Manual for BiPV Projects

A publication by

ODERSUN

Preface

The integration of renewable energy systems into architectural design is a topical and prevalent theme that presents opportunities for innovative approaches. As consultants and drivers of innovation, architects and design engineers have a decisive role to play in recognising the advantages and potentials of building-integrated photovoltaics (BiPV) and applying them to meet specific project requirements. This involves combining energetic, architectural, engineering design, and economic considerations.

As a manufacturer of innovative solar elements that can be customised to meet project-specific architectural requirements, Odersun AG is the ideal partner and consultant when it comes to designing, planning and constructing innovative, energy-optimised solar solutions for the building envelope.

This document aims to provide an overview of the design potential of BiPV modules and the factors that influence planning considerations, and can be used as a guideline for relevant projects.

Contents

1. What is BiPV?

The terms component-integrated and building-integrated photovoltaics (BiPV) refer to the concept of integrating photovoltaic elements into the building envelope, establishing a symbiotic re-lationship between the architectural design, functional properties and economic regenerative energy conversion.

The photovoltaic modules (PV modules) thus replace conventional construction materials, taking over the function that these would otherwise perform. Although this idea is not new, it is not widely harnessed due to the extensive planning and architectural challenges currently involved.

In principle, BiPV can be used in all parts of the building envelope. Although roof surfaces are the preferred area for installing PV elements due to their advantageous irradiation values, façades also offer enormous potential.

The ratio of façade surface area to roof surface area increases along with the building height. In addition, the available roof area is often reduced due to the installation of facilities and superstructures, which means that BiPV façades are of particular value in high-density urban centres.

2.

Design potential

With regard to the aesthetics of the building, a PV module should have a homogeneous appearance and either blend subordinately into the overall design or dominantly shape it.

The appearance of the PV module is determined essentially by the type of technology used in the PV cell and by the design possibilities offered by the selection of materials used in the module.

2.1. Technologies

The PV market, as an innovative and rapidly growing market, offers a wide range of different technologies. Generally, these can be divided into two main groups based on the type of manufacturing technology, namely crystalline cells and thin-film cells. The approach adopted for Odersun's CISCuT solar cells, however, results in an architecturally interesting solution that unites the design benefits of both of these groups.

2.1.1. Crystalline silicon

Crystalline solar cells usually consist of approximately 15×15 cm (6"×6") square plates with a metallic blue or black surface that is subdivided by silver-coloured contact grids, which collect the current. Special anti-reflective coatings can be applied to create other metallic shades.

Modules are created by connecting several silicon cells to form larger strings. The light transmission through the modules can be adjusted by altering the spacing between the cells. Since the size of the cells is not variable, any change in the module size leads to a change in the light transmittance or to a suboptimal arrangement of cells.

2.1.2. Traditional thin-film

Thin-film modules consist of a semiconductor, just a few micrometres thick, typically deposited on a carrier of thin non-hardened glass by means of vapour deposition. The resulting coating hereafter is subdivided into individual thin linear cells. The cells are usually reddish brown to black and are broken up by metallic or transparent lines.

The size of the modules is predetermined by the size of the carrier plate and is only rarely broken into smaller segments. Unfortunately, because the individual cells are connected in series, it is not possible to create special shapes. However, this technology does enable a constant level of transparency to be created across a surface by the selective removal of film in individual areas.

2.1.3. Odersun CISCuT

A narrow copper strip, over a kilometre in length, serves as the carrier and contact material for a micrometre-thick solar cell. This cell can be cut to any length and the cell stripes are connected together with a slight overlap, using an electrically conductive adhesive, to form a string. The surface colour ranges from graphite grey to black and does not require a visible contact grid.

An individual string or several individual strings of various sizes, the so-called Odersun Super Cells, are connected together to form a freely definable module. This enables the manufacture of customised and project-specific module sizes and special shapes.

The level of transmittance can be individually controlled by adjusting the spacing between the strings of cells.

2.2. Efficiency and output

In order to compare the different types of cell technology, the rated output of each type is determined on the basis of standardised measurements, usually under standard test conditions (STC).

This involves applying a light source of 1000 W per m^2 vertically to the modules, at an ambient temperature of 25° Celsius. The spectral composition of the light is 1.5 AM (air mass) for the purpose of this measurement.

The air mass factor represents the path length of the solar radiation through Earth's atmosphere. If the solar radiation is vertical, the light takes the shortest path through the atmosphere (air mass = 1). If the angle of incidence is shallower, the path of the light through the atmosphere is longer and the AM value increases accordingly.

The output measured under these conditions determines the solar element's rated module output that the manufacturer is obliged to state. The ratio of the applied radiation (1000 W/m^2) to the measured values gives the efficiency of the solar module.

Generally, the older and already highly developed crystalline technologies still provide the highest commercially available efficiency values, with 12 % to 17 % for multicrystalline modules and up to 20 % for monocrystalline modules.

The efficiency of thin-film technologies currently lies below these values, typically ranging from 5 % for amorphous silicon up to 13 % for CIS modules. With maximum efficiency values of approximately 20 %, current research promises further optimisation of the yield per unit area of solar elements, particularly in the field of CIS technologies.

2.3. Module design

Solar modules are available as laminates made of glass or film. As a rule, façade and overhead glazing systems use laminates made of glass only. In addition to providing protection for the solar cells, these laminate elements can also meet structural and design requirements.

Various parameters can be taken into account in the design of the modules. Examples of possible options are:

- Module size
- Module shape (e.g. rectangles or special shapes)
- Covering glass
  - Glass quality
  - Strength
  - Structure
  - Coating
  - Colour
  - Tinted glass
  - Coloured printing
- Cell background or reverse side of module
- Semi-transparency
- Arrangement of solar cells in the module
- Interconnections
- Multi-layered superstructures such as insulated glazing
- Cell colour

2.3.1 Semi-transparency

The effect created in the module by the combination of transparent unoccupied areas and opaque solar cells is referred to as semi-transparency. The arrangement and distribution of the solar cells within the module thus controls the degree of transparency.

This makes it possible to create interesting and innovative light effects. If the module is required to have no transparency, the intermediate areas not filled with cells can also be coloured.

Since the solar cells are usually opaque and need to absorb the sunlight for energy conversion, it is not possible to create fully transparent solar generators. Depending on the type of technology, however, the pattern of transparency can be arranged in various ways.
→ *2.1. Technologies*

Fig. 1 CISCuT module with orange backing

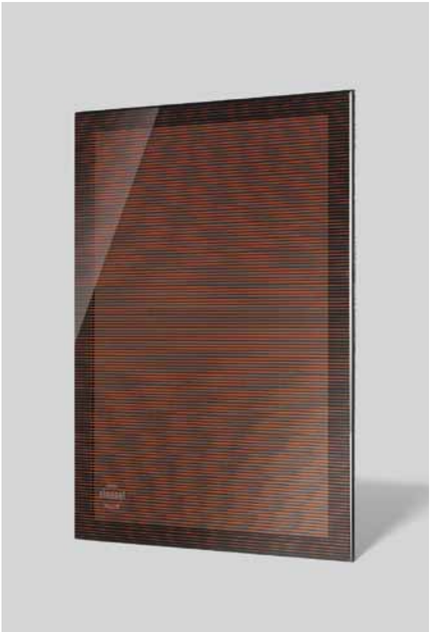


Fig. 2 CISCuT module with 25 % printed lines

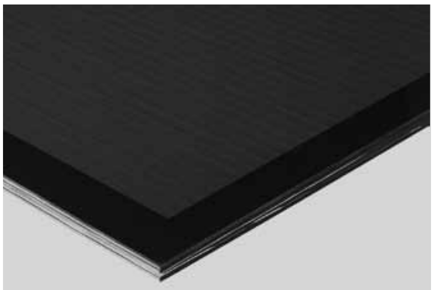


Fig. 3 Surfaces: structured glazing

2.3.2. Colour

To achieve colour effects that differ from the cell colour, coloured printing, coatings or films can be used. This makes it possible to create interesting effects such as logos on PV modules or colours that match the existing building, since the entire range of RAL colours is available.

The following methods can be used for colouring solar modules:

- The use of coloured glass.
- Glass with full area print (Glass Enamel) with various patterns: resilient and durable.
- The application of a coloured film (low resistance)
- Anti-reflective coatings.

These creative design measures on the front surface of the module naturally result in a reduction in the sunlit surface area or in the reflection of some of the incident light. The output of the solar module is therefore always reduced.

For this reason, a compromise between design and output must always be found when designing coloured solar modules. To minimise the reduction in efficiency, the coverage rate of the colour printing or the intensity of the colouring must always be kept as low as possible.

→ Fig. 1, 2

Fig. 4 Pliable CISCuT cells (Odersun)

Fig. 5 Electrical contacts between mono-crystalline cells

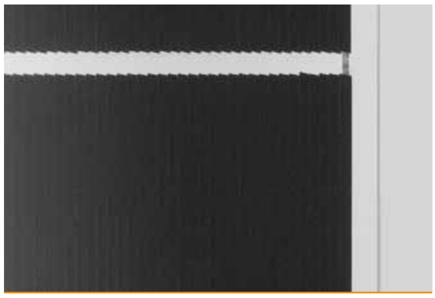


Fig. 6 Electrical contacts between CISCuT cells (Odersun)

2.3.3. Glass surfaces

Provided there are no process-related limits to the range of possible glazing-types, all available quality grades and types of glass can be used for solar modules. This means that the structural and safety requirements for specific types of application can be met by using toughened glass or different thicknesses of glazing.

To ensure optimum yield, the cover glass should preferably be white glass with low iron oxide content and high transmission. The lower iron oxide content also reduces the typical greenish tint of the glazing.

The yield of a solar module can also be increased by using structured glass for the cover glass. The surface of the structured glass is made up of wave-shaped, rounded depressions that act as light traps. Some of the radiation that would normally be reflected into the environment and lost is directed back into the cell. This increases the amount of incident radiation and can increase the output of the solar modules by up to 3 %. From an architectural point of view, however, the fascination of this type of glazing lies in its matt appearance and non-reflective surface. *→ Fig. 3*

2.3.4. Pliability and flexibility

The pliability and flexibility of solar cells depends on the materials used, the substrates and the thickness of the cells. Various technologies can produce pliable solutions when they are based on metal or film. Tight bending radii are possible if thin-film technologies such as amorphous silicon or CIS are deposited on flexible metal or synthetic substrates. Due to the thickness of the cells, crystalline cells, on the other hand, are much more limited since they are brittle and porous.

Mechanically flexible solutions are already available from some manufacturers for specialist applications such as roof sheets, but only in fixed sizes.

Module layers made of glazing that allows cold bending of the module are proving to be more stable in the long term and to offer more variation in size. Either very thin and malleable glazing can be used or the glazing can be held in form using special fixing systems.
Hot bending of the solar modules is not possible due to the high temperatures required. *→ Fig. 4*

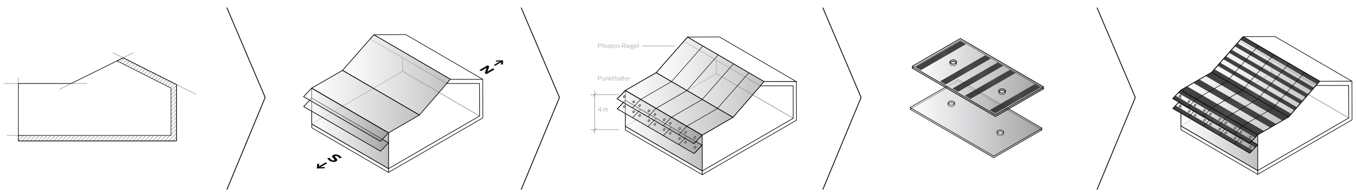
2.3.5. Cell contacts

Electrically conductive contacts are required to connect the individual cells and Super Cells within the module. Often, these are made of conductive materials such as copper and significantly affect the appearance of the module.

Depending on the type of technology used, however, these electrical contacts can be made invisible if required. *→ Fig. 5, 6*

3.

BiPV design guidelines



Successful building-integrated PV solutions are taken into account in even the preliminary planning and design stages of a project so that project-specific characteristics can be considered at an early stage.

PARTIES INVOLVED

- BiPV manufacturer
- Architect

In the case of complex installation situations, the BiPV manufacture provides advice regarding the possibilities for project-specific module designs. Support is also given to the electrical engineer with regard to the design of the electrical installations for the BiPV system.

PARTIES INVOLVED

- BiPV manufacturer
- Architect
- Project manager
- Structural engineer
- Electrical engineer
- Building shell design engineer

The product specifications are determined cooperatively and the interfaces are defined. A detailed calculation of the yield from the PV system can be made.

PARTIES INVOLVED

- BiPV manufacturer
- Architect
- Project manager
- Electrical engineer

Close cooperation between the BiPV manufacturer and the other service providers involved in the project ensures the development of a precisely tailored product that meets all the specific requirements.

PARTIES INVOLVED

- BiPV manufacturer
- Architect
- Façade contractor
- Electrical engineer
- Structural engineer

Partner companies install the customised solar modules on site. The quality of the individual solar modules is assured by means of guarantees.

PARTIES INVOLVED

- BiPV manufacturer
- Architect
- Façade contractor

Fig. 7 Project stages

The design of a BiPV system can often be a complex process. This stands to reason, since it is necessary to reach a consensus between optimum operating conditions for the photovoltaic system, the architectural context, economic considerations and building regulation requirements.

The supposedly definitive rated output data for the PV modules, which is based on standardised measurements, is of only limited relevance here.

In this case, it is more important to carefully select the right system, to tailor the design of the BiPV elements to suit the requirements of the project, and to take these elements into consideration at an early stage in the planning process in order to achieve electrically and architecturally optimised systems. Particular attention must also be paid to the planning processes and to the allocation of responsibilities before and beyond project completion. The planning, design and implementation of a building-integrated system require the cooperation of several different trades, such as electrical installation and façade construction specialists, which would traditionally have very little overlap during the detailed design stage.

It is vital, therefore, that the services provided by the different trades are precisely defined and demarcated. → Fig. 7

As a basic principle, however, the steps and questions described in more detail below should be observed in the planning phase and should be reflected in the design and implementation:

- Design strategy
- Environmental variables
- Multifunctionality
- Construction system and installation situation
- Glass layer structures
- Module design
- Electrical components
- Economic aspects

3.1. Design strategies

The use of renewable energy sources in architecture is by no means a new concept, but it has become more topical recently, particularly as architects, property developers and building users become more inclined to consider issues of resource conservation.

Sustainable or energy-active systems in the building envelope present the possibility of meeting this requirement using innovative types of application within the context of the proposed building or refurbishment project.

In order to integrate photovoltaic systems in a sensitive and satisfactory way, energetic, architectural and structural factors as well as economic considerations must be taken into account and reconciled at an early stage.

3.1.1. Architecture

In this context, architects have the important task of recognising, as accurately as possible, the advantages and the potential of applications such as building-integrated photovoltaics and of presenting these to the developer in their role as consultant and provider of ideas.

Photovoltaic systems can be integrated in various ways. Depending on the desired appearance, various strategies are employed in practice that can influence the overall effect of the building. Common strategies include:

- Adjustment
- Contrast
- Dominance
- Dialogue

3.1.2. Urban space

Aesthetically pleasing BiPV solutions are particularly needed in the field of urban development. Many local authorities are laying down design regulations, either separately or in the relevant development plan, which stipulate requirements that must observed and met be-fore building permission is given.

Façades, visible roof areas and street furniture determine the character of public spaces. By designing BiPV systems to meet the specific requirements it is possible to incorporate PV systems in the townscape in a visually harmonious way. Coloured designs or invisible fixings are often requested in this context.

The integration of PV systems in existing or even protected buildings presents a particular challenge, since the surfaces available for PV integration are often very limited.

Comprehensive information on this subject can be found in the leaflet “PV im Denkmalschutz” (PV in listed buildings) from the specialist group “Bauwerkintegrierte Photovoltaik” (Building-integrated photovoltaics) of Bundesverband Bausysteme e.V. → www.bv-bausysteme.de

3.1.3. Landscaping

The acceptance of PV systems is determined to a large extent by their sensitive integration in the landscape. Conspicuous systems can look strange and unfamiliar and can even be perceived to spoil the landscape. This is particularly evident in the case of typical free-standing systems that cover large areas of land and are designed and installed taking only the economic aspects of yield optimisation into consideration.

The fundamental issues of landscape integration relate to the type of installation, the method used to fix the PV elements, the colouring of the elements and, not least, the choice of installation location and the necessary safety and security measures.

If these parameters are precisely and sensitively controlled, innovative and congruent solutions can be generated and even be used to create attractive landscape design features.

3.2. Environmental variables

When designing a BiPV system, a compromise must be reached between the requirements of yield optimisation and those of the architectural environment. The rated output data for the PV modules, which is based on standardised measurements, is not the most important criterion here.

→ *2.2. Efficiency and output*

The selection of the right type of technology for the environment in question is more important in this case. Often, the usually less efficient thin-film technologies represent the best choice here, particularly in situations with suboptimal environmental variables.

3.2.1. Orientation

The amount of incident solar radiation on a surface depends on its orientation and angle of inclination. The optimum angle of inclination varies according to the latitude of the installation site: the further the distance from the equator, the steeper the optimum installation angle. In Germany, surfaces that face south and are set at an angle of 35° to the horizontal receive the maximum possible solar radiation. However, slight deviations in angle, between 20° and 45°, and slight displacements to the east or west often result in only minor losses in radiation.

In the case of BiPV systems that are arranged according to architectural criteria, however, optimal positioning of the modules is rarely possible. Nevertheless, good power yield can still be achieved even with suboptimal alignments provided that the characteristics of the PV modules allow this. Modules that perform well in weak and diffuse light, for example, can be used to good effect in situations where the orientation is unfavourable.

Thin-film solar modules possess these properties and regularly generate higher yield here in comparison to crystalline systems, which prefer directly incident, high-energy solar radiation. The use of thin-film modules is recommended in situations where there is a significant proportion of diffuse light due to reflection and light-scattering.

Consequently, despite their vertical alignment, façades represent an interesting application scenario for PV systems They can be found in all types of structures in every town and, in contrast to free-standing, open-field facilities, they generate electricity in the immediate vicinity of the user – without the power losses associated with transport and storage.

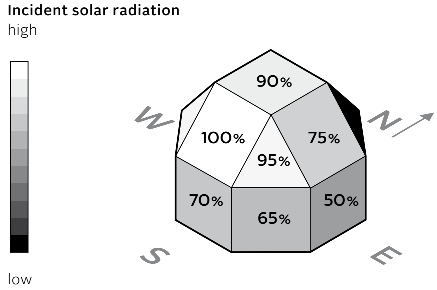


Fig. 8 Solar radiation on inclined surfaces

In Germany, a surface area of around 3000 km² could be used for building-integrated systems, which would amount to an installed power output of approximately 300 GW. In urban settings, façades represent the greater part of the area available for BiPV.

High-rise buildings have a much higher proportion of façade area than roof area. The incident solar radiation on south-facing vertical façades in Germany, for example, is more than 80% in comparison to a horizontal surface and is therefore well suited to BiPV.

→ *Fig. 8*

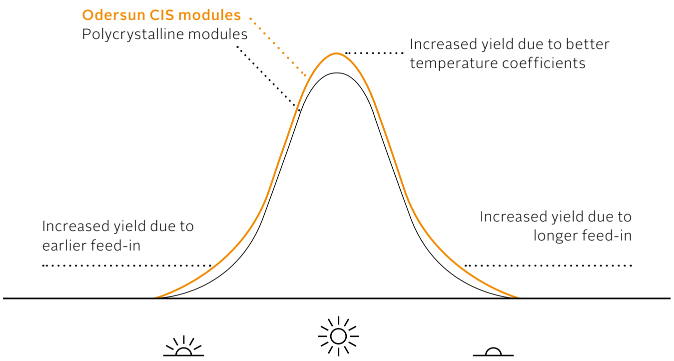


Fig. 9 CIS modules start to generate electricity earlier in the morning and continue later into the evening, and perform more stably at higher temperatures than crystalline types of module.

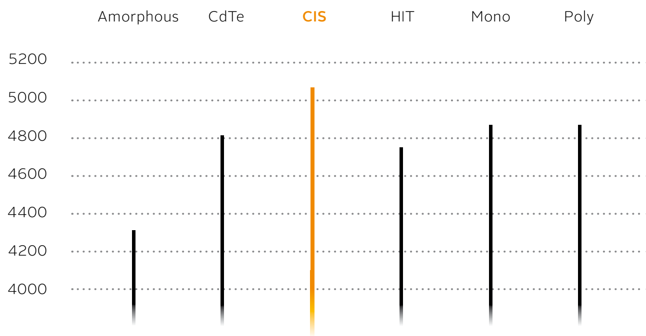


Fig. 10 CIS modules get the maximum benefit from every installed Watt of generating capacity. (Source: IPE University Stuttgart 2010) Graph shows accumulated yield in kWh.

3.2.2. Low-light performance and spectral sensitivity

The sun radiates constant, high-energy, direct light to earth. This direct light is ideal for solar modules, and highly efficient silicon solar cells in particular are very good at converting it into electrical power. The direct sunlight is scattered, however, by water vapour, dust and soot particles as it reaches earth and is reflected from the objects it strikes. This results in indirect or diffuse light. The ability of solar cells to convert diffuse or scattered light into energy is referred to as low-light behaviour.

Thin-film solar modules demonstrate better efficiency in low light and produce higher relative yields in comparison with crystalline systems. They are therefore recommended for applications with a significant proportion of diffuse light and in cloudy or dull weather. They also enable suboptimal or even north facing façades of buildings to be included in the BiPV concept. → *Fig. 9, 10*

Spectral sensitivity

The sun's spectrum ranges from short wavelength UV light to long wavelength infrared light. Solar cells react differently to the different wavelengths of the sunlight.

In contrast to crystalline cells, which absorb primarily long wavelength radiation, thin-film solar cells can absorb a wide spectral range. In diffuse light there is less difference in efficiency, since the short wavelength blue light is absorbed well by the thin-film solar cells on cloudier days or when the sun is low in the sky.

3.2.3. Shading

Shading can significantly affect the yield of a PV system. It can have many different causes, such as vegetation, neighbouring buildings, self-shading due to construction elements, or layers of dirt on overhanging parts of the mounting system. This shading can also change due to growth, new buildings or different user behaviour.

Such sources of shade can be minimised by careful planning in order to maximise the incident solar radiation. Simulations of the daily and yearly path of the shadows can be carried out to enable the position of the solar modules and the orientation and cubature of the building to be optimised accordingly. If shading cannot be completely avoided, its effects can be reduced by adapting the module technology, the module design and the electrical connection of several modules.

→ *Fig. 11, 12*

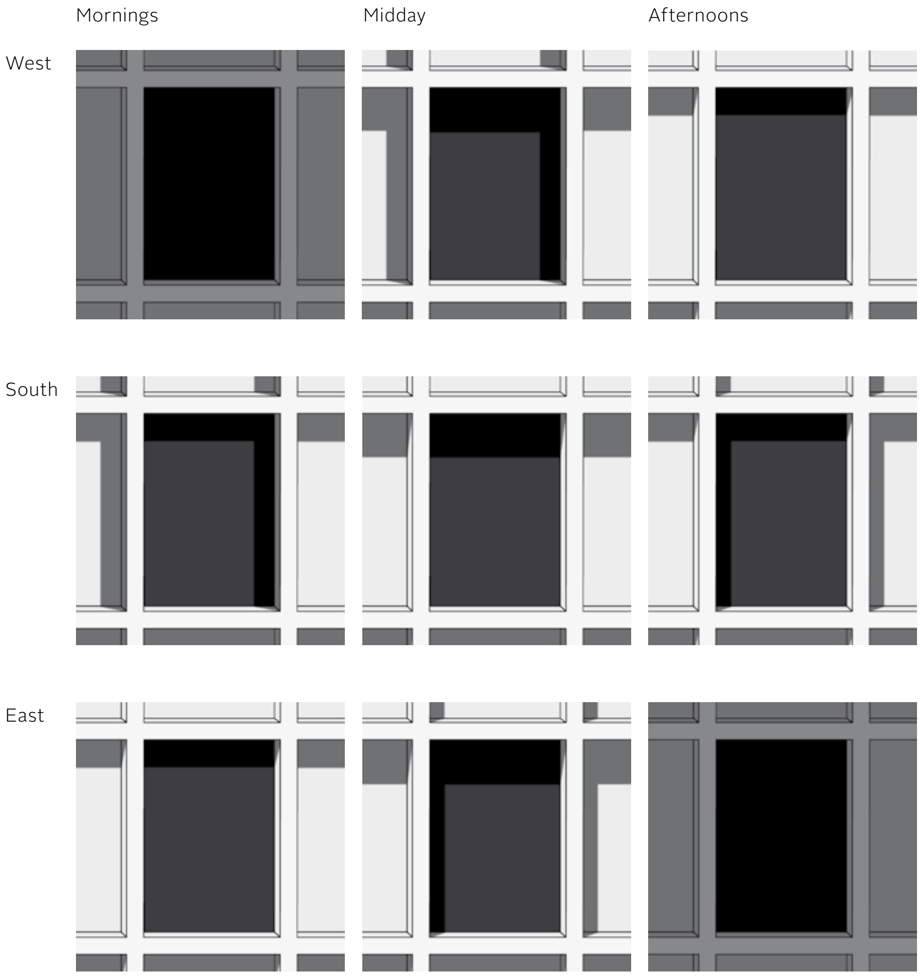


Fig. 11 Self-shading due to the type of fixing system selected

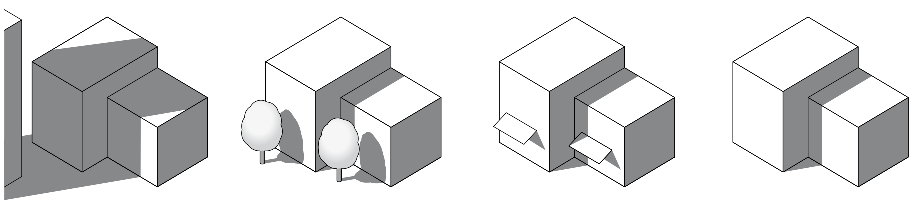


Fig. 12 Shading due to cubature and the environment

3.2.4. Temperature

If the PV modules heat up, a reduction in output is inevitable. The output losses vary depending on the type of cell technology used. The losses from silicon cells are approximately 0.5 % per Kelvin, which can sometimes equate to twice the amount lost by thin-film modules.

This effect must be taken into account, since the standard output measurement for solar modules is taken at 25°C, whereas additional 55°C can be expected in the case of façades that have no rear ventilation. From a yield point of view, therefore, it would be expedient to increase the rear-ventilation dimensions in order to keep the module temperature as low as possible.

3.3. Multifunctionality

Due to their mechanical module structures, PV modules can perform the functions of the building envelope in addition to their main function of silent and emission-free energy conversion, and can thus replace conventional construction materials.

The extent of this functionality is determined by the design of the module structure, which in turn defines the technical, economic and architectural design aspects. The silent, emission-free conversion of energy, however, is the defining characteristic of photovoltaic systems.

By taking on further functions, solar construction elements can be used for various types of application in buildings, and can even be used as a substitute for separate systems, such as shading systems, that would otherwise be required. Such substitutions make it possible to reduce the module price paid for BiPV modules, which is otherwise usually higher than the price of standard PV elements. Thus, despite their higher initial costs, building-integrated PV systems can be significantly more cost-effective than traditional construction materials.

3.3.1. Types of application

Since BiPV modules can be structured in many different ways, there is a correspondingly large variety of possible applications for the integration of PV systems in and on buildings. PV cells can be incorporated into just about any glass layer structure, so that even walk-on glazing and thermal insulation glazing systems are possible. Examples of possible applications include:

- Solar protection fins and louvres
- Sun protection panels and canopies
- Façade cladding for curtain façades and rear-ventilated façades
- Double façades
- Semi-transparent window areas
- Roofing
- Privacy protection panels
- Sliding shutters
- Canopy roofs
- Street furniture
- Noise protection walls

3.3.2. Functions

Privacy screening

The relationship between the interior and exterior world is of great importance in architecture. The use of semitransparent solutions combines transparent areas with opaque PV cells in order to establish this relationship. In contrast to purely opaque solutions, the architectural design potential is increased here due to the use of selective screening.

Sun protection

The PV cells provide sun protection in a similar way to screening, acting as opaque elements or providing the desired degree of semi-transparency in accordance with a targeted design.

Energy conversion and shielding

A possible special application for PV systems could be the reception and transmission of high-frequency signals, as a repeater antenna for mobile phone systems, for example. Alternatively, the metallic semiconductor layer can also act as a shield against electromagnetic radiation.

Architectural design element

The wide range of designs of PV modules makes it possible to use them as architectural design elements, which can be taken into account and systematically managed during the planning stage.

Heating

The temperature of a photovoltaic module can increase significantly when the module is exposed to radiation. This is particularly the case with direct radiation on the module, which occurs in the summer months and in the winter months when the sun is low. The heat that the modules then radiate into the environment can be harnessed to provide hot water or technical process heat.

Thermal insulation

Depending on their thickness, the multilayer glass structures of PV modules can be used to provide thermal insulation. In addition, most solar modules can also be integrated into insulation glazing structures or used as alternative front cladding for curtain insulation elements.

Weather protection

In general, the mechanical structure of PV modules always provides weather protection - if only for the purpose of protecting the solar cells against weather influences. With the correct choice of cover glazing layers or films in combination with the building-integration mounting system, PV modules can provide rain-proofing, wind-proofing, wind load resistance and ageing resistance.

Burglary protection and residual structural support

Burglary protection can be provided by selecting the right type of cover glass or base glass and the right intermediate film. As a rule, panels made up of multiple layers are used. The type of solar cells used can also play a decisive role here. Solar cells set on extensive metallic carrier sheets (CISCuT), for example, increase the breakthrough resistance of the elements.

Sound protection and sound insulation

PV modules can reflect or attenuate sound depending on their construction. For this reason, they can also be used as sound protection elements. PV façades or roof elements already possess sound insulating properties thanks to their multi-layer structure, and the module design can be adapted to meet specific local requirements regarding sound insulation. The sound reduction index can be adjusted by increasing the thickness of the glazing and by using asynchronous cover layers and specific intermediate layers.

3.4. Mounting system and installation situation

Due to the specific properties of the system, such as shading, for example, and the regulatory specifications with regard to the safety and loading capacity of the materials used, the chosen type and method of fixing have a decisive impact on the design of the solar module.

3.4.1. Mounting systems

3.4.1.1. Linear mounting systems

Mullion-transom façades

→ Fig. 13, 14

Mullion-transom constructions consists of vertical mullions and horizontal transoms. The mullions transfer the main loads and the transoms act as horizontal bracing. The solar modules are set in this framework structure as fill elements. Clamping rails are fitted from the outside as linear fixings for the modules.

The circumferential profiles, however, can shade the solar modules and also result in the accumulation of dirt and snow. The module design should be adapted to take this shading into account. The costs for maintenance and cleaning should also be taken into account, if applicable, particularly for roofing applications.

The dimensions of the façade grid vary from project to project and customised solar modules are usually required. Mullion-and-transom façades count as "warm" or thermally insulating façades. Consequently, not only must the profiles be thermally separated, but the U values of the fill elements must be correspondingly low. For this reason, PV modules are often integrated in a thermal insulation glazing structure.

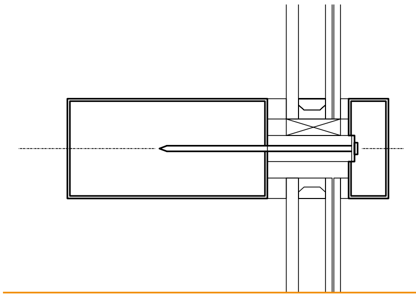


Fig. 13 Mullion-tRansom Façade

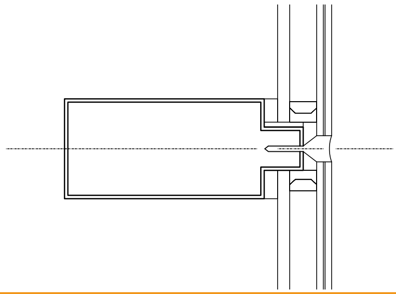


Fig. 15 Structural Sealant Glazing

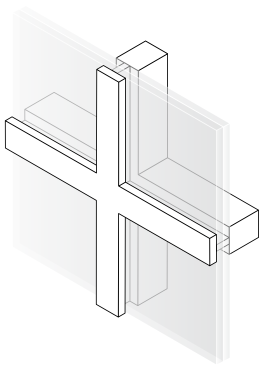


Fig. 14 Mullion-tRansom Façade, Axonometric view

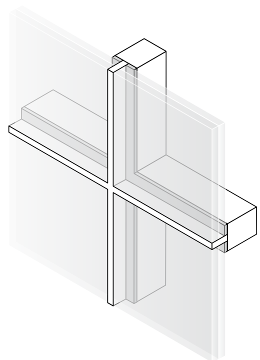


Fig. 16 Structural Sealant Glazing, Axonometric view

Structural sealant glazing (SSG)

→ Fig. 15, 16

With structural sealant glazing façades, the solar modules are fixed in place on a metal frame by means of circumferential load-transferring bonds.

This produces façades with a homogeneous and smooth appearance. Furthermore, SSG façades have no external protruding parts, which means that shading and dirt traps are avoided.

In contrast to other countries, German regulations require an additional mechanical safeguard to prevent panels installed above a height of 8 m from plummeting. In addition, provision for the mechanical transfer of loads must be made. The combination of SSG with solar modules is treated as a special system, so that both product-specific building permission (Allgemeine bauaufsichtliche Zulassung, AbZ) and project-specific building permission (Zulassung im Einzelfall, ZiE) must be obtained.

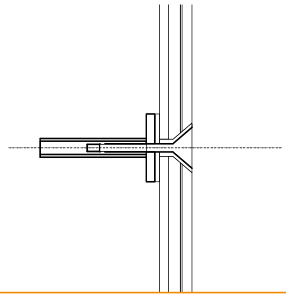


Fig. 17 Drilled spot fitting

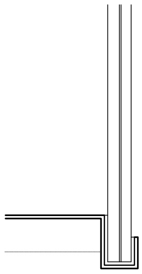


Fig. 19 Clamp fixings

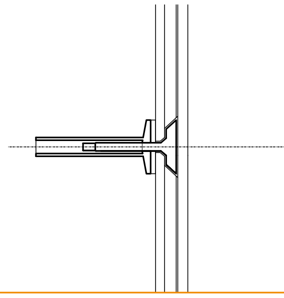


Fig. 21 Undercut anchor fixing system

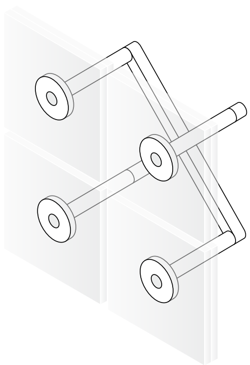


Fig. 18 Drilled spot fitting, Axonometric view

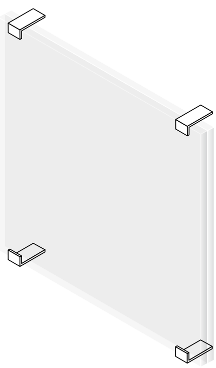


Fig. 20 Clamp fixings, Axonometric view

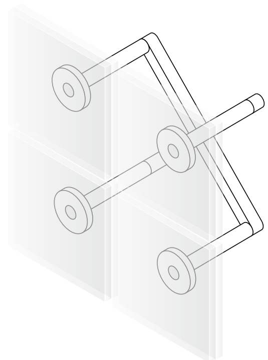


Fig. 22 Undercut anchor fixing system, Axonometric view

3.4.1.2. Point-fixing systems

Particularly delicate designs can be achieved using point-fixed façade systems. Typical point-fixing systems are clamp fixings, drilled glass panes with drilled spot fixing, and undercut anchor fixing systems.

Although point-fixing systems cause hardly any shading in comparison to frame systems and are less prone to accumulating dirt, they can only be used with a few types of solar module.

Since holes drilled in glass must maintain a minimum offset from the edge of the pane and since drilled spot fixing always shade part of the module, the only solar modules that can be used here are those that allow cut-outs to be made in these areas in the module design and permit drilled panes to be used independently of the cell production. Standard thin-film modules are not usually favourable or cannot be used at all in such cases.

Drilled spot fixing

→ *Fig. 17, 18*

Drilled spot fixing are construction components that are used for point-fixing glass panes. They comprise two metal discs and a bolt that is inserted through a drilled cylindrical hole in the glass pane to connect the two discs. These circular pads must measure at least 50 mm in diameter and be offset from the edge of the glass by 12 mm.

Clamp fixings

→ *Fig. 19, 20*

Clamp fixings are U-shaped brackets that fit around the edge of glass panes and dispense with the need to drill holes in the glass. The fixings must overlap the glass by at least 25 mm and the clamped area must be greater than 1000 mm².

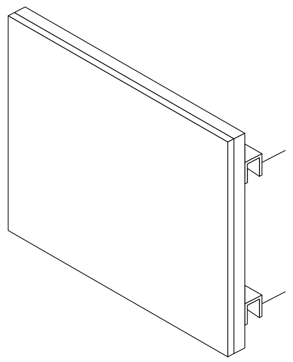


Fig. 23 Ventilated curtain wall system, Axonometric view

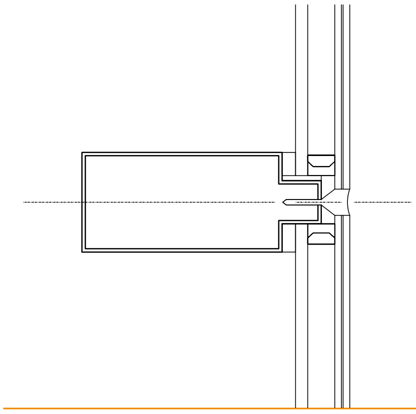


Fig. 24 Ventilated curtain wall system

Fig. 25 Photovoltaics in Combination with Stone and Glass (Lithodecor, Airtec system for ventilated curtain wall façades)

Undercut anchor fixings

→ Fig. 21, 22

Undercut anchor fixings are mechanical point-fixings that remain invisible, since the glass is not drilled right through. This allows more efficient use of the PV surface area. These fixings generate higher stresses due the reduced contact area of their cylindro-conical drilled holes, which means that toughened glass, semi-tempered glass or laminated safety glass must be used.

3.4.2. Ventilated curtain wall systems

The function of the cladding of ventilated curtain wall systems) is to provide weather protection and to serve as an architectural design element. This outer cladding is fixed to a rear load-bearing wall using a fixing system (agraffes and/or rails).

A layer of air between the load-bearing wall (or the insulation layer attached to it) and the building envelope ventilates the solar modules from the rear and can be used for laying electrical components and sockets.

Many different types of material, such as plaster, ceramic tiles, bricks, glass or metal can be used for this kind of construction. Façades can thus be created using a wide variety of material combinations together with PV modules. Above all, ventilated curtain wall systems are taken into consideration in energy-efficient façade renovation projects. *→ Fig. 23, 24, 25*

3.4.3. Installation situations

The demands made of façade systems vary according to the type of fixing system and installation situation.

The following information refers to German rules and regulations.

Vertical glazing

All solar modules set at an angle of less than 10° to the vertical are classified as vertical glazing. Standard installation situations are described in the TRAV (Technical rules for the use of fall-proof glazing) and TRPV (Technical rules for point-supported glazing) guidelines. Hitherto, solar modules made of toughened glass were often considered to meet the requirements although the module structures do not correspond to the standard types in accordance with the requirements of Building Rules List A.

Overhead glazing

Solar modules installed at an angle greater than 10° are classified as overhead units and must comply with more stringent requirements. As a rule, laminated safety glass with a PVB intermediate film should be used as standard. Solar modules that have cells within the intermediate film or have an intermediate film made of EVA are classified in the Building Rules List as laminated glass and not as laminated safety glass and therefore require product-specific building permission (Allgemeine bauaufsichtliche Zulassung, AbZ) or project-specific building permission (Zulassung im Einzelfall, ZiE).

Walk-on glazing

Due to the type of use, walk-on glazing is at greater risk of being damaged by knocks. Its stability and fitness for use must be demonstrated by means of structural analysis if unfavourable loading conditions apply (1.5 kN individual loading, 3.5 kN/m² traffic loading). Only laminated safety glass with at least three layers may be used. The topmost layer must be thicker than 10 mm and be made of toughened or semi-tempered glass. The bottom layers must be thicker than 12 mm and be made of float glass or semi-tempered glass.

Step-on glazing

Step-on glazing is usually only intended to support loading during maintenance or cleaning by one person at a time and must be made of laminated safety glass panes with at least two individual sheets.

If trafficked areas beneath step-on glazing are not sealed off while the glazing is being walked on (see the FKG trade association leaflet on step-on glazing: “Betretbare Verglasung”), this glazing is then classified as overhead glazing.

3.5. Glass layer structures

The combination of solar cells with various types of glass layer structures makes it possible to use solar modules in many different installation situations. Requirements regarding overhead glazing and fall-safe glazing can also be met in this way.

3.5.1. Glass-glass-PV modules

→ *Fig. 27*

Double-glazed solar modules comprise two sheets of glass and use EVA (ethylene vinyl acetate) or the more conventional PVB as a bonding material. The modules are classified as laminated glass, due to their use of non-regulated bonding materials (EVA) and the use of solar cells that lie within the panes and are also non-regulated with regard to the Building Rules List.

Since the current guidelines allow the use of laminated safety glass only, i.e. double glazing with an intermediate PVB film and no solar cells, as overhead glazing, project-specific building permission is required for overhead glass-glass solar modules, and particularly for those containing EVA film, if the module manufacturer does not have approval for the module structure.

3.5.2. PV thermal insulation glazing

→ *Fig. 29*

For the integration of solar modules in transparent façades or roofs behind which lie heated rooms, the use of PV thermal insulation glazing is a standard requirement. Both crystalline and thin-film solar cells are suitable for the manufacture of PV thermal insulation glazing. As a consequence of the heat-insulating properties of this module structure, the solar cells heat up and this results in a reduction in the efficiency of the cells. Monocrystalline solar cells are more sensitive to temperature than thin-film solar cells in this respect.

Glass-glass-PV modules can be used for thermal insulation configurations. Fixed either at the front or rear side, depending on the position of the module socket, these modules include spacers, an insulating gas or vacuum layer and a single or laminated glass sheet.

3.5.3. Three-layer laminated glass

→ *Fig. 28*

A further possibility for overhead applications is the use of solar modules with three layers of glass. Modules with this type of structure consist of two glass sheets bonded together, as in the glass-glass solar module units, plus an additional glass layer, which is usually fixed at the front side of the module. Such module constructions can be used as walk-on glazing, although the same limitations apply as for the glass-glass module with regard to eligibility for approval.

Fig. 26 Glass-Film Module Structure

Fig. 27 Glass-Glass Module Structure

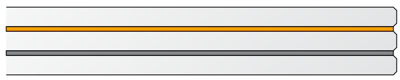


Fig. 28 PV with Three Layers of Glass

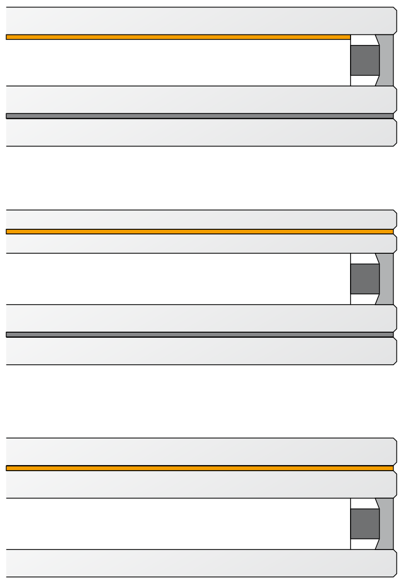


Fig. 29 PV Thermal insulation glazing

3.5.4. Glass-film-PV modules

→ *Fig. 26*

Glass-film modules are typically available as standard solar modules and have the advantage of very low module weight, as a result of their combination of a lightweight synthetic film on the rear side and a usually thinner glass cover sheet. If toughened glass is used for the cover glass and if the thickness complies with the structural requirements, then glass-film modules can also be used for building integration. Indeed, glass-film laminates have already been approved many times for use in overhead situations.

3.6. Module design

The module design options described in the previous paragraphs are limited by the technology of the type of solar cells used, the process used to manufacture them, and, not least, the different variation options offered by the relevant manufacturer.

Insofar as different module designs are available, this information must be obtained individually from the manufacturer.

By combining a strongly customer-oriented approach with an extremely flexible type of technology that allows many configuration options, Odersun AG is able to offer a wide variety of designs.
→ Fig. 30

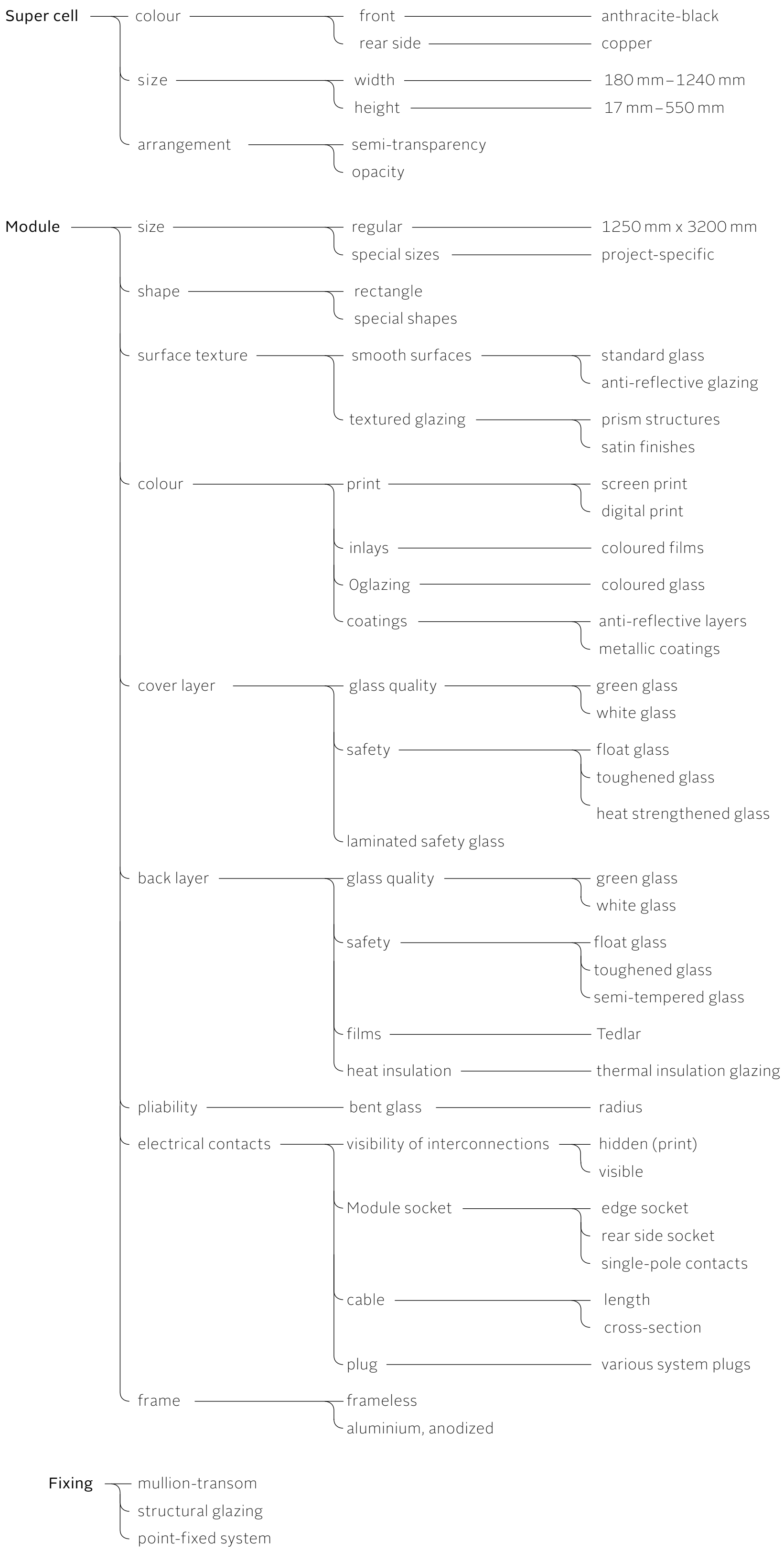


Fig. 30 Solar module design options, using Odersun AG products as an example

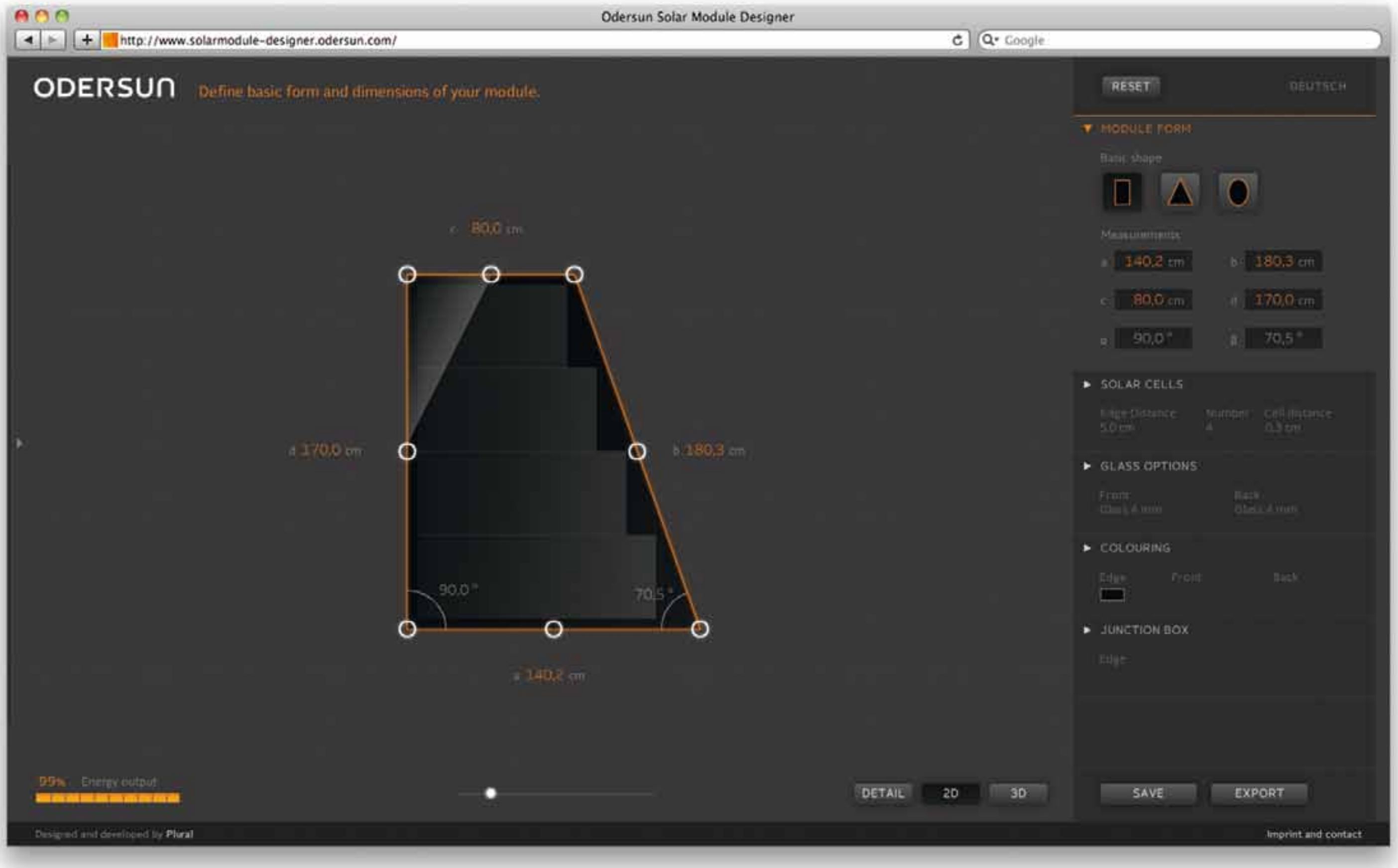


Fig. 31 Solar module designer

In order to provide a clear overview of the wide variety of possible designs for project-specific solar modules and to give a first impression of the design process, Odersun AG has developed a module design program that is available online for users to design their own individual modules and to export their customised designs in CAD format.

→ *Fig. 31, 32, 33*

→ www.solarmodule-designer.odersun.com

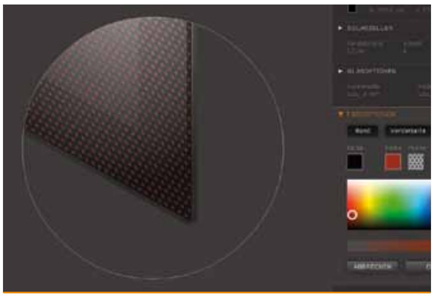


Fig. 32

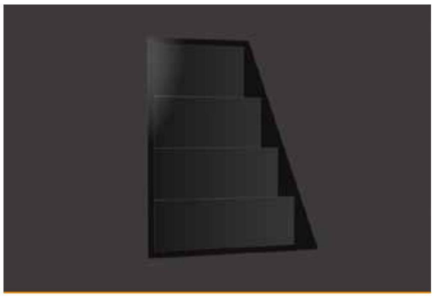


Fig. 33

reddot design award
winner 2011

3.7. Electrical system

In a PV plant, several PV modules are usually connected together in a string to form the actual solar generator. This solar generator generates a direct current, which is fed to an inverter. Here the direct current is converted to alternating current. Provided that it is not consumed or stored directly on site, this electrical power is registered via an electricity meter and fed into the public supply grid.

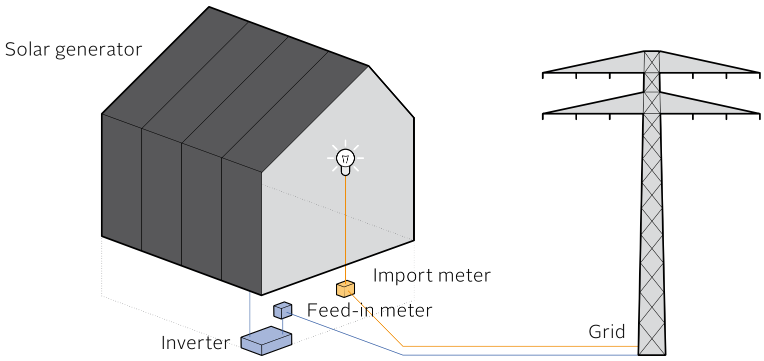


Fig. 34 The components of a PV system

3.7.1. The components of a PV system → *Fig. 34*

Solar module

A photovoltaic module consists of several solar cells that are interconnected within the module. The way in which these internal connections are made determines the relationship between voltage and current and is usually limited by process-related factors. Connecting the individual cells in parallel increases the voltage, while connecting them in series increases the current generated by the module.

The electrical connection is usually made on the rear side of the module via a connection socket, which is normally fitted with a diode. Edge sockets or connections on the front face are also possible, however.

To ensure easy and safe installation, cables are used at the connection sockets together with touchproof plug connectors that are protected against polarity reversal.

Solar generator

The solar generator is the name given to the entity comprising all the solar modules that are connected together in a single system. The type of connections between the PV modules determines the cabling system, the system stability and the necessary cable dimensions.

PV modules can be connected in parallel or in series to form an array.

Serial connections

When the solar modules are connected in series, the voltage increases with each module while the current remains constant. Since the same current flows through all the series connected modules, the same cable cross-section can be used throughout.

Parallel connections

When solar modules are connected in parallel, the current increases with each module while the voltage remains constant. This means that the requirements for safe low voltage systems can be met. On the other hand, larger cable cross-sections are required.

The interconnections for BiPV systems can be complex due to the different orientations, shading conditions, temperatures or even output ratings of the individual modules. A BiPV system should therefore be subdivided into several segments with environmental influences that are as similar as possible. The smaller and more differentiated these segments are, the more stably and efficiently the generator will be able to run.

Cables and connections

As a rule, solar modules have two connection cables with plug connectors that are waterproof and protected against polarity reversal. This makes it easy to connect the different modules together. The requirements to be met for PV module cabling are significantly higher for direct current cables than for alternating current cables, due to the relevant safety regulations.

Cables for solar systems must be UV resistant, protected against moisture and sufficiently insulated. When determining the cross-section of the cables that link the modules, possible line losses in the system must be taken into account and it must be ensured that the cables cannot overheat too quickly.

The cable routing depends on the type of façade system. With rear-ventilated façades, the connections and cables are routed through the air gap. With mullion-transom façades, on the other hand, and particularly if semi-transparent modules are used, the cables are often routed through the profiles of the façade. In this case solar modules with edge sockets must be used.

DC load-break switch

The DC isolating circuit breaker allows all the poles of the photovoltaic electricity generator to be switched off and is installed in the interconnecting cables between the modules and the inverter. Thus, it is possible to switch off the system on the direct current side, for safety reasons.

Inverter

The solar inverter converts the direct current from the solar modules into grid-compatible alternating current (frequency and voltage) and thus forms the link between the PV electricity generator and the public supply grid.

Further important tasks carried out by this component are the regulation and optimisation of the output and the recording of essential operating data.

Depending on their capacities, inverters can be used as a central inverter for the entire system, as array inverters for each module array or as module inverters for each individual module. Inverters should be installed in positions where they will remain as cool or as well ventilated and protected as possible.

As already mentioned, BiPV systems should be divided into several segments or subsystems with the same environmental influences and output capacities. This means that centralised inverter concepts are not usually possible. The inverter must be selected, first and foremost, to suit the optimum segment sizes, so that each part of the systems has its own MPP tracker. This MPP (Maximum Power Point) tracker ensures that the solar generator always operates within an optimised output range.

In contrast to purely yield-optimised systems with optimal environmental variables, the inverters of a BiPV system that rarely operates in direct sunlight and is not optimally aligned can often be scaled down or the maximum module output that can be assigned to the inverter can be significantly exceeded.

Feed-in meter

A feed-in meter is required if the solar electricity is to be fed into the public supply grid. In principle, this meter performs the same function as a standard electricity consumption meter, except that it measures the electricity that is fed into the grid instead of the purchased electricity. This meter, like the feed-in meters of local electricity suppliers, is normally paid for on the basis of a monthly rental fee and is usually installed close to the building's main electricity connection box.

The meter readings are used to calculate the payment received, on the basis of the German Renewable Energy Sources Act, from the local supplier for the electricity that is fed into the grid. The connection of the solar plant to the public grid must be carried out by a qualified electrical specialist and by the electricity supply company.

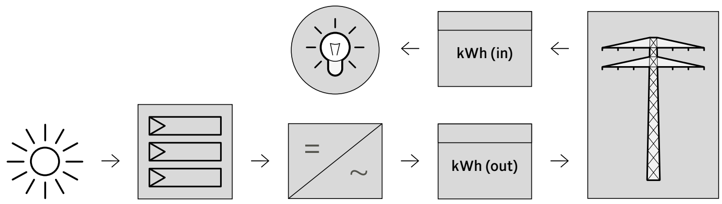


Fig. 35 Grid-connected PV system

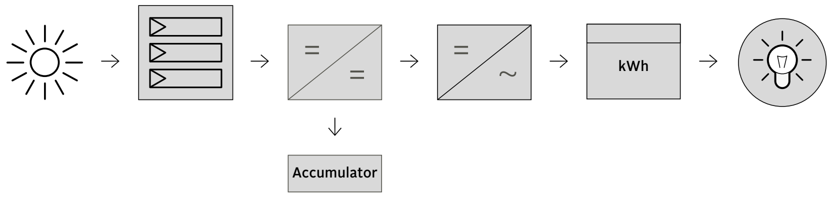


Fig. 36 Grid-independent PV system

3.7.2. Solar plant concepts

Grid-connected PV plants

→ *Fig. 35*

Plants that are connected to the public grid via a feed-in point and can feed the generated electricity into this grid are referred to as grid-connected plants. They can feed in either all the generated electricity or just the excess electricity that is not required on site. Consequently, the plant operator can decide, according to his requirements, whether to store the generated electricity in batteries, use the electricity directly or sell it to the electricity supplier. Such grid-connected plants with partial "own-consumption" can be managed efficiently and automatically using special inverters. In Germany, own consumption (where the solar electricity produced is consumed by the plant owner) has been remunerated since 2009.

Grid-independent PV plants

→ *Fig. 36*

PV plants that have no connection to the public grid are referred to as autonomous off-grid PV plants or island systems. All the electricity generated is used by the plant owner. As a rule, this means that intermediate storage of the solar electricity using batteries is necessary.

Hybrid PV plants

PV plants that are combined with other systems for energy conversion are referred to as hybrid systems. Wind power plants, diesel generators, biogas plants, fuel cells or micro hydro plants are typical systems. The advantage of such combined systems is that they ensure a continuous and redundant supply of energy. Thus, if one of the plants breaks down, the continued supply of electricity is still ensured. Furthermore, the plants complement each other to provide a constant supply of electricity during the course of the day or year.

3.8. Economic aspects

The costs for BiPV systems are often significantly higher than those for standard PV systems. However, the architecturally compatible design of BiPV elements, using application-specific module structures and placing high demands on the quality of their appearance, results in a corresponding increase in value. When considering the economic factors, therefore, functional and architectural contributions must be taken into account as well as the revenue generated by feeding power into the grid. Since BiPV systems are used in place of other construction components, the cost of procurement and installation of these components can be subtracted.

Furthermore, in addition to the remuneration received for the solar energy generated by the system, this energy can also be included in the energy balance calculation for the building, in accordance with the German Energy Conservation Regulations (EnEV), which means that costs for alternative energy efficiency measures can be avoided. Further effects, such as the impression that the building makes due to its manifest environmental awareness, can also add value and shape its image. Thus, it is not unusual for the economic viability of a BiPV system to be determined by its architectural integration.

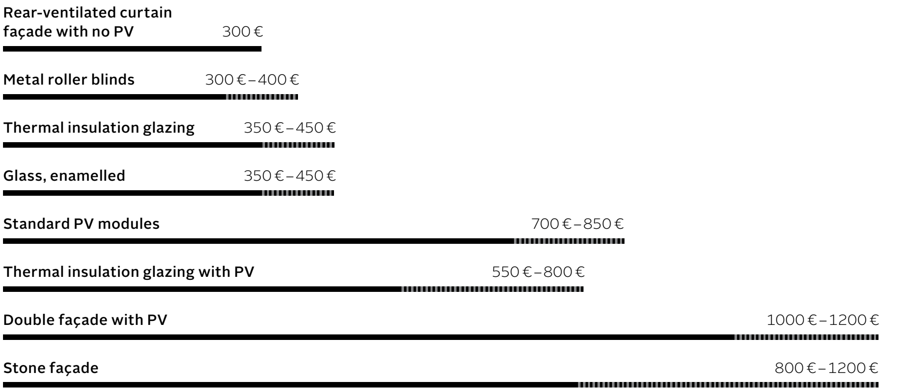


Fig. 37 Prices of façade materials (€/m²)

3.8.1. Construction component value and substitution

Solar modules that are integrated into the architecture of a building replace other essential elements of the external skin, such as façade cladding or shading elements, with respect to design and function. To achieve this, the structure of the BiPV modules is specially designed to perform the specific functions required.

When considering issues of economic efficiency, the value of the construction elements replaced by the modules can be subtracted from the overall investment. In order to profit from these economic benefits, this construction component character must be taken into account in the initial design phase. Depending on the type of application, the value of the replaced components can be decisive with respect to the economic efficiency of a system.

The substitution values for solar plants installed on typical tiled roofs are usually very low, which often makes them unsuitable for use as integrated systems unless there are other influential factors with regard to economic efficiency that the developer can take into account.
→ *Fig. 37*

3.8.2. CO2 emissions and energy conservation regulations

Photovoltaic systems are extremely environmentally-friendly, since the amount of energy they generate is significantly higher than the amount used in the manufacture of the plant. A further environmentally-friendly aspect is that these plants require no fuel and consequently emit neither dust nor CO_2.

This means that for every kilowatt-hour, the emission of approximately seven tonnes of CO_2 is avoided. The reduction of CO_2 emissions is regarded as one of the most important measures required to combat climate change. Today's CO_2 emissions stem mostly from the construction and operation of buildings. BiPV solutions are helping to resolve this conflict by making sustainable and emission-free energy conversion possible at the point of use.

In particular, the combination of clean sources of electricity, energy-efficient devices and the expedient management of electricity demands presents the potential for further savings in the energy consumption of buildings, both now and in the future.

This is also taken into account by the German legislature, which allows the electricity supplied to the building by the BiPV system to be included in the calculations required by the German Energy Conservation Regulations (EnEV). Consequently, it may be possible to dispense with other alternative measures that may have been proposed for optimising the building's energy consumption. → *Fig .38*

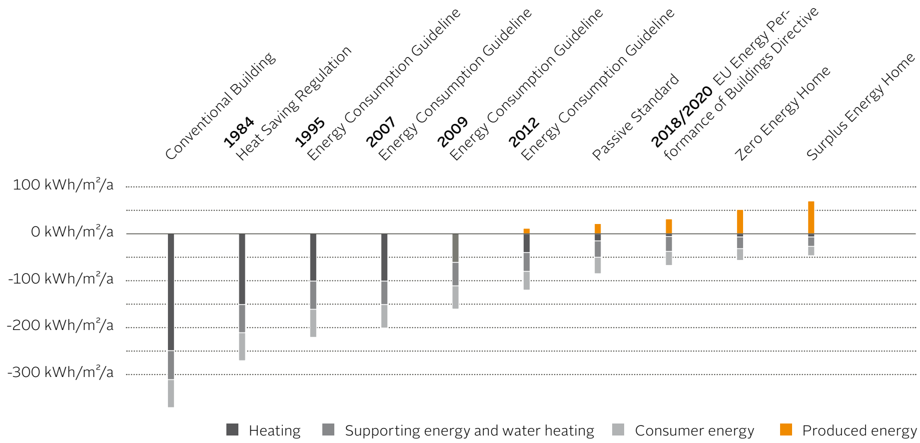


Fig. 38 Increasing requirements of the energy standards

3.8.3. Feed-in tariff

The German Renewable Energy Sources Act (EEG) provides for the 20-year obligation of local energy supply companies to purchase and provide remuneration for electricity generated by PV systems. This type of remuneration for photovoltaic energy is paid in cents per kilowatt-hour and depends on the date of commissioning and the size of the plant. The standard tariff paid for solar electricity on the day that the plant is commissioned is paid at this same rate for a period of 20 years, independently of any subsequent periodic reductions in the feed-in tariff.

Own consumption

In accordance with Article 33 of the German Renewable Energy Sources Act (EEG), remuneration is also paid for the electricity consumed directly by the plant owner. Since the electricity generated by a plant can be partially or wholly used directly on site (own consumption or self consumption), the amount of remuneration is dependent on the proportion of solar electricity directly consumed. To be eligible for this type of remuneration, the electricity consumed must be used in the immediate vicinity of the solar plant and the plant must have an output of no more than 500 kWp.

The German system of feed-in tariffs has now been adopted in other European countries. In contrast to Germany, however, some countries pay higher tariffs for electricity generated by building-integrated systems in an attempt to encourage the use of aesthetic systems and systems that produce energy at the point of use.

3.8.4. Funding programmes

To assist with the financing of BiPV systems, funding programmes are also available from the Kreditanstalt für Wiederaufbau (KfW) development bank.

The "Renewable Energies" and "Generating Solar Electricity" development loan schemes are available, for example, depending on the suitability of the photovoltaic systems. These schemes provide loans covering up to 100 % of the eligible net investment costs for the installation, purchase or extension of PV systems. It is also possible to combine these loans with other funding programmes. The total of all the subsidies received must never exceed your total construction costs, however.

The KfW development bank also offers special credit terms for the construction of new low-energy houses as well as subsidies for energy-saving renovation measures in existing buildings. Up to 100 % funding can be provided in this case.

We look forward to receiving your comments and suggestions on this first version of our design guidelines, which we are continuously expanding and which we are pleased to be able to present to you for use as a tool and a source of ideas.

We would be pleased to help you with any questions you may have regarding your BiPV projects.

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