projects, the ‘Community carbon reduction project’. This department was keen to show commitment to reducing CO_2 emissions. The building has glass/glass PV fitted to the atrium like arrangement on the top floor. It has been designed to maximise the potential for demonstrating PV - both on the vertical and gently sloped roof surfaces. Glass/glass laminates were selected to give semi-transparent glazing that also included PV.

Roof installation in ZICER Building, University of East Anglia.
Semi-transparent PV modules

Integration of PV into a flat roof (transparent roof)

Project Name	Town Hall
Location	Dongen -GERMANY
Latitude/Longitude	51°37'56.27"N 4°57'32.23"E
Year	2002, January
Source:	SSG
PV power total	53 kWp
PV application	Integration of customized semi-transparent PV-modules

Summary

The roof of the town hall has a surface of 545 m² and a slope starting at 5 degrees and ending at 10 degrees. It consists of 288 customized semi-transparent PV-modules, 85% covered by cells and made by Scheuten Solar Technology. The modules also have an insulation gap and safety glass. Each module has a surface of 1.8 m², a power output of 184 Wp and a weight of 100 kg. The DC-AC conversion is handled by 16 SMA SWR 2500 inverters, which are all monitored by a computer. In the main entrance, the public can see the performance of the PV-installation on a central display.

Customer: Municipality of Dongen / Bovema Glasconstructies.

Number of modules: 288 pieces of 184 Wp / module.

Flat roof in Dongen. Source: Scheuten Solar

Adaptation of PV modules to the domed roof

Project Name	Azienda Agraria Anfossi
Location	Savona- ITALY
Latitude/Longitude	44°13′59″N 8°30′E
Year	2004
Source	Azienda Agraria Anfossi
PV power total	16.20 kWp
PV application	Integration and adaptation of modules to the domed roof.

Curve roof integrated into commercial buildings

Integration of PV modules into curves overhead

Project Name	New Central Station
Location	Berlin- GERMANY
Latitude/Longitude	52°34'1.81"N 13°27'24.76"E
Year	2002
Source	SSG
PV power total	189 kWp
PV application	Overhead integration

Summary

The frameless PV-modules substitute the laminated glass of the transparent station hall, which are linear mounted over a grid steel structure. Due to the curvature of the hall, each PV-Module geometry is different, with surfaces varying between 1.5 and 2.5 m^2. Different inclinations of the almost optimally aligned modules lead to a grid-connected string-inverter concept, that not only maximizes energy production but also optimises the monitoring solution and reduces costs due to standardisation, series manufacturing and reduction of DC-cabling. An example of an architecturally integrated PV system, with almost optimal alignment, demonstrating new horizons for PV.

Area: 1,700m²

Rated power: ca. 189 kWp

Number of modules: 780

Lehrter Bahnhof, Berlin. Different curvatures and sizes of PV modules demonstrate new horizons for PV.
Source: Scheuten Solar

Integration of PV modules into flat overhead

Project Name	Academy Mont-Cenis
Location	Herne - GERMANY
Latitude/Longitude	52°37'18"N 1°14'16"E
Year	1999
Source	SSG
PV power total	1000 kWp
PV application	Integration. Glass envelope: overhead and within the vertical façade

Summary

The French team of architects Jourda et Perraudin (in co-operation with HHS, Kassel) designed a new building concept, enclosing the academy, a hotel, offices and a library with a glass envelope spanning 180 m by 72 m at a height of 16 m. The buildings inside the glass envelope are protected from wind and rain and surrounded by a climate comparable to that of Nice. Indoors, an avenue of trees and water features provide pleasant surroundings for strolling and relaxing all year round. Scheuten Solar was the general contractor for the complete photovoltaic installations as well as the glass supplies. Die PV system was designed, manufactured, incorporated and commissioned by FSI. The integrated OPTISOL® elements were produced at the Scheuten Solar site at Gelsenkirchen/North-Rhine Westphalia. The inverters were produced by SMA, a subsidiary of Scheuten Solar.

Active Area: 10,000 m^2

Number of solar cells: 600,000

Electricity yield: 700,000 kWh/year

CO_2 emissions avoided: 500,000 kg/year

Academy Mont-Cenis, Herne. 10,000 sq m OPTISOL® single glassed overhead and within the vertical façade.
Source: Scheuten Solar

Good examples for integration of PV modules and elements into façades

Integration of PV modules into façade: mounted

Project Name	Multifamily Dwellings
Location	Tavros area, Athens-GREECE
Latitude/Longitude	37°58'32.15N 23°43'7.66"E
Year	2002
Source	SOURSOS
PV power total	11.9 kWp
PV application	Integration into a double façade.

Summary

There are different sizes of polycrystalline PV modules (innovative approach)

Active Area: 426 m^2 of south façade

480 modules of multiplayer safety glass

Electricity yield: 25000 kWh/year

Overall cost of system: €3.6m

Architects: Seners LTD

The project was co-financed by the THERMIE programme.

Integration of PV in multifamily dwellings (Tavros, Athens) (by SOURSOS). Integration into façade.

Project Name	Social housing residential building
Location	Helene-Weigel-Platz (Berlin)- GERMANY
Latitude/Longitude	52°34'1.81"N 13°27'24.76"E
Year	2000
Source	PREDAC 5FP
PV power total	48 kWp
PV application	Façade integration. Example of refurbishment

Summary

426 m^2 of south façade

480 modules of multi-layer safety glass with 72 multi-crystalline solar cells

Annual production: 25000 kWh/year

Overall cost of system: €3.6m

Electricity from PV system covers part of the electricity demand for lifts, ventilation, emergency lighting, etc in the building. Additionally, the solar installation is connected to the public grid to transfer the excess electricity not consumed in the building. With the reconstruction of the double tower block dwellings, the building owner wanted to set a persuasive precedent and showcase possible solutions for the future-oriented management of apartment tower blocks. The architecturally magnificent PV-design was presented in the framework of the Berlin "21 bridges to the Solar Age" decentralised project of the Hannover Expo2000.

Owner: Wohnungsbaugesellschaft Marzahn mbH, Berlin,

Architect Becker Gewers Kühn und Kühn

CO_2 savings: 72 tons/year

Energy savings €4,500/year (corresponding to an average of 12 per apartment)

Overall cost of PV system €3.6m

Façade integration in social housing residential building. Example of refurbishment. Berlin (Germany).. Source: PREDAC 5FP

Project Name	SOLAR XXI building, INETI
Location	Lisbon - PORTUGAL
Latitude/Longitude	38°42'27.42"N 9°8'2.77"W
Year	NA
Source	IST
PV power total	12 kWp
PV application	Integration of PV modules into façade (mounted)

Summary

SOLAR XXI is the home of the Department of Renewable Energy of INETI, the National Institute of Engineering, Technology and Innovation. The building has a floor area of 1500 m^2, mainly consisting of offices, meeting rooms and laboratories. Photovoltaic panels were integrated into the south façade, covering an area of approximately 100 m2 perfectly matching glazed areas.

The photovoltaic system was designed to take advantage of the heat generated in the back of the panels for space heating of adjacent offices in the wintertime.

The photovoltaic system integrated in the south façade of the building is grouped in modules of polycrystalline silicon in the vertical position. These panels have a total installed capacity of 12 kWp, and will generate about 12000 kWh of electricity per year.

The innovative feature of the system, however, is the use of heat generated in the back of the PV panels for space heating office space by natural convection. The figure below shows the natural ventilation strategy to be used in the building. In summer, the space behind the panels can be used to cool down the PV panels, thus increasing the efficiency of photovoltaic conversion.

SolarXXI building, showing a 100 m^2 PV façade

Transparent PV vertical façade

Project Name	Pompeu Fabra Library,
Location	Mataró - SPAIN
Latitude/Longitude	41°32'51.98"N 2°27'33.81"E
Year	1996
Source	TFM
PV power total	52.7 kWp
PV application	Integration PV system in façade of a public library

Summary

The Pompeu Fabra library in Mataró was designed with the twin aim of producing solar and thermal energy and ensuring maximum comfort. The installation consists of a curtain wall with polycrystalline silicon solar cells, allows interior visibility.

There are three curtain-wall type windows with opaque monocrystalline silicon solar cells.

Surface: 603 m^2

Annual energy production: 50MWh

Emissions saved: 11,5 Tons CO_2/year

Integration of PV system in façade. Pompeu Fabra Library, Mataro (Spain). Photographs: TFM

Project Name	Chemical Engineering Dept, National Technical University of Athens
Location	Zografou area, Athens-GREECE
Latitude/Longitude	37°58'32.15"N 23°43'7.66"E
Year	2001
Source	Germanos
PV power total	50 kWp
PV application	Integration

Summary

PV description: The modules are distributed along the façade with various inclinations (mainly vertical) and orientations

PV modules: Monocrystalline and Polycrystalline PV modules

Annual production: N/A

Additional data: Architects: TUA, ATERSA, Network. The project was co-financed by the THERMIE programme.

Integration of PV in the building of the Chemical Engineering Dept, National Technical University of Athens (by Germanos)

Transparent PV inclined façade

Project Name	Ministry of Economic Affairs – Conference area
Location	Berlin- Germany
Year	1999
Source	SSG
PV power total	100 kWp
PV application	Integration. Semitransparent modules in roof Tilted PV façade

Summary

The photovoltaic façade is integrated into the front of the federal ministry of economy and technology building. The façade comprises 712 double glazed OPTISOL® elements measuring 1.0 x 1.4m and 2.7 x 1.4 m. The total area of the PV-façade is 920 m2 with a rated power of 100 kWp.

In section the OPTISOL® elements consist of 5 mm front glass, 2 mm cell gap, 5 mm back glass, 16 mm air gap with rare gas filling and 10 mm inner laminated safety glass.

Architect: BAUMANN & SCHNITTGER

Semitransparent modules in roof. Ministry of Economic Affairs – Conference area. Right: inside view. Tilted PV façade.
Source: Scheuten Solar

Double-skin PV façade

Project Name	Double-skin PV façade in an educational Centre- Universidad de La Salle
Location	Barcelona- SPAIN
Latitude/Longitude	41°23'51.62"N 2°12'32.18"E
Year	2002
Source	TFM- SSG
PV power total	18 kWp
PV application	Integration. Double Skin PV façade

Summary

In 2002 OPTISOL® – Scheuten Solar's building integration elements were manufactured in Germany. 258 elements were installed as a façade in Barcelona (at the Universidad La Salle), Spain. The installation consists of 132 PV double glazed modules and a further 126 screen-printed panes. The screen-printed panes have a perfect optical replica of a PV module, for the sake of aesthetic uniformity. The PV-façade has a total area of 625 sq m. These OPTISOL® PV elements have a junction box instead of being connected on the side, as usual; this was necessary to adapt the modules to the narrow space available. The futuristic look of the façade has become an emblem of the Salle building.

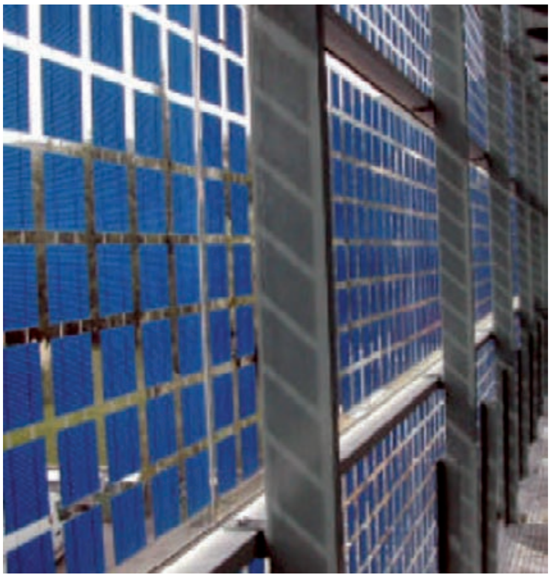
Architect Robert & Esteve Terradas

Area: 625 sqm (215 sqm PV)

Rated power: 18 kWp

Number of modules: 132, 140 Wp each

Installer: TFM



Double-skin PV façade in an educational centre (Barcelona) Universidad de La Salle.
Allows for interior vision.

Building structures with PV: pergola

Project Name	Environmental education centre
Location	As Pontes, A Coruña - SPAIN
Latitude/Longitude	43°27'3"N 7°50'27"W
Year	2003-12-15 (Operation start date)
Source	ISOFOTON
PV power total	14.3 kWp
PV application	Integration of PV with other elements. Skylight in a PV roof

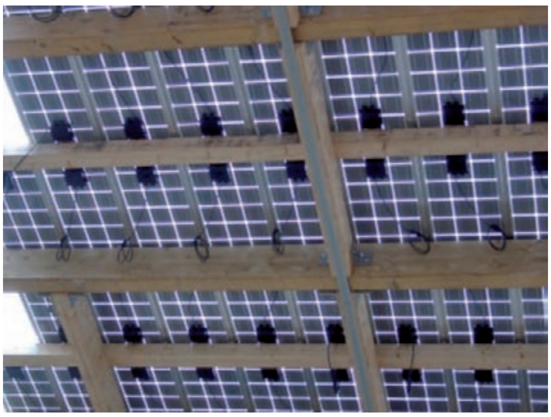
Summary

The environmental education centre in As Pontes develops management programmes and systems to improve environmental quality through activities such as conferences, courses and workshops. It includes a series of small buildings located around a circular courtyard, covered by a skylight with a wooden structure (multi-laminated wood, with very low environmental impact) divided into 10 equal pyramidal sectors. The northern part (5 sectors) is fully glazed, while the southern part (the remaining 5 sectors) is partially covered with semi-transparent PV modules. Due to the fact that the glazed skylight surface is large enough to provide natural light to the patio, the conventional distance between the solar cells in the PV modules has been used.

Annual production: 11740 kWh calculated

PV cell type: Crystalline silicon – mono

Architect: Xuan Bello (As Pontes city council), Jerónimo Vega (Architecture Department of Isofotón)



Integration of PV with other elements. Skylight in a PV roof. As Pontes, Galicia. Source: ISOFOTON

Project Name	Kowa elementary school
Location	Nerima, Tokyo - JAPAN
Latitude/Longitude	35°44′45″N 139°36′26″E
Year	2004-03 (Operation start date)
Source	
PV power total	2047 kWp
PV application	Structures - building structures with PV: roof (e.g. pergola), Flat roof - mounted & mechanical fixing

Summary

Nerima city planned a project to develop an eco-school utilizing natural energy, based on a concept of symbiosis with nature in an urban area, involving retrofitting the school building of Kowa elementary school. The project was certified as an 'Eco-school pilot model project', i.e. a project for promoting environmentally-friendly school facilities. The PV system has a total capacity of 20kW and the system consists of two kinds of PV array. One is installed as a terrace roof and the other is mounted on the roof. The two PV systems have a capacity of 10kW each.

The PV modules installed as the terrace roof are of framed-transparent type, to create an aesthetically appealing appearance and a well-lighted space.

In addition to the PV system, other environmentally-friendly facilities such as wind power generation (0.9 kW), solar thermal water heater, a system for reusing rainwater, etc. were implemented, as an example in environmental education for students.

Building structures with PV flat roof - mounted & mechanical fixing. Kowa elementary school, Tokyo - JAPAN

Building structures with PV: canopy

Project Name	Student Union building
Location	Malmö - Sweden
Latitude/Longitude	55°36’31.55”N 12°59’36.75”E
Year	2006-09-01 (Operation start date)
Source	
PV power total	25.6 kWp
PV application	Façade - integrated in fixed sunscreens Façade - mounted

Summary

Malmö Stadsfastigheter is owned by the municipality of Malmö, which manages the public buildings in the municipality. They have taken a particular interest in solar energy and initiated several PV projects. This is one of the first projects initiated as a result of the Swedish support programme for PVs on public buildings. The PV modules are mounted on the façade and as fixed sunscreens over the windows with the twin function of generating energy and creating shade.

Example of fixed sunscreens over the windows.
Malmö Stadsfastigheter - Sweden

Building structures with PV: lamelas

Project Name	Wirtschaftshof Linz
Location	Linz - AUSTRIA
Latitude/Longitude	48°18'27"N 14°17'36"E
Year	1999 (Operation start date)
Source	Colt Solar Technology AG
PV power total	20 kWp
PV application	Façade - integrated in movable sunscreens

Summary

The PV system of this building is particularly innovative in that it uses a solar-tracking lamella system for shading the façade (solar-tracking means that the lamellas can move around the horizontal axis and follow the sun, to stay at a constant 90° angle to the sun. The mechanism to move and direct the system is completely solar driven with a thermo-hydraulic system, developed by ZSW in Stuttgart, Germany. Two thermal collector tubes are installed with the lamellas oriented in opposite directions. If one side gets more sun the thermal liquid of that tube gets warmer and produces pressure in the hydraulic cylinder, which moves the lamellas until both tubes get equal sunlight. In this position the lamellas are optimally directed towards the sun. The 20 kWp PV modules are integrated into an area of 250 m^2 of louvers with 13 different orientations. Thermie project.

Example integrated in movable sunscreens over windows Wirtschaftshof Linz - AUSTRIA

Good examples for the integration of PV modules and elements into the urban environment

The principal urban elements are streetlights, noise barriers, pergolas, etc. The following examples show some of these solutions, together with the source of the photograph.

Pergola

Project Name	PV Pergola in the Andalusia Technology Park
Location	Malaga - SPAIN
Latitude/Longitude	36°43′0″N 4°25′0″W
Year	2004-11-01 (Operation start date)
Source	
PV power total	56 kWp
PV application	Structures - non-building structures

Summary

PV pergola installed in the Andalusia Technology Park in Malaga, Spain. Design objectives were to provide shading along a walking path, to demonstrate the feasibility of using different orientation and tilt angles for the PV modules, and to analyse the architectonic behaviour of PV laminates (structural and mechanical aspects). The PV fields are designed in a singular zigzag shape; the inverter room is also specially designed along aesthetic lines. The PV system is monitored using a novel concept based on wireless communication and OPC (Ole for Process Control, widely used for control purposes in industrial environments).

PV Pergola in the Andalusia Technology Park

Car parking

Project Name	Vidurglass car parking
Location	Manresa, Catalonia, Barcelona - SPAIN
Latitude/Longitude	41°44’0”N 1°30’0”E
Year	2007-04-17 (Operation start date)
Source	Vidursolar
PV power total	3 kWp
PV application	PV non-building-structures, transparent modules, pergola

Summary

The roof in the outdoor car park at Vidurglass is a multifunctional design that not only shades the parked cars, but also generates clean electricity. Special importance has been given to visibility aspects, with an attractive design of the car parking structure. The PV modules used are of glass-glass type and 115 Wp each (multi-crystalline solar cells), with a translucent percentage of 27%. In order to provide a pleasing aesthetical appearance, in addition to the PV modules, the design also includes conventional panes with a dark screen printed motif with the name “Vidursolar” (transparent letters) which is reflected onto the surrounding ground surface.

Car park in Manresa.
Barcelona - Spain.
Source: VIDURSOLAR

PV Noise Barrier

Project Name	PV Noise Barrier A27
Location	De Bilt, Utrecht - NETHERLANDS
Latitude/Longitude	52°5'50.3"N 5°9'27.1"W
Year	1995-05 (Operation start date)
Source	Shell Solar Energy
PV power total	55 kWp
PV application	PV non-building-structures, Noise Barrier

Summary

Under contract from Rijkswaterstaat, a PV sound barrier has been built beside the A27 in De Bilt, direction Utrecht. The noise barrier is 550 meters long and has a grid-connected PV system of 55 kWp. The PV panels are installed on top of the lower (concrete) part of the sound barrier, in such a way that they contribute to the noise reducing properties of the sound barrier. In total 1116 PV modules are used, which are coupled through a 40 kW inverter to the grid. Indeed, the PV system constitutes a small power plant. The system started operation in May 1995. The practical experiment showed that PV panels can be used for sound barriers, while the combined functions of energy production and noise reduction can be a cost-effective application of solar energy in the future.

PV Noise Barrier A27 De Bilt, Utrecht - NETHERLANDS

Good examples of urban scale PV

Project Name	Solarsiedlung am Schlierberg,
Location	Freiburg, Breisgau - GERMANY
Latitude/Longitude	48°0′0″N 7°51′0″E
Year	2006-06-00 (Operation start date)
Source	
PV power total	445 kWp
PV application	Integrated: PV roof tiles

Summary

This solar settlement is part of a larger urban redevelopment in Freiburg. Over a period of approximately ten years 60 "Energy-Surplus-Houses®" and a 125 m service block, called "Sonnenschiff", have been built. The "Sonnenschiff" provides retail, office and living spaces. The terraced houses are two and three storeys high. The "Sonnenschiff" is four to five storeys high and thus screens the community from the traffic on Merzhauser Straße. All roofs are covered with large area Photovoltaic (PV) modules which are integrated in a plane above the south facing roofs of the buildings. With this project Rolf Disch wanted to prove that his idea of an "Energy-Surplus-House®" works well for terrace houses and commercial buildings. He was both the architect and the developer of the Solarsiedlung am Schlierberg. This double function allowed him to ensure that his idea of the "Energy-Surplus-House®" was properly implemented. He also took a large personal risk to make this privately-funded project happen and to provide proof that today's homes are capable of generating more energy than they need.

Solarsiedlung am Schlierberg, Freiburg (Germany)

6 Frequently asked questions

1. How do photovoltaics work?

Photovoltaics is the direct conversion of sun power into electricity.

Photons of a high enough energy are absorbed by a semiconductor material creating electron/electron hole pairs which come under the influence of an electric field and are conducted through an external circuit.

2. What is the difference between a solar collector and a photovoltaic system?

There are two types of "solar panels", electrical and thermal. The electrical type is generally referred to as a "photovoltaic panel". It is a solid state device or assembly of solid state devices and produces electricity only. The thermal type of panel generally consists of water piping, glass and insulation and is much larger in size. This thermal type of panel is referred as a "solar collector".

3. Why should I use photovoltaics?

Mainly for the following two reasons:

- to cover your energy needs and
- for environmental protection. Each kWh of electricity produced from fossil fuels charges the atmosphere with at least 1kg of CO_2 (the gas most responsible for climate change).

In particular, photovoltaics

- will operate unattended and require minimum periodic maintenance,
- can be designed for easy expansion. If the power demand increases in the future, the ease and cost of increasing the power supply should be considered,
- are based on proven technology that has shown little degradation in over 15 years of operation.

4. What differentiates an autonomous PV system (off-grid) from an interconnected (on-grid) one?

Interconnected PV systems supply electricity directly to the grid, while autonomous systems directly supply houses or other facilities. Off-grid systems usually use a battery to store the electricity produced.

5. What kind of energy needs can a PV system cover?

Lighting, telecommunications, cooling, sound and generally all the needs that can be covered with energy from conventional technologies.

However PVs are not recommended for the supply of thermal electric appliances, eg cookers, water-heaters, etc. For these uses there are very economical solutions such as solar water-heaters, solar/geothermal air-conditioning or gas heating systems, gas, biomass, etc.

In contrast, requirements lighting and electronics (computers, audio systems, refrigerators, televisions, telecommunications etc.) can easily and economically be met with PV systems.

As a general rule, a 2-3kWp PV can meet the needs of a three-member family.

6. Aren't PVs efficient only on sunny days? What happens on days with no sun or at night?

Electricity production from PV panels, needs solar radiation light, rather than heat. Even on a cloudy winter day, during daylight, PVs produce electricity – albeit with reduced efficiency (on an absolutely overcast day, PV panels will produce 5-20% of maximum power).

In Germany, for example a 3kWp PV on a roof can produce approximately 3,000 kWh a year, enough energy to cover the annual electricity demands of an average household.

7. Which are the disadvantages of the PV systems?

- The initial cost is the main disadvantage of installing a solar energy system, mainly because of the high cost of the semi-conducting materials used in building one.
- Solar panels require quite a large installation area to achieve a good level of efficiency.
- The production of solar energy is influenced by the presence of clouds or pollution in the air.
- No solar energy will be produced at night, although a battery backup system and/or net metering will solve this problem.
- Solar cells produce DC which must be converted into AC (using a grid tie inverter) when used in currently existing distribution grids. This incurs an energy loss of 4-12%

8. In what ways can a PV system be installed in existing or newly constructed buildings?

There are two chief possibilities:

- Real integration, where PV modules actually replace several building materials, and
- Superposition, where PVs are placed on existing external surfaces of buildings (roofs, façade)

Obviously, the first case is preferable. The most important advantage is a reduction in the indirect cost of the PV system by substituting building materials (such as glass panes, roof and materials and skylights). In addition, full integration into the building structure significantly improves the aesthetics of the construction.

9. What does "BIPV" mean?

BIPV (Building Integrated Photovoltaics) refers to PV systems integrated with the building phase of an item. It means that they are built / constructed along with the item and also planned together with it. They could, however, be built later on (this is superposition). The task requires the cooperation of many different experts, such as architects, civil engineers and PV system designers.

BIPV consists of building materials for the shell of the building, that also act as producers of clean energy from the sun, thus saving costs in terms of both materials and energy.

10. Is my house suitable for photovoltaics?

- PV panels can be used on buildings with a south-facing wall or roof. Chimneys, roof lights, trees or buildings can all shade your panels and need to be taken into consideration when deciding where to position the system as shading makes a huge difference to the performance of the system.
- A typical installation requires at least 7-15m^2 of roof area.
- PV panels are quire heavy so the roof must be strong if they are to be placed on top of existing tiles. This depends on the technology used.
- If the system is grid-connected, the house should be close to the grid, as otherwise the cost could shoot up.
- For an off-grid system enough space will be needed for the batteries.

11. What are the most common BIPV systems?

- Façade or roof systems added after the building is completed. This is superposition.
- Façade integrated photovoltaic systems built along with a feature.
- Roof-integrated photovoltaic systems built along with a feature.
- "Shadow-voltaic" - PV systems also used as shadowing systems, built along with a feature or added later.
- "Architectural interventions" in stages, parks, squares, streets, etc.

12. Can I walk on PV modules on my roof?

PV modules are most often encapsulated in two layers of tempered low-iron glass or between glass and tedlar (a polymer) so they are flexible and less rigid than 100% glass. This is to give the modules the strength they need to withstand the most severe hail fall.

Nonetheless, PV modules are not designed to be walked on. It is recommended that you protect the modules with lengths of wood before walking on them, just as you would protect other glass roofing materials.

13. How heavy are photovoltaic modules? Does the support structure need to be reinforced?

Standard photovoltaic modules are relatively light, weighing around 10 to 15 kg/m2. This means that in most circumstances there is no need to reinforce existing structures.

Made-to-order modules may be heavier - insulated double and tripled glazed modules, often used in sunroofs and atriums will be 2 to 3 times heavier. Other factors that may affect the weight of a photovoltaic system are the type of module frame and the connection method selected.

It is essential that PV installations comply with local building regulations and safety codes.

14. How much light does a transparent PV roof element let through?

Transparent PV modules generally come in one of two main types:

- normal cells in a double glass frame; the gaps between the cells are transparent
- thin films deposited on a glass surface; the PV layer is thin enough to let a certain amount of light through.

The gaps between normal PV cells in a double-glass module can be increased or decreased to change the transparency level of the module. Generally, the gaps between cells are such that the transparency is between 5% and 30%. A classic double glass module will have a transparency of roughly 4% to 5%.

The transparency of thin film modules depends on the transparency of the support and the thickness and type of cell used. It is normally around 5% to 10%.

Nearly any degree of transparency can be made to order, but it is common to balance the natural light gains against potential overheating due to increased thermal gain.

15. How much space do I need to install a PV system?

It depends on the technology used. For example, a 3 kWp, Poly-Si needs a south-facing roof area of about 25m^2.

In general, PV technology does not require large areas. In order to cover the entire electricity demand of Europe, 0.7% of its total land area would be sufficient. There is enough available surface which does not compete with other land uses, such as the façades and roofs of buildings.

16. How much does the integrated PV installation will cost?

The cost of the PV system depends on:

- the panel technology (e.g. amorphous silicon panels cost less, but require approximately twice the size of Mono-Si),
- the origin of the panels and other items of equipment (European panels are more expensive but usually more reliable than Chinese ones),
- the size of the PV system (the less the power, the greater the cost per installed kW),
- the difficulty of the installation (inaccessible areas or installations with increased technical difficulty cost more),
- the distance from the grid,
- the energy needs of the building .

The cost per kW installed ranges from €4,200 (for amorphous silicon panels) to €7,500 (for Poly-Si panels). For an initial estimate, the investor can calculate an average target price of €6,000 per installed kW.

System designers know that every decision made during the design of a PV system affects the cost. If the system is oversized because the design is based on unrealistic requirements, the initial cost is increased unnecessarily. If less durable parts are specified, maintenance and replacement costs are increased. The overall estimates of the life-cycle cost of the system can easily double if inappropriate choices are made during system design. Don't let unrealistic specifications or poor assumptions cause unreasonable cost estimates and keep you from using this attractive power source.

17. What is the lifetime of a PV installation? Do PV systems have a high operating cost?

A well-designed and maintained PV system will operate for more than 20 years. The PV module, with no moving parts, has an expected lifetime in excess of 30 years. Experience shows most system problems occur because of poor or sloppy installation. Failed connections, insufficient wire size, components not rated for DC application, and so on, are the main culprits. The next most common cause of problems is the failure of electronic parts (controller, inverter, and protection components).

Generally the operating and maintenance cost of PV systems is low.

18. Why are roof-integrated products so expensive compared to standard modules?

At present, roof-integrated PV modules and systems are still custom-made, requiring a lot of design work and manual manufacturing. If standard solutions for roof-integration could be provided on a larger scale, these product prices would drop to a comparable level.

19. What steps should I follow?

- Describe your energy needs in detail. Record the electrical appliances you use and the time they are turned on. If you are already connected to the grid read over the last year's accounts carefully.
- Follow some simple energy-saving practices. Calculate, even roughly, the expected reduction in electricity consumption.
- Contact dealers and PV installers and report these figures to them. Invite them to see your building and estimate the power that will cover your needs.
- Ask companies to show you some of their previous projects. If possible, visit some of their clients and ask their opinion. Did they meet their needs? Are they satisfied with the quality of work and technical support?
- Study the offers. Ask for details of the proposed system.
- Compare the prices, guarantee and technical support offered by each company.
- Investigate the possibility of investment subsidies in your country.

20. Is it possible to recycle PV panels?

Yes, all components in a solar module can be recycled. The most valuable parts are the solar cells themselves, which can be recycled into new silicon wafers as the basis for new solar cells. The aluminium frames, glass and cables can also be recycled.

21. When will PV be cost-competitive?

In many cases PV is already cost-competitive, especially for stand-alone applications where no access to the distribution grid is available. However, the electricity generation costs for PV systems are still higher than for other energy sources, if the environmental costs of conventional electricity generation are not taken into account. In any event, in Southern Europe, grid-connected PV electricity will be cost-competitive by 2015, due to the expected reduction of PV costs and the present continuous increase in the electricity tariff. Meanwhile, financial support is needed to develop a strong industry with economies of scale. Therefore, in countries with feed-in tariffs, PV is already a very attractive investment.

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A great deal of additional information on the PURE project is available on the web at: www.pure-eie.com. We would welcome feedback on this publication, if you have comments or questions please contact the project coordinator.

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