A Manual

INVISIBLE
PHOTO
VOLTAICS

PV Basics +
25 Design Examples

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PV Basics +
25 Design Examples

MANUAL COVERAGE

This manual is intended for architects and designers.
Its main objective is to address PV technology as a building material alternative for the architect to incorporate in his design repertoire.

All examples showcased are of recent buildings, the guidance Theory is equally relevant.

Part 1 covers the basic principles:

- Section 1 is an introduction to PV technology.
- Section 2 defines BIPV and discusses aspects of design.
- Section 3 presents an overview of a PV systems.
- Section 4 deals with PV miscellaneous details.

Part 2 consists of Section 5, and forms the core of the handbook. This section presents in detail the design integration of PV Modules in the building envelope through-out 25 case-study Projects.

The study-cases are classified based on the transparency aspects of the PV cell and module :

- Opaque systems
- Transparent systems

Finally collated statistics from all the case studies are presented.

PREFACE

Transforming buildings into energy producing plants is a result of comprehensively integrating energy producing strategies, not just throughout the implementation of Photovoltaics. Not part of this document are feed-in tariffs cost implications, subsidies, or carbon prices, these are dependant of local regulations which change rather quickly. Nano cell technology is only briefly mentioned ,since the technology is still emerging few cases of this nature are available.

In the following document we have provided a basic introduction to building integrated photovoltaic (BIPVs) and case studies covering varying building types and designs.

We believe that PV must be visually attractive as well as functional and efficient. And we think, this is the way to a solar new beginning.

We invite the reader to further continue the education process and to go further in this enterprise.

Good Luck !

Pamela, Natalia and Lieuwe

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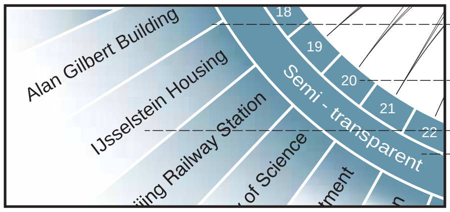

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Case study name

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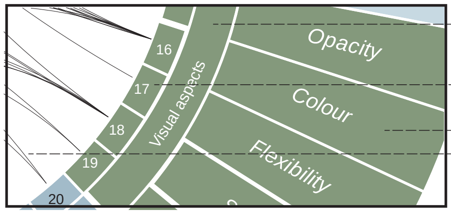

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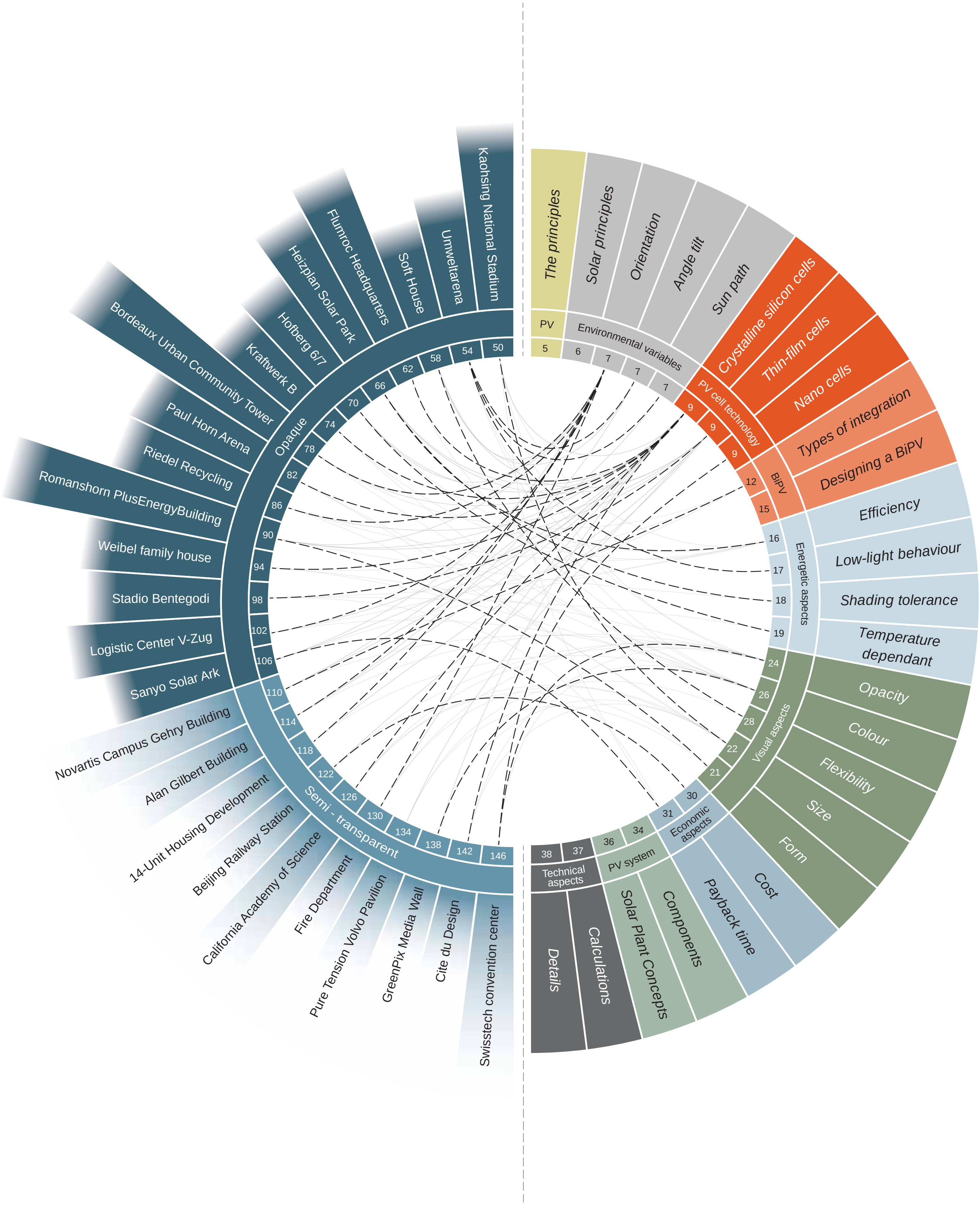
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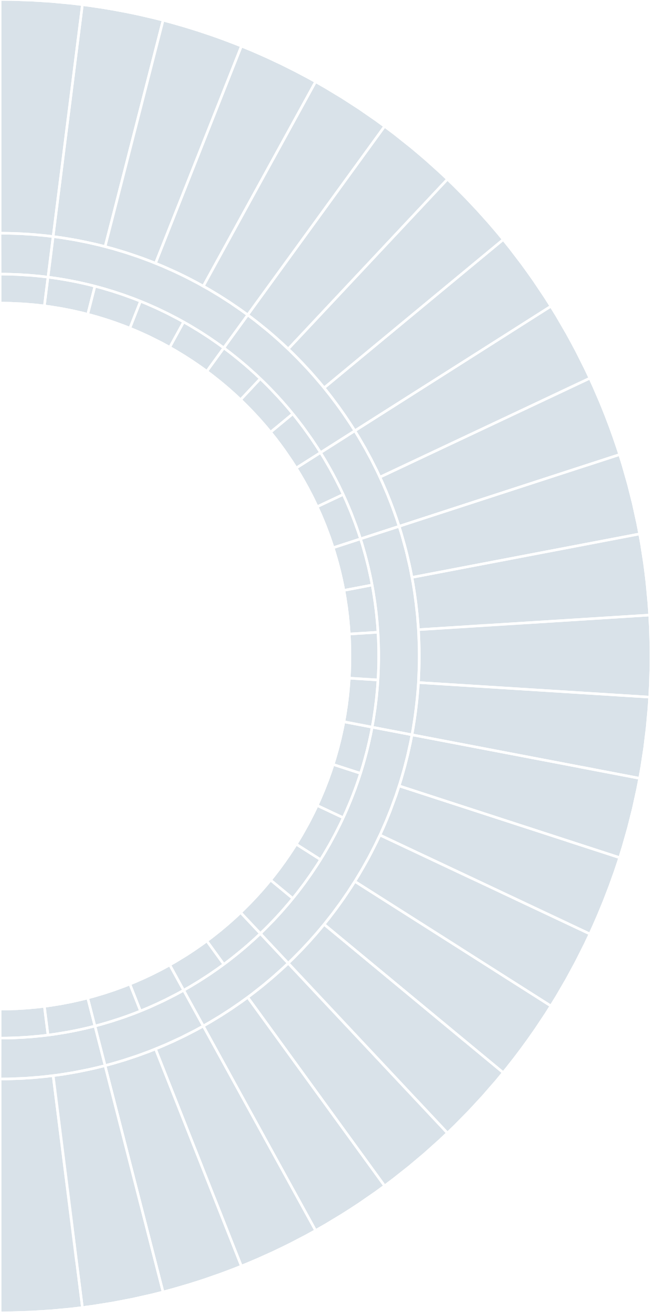
PART 1

PV BASICS



1. PHOTOVOLTAICS

Solar energy from the sun, can be harnessed by numerous and rapid evolving technologies. Active solar technologies include converting sunlight into electricity directly via photovoltaic (PV).
A photovoltaic system converts light into electrical direct current (DC) by taking advantage of the photoelectric effect.
Solar PV technology is a multi-billion, fast-growing industry, and due to fast evolving new developments it continues to improve its cost-effectiveness, and has the most potential of any renewable technologies.
In 2011, the International Energy Agency said that “the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries’ energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared”.

1. Innotech solar panels

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1.1 The PV Principle

Photovoltaics is a word that has been devised to describe the physical principle of solar cells. These cells absorbe solar irradiation and convert it into electricity in a clean and silent process.

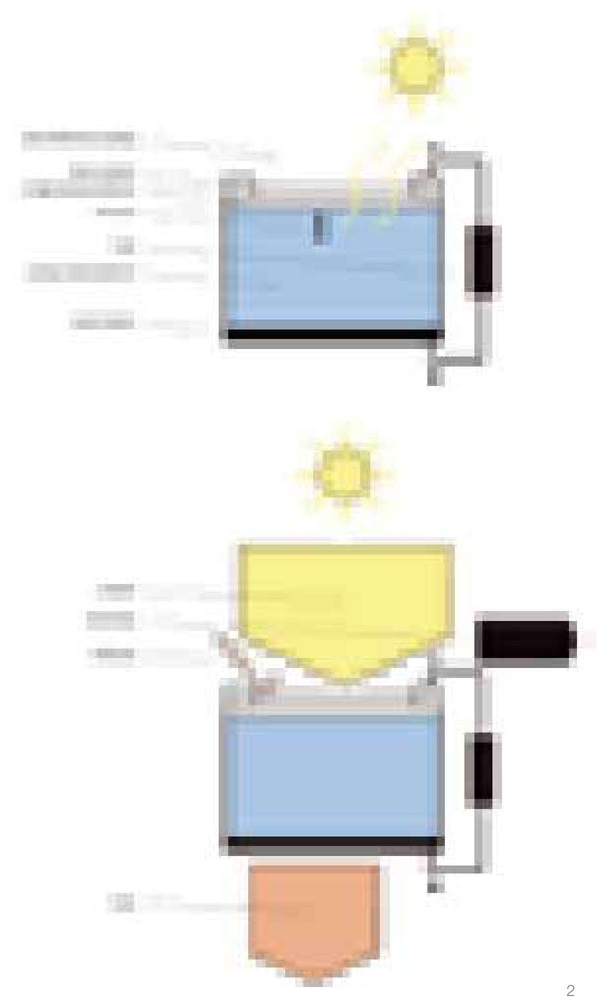
The basic component of a solar cell is a semiconductor, a special material in which the bound electrons become free electrons when they absorb solar energy (photos). This is known as the photoelectric effect. When a a bound electron is free, an empty pocket is left behind, this creates an “electron-hole pair”.

The creation of these free electron-hole pairs is the start point that makes a photovoltaic cell, they create the free charges only, but not the potential difference that allows them to circulate as current and allowing them to generate electrical power. A second process is necessary –doping.

The photons of the incident solar energy on the solar cell have enough energy to break the electron-hole pairs and render them free. The free electrons close to the electric field are sent to the n side and the holes to the p side. At this point an external load is needed in order to enable the electrons to flow to the p side and recombine with the holes there.

The basic element of the system is the photovoltaic cell. The cells linked together create a module. A system is created when the PV modules are connected together.

In following sections, different technologies will be explained. These vary depending on the type of the cell or technology used.



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1.2 Environmental variables

Solar principles

The amount of incident solar radiation on a surface depends on its orientation and angle of inclination of the photovoltaic system. In order to understand their significance, we need to appreciate how light reaches building surfaces.

Irradiance is the amount of light incident on a surface at one point in time.

Global Irradiance is the amount of light incident on a surface at one point in time. Global irradiance onto a site is a combination of direct and diffuse irradiance.

Direct irradiance is dependent on the sun's position and the sun's path tracing a range of angles through the day and year.

Diffuse irradiance arrives at a surface from clouds and haze, and also makes a contribution to PV output.

Insolation, a shortened form of incoming solar radiation, is the total amount of light energy received at a particular angle over a period of time, such as a whole year.

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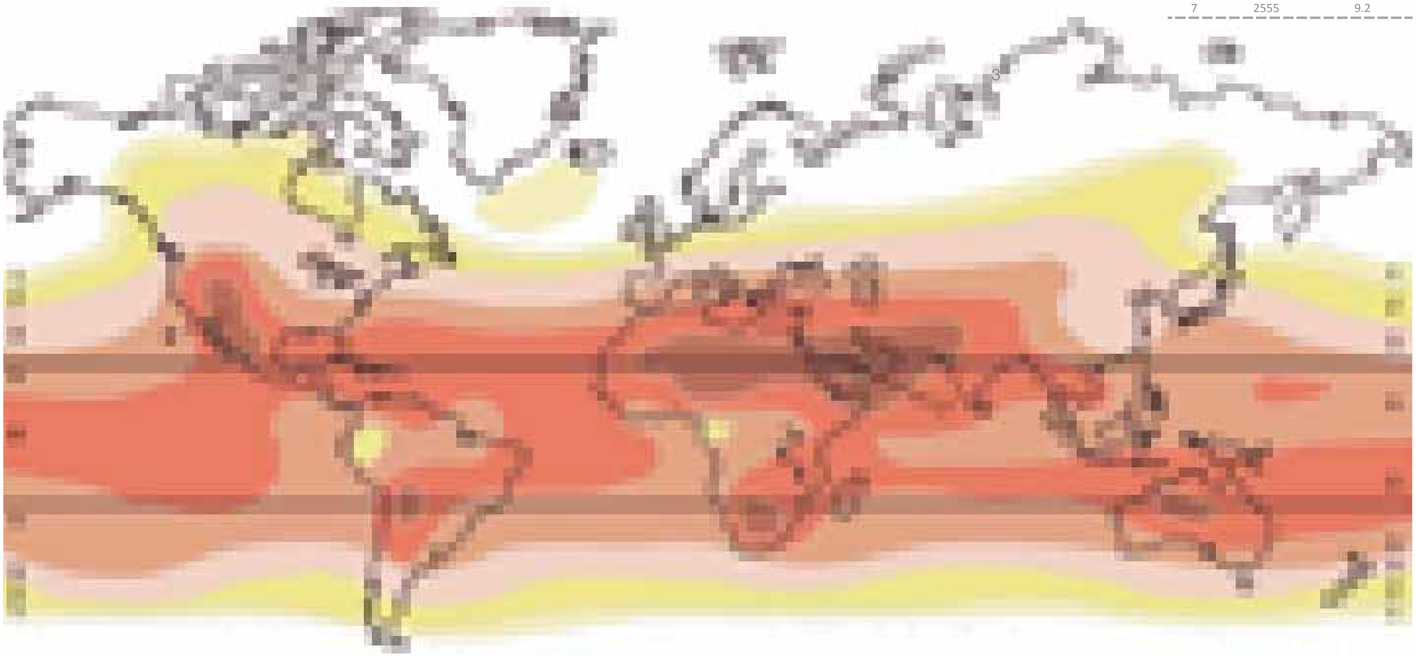
ZONE	kWh/(m2·y)	MJ/(m2·y)
1	365	1.3
2	730	2.6
3	1095	3.9
4	1460	5.3
5	1825	6.6
6	2190	7.9
7	2555	9.2



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Orientation

The orientation of the PV system is based on the azimuth angle, being this the direction from which the sunlight comes. The azimuth angle is conformed by the horizontal direction of the sun and a reference plane (north or south).

At solar noon, the sun is always directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the day.

Inclination or Tilt angle

The inclination or tilt angle is related to the elevation angle of the sun. The elevation angle (or altitude angle) is the angular height of the sun in the sky and the horizontal. At sunrise, the angle is 0°, while at sunrise, when the sun is directly overhead, is 90° (at equatorial regions during spring and fall equinoxes). The elevation angle varies throughout the day. It also depends on the latitude of a particular location and the day of the year

Sun path

This diagram presents the daily path of the sun for each month in the form of a curve consisting of azimuth angle and elevation angle. In order to calculate the sun's position throughout the day, the elevation and azimuth angle must be calculated throughout the day.

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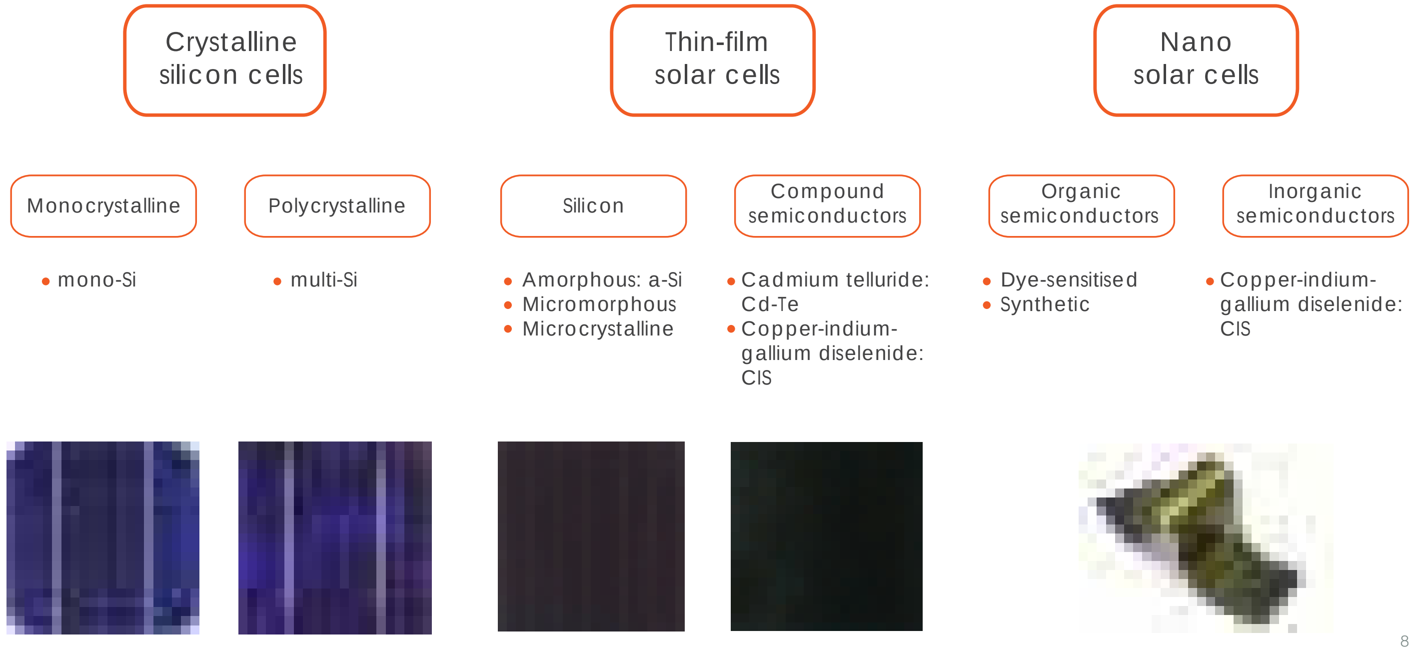
3. Relative annual incident radiation on various surface orientations in the Netherlands in comparison to a horizontal surface.
4. Annual average of daily insolation on a horizontal plane (tilt=0°) across the world.
5. Orientation angle schema.
6. Inclination angle schema.
7. Sun path diagram.

1.3 PV Cell Technology

The PV market, as an innovative and rapidly growing market, offers a wide range of different technologies. The solar cells available commercially differ in terms of their structure and materials employed. Both aspects influence the efficiency of the energy conversion and the aspect of the cells.
Generally, cell types are divided into three principal groups based in the technology involved. The first generation and until now the most commonly applied are the crystalline silicon cells, a second group are the thin-film cells and the newest ones and still in development: the nano solar cells.



8. Solar cell classification based on technology.

Crystalline Silicon

Crystalline solar cells represent the 85% of the cells used worldwide. They usually consist of approximately 15 × 15 cm 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.

They can be classified as monocrystalline and polycrystalline solar cells. The monocrystalline cells are usually manufactured from a single crystal ingot of high purity. The polycrystalline cells have a simpler and cheaper production process, for this reason they are encountered more frequently than monocrystalline ones; however they have a lower conversion efficiency.

Thin-Film

Thin-film is classed as the second generation of solar cells, following on from crystalline technology. The solar cells and their contacts are applied as thin layer to a low-cost backing material, usually a pane of glass. One of their advantages is the design potential. Due to the flexibility and lightweight of the cells, this type can be easily integrated into roof and façade systems. However, they have lower conversion efficiency rates compared to the crystalline silicon cells.

They can be classified based on the semiconductor material of the cell: silicon or compound semiconductors. The most common thin-film cells are the amorphous silicon ones. Solar cells made from compound semiconductors are the cadmium telluride (CdTe) cells and the copper indium diselenide (CIS) cells.

Nano Cells

They are based on organic photo active layers. The technology of these cells can be compared to photosynthesis. This group constitutes the third generation of solar cell type. They have become very popular due to its very inexpensive production processes. They also have the ability to create semi-transparent, coloured, flexible modules. Another important feature is that they are more environmentally friendly than the before-mentioned cells. Among these cells, we can found dye sensitized solar cells (DSSC) and polymer solar cells.

The dye sensitized are made by using conventional roll-printing techniques. They are semi-flexible and semi-transparent, and most of the materials used are low-cost.

The polymer solar cells are made from synthetic semiconductors (polymers) based on polymers. They are usually processed by spin-coating or ink-jet printing.

2. BUILDING-INTEGRATED PHOTOVOLTAICS

The term Buiding-integrated photovoltaics (BiPV) refers to the concept of integrating photovoltaic elements into the building envelope. In this way, a symbiotic relationship between architectural design, functional properties and energy production is establised.
PV systems are generally considered to be building-integrated, if the PV modules replace a building component. Thus, in addition to their main purpose of producing solar energy, PV modules perform the functions of the envelope such as weather protection, noise insulation, heat insulation, sun shading and safety. Indeed, these aditional functions enable the fusing between the PV installation and the building into a virtually inseparable unit.
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 on buildings.
The basic categories of integrating PVs in buildings are facade systems, solar shading devices and roofs.

9. Powerhouse 1, a BiPV joint project of Entra Eiendom, Skanska, Snøhetta, Zero and Wicona

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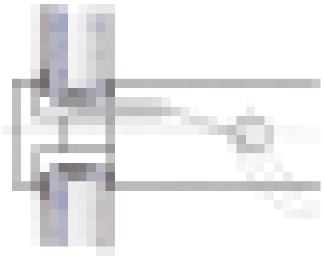
2.1 Types of integration

Facade systems

Facades have significant potential as PV systems due to their greater size comparing to any other envelope element. In modern buildings, huge glass surfaces are designed. Innovative solar cells can be simultaneously integrated within the glass sheets.

Currently, the systems in use are classified according to their thermal properties:



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Cold Facade

Cold facades

They are cavity wall structures. The exterior leaf normally constitutes the weatherproofing cladding and provides the building its external architectural appearance.

The PV system substitutes this cladding, while it benefits from the rear ventilation in the cavity.

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Warm Facade

Warm facade

It is a double-leaf facade. The PV elements are incorporated into insulating glass units, hence they can satisfy all facade functions.

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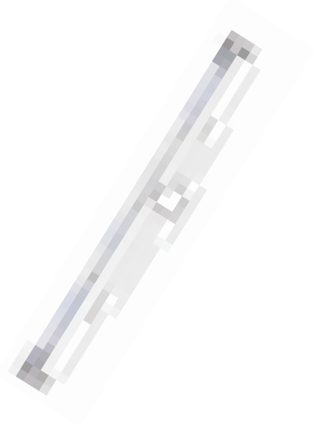
Solar shading devices

While solar shading devices protect from solar radiation, photovoltaics need it. This relationship makes sunshading elements ideal for energy harvesting.

As fixed sunshades, they protect the building from overheating. However, if they are movable sunshades, they can be adapted to the optimal tilt solar angle, and hence increasing the PV system performance.



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Louvres

Louvres:

When the louvres are arranged above one another, only the lower parts of the louvres are covered with cells in order to avoid the shadow of the above louvres. The framless louvres are point or linear supported and are mounted on a cantilevered fixing or a continuous supporting tube.

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Balconies

Balcony

PV systems can also be integrated to exterior elements as balconies. The natural ventilation for the PV system constitutes an advantage of the integration on these elements.

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10. Typical detail of PV integrated in facade cladding
11. Center for Water Education
12. Kraftwerk
13. Detail of PV integrated in horizontal louvres: point fixing with module clamps
14. Detail of the external PV louvres on the Galleria Naviglio.
15. Balconies in project Hofberg

Roof-based systems

The PV modules lie in the plane of the roof covering providing a weather protection layer. Therefore, the mounting system needs to be rain-proof between the modules and at the edges of the installation. In order to avoid moisture, adequate ventilation behind the modules is required.

PV systems on roofs normally are free of overshadowing, so their energy output is not reduced.

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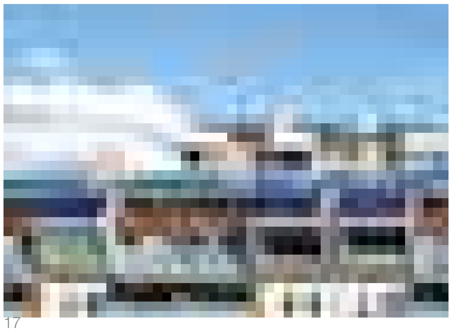
Pitched Roof

Pitched roof

Roof slope can be adapted to enhace the performance of the PV system.

For inclined roof designs, it is recomended to have a subframe for mounting the PV modules ont the roof structure.



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Flat Roof

Flat roof

A weak point of integrating PV in flat roofs is the PV arrays usually have very flat tilt angles and higher module temperatures, in this way its performance is reduced. The accumulation of dust is a factor that should be though in order to avoid the modules to become dirty.

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2.2 Designing a BiPV

The most basic unit of a PV system is the solar cell itself. The different cell technologies were mentioned in section 1.2. The cells are connected electrically in series or/and parallel to set a cell string.

A photovoltaic module consists of four to six cells strings sealed in an environmentally protective laminate. A PV string is a grouping of modules wired in series.

Finally, the arrangement of the whole group of modules into the building is known as the PV array.

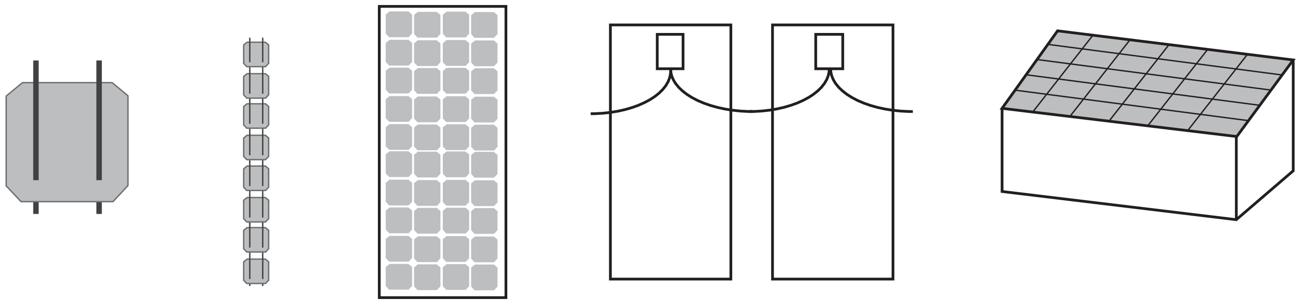
The ambition of an attractive architectural design with photovoltaics is to integrate the PV system harmoniously into the building.

For the sake of minimising the differences between PV components and traditional building materials, the photovoltaics design should be oriented to:

- Create a consistent appearance.
- Match the building's scale.
- Resolve modularity.
- Reduce glossiness of its surfaces.

The fundamental building element of the PV system is the **photovoltaics module.**

In order to illustrate the design potential of a PV system, an extensive analysis of the module based on energetic, visual and economical aspects is done. The combination of the diverse parameters would give the character of the envelope and therefore the design of the BiPV.



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16. Typical structure for PV integrated in roofs.
17. View from the north onto the K2 apartment development
18. Hybrid PV modules on the cantilevers of the Vauxhall Transport Exchange.
19. The modular principle of photovoltaics. The elementary component: the solar cell, any number of which can be a ssembled to form a solar electricity system.

2.3 Energetic aspects

Efficiency

The main factor that influences the energy output of a PV system is the efficiency of the solar cell. Therefore, efficiency is normally the aspect to be compared between the different types of cell technology.

This value is determined under standard test conditions (STC). It means that, a light source of 1000 W per m² is applied vertically to the modules, at an ambient temperature of 25° Celsius and a spectral composition of the light of 1.5 AM (air mass).

The measured output under these conditions determines the solar element's energy output that the manufacturer is obliged to state. The ratio of the applied radiation (1000 W/m²) to the measured energy output results on the efficiency rate.

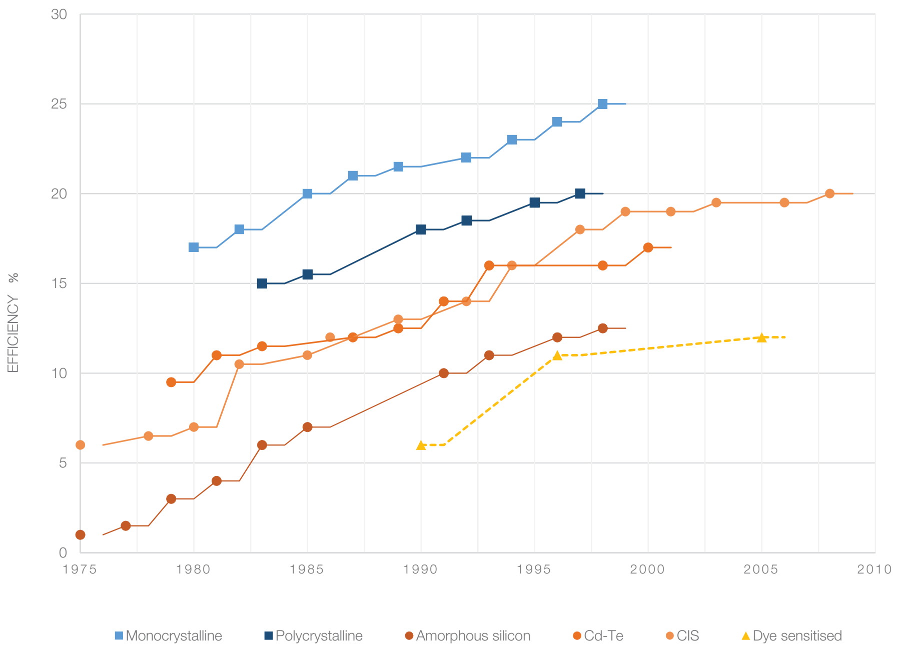
Typically, crystalline technologies still provide the highest commercially available efficiency values. While monocrystalline modules are up to 20%, multicrystalline modules range from 12% to 17%.

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

Although conversion efficiency of nano cells is lower than the best thin-film cells, the ratio between cost and performance is good enough to be considered as a suitable material for façade applications.

Although conversion efficiency of the solar cells is a given rate, this value is afffected by the particular characteristics of each project, such as:

- Climate and shadow conditions at the location.
- Orientation and inclination of the modules.
- Mounting situation (ventilation and temperature gradient)
- Manufacturing tolerances: temperature behaviour of the modules.
- Quality of the system technology, including planning and Installation



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Low-light behaviour

The sun radiates constant, and direct light to Earth. However when the direct sunlight is scattered by water vapour, dust and soot particles as it reaches Earth, it resuts in indirect or diffuse light.

The performance of the PV cells under diffuse light conditions is referred to as low-light behaviour or spectral sensitivity.

Generally, it is known that the direct light is ideal for solar modules, and highly efficient silicon solar cells in particular are very good at converting it into electrical power.

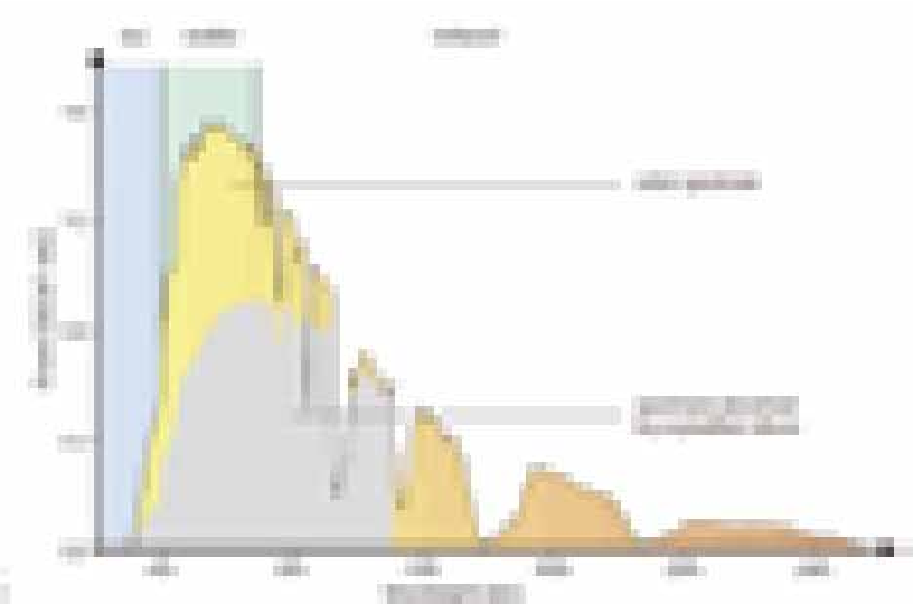
In the other hand, thin-film solar modules demonstrate better efficiency in low and diffuse light conditions. They produce higher relative energy yields in comparison with crystalline systems.

In the case of amorphous cells, this effect can be increased to more than 30% above their regular efficiency. For CdTe cells, the efficiency is up to 14% higher than the regular conditions.

Recommendations

After having mentioned how cell types perform differently under diffuse light, some practical recommendations, regarding to the design, could be set:

- For projects in latitutes, where the number of cloudy days is relatively high, the application of thin-film technology would be recommended.
- The use of thin-film modules in surfaces, which present non-optimal orientation. For instance, north facing facades of buildings in the northern hemisphere.



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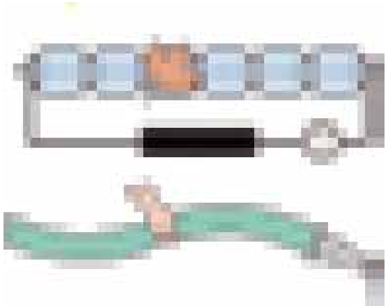
20. Solar cells' efficiency through the years.
21. Comparative spectra for solar input and the spectral parts absorbed by crystalline silicon PV cells.

Shading tolenrance

Under shading the performance of a PV system decreases. This aspect refers to the tolerance degree of the solar cells under this condition.

Crystalline cells are highly sensitive to shade. On standard modules, complete shading of a cell usually leads to the collapse of half the module approximately. This effect may be compared to a hose, which is squeezed. The water will not be able to pass through, same will happe with energy in the solar module. Img.22

In the other hand, compared to crystalline modules, thin-film modules have a greater shading tolerance. Due to their stripe-shaped individual cells, when part of a module is shaded, the power decreases proportionately to this shaded area. However, shadows parallel and perpendicular to the cell strips have different effect on the module, this aspect should be analised when designing.



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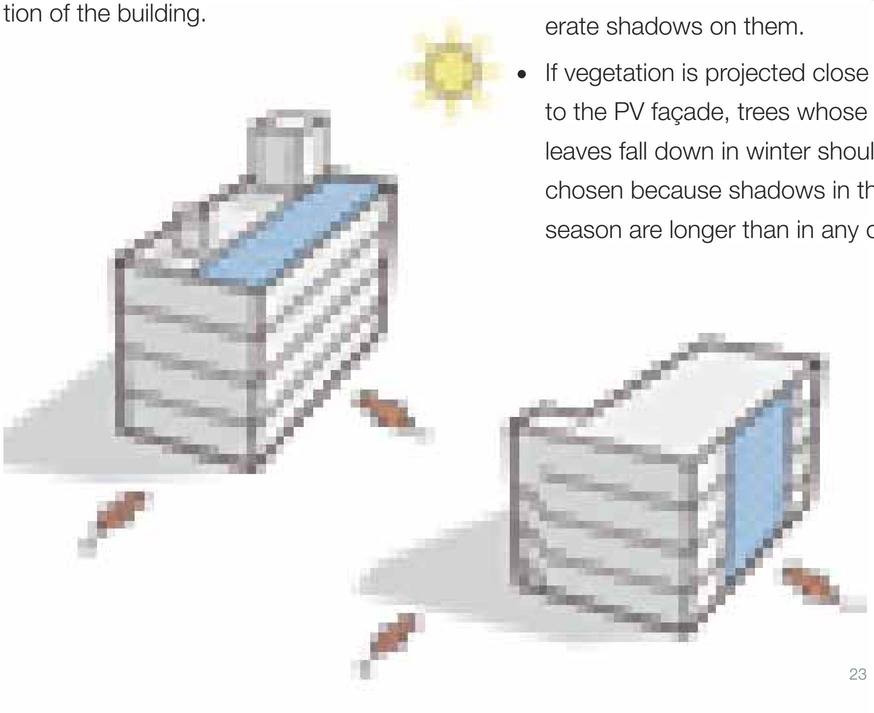
Recommendations

In the pre-design phase, the geographical and urban context of the site should be analysed. Since the presence of high-rise buildings generate shades in the adjacent constructions, the design must avoid these shadows. An in-situ analysis considers the annual and seasonal variations of the shadows, a sun path diagram helps to visualize if objects interrupt the sun trajectory and for how long. Simulations of the daily and yearly path of the shadows can also be carried out to enable the position of the solar modules and the orientation of the building.

For the design phase, it is important to avoid shading produced by the structure's own architectural form. Some guidelines could be followed to minimize its impact:

- Installations on roofs, that could be potential obstacles such us: lift rooms, water tanks, chimneys or ventilation stacks should be located in the north part of the building.
- In the case of facades, staircases should be facing the north.
- It should be avoided to install PV modules on facades close to trees or urban elements that would generate shadows on them.
- If vegetation is projected close to the PV façade, trees whose leaves fall down in winter should be chosen because shadows in that season are longer than in any other.



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Temperature dependant

When the temperature on the PV modules increases, a reduction in the performance of the module is inevitable. This reduction varies depending on the type of cell technology used in the module.

Generally, the performance decrease is more marked for crystalline modules than for thin-film modules. The losses from silicon cells are approximately 0.5 % per Kelvin, which can sometimes equate to twice the amount lost by thin-film modules.

In the case of thin-film amorphous silicone cells, due to their larger band gaps, less power is lost at higher temperatures. CdTe modules still achieve the same performance with increasing temperature. However, CIS modules present similar temperature behaviour as crystalline silicon modules, so a drop in the performance is produced.

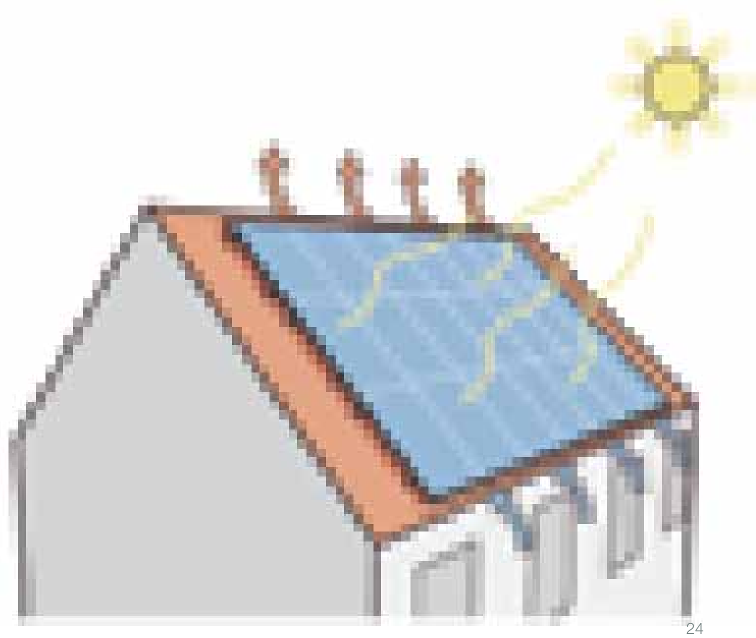
Recommendations

It can be conclude that the advantage of thin-film technology lies in the integration of the PV modules in areas where ventilation is difficult to obtain.

Normally, the standard output for PV modules is taken at 25°C. However, this temperature can increase easily. For instance, in conditions of high radiation, say 700-750 W/m^2, a facade that have no rear ventilation can reach up to 40°C above ambient temperature.

To minimize the negative effect of the temperature on the modules, it is primordial that the module supporting structure allow air to flow over the backs of the modules.

In the case of facades, the gaps between rainscreen cladding elements should be 100mm minimum, however the performance could be improved with gaps up to 200mm or more.



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22. Schematic to emphasise that shading of just one cell of a PV module reduces the electricity output markedly, just as water is prevented from flowing in a hose when one part is squeezed.
23. Strategies at design stage of a building project
24. PV system in roof, schema shows installation of an array where gaps allow ventilation.

2.4 Visual Aspects

Considering the module as the design tool to create outstanding photovoltaic architecture, its aesthetics plays the most important role in the appearance of the building's envelope.

The module can be thought as a composite building material, which comprises various layers and components. Since several of these components are visible simultaneously, it is difficult to talk about aesthetics of one material. For instance, the classic dark blue appearance of the PV surfaces is determined by the crystalline cells and their antireflection coating.

Unfortunately, it is important to mention that deviations from the standard products will affect the performance and energy yields of the modules.

Generally, there are two approaches for the application of PV technology. On the one hand, the conscious use of the modularity of the standard commercialized units; and in the other, the whole range of design options for the customized modules with respect to size, shape, colour, degree of opacity, flexibility. This chapter presents the mentioned aspects and their design alternatives.

FORM	STANDARD	rectangular
	NON-STANDARD	square, circular, triangular
SIZE	STANDARD	crystalline modules: 100mm x 100mm; 125mm x 125mm; 150mm x 150mm; 210mm x 210mm thin-film modules: 0,60m x 1,00m to 1,00 x 2,00m.
	CUSTOM MADE	
OPACITY	OPAQUE	
	SEMITRANSPARENT	
	TRANSPARENT	
COLOUR	CELL	blue, black, grey, yellow, red, green, silver and pink.
	MODULE	
FLEXIBILITY	RIGID	
	FLEXIBLE	

Form

The majority of the photovoltaic modules are rectangular elements. This shape has become the standard form due to the following reasons:

- Cost-effective production of the panels.
- Arrangement and interconnection of the cells.
- Formats of the components such as glass, frames and fixings.
- Manageability of the modules during transportation.
- Rational assembling process.

However, custom shapes are also possible. So far, custom modules in square, rectangular or even circular, triangular or trapezoidal form, have been installed in existing projects.

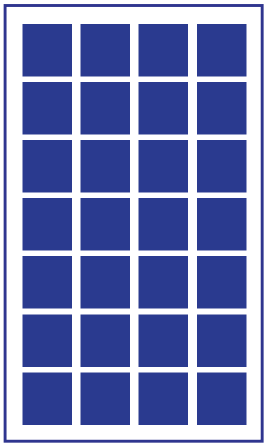
Depending on the panel geometry, it can lead to complicate the interconnection between cells. This aspect would increase the cost of a module, so it may be more practical to leave certain cells unconnected. These unconnected cells are called dummy cells.

Other special modules are:

Modules in which the solar cells are already integrated into a building material, i.e. glued to metal sections or roof tiles.

Modules with plastic frames made from polyurethane (PUR) with attractive designs and multiple functions, e,g. cast-In electrical connections and fixing elements.

In the case of thin-film technology, the modules can be attached to any size of glass pane with a square or rectangular active area.



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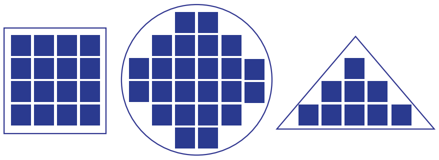

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25. Visual aspects opportunities.
26. Standard form of crystalline PV modules.
27. Non-standard forms of crystalline PV modules.
28. V-3 Cone Shaped Solar Module
29. Module with integrated solar cells.

Size

There is a limited range of standard module sizes since their dimensions are determined by the size of the cells and number and distribution of them within the module.

Crystalline

Generally for crystalline technology, the cell dimensions are:

- 100mm x 100mm;
- 125mm x 125mm;
- 150mm x 150mm;
- 210mm x 210mm

In this way, theypical crystalline solar modules are available in sizes from:

0,60m x 1,00m to 1,00 x 2,00m.

Some manufactures fabricate larger modules up to a maximum of 2,00m x 3,00m.

The weight of glass/ plastic laminates is approx., 12-16 kg/m2; glass/glass laminates can weigh up to 30 kg/m2.

Thin-film

Thin-film cells are not limited by standard wafer sizes but only by the size of the substrate glass. So, in theory, manufacturers can attach thin-film modules to any size of glass pane with a square or rectangular active area.

However, the majority produces standard sizes and just supply custom formats, out from the standard elements, when very large quantities are required.

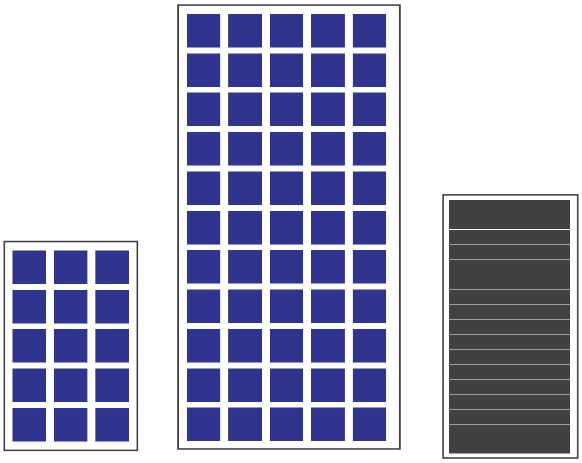
Up until recently, a format of about 0.60 x 1.20 m and an output of less than 100 Wp was common for thin-film modules, but now the new production plants are producing modules up to 5.7 m2 in area.

Regarding to the module size, there are two approches to integrate the photovoltaic elements into the building:

- Designing within the size constraints of a standard module and dimensions of the building element.
- Specify a custom module size for the project.

For the first approach, an example of integration is seen in Img. 32. Standard modules are used. The module's width suits the space horizontally. For the vertical dimension, two modules are slightly taller than the floor-to-floor height, however it is not as serious to need a custom module size.

Another example is when the facade is filled with standard modules. However, in critical areas where the module was not suitable any more, custom dummy modules are applied. These modules have the same type of cell but without any electrical connection. In this way, they ensure a uniform appearance with the regular modules.



0.60m x 1.00m

1.00m x 2.00m

0.60m x 1.20m

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30. Typical sizes for crystalline and thin-film modules.
31. Integration of standard PV module sinto design: Stadium in Kaohsiung, Taiwan.
32. Example of PV modules on a facade.

Opacity

The semi-transparency of the cell, defined as the quantity of light that passes through, varies depending on the cell technology. However, the efficiency decreases proportionally.

For partially transparent PV applications glass is normally employed as the backing material to guarantee light permeability between the cells. If the module is required to opaque, the intermediate areas between cells can be coloured.

Crystalline Cell:

Creating a semi-transparent effect with the crystalline cell in the module can be achieved in two ways:

Arrange within the panel:

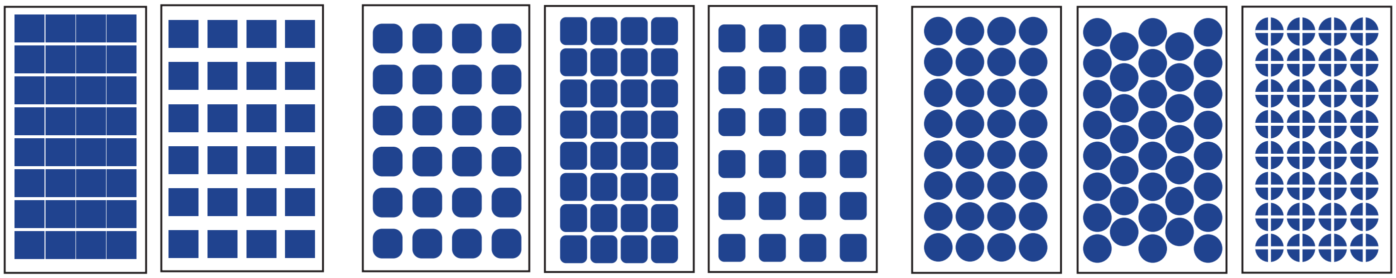
The crystalline cells are symmetrical units with a side length of 100-150mm or diameter of 120-150mm approximately. The arrangement and distribution of the solar cells within the module controls the degree of transparency. The cells can be arranged in order to produce a variety in patterns visualize in the module. Circular cells result in fewer cells per unit area, but they are especially advantageous in partially transparent applications. From the point of view of energy efficiency, the cell separation must be the smallest, while for aesthetics or building integration reasons, a greater separation can be chosen.

Laser perforations.

The crystalline silicone cells are generally opaque. However, it is possible to implement perforations with laser in order to punctually remove the material and give a semi-transparent effect.

Thin-film Cells:

However, this technology enables a constant level of transparency to be created across a surface by the selective removal of film in individual areas. For thin-film cells, transparency is determined by the absence of the reflective layer placed below the cells, or by a laser etching process that allows to create a semi-transparent effect.



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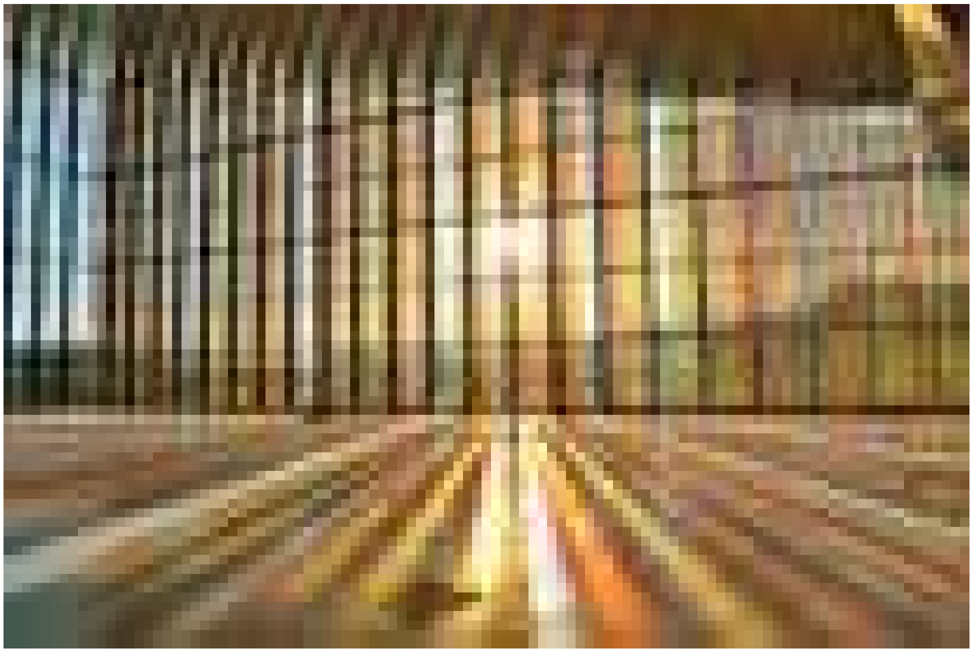

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33. Types of arrangement of crystalline cells within a module.
34. Close up of a semi-transparent module. Laser perforations were done in the crystalline cells. Project: Solar Decathlon 2007 TU Darmstadt, Germany.
35. Dye sensitized cells applied to the facade of the SwissTech building, Switzerland.

Colour

Cell

Depending on the material used as semiconductor the colour appareance of solar cells varies. Generally, the blue color of the crystalline silicon cells results from the anti-reflecting covering normally used. It goes from dark blue to black. In the case of thin film cells, for the amorphous silicon is blue to violet. The micromorphous cells darker in colour, from dark grey to black. The cadmium telluride (CdTe) cells appear black to greenish sheen and the copper indium diselenide (CIS) cells' colour is dark grey to black.

Although these type of cells have a range of colours depending on the materials used; nowadays, in the market the choice of possible colors is wide. In the market, there are, in fact, cells in grey, yellow, red, green, silver and pink.

Module

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.

The following methods can be used for colouring solar modules:

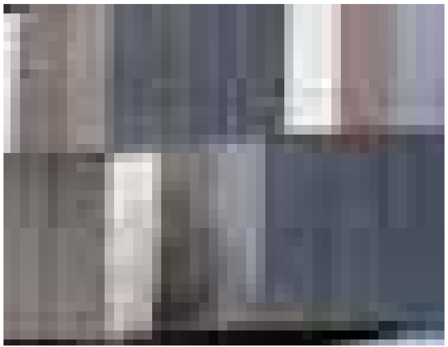
- The use of coloured glass.
- Glass with full area print (glass enamel) with various patterns: resilient and durable.
- The application of a coloured film (low resistance) Anti-reflective coatings.

A downside is the reduction on the sunlit surface area or in the reflection of some of the incident light. Therefore the output of the solar module is 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.

Traditionally, the background colour of the modules is white or black. It is however possible to change the background color by varying the color of the encapsulant material (usually EVA or Polyvinyl Butyral - PVB).

The use of glass in the photovoltaic modules permits the variation of color, features and creation of engraved drawings.

The background may also be transparent. This way the modules can be used in the construction as semitransparent materials.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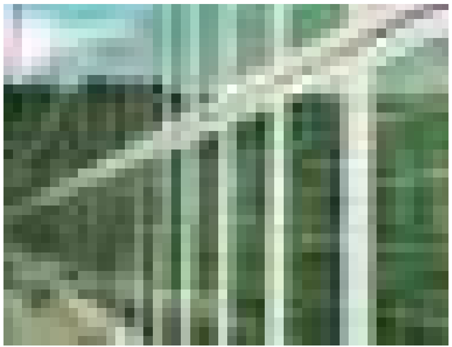
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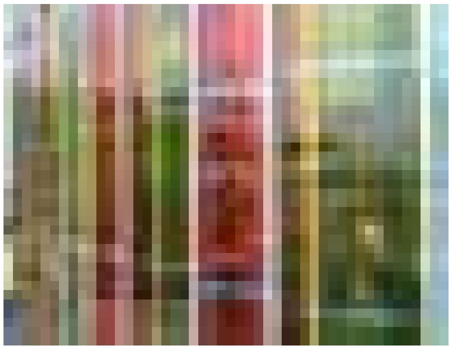
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Monocrystalline cells

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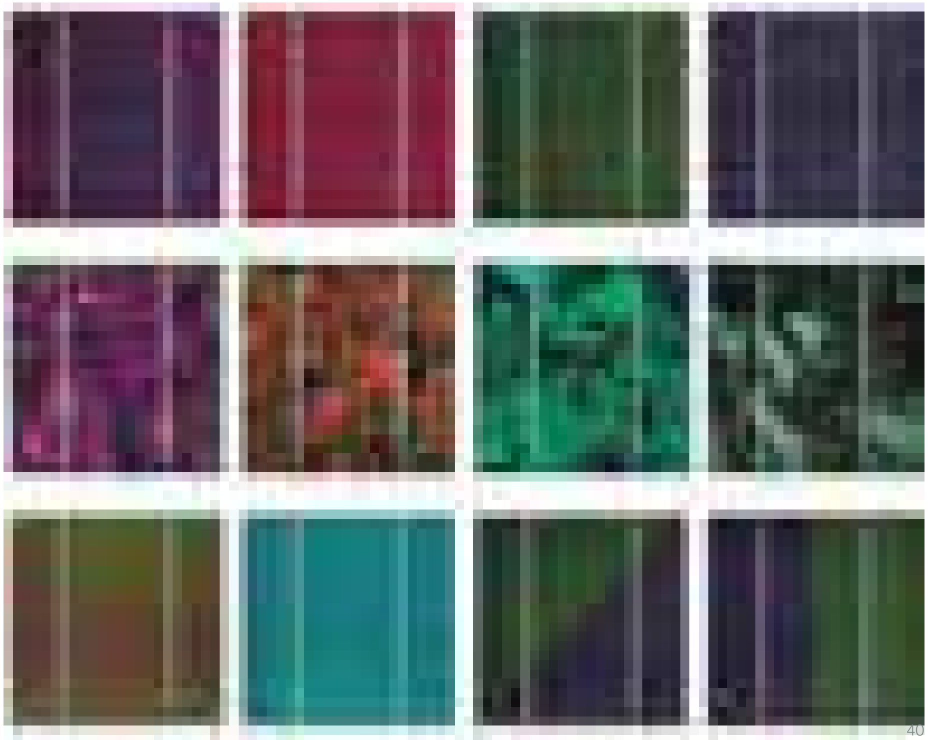
Polycrystalline cells



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36. Different colour cells applied into projects: V-Zug Logistic.
37. Different colour cells applied into projects: Paul-Horn Arena
38. Different colour cells applied into projects: Swiss Tech.
39. Colours for monocrystalline cells
40. Colours for polycrystalline cells

Flexibility

The flexibility of solar cells depends on the materials used, the substrates and the thickness of the cells.

The crystalline silicon cells use silvery grey discs as blanks for the cells. A thickness of just 0.05 mm is sufficient for light absorption. However the disks are thicker for mechanical reasons. For this motive, these cells are much more limited since they are brittle and porous.

Thin film cells can be very flexible, for example, only a coating on the back enables the use of opaque substrates such as metallic foils or plastic films as a basis for lightweight and flexible solar modules.

Although nano cells are still in an early stage of development, this technology could provide solar paint, which could be applied to any surface.

Although the nature of crystalline cells is brittle, they could be adapted to an exclusive and sophisticated module, which enables the cells to adhere perfectly to a curved glass surface. More info…

Creating curvatures with tight bending radius are possible if thin-film technologies such as amorphous silicon or CIS are deposited on flexible metal or synthetic substrates.

Mechanically flexible solutions are also available from some manufacturers for specialist applications such as roof sheets, but only in fixed sizes. The aluminium infrastructure is totally or partially covered with thin film modules. The solar sheets are extremely robust and can be used to cover roofs with convex and concave forms.


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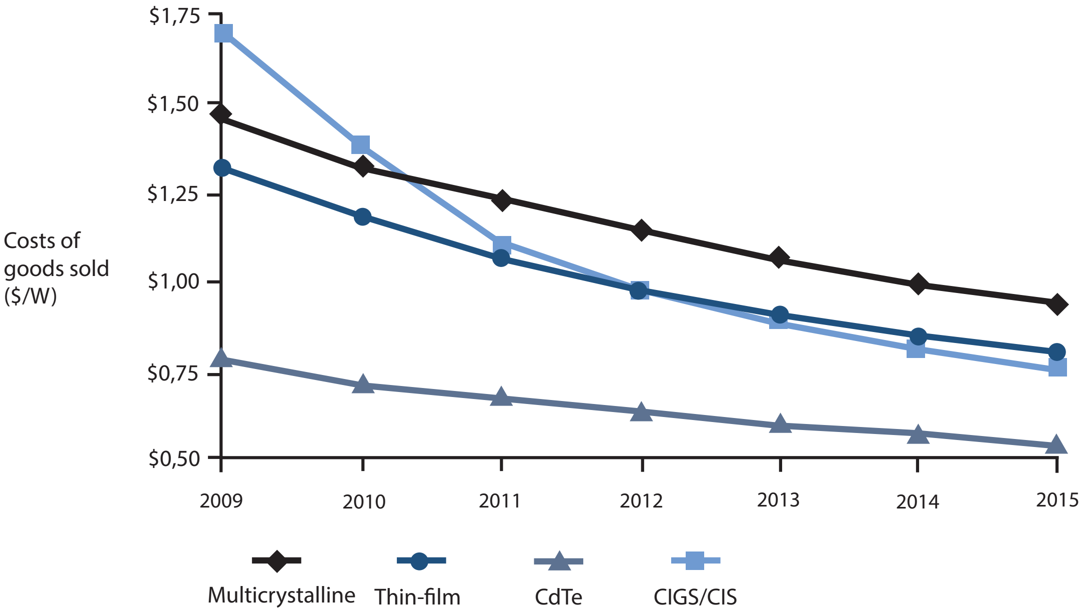
41. Monocrystalline flexible module
42. Polycrystalline flexible module
43. Thin-film flexible module
44. Thin-film modules applied to a curved roof.
45. Solar cells in ETFE module.

2.5 Economic Aspects

Cost

Although thin-film technology has a relatively low conversion efficiency, its cost-effective production enables it to have a low price per unit area. They therefore represent a resonable economical alternative to the more efficient but also much more expensive cells: crystalline technology.



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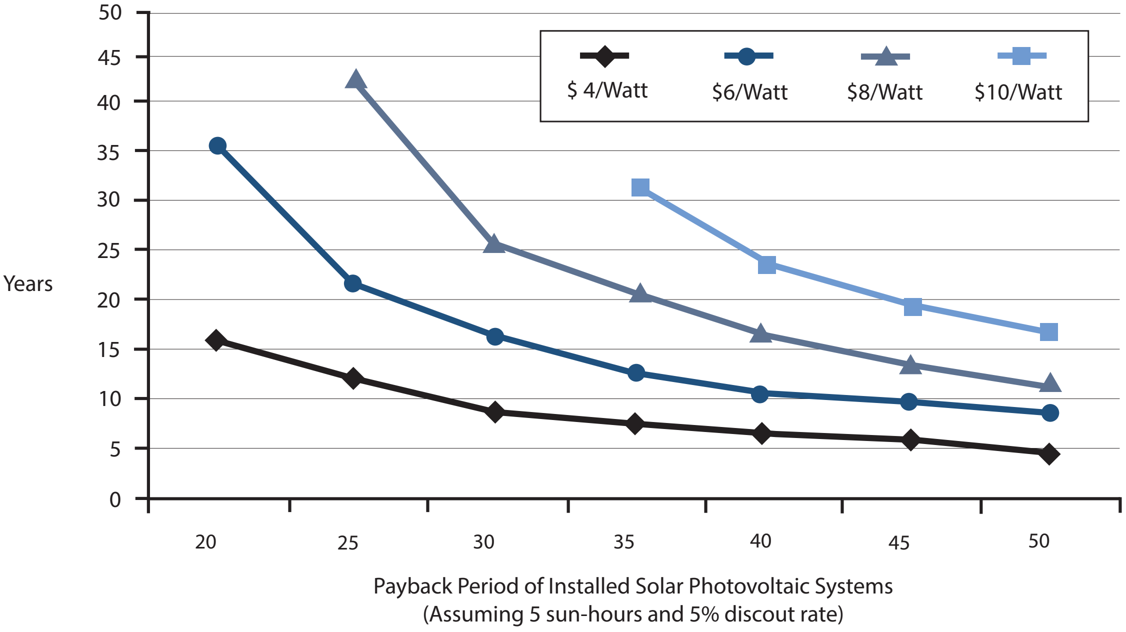
Payback time

The energy payback time of the system depends on the amount of radiation, the type of system and the technology. Average estimates calculate that for a standard system the payback time is 3 years, with a module lifetime of 25 years and a production of clean energy of 22-24 years.

The cost of BiPV systems are more expensive than standard applied PV systems.

However, because the BIPV systems replace functions taken by other materials, the functional and architectural contributions need to be taken into account as well as the revenue generated.



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46. Cost of solar cells through the years.
47. Payback period for solar cells.

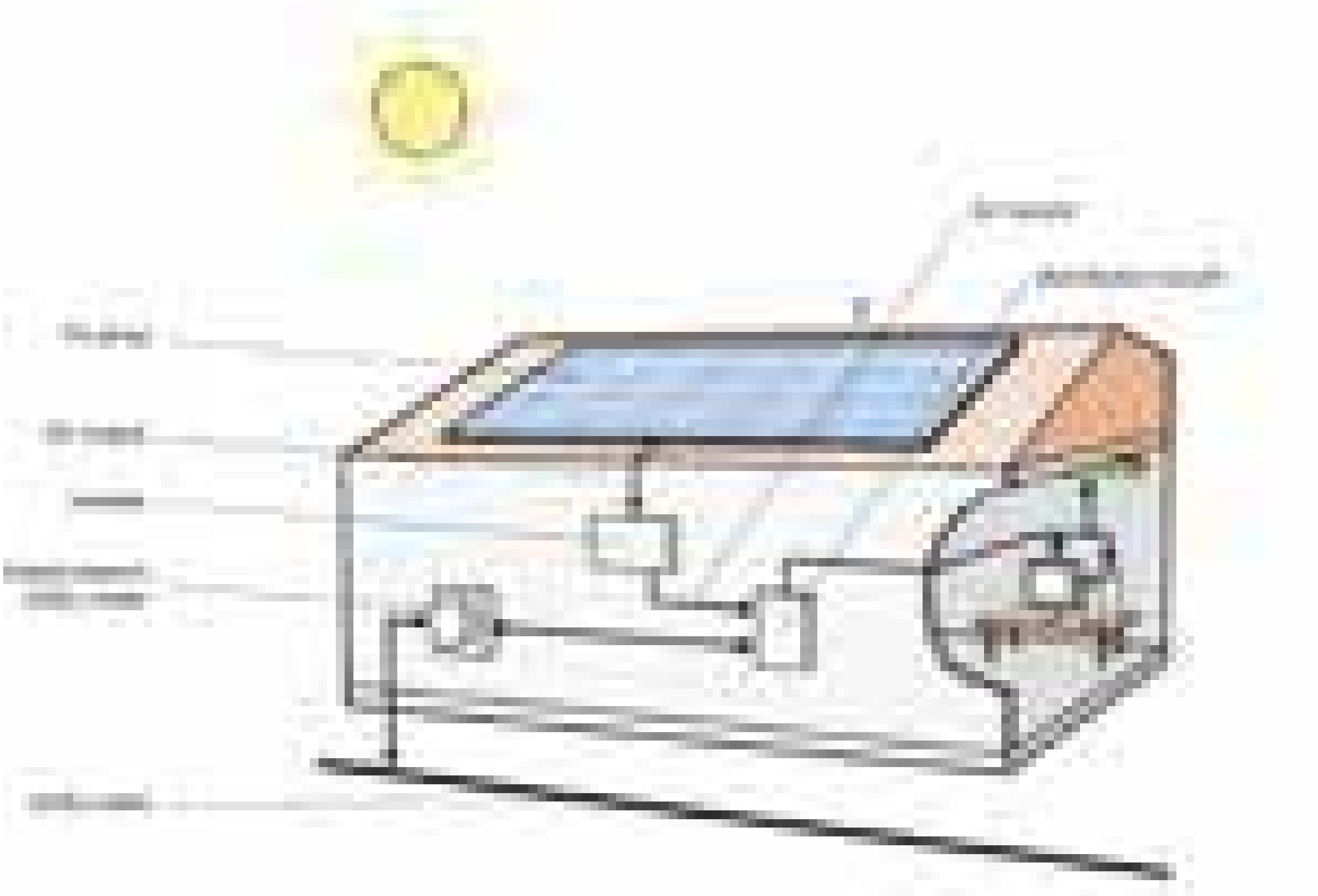
3. PV SYSTEM OVERVIEW

PV systems work basically by transforming sunlight directly into electricity. The process of conversion occurs in the solar or PV cell. These cells need to be encapsulated and need to be connected as a group into a larger electrical unit, known as the module (also known as a PV panel). The modules grouping is referred as the PV array. The modules are placed outside in order to capture maximum sunlight.

This chapter explores, in a general way, how a typical PV system works. Although the module is the basic component of the system, other elements play an important role in the production of electricity.

Moreover, the distinction of the two types of PV plants is mentioned: Grid-independent and Grid dependent.

A very practical PV calculation has been added to this section. It can help to have a general overview of the energy that the system will generate, however, for installations it is necessary more precise calculations.



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48. Schema of a PV system installation on a typical house.

3.1 Components of PV system

Solar Module

As previously mentioned a module consists of many solar cells that interconnected within the module. The relationship between the voltage and current is determined by the way the cells are interconnected. If the individual cells are connected in parallel the voltage is increased, contrary if the cells are connected in series this increases the current generated by the module. Generally, the electrical connection is ussually done on the rear side of the module throughout a connection socket, that normally is fitted with a diode. However, front sockets or connections are also possible. To ensure safety, the cables used have touch proof plug connectors ensuring no polarity reversal will occur.

Solar Generator

The solar modules connected together in a single systems is called the solar generator. And the connections between all other components determine the cabling system, the system stability and the necessary cable dimensions. As mentioned, PV modules can be connected in parallel or in series to form an array.

DC load-break switch

The DC isolating circuit breaker allows all poles of the PV system generator to be switched off, it is generally installed between the modules and the inverter in the interconnecting cables. This is done as a safe preventive measure, as it allows the system to be switched off on the direct current.

Cables and connections

Serial connections:

Connecting the solar module in series increases the voltage with each module, while the current remains constant. With the same current flowing thought all the connected modules, the same cross-section can be used throughout.

Parallel connections:

Contrary to in series connection, parallel connection increases the current with each module while the voltage remains constant. This means, that higher levels of safety need to be met and larger cross-section cables are needed.
The implementation of BIPV systems can be complex due to the different orientation, shading conditions, temperatures and output ratings of the individual modules. It is advised to subdivide the system into several segments with influences that are similar as much as possible. The smaller the differences between these segments, the more stable and efficient the plant will be.

Inverter

The solar inverter plays an important role in the PV system. It converts the direct current from the solar modules into grid--compatible alternating current (frequency a voltage) and creates the link between thee PV generator and thee supply grid. In addition, it regulates and optimizes thee output and the recording which is essential to the operating data of the system.

Different inverters can be used depending of their capacity, a central inverter for the entire system, as array inverters for each module or as module inverters for each module. The position of the modules is to allow ventilation and cool temperatures.

Since fragmentation of the system is positive, central inverters are not usually possible. The inverter must be selected first to suit the optimum system segment sizes, to ensure that each part of the systems has its own MPP tracker. This MPP (Maximum Power Point) tracker guarantees that the solar generator always operates within an optimized output range.

Feed-in meter

If the solar electricity is to be connected to the grid, then a feed-in meter is required. The meter performs in the same fashion a standard electric consumption meter does. Except it measures the flow of electricity back to the public grid. It is usually paid for on the basis of a monthly rental fee and is typically installed close to the building’s main electricity connection box. However, local regulation apply and vary from place to place. Close attention is to be paid to this aspect in order to remain in compliance.

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49. Components of a PV system.

3.2 Solar Plant Concepts

Grid-connected

Plants that are connected to the public grid via a feed-in point and can feed and be fed from the grid are referred to as grid-connected plants. All, or just some of the electricity can be sent to the public grid.

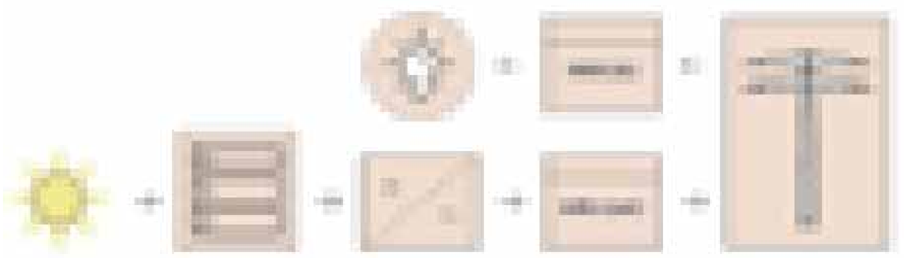
This allows the plant owner to decide whether the energy is stored in batteries, used or sold to the supplier. The inverter will control and manage the flow of the electricity.

Grid-independent

Grid independent plants are such that are not connected to the grid and are referred as autonomous systems. All the electricity generated is used by the plant owner. This means an intermediate storage of the solar electricity is needed.

Hybrid PV plants

It is possible to have a mixed system that combine different sources of renewable energy. These are referred as hybrid systems. Wind power plants, diesel generators, biogas plants, fuel cells or micro hydro plants are some. The combination of system ensures a continuous supply of energy.



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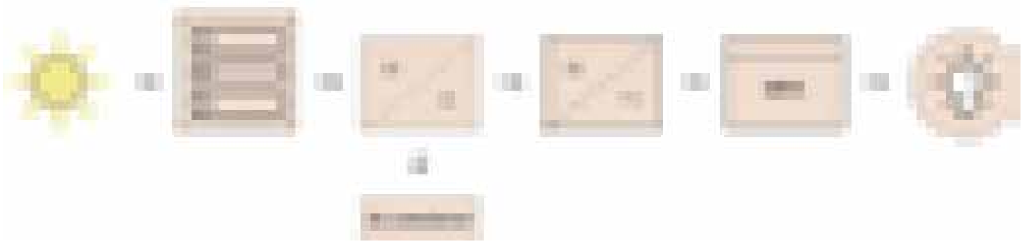

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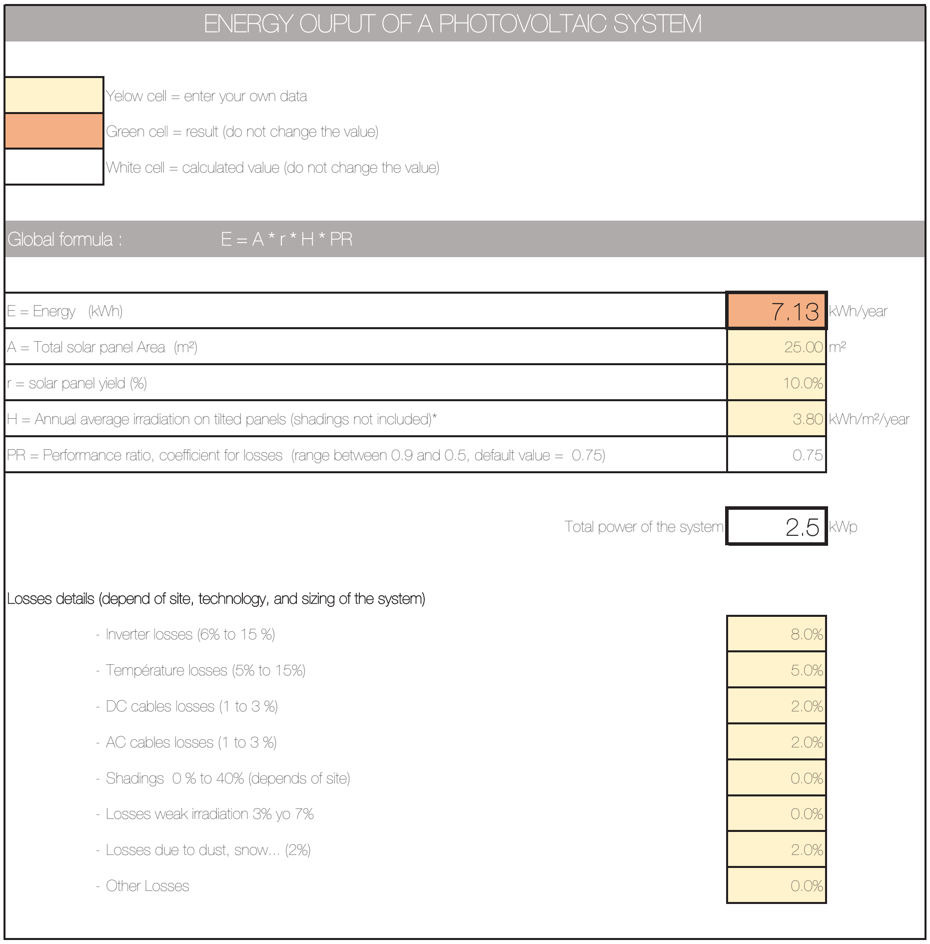
3.3 Basic pv calculation



ENERGY OUPUT OF A PHOTOVOLTAIC SYSTEM

	Yelow cell = enter your own data
	Green cell = result (do not change the value)
	White cell = calculated value (do not change the value)

Global formula : E = A * r * H * PR

E = Energy (kWh)	7.13	kWh/year
A = Total solar panel Area (m²)	25.00	m²
r = solar panel yield (%)	10.0%	
H = Annual average irradiation on tilted panels (shadings not included)*	3.80	kWh/m²/year
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)	0.75	

Total power of the system 2.5 kWp

Losses details (depend of site, technology, and sizing of the system)

- Inverter losses (6% to 15 %)	8.0%
- Température losses (5% to 15%)	5.0%
- DC cables losses (1 to 3 %)	2.0%
- AC cables losses (1 to 3 %)	2.0%
- Shadings 0 % to 40% (depends of site)	0.0%
- Losses weak irradiation 3% yo 7%	0.0%
- Losses due to dust, snow... (2%)	2.0%
- Other Losses	0.0%

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50. Grid-connected PV plant system
51. Grid independant PV plant system
52. Basic PV calculations for energy output

4. DETAILS

Some typical details for facade, roof and shading devices are explored in this section. The aim is to give the reader an overview of how a typical PV system is buit. However, further research is needed for technical installations.

53. Installation of a PV system.

4.1 Facade

Rainscreen system

LEGEND
1 Structural wall
2 Plasterboard
3 Insulation
4 Fixing bracket
5 Aluminium fixing rail
6 PV module
7 PV connection box

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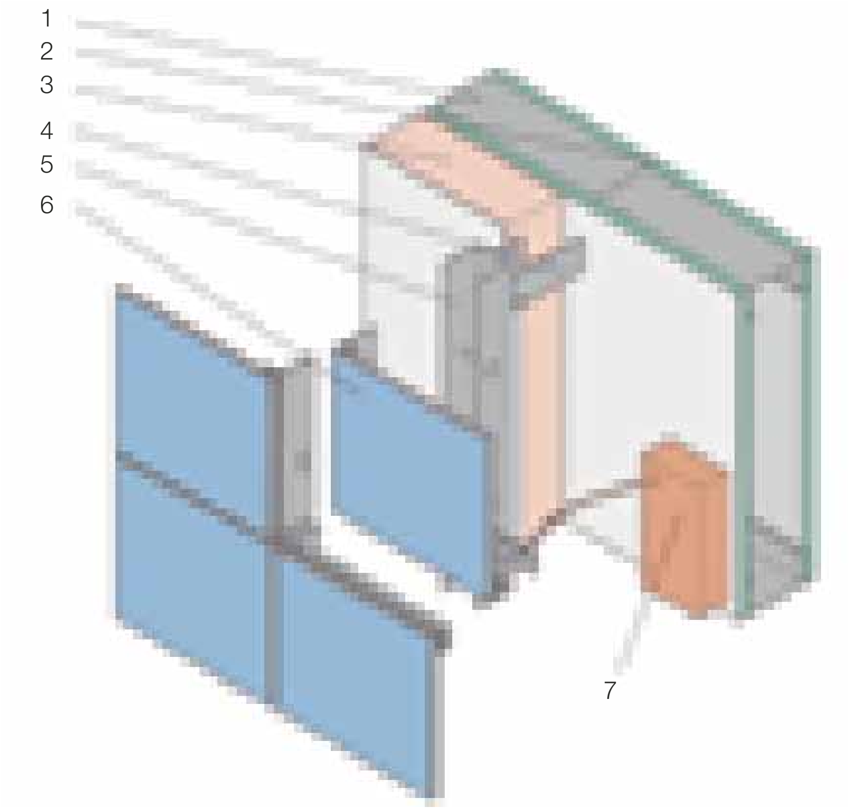

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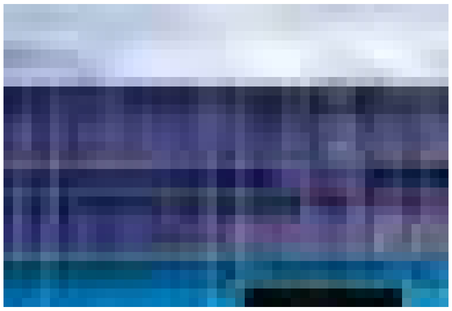
Unitised Curtain Walls

LEGEND

1 Cabling
2 Aluminium mullion
3 Aluminium transom
4 Structural silicone
5 Spacer bar
6 Inner glass panel
7 PV module



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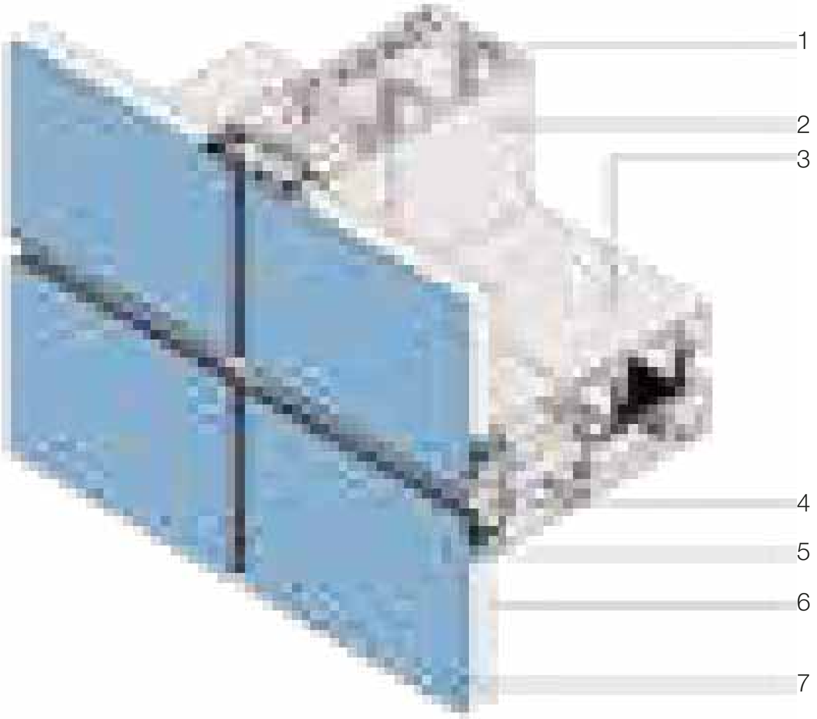

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54. PV integration in a rainscreen on
Manches ter College of Art & Technology.
55. Detail of a rainscreen panel integrated
with a PV module showing electrical connections.
56. External view of the Alan Gilbert Building
showing the PV in the two top storeys only.
57. Detail of a unitised curtain wall system
with PV modules in double-glazed panels. Note
routing of cables through the mullion.

Curtain Walls: Stick-system

LEGEND

1 Aluminium mullion
2 Space bar
3 Cabling
4 Aluminium transom
5 Aluminium pressure cap
6 Gasket
7 Inner glass pane of double-glazed unit
8 Glazed PV modue laminated onto carrier glass

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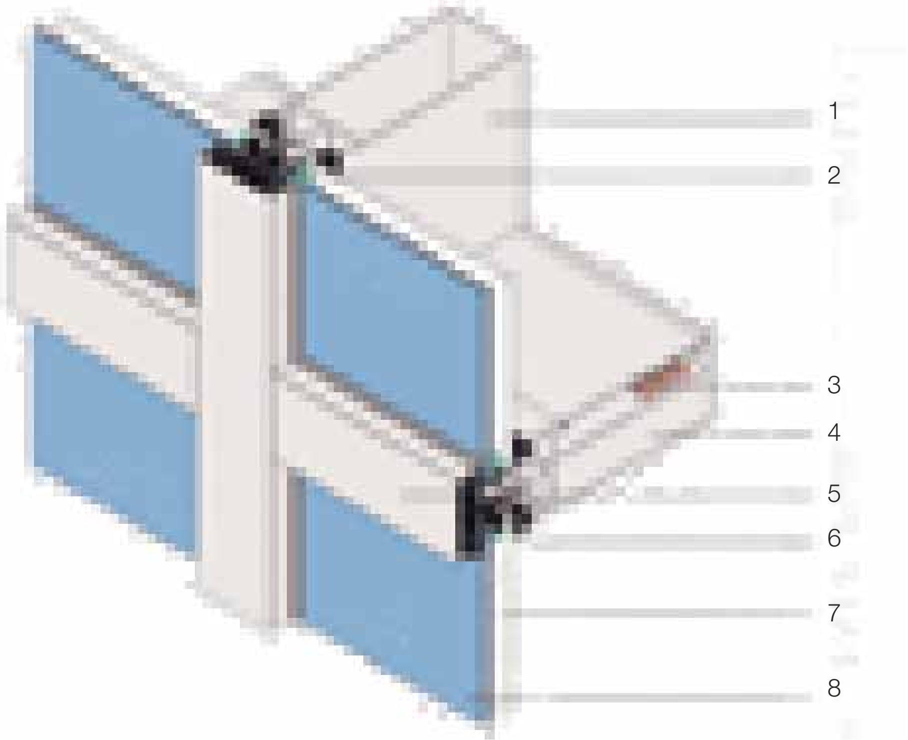

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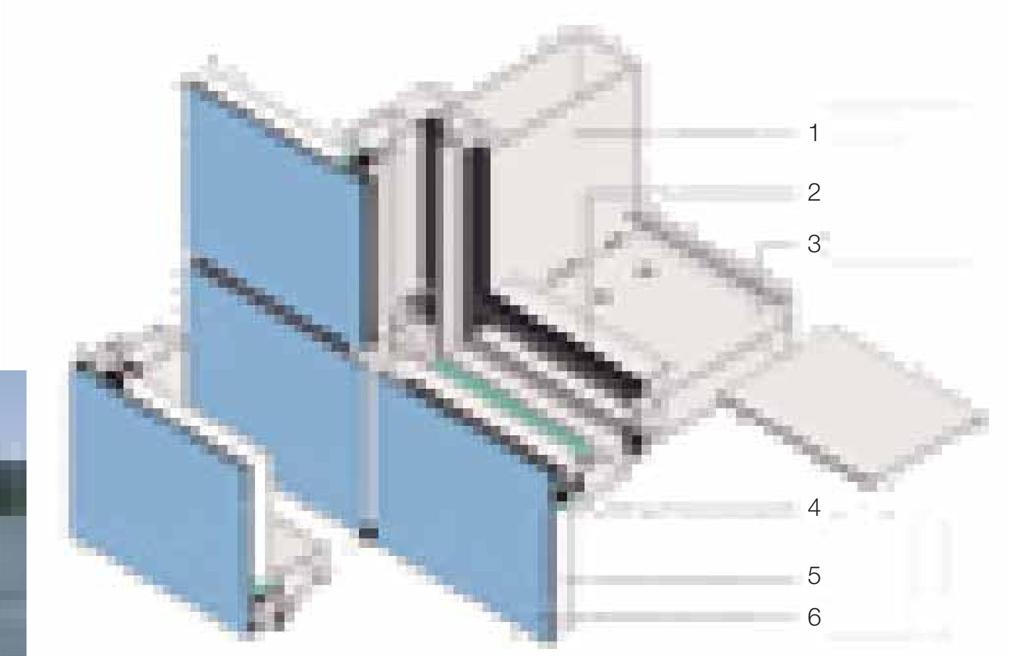
Structural Sealant Glazing

LEGEND
1 Aluminium mullion
2 Gasket
3 Aluminium transom
4 Spacer bar
5 Inner glass pane
6 Glazed PV module



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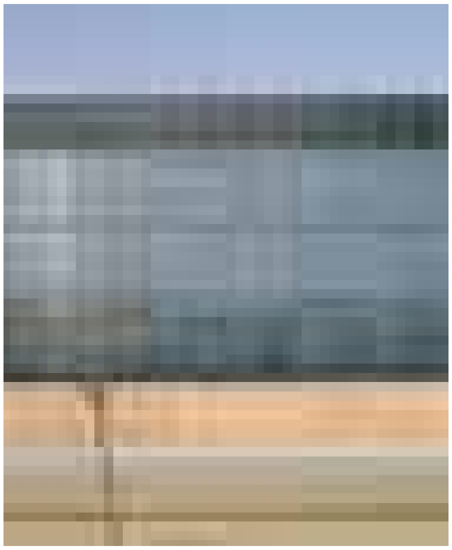

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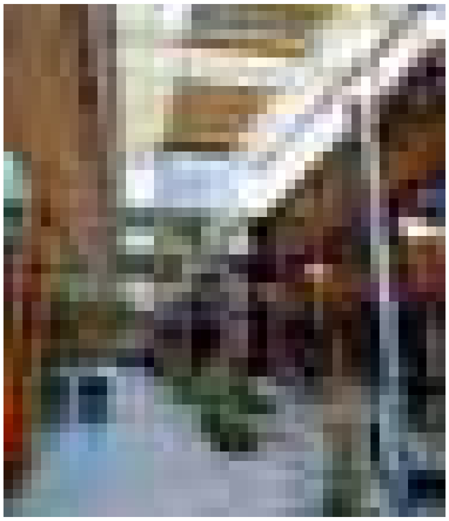
58. South façade of the Tobias Grau GmbH Head office west building in Rellingen showing the PV structural glazed panels.
59. Detail of PV modules and connections in a stick system curtain wall. The PV modules are laminated onto a carrier glass.
60. View from the south of the PV double-skin façade of the Pompeu Fabra Library, Mataró (E).
61 Exploded view of a stick system curtain wall with PV modules fixed with structural silicone.

5.2 Roof

Flat roof

LEGEND
1 Structural silicone glazing
2 Glazed PV module
3 Glazed panel
4 Spacer bar
5 Aluminium glazing frame
6 Aluminium counter batten
7 Aluminium rafter
8 Cabling



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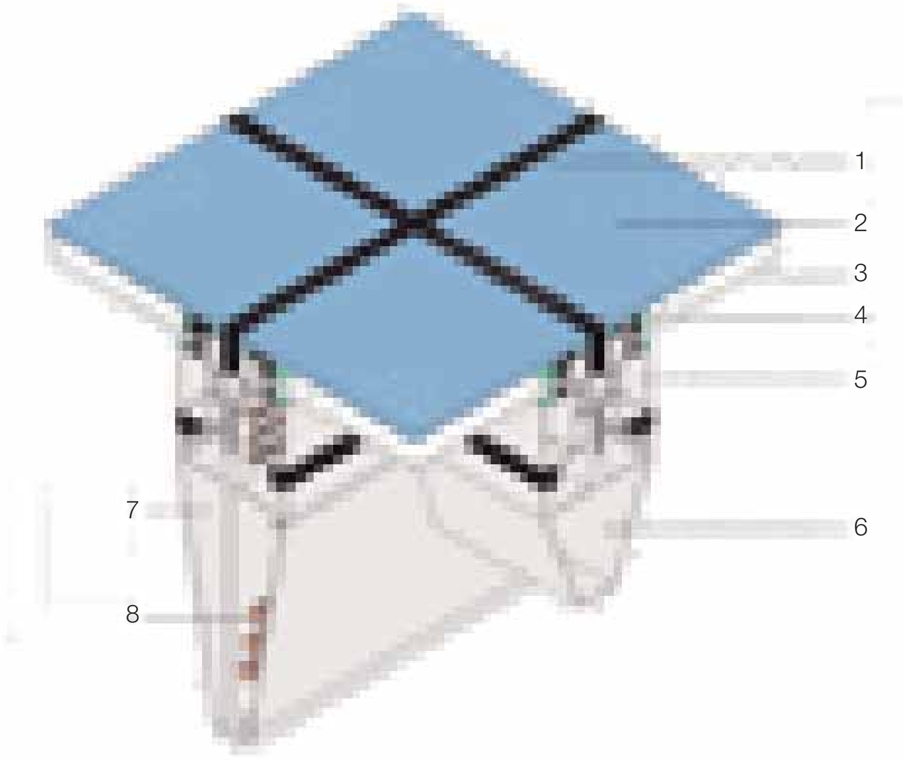

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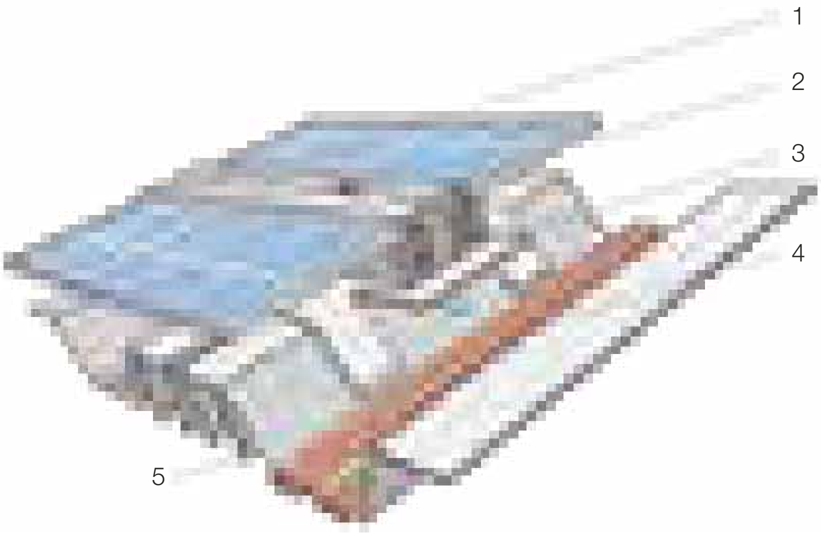
Pitched roof

LEGEND
1 PV module
2 Aluminium frame
3 Horizontal structure
4 Cables
5 Vertical structure



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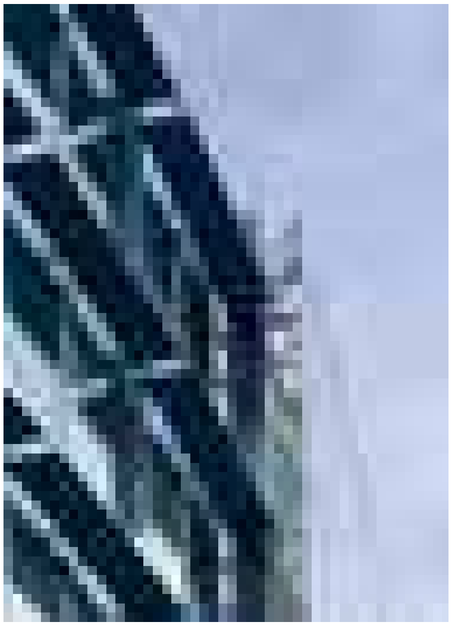
62. Atrium of the School of Management and Finance, Jubilee Campus, showing PV modules integrated into the central section of the roof.
63. Detail of a horizontal overhead glazing system with PV modules.
64. Hybrid PV modules on the cantilevers of the Vauxhall Transport Exchange.
65. Fixing system of the PV modules to the Vauxhall Transport Interchange.

5.2 Shading device

Flat roof

LEGEND
1 Floor slab
2 Floor bracket
3 Louvre
4 Louvres attachment bracket
5 Glazed unit
6 Aluminium mullion
7 Aluminium transom
8 Glazed spandrel panel



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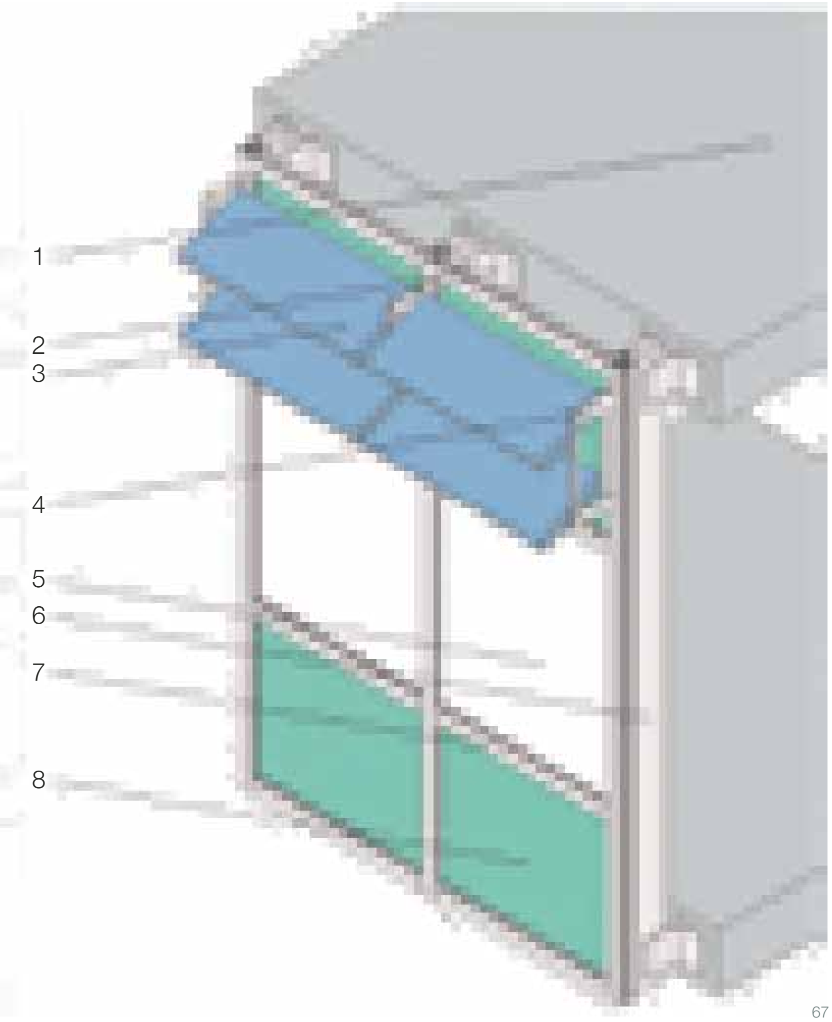

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66. Briese soleil sun shading devices.
67. Curtain wall with louvres.

PART 2

25 Design Examples

Opaque
Sports Facility

Pitched
Roof

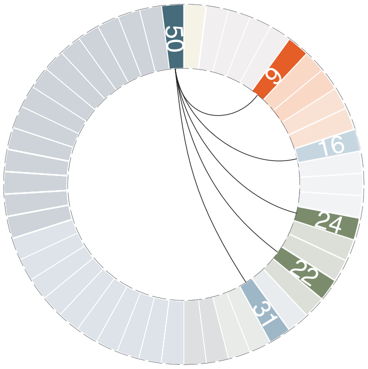
KAOHSIUNG NATIONAL STADIUM

Arch. TOYO ITO & ASSOCIATES
GAOXIONG, CHINA TAIWAN
2009

At One megawatt nominal power output, the Kaohsiung World Stadium is the biggest integration of photovoltaic construction in a sports facility of this magnitude. The system includes 8844 modules (Delta 105 WP & 125 WP Light-thru BIPV) and hundreds of small solar inverters (279 x Delta 3.6 kW). The failure of one small inverter has a much lower impact on the total power production than the failure of a big central inverter.

The BIPV solar panels power generation reduces 660t of annual CO2 output. The BIPV system provides electricity during games meanwhile any surplus energy produced during the year is sold to the city electric company. Further, all materials used in the main stadium are 100% reusable.

The building main structure is steel frame and reinforced concrete. The PV cells area account for 55% of the building total area.

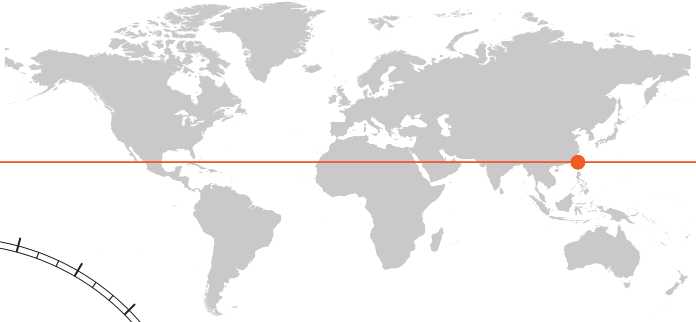


50	*Kaohsing National Stadium*
9	Crystalline silicon cells
16	Efficiency
24	Opacity
22	Size
31	Payback time

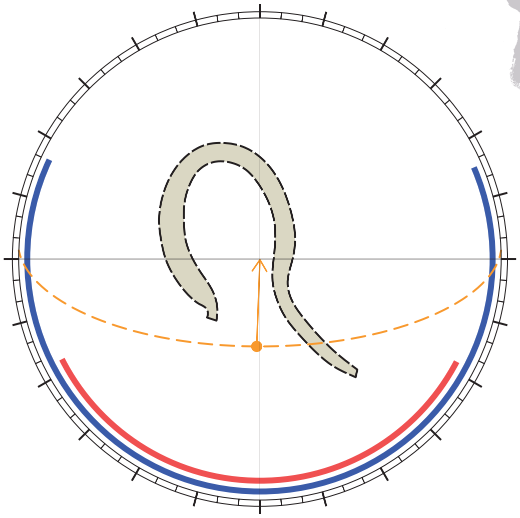
1. Aerial view of the complex

1

1,341 kWp
14,155 m^2



22° 38’ N



COMPONENTS

Cell Type: Polycrystalline Silicon
Module: 4-sided structural glass

PV OPTIMAL TILT

Summer: 91.5°
Winter: 44.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 1.1 Million KWh/year

2

3

4

5

2. Close up view of the roof mounted 4-sided s
ealed framed glazing modules.
3. Roof PV modules mounted overr curving steel structure.
4. Overal view of the complex PV modules.
5. View of the exposed PV modules from below.

For more information visit: http://www.delta-emea.com

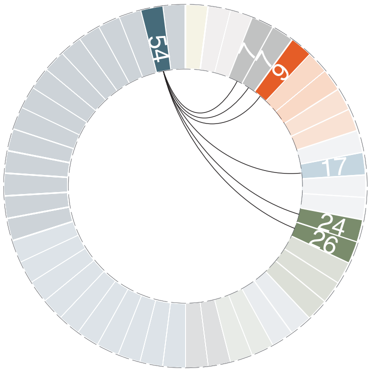
Opaque
Institutional

Pitched
Roof

UNWELT
ARENA

Arch. RENE SCHMID ARCHITECTS
SPREITENBACH, SWITZERLAND
2012

The building, with 203% of energy production and null CO2 balance, stands out as a great example in which architecture, aesthetic and ecology perfectly merged. The center focuses completely on environmental issues and sustainability.
It is it is the first Swiss building of its kind with the largest PV integrated plant. The plant functions as part of the structure, thermal accumulation while representing the exterior finishes of the facade. The facade is composed of prefabricated wooden sandwich panels of excellent insulation values. The plant produces twice the energy demand of the building. The facade and roof integrate in the design, it has an octagonal shape with 33 different surfaces and angle slopes orientations varying from 6° to 62°.Stretching almost to the ground, the entire exterior envelope is covered with PV modules.



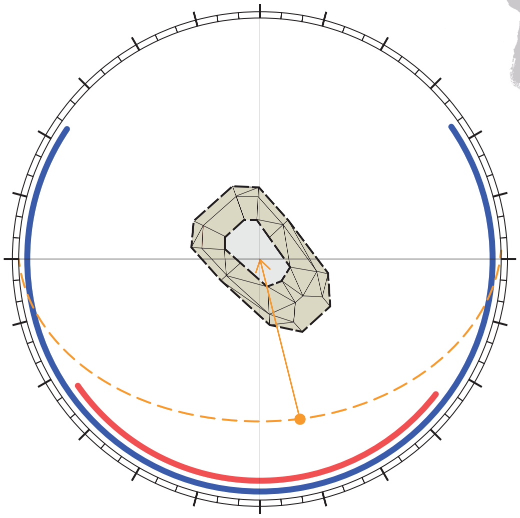
54	*Umweltarena*
7	Angle tilt
7	Sun path
9	Crystalline silicon cells
17	Low-light behaviour
24	Opacity
26	Colour

1. South-West Facade exterior view

1

736 kWp
5,342 m^2

47° 25 N



COMPONENTS

Cell Type: Monocrystalline Silicon
Module: 3S MegaSlate® II 160 Wp

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19..5°

ENERGY

Cell Efficiency: 20%
Energy Production: 625,600 KWh/year

20%

2

3

4

For more information visit: www.umweltarena.ch; www.benetz.ch

2. Close up view of the roof mounted PV modules.
3. North-East Facade elevation.
4. Overal view of the complex

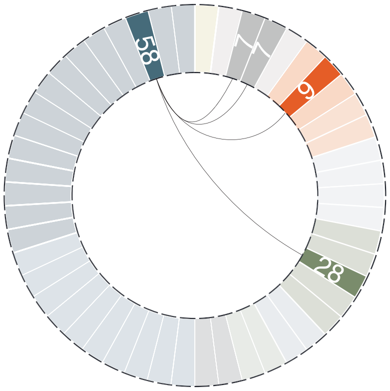
Semi-Transparent
Residential

Louvres

SOFT HOUSE

Arch. KENNEDY & VIOLICH ARCHITECTURE
HAMBURG, GERMANY
2013

The Soft House is a set of live/work residences, it offers ecologically responsive solutions thought out a new form of architecture that reinterprets the soft and hard materials in construction.
Like a “sunflower”, the Soft House PV shading system moves to harvest maximum available solar energy. Flexible photovoltaics in kinetic sunshades are attached to flexible composite roof components, offering adaptation for daily and annual sun tracking.
The Soft House structure is made of wood panels construction. Flexible solar nano-materials in a lightweight structure, integrate into the smart energy-harvesting textile cladding wings to respond to the always changing sun angles or to open views. The PV cells are mounted over textile cladding shades over the large glass facade openings.

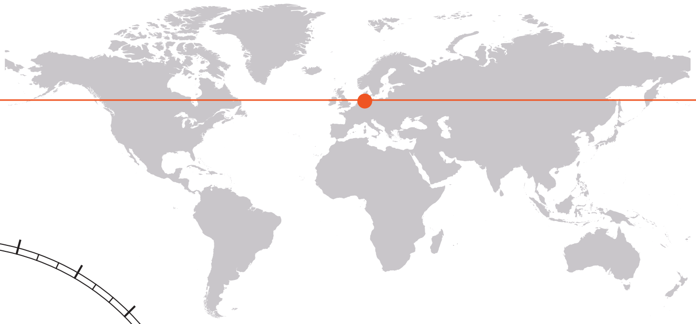


58	*Soft House*
7	Orientation
7	Angle tilt
9	Thin-film cells
28	Flexibility

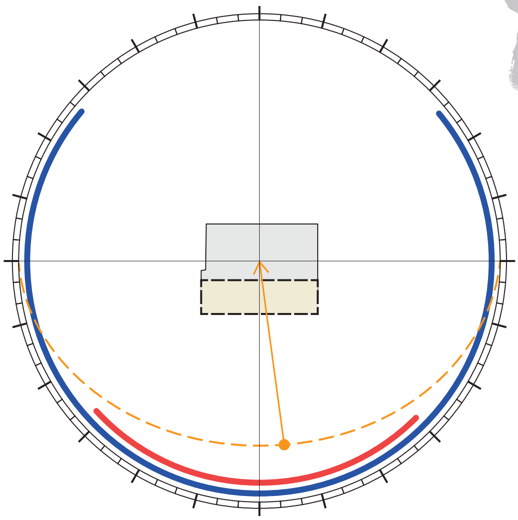
1. South facade exterior view

1

6 kWp
124 m^2



53° 33 N



COMPONENTS

Cell Type: Thin Film
Module: Flexible Sunshade Fabric

PV OPTIMAL TILT

Summer: 60.5°
Winter: 13.5°

ENERGY

Cell Efficiency: 7%
Energy Production: 5,040 KWh/year

2

3

4

2. Close up view of the roof mounted PV modules.
3. Interior view of the sunshade system.
4. Overal view of the PV sunshade system over the terraces.
5. BIPV Sunshades different orientation configurations.

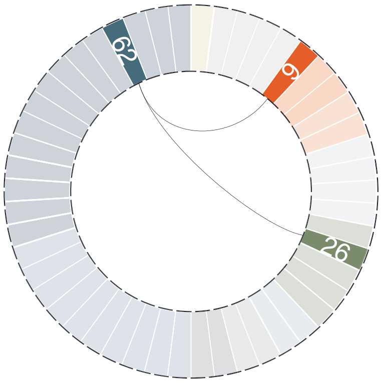
Opaque
Commercial

Warm
Facade

FLUMROC HEADQUARTERS

Arch. VRIDEN + PARTNER AG
FLUMS, SWITZERLAND
2014

BIPV Flumroc office building circa 1980, producer of insulating material, is a renovation of an existing building that demonstrates BIPV implementation over an existing structure. The project carries over the implementation of photovoltaics following the energy strategy 2020. The objective of the project was to achieve energy sufficiency and satisfy sustainability requirements while preserving the original structure. Besides the facade, the roof also includes PV, covering up to 61% of the energy demand.



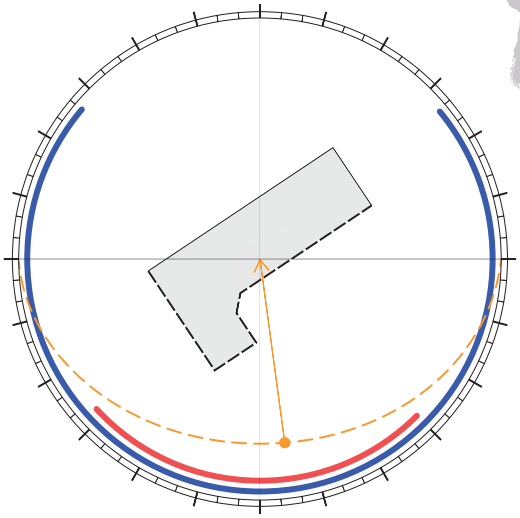
62	*Flumroc Headquarters*
9	Crystalline silicon cells
26	Colour

1. South facade exterior view

1

146 kWp
816 m^2

47° 5 N



COMPONENTS

Cell Type: Monocrystalline
Module: Solar Frontier SF-170-S

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 117,504 KWh/year


2

3

2. Close up view of the roof mounted PV modules.
3. Overal exterior view of the building.

For more information visit: www.gasserfassadentechnik.ch

Opaque
Industrial

Warm Facade

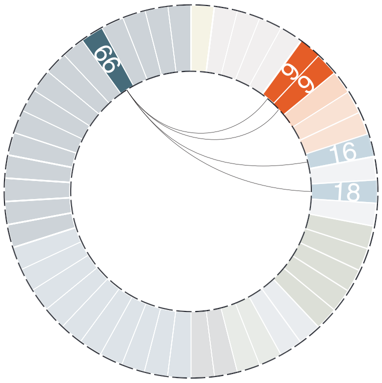
Flat Roof

HEIZPLAN SOLAR PARK

Arch. ATM3, WERNER VETSCH
GAMS, SWITZERLAND
2014

Winners of the Swiss Solar Prize for “new building” category, the Heizplan Solar Park stands out as an example of a complete energy-efficient building. Thanks to the triple-glass windows, airtight insulation and controlled ventilation system, the building meets Minergie standards. With total energy consumption of around 13,000 kWh/y and a usable power generation of over 58,000 kWh/y, the building produces four times more energy than it consumes.

Two PV plants integrated into the southern and eastern facades produce 24 % of total output. On the south side black vertical monocrystalline modules, alternating at the windows, and on the east side red-brown amorphous modules reflect the landscape around. In addition, there is a plant installed on the flat roof, with inclination of 20°, and a tracking systems. Further, a heat pump operated by solar thermal electricity generates the energy required for hot water generation. The rest of the thermal heat is supplied by a 25 m2 large thermal solar plant.



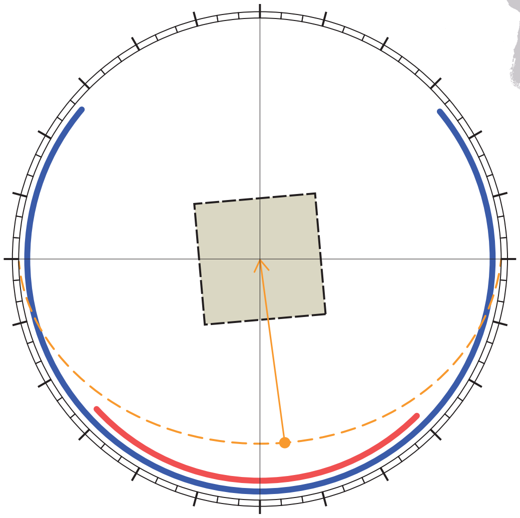
66	*Heizplan Solar Park*
9	Crystalline silicon cells
9	Thin-film cells
16	Efficiency
18	Shading tolerance

1. South facade exterior view


1

68.8 kWp
440 m²

47° 5 N



COMPONENTS

Cell Type: Monocrystaline & Thin Film
Module: 3S; Schott Solar; Schuco

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 7 - 20%
Energy Production: 124,400 KWh/year

20%

2


3

2. Close up view of the facade corner mounted PV modules.
3. Overal exterior view of the building.

For more information visit: www.heizplan.ch; www.atm3.ch

Opaque
Residential

Balcony

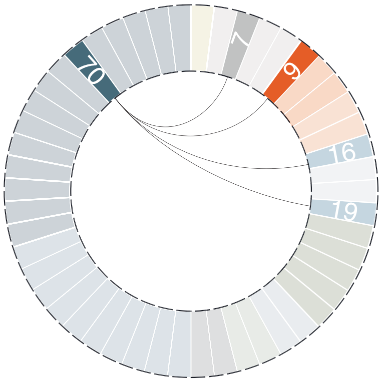
Flat Roof

HOFBERG 6/7 RESIDENCES

Arch. FENT SOLARE ARCHITECTS
WIL, SWITZERLAND
2014

Recipient of the Norman Foster Award 2012, the 7-story building PV plant produces 186% of energy surplus.
High-efficiency monocrystalline modules installed both on roof and on south facade, in correspondence of the floor bands, complement the architecture language of the building. The PV system is capable of charging 16 electric cars.

The PV modules are placed in response to the seasonal position of the sun and integrate with the exterior components of the facade. All components are recyclable. In addition, a solar heat pump system with two geothermal plants at 211 M depth produce heat for heating and hot water.



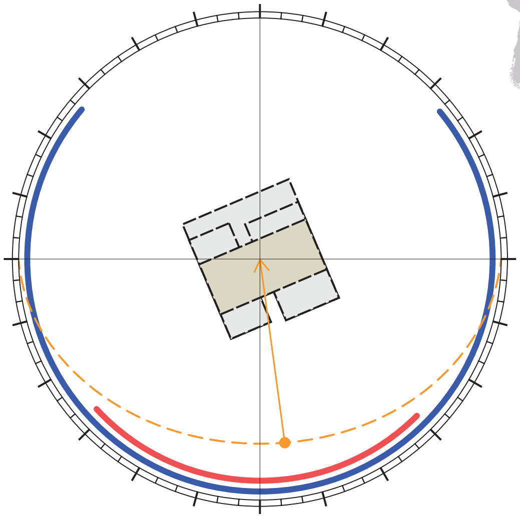
70	*Hofberg 6/7*
7	Orientation
9	Crystalline silicon cells
16	Efficiency
19	Temperature dependant

1. South facade exterior view

1

50.8 kWp
344 m^2

47° 28 N



COMPONENTS

Cell Type: Monocrystalline
Module: Sunpower Sondemodule

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 53,300 KWh/year

2

3

4

2. Close up view of the facade corner mounted PV modules.
3. Detailed view of the balconies PV modules
4. Overal exterior view of the building.

For more information visit: www.fent-solar.com; www.lucido-solar.com

Opaque
Residential

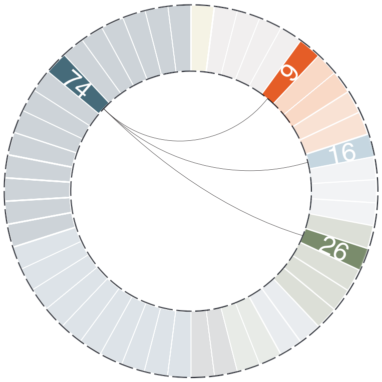
Warm Facade

Pitched Roof

KRAFTWERK B PLUS ENERGY HOUSE

Arch. GRAAB ARCHITECTS AG
BENNAU, SWITZERLAND
2014

Conceived from its inception as an environmentally sustainable multifamily house able to produce all its energy demands, the design fully integrates the PV system on the roof and on the facade of the building. The building produces more energy that it needs, exceeding his energy demands it supplements some energy requirements of the neighboring houses. The PV modules act as solar energy harvesting devices and replace conventional roof and facade cladding material.



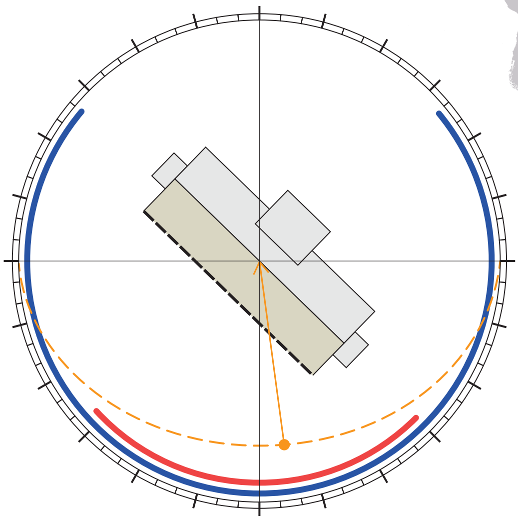
74	*Kraftwerk B*
9	Crystalline silicon cells
16	Efficiency
26	Colour

1. South West facade view

1

32 kWp
261 m^2

47° 80 N



COMPONENTS

Cell Type: Monocrystalline
Module: EPV Megaslate

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 32,000 KWh/year

20%

2

3

4

5

2. Close up view of the PV facade system.
3. Detailed view of the PV modules.
4. Overal exterior view of the building.
5. View of the PV facade compostion.

For more information visit: www.amena.ch; www.grabarchitekten.ch

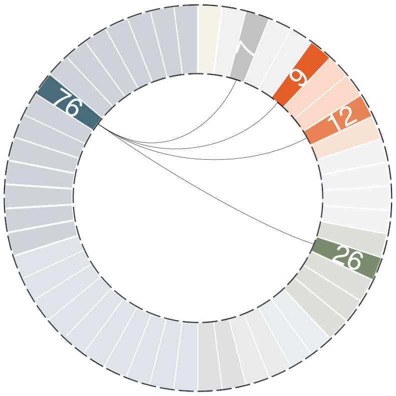
Opaque
Commercial

Warm
Facade

BORDEAUX URBAN COMMUNITY TOWER

Arch. BDM AARCHITECTS
BORDEAUX, FRANCE
2011

The mid-rise building is the first public Plus Energy Building in Bordeaux. Due to the combination of energy efficient strategies used for air cooling and heating, insulation, ventilation and also lighting systems the building was labeled HQE ® and BBC Effinergie. The main architectural characteristic of the building design is in the south façade. Its PV glass, with special modules of different colors, decorate the exterior of the building as a big artistic mosaic.



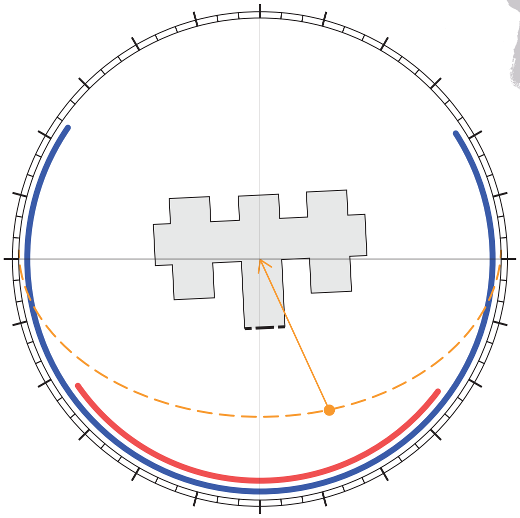
76	*Bordeaux Urban Community Tower*
7	Orientation
9	Crystalline silicon cells
12	Types of integration
26	Colour

1. South West facade

1

350 kWp
1,250 m^2

44° 50 N



COMPONENTS

Cell Type: Polycrystalline
Module: CENIT Design-ISSOL

PV OPTIMAL TILT

Summer: 69.5°
Winter: 22.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 119,00 KWh/year

2


3


4

2. Close up view of the PV cell.
3. View of the installed PV plant mosaic design
4. Overal exterior view of the building.

For more information visit: www.bdm-architectes.com

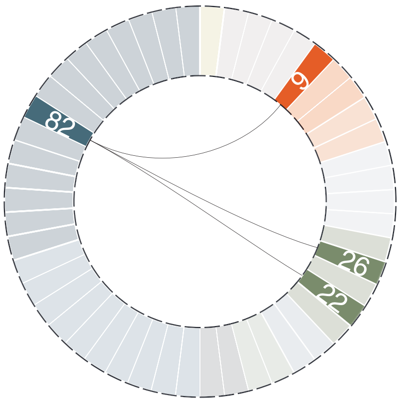
Opaque
Commercial

Cold Facade

PAUL-HORN ARENA

Arch. ALLMAN & SATTLER & WAPPNER
TUBINGEN, GERMANY
2004

Four different facades characterize the multi-functional sports facility. Each one is integral to the design concept.
The PV plan is located in the south-western facade. The PV wall is composed of green colored modules of crystalline cells fixed to the main primary structure by inconspicuous mechanical point anchors. The green color seeks to blend the facade and the building itself into the natural context. The Paul Horn-Arena has been awarded with the Hugo -Häring - Prize in 2009.

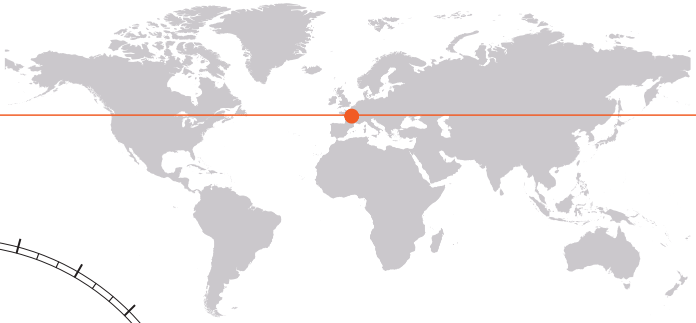


82	*Paul Horn Arena*
9	Crystalline silicon cells
26	Colour
22	Size

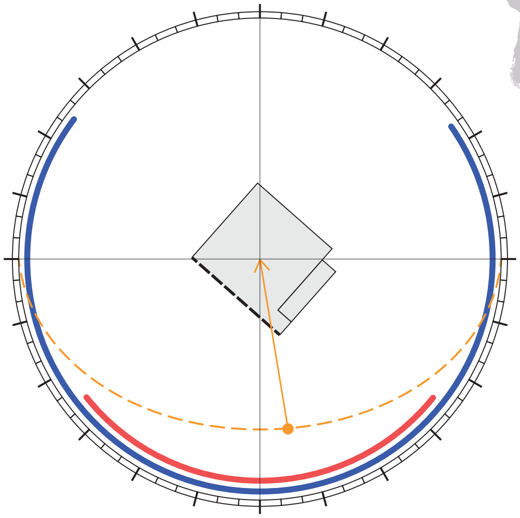
1. South West facade

1

43.7 kWp
420m^2



48° 31 N



COMPONENTS

Cell Type: Polycrystalline
Module: GSS Gebäude

PV OPTIMAL TILT

Summer: 65.5°
Winter: 18.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 37,145 KWh/year

20%

2


3


4

2. Close up view of the PV modules.
3. View of the installed PV plant squared pattern configuration.
4. Close up of the PV modules.

For more information visit: www.transsolar.com

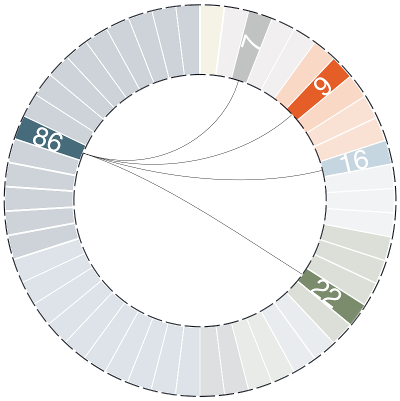
Opaque
Industrial

Pitched Roof

RIEDEL RECYCLING

MORSE, GERMANY
2008

Circa 1970, Riedel Recycling industry gets renovated by implementation of a new PV super power plant. Thin film PV cover the existing thin shell concrete roof and wall enclosure, covering the entire building solid opaque roof and facades envelope, more than 11 thousand modules in Cadmiun Telluride (CdTe), manufactured by American industry First Solar, bring this mega energy plant to life. With a peak capacity of 837 kWp, this installation becomes the widest in Germany over an existing industrial facility. With optimal roof slope and southern exposure of the building’s design type and location conditions turn ideal for the installation of such a plant.
The modules were not rigidly fixed so that an expected temperature change under expansion and contraction of the roof can be compensated in the future.
The photovoltaic modules used are thin film modules from First Solar. Due to a very good low-light performance in combination with a low temperature coefficient.
All electrical cables were laid below the modules. The total weight of the system together with a new roof is about 200 tons.

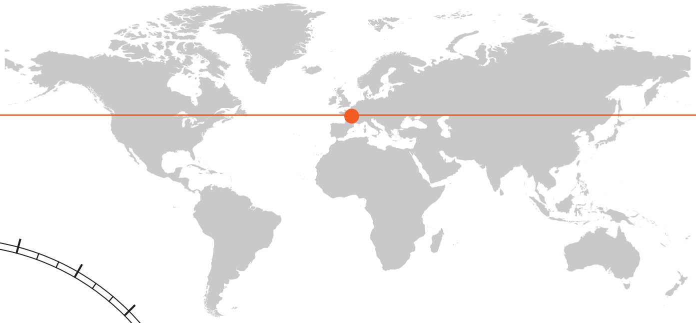


86	*Riedel Recycling*
7	Orientation
9	Thin-film cells
16	Efficiency
22	Size

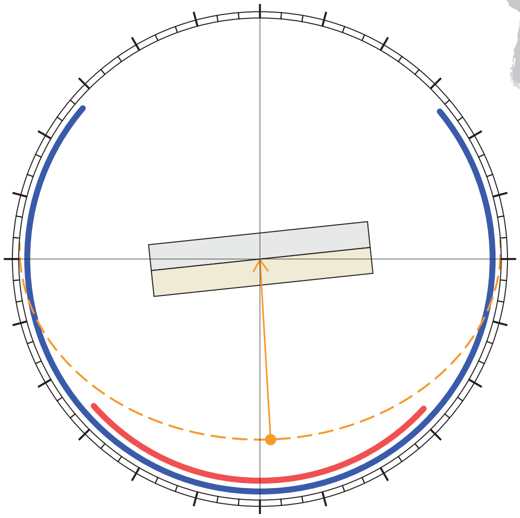
1. Overall view of the PV plant

1

837 kWp
9,500 m^2



52° 23 N



COMPONENTS

Cell Type: Thin-Film
Module: CIS modules (First Solar)

PV OPTIMAL TILT

Summer: 61.5°
Winter: 14.5°

ENERGY

Cell Efficiency: 5-10%
Energy Production: 750,000 KWh/year

5%

2

3

2. Close up view of the PV cell andd module installation.
3. Close up view of the completed installation of the PV plant.

For more information visit: www.das-solardach.de; www.solaxis.de

Opaque
Commercial andd Residential

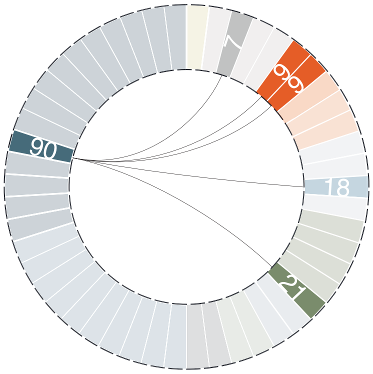
Balcony

Flat Roof

ROMANSHORN PLUS ENERGY BLDG.

VIRIDEN + PARTNERS AG
ROMANSHORN, SWITZERLAND
2013

Dated 1960, this commercial and residential building received a complete refurbishment in 2013. The renovation included a new energy production plan via a PV integrated system. And became the largest plus energy building in Switzerland of this characteristics, winning the Swiss Solar Prize in 2013..
The numbers of residential units was increased, however the new energy production plant, allows coverage of 70% of the demand. The installed panel cover the facade and due to the anti-reflection blend in as a finish material.
In addition, the building has triple-glass windows, a solar collector and heat recovery system, allowing for a good balance between passive devices and integrated solar technology.

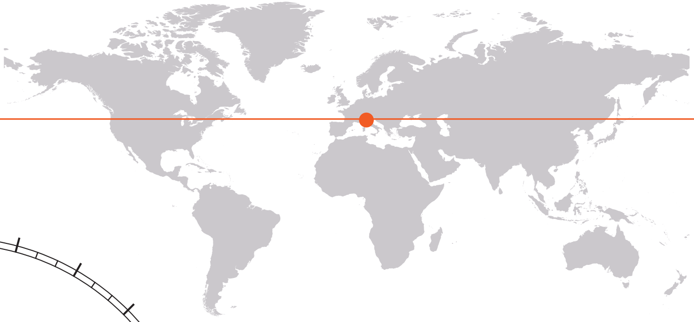


90	*Romanshorn PlusEnergyBuilding*
7	Orientation
9	Crystalline silicon cells
9	Thin-film cells
18	Shading tolerance
21	Form

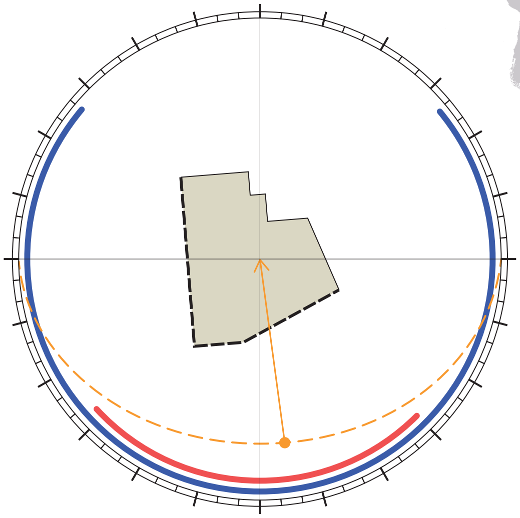
1. Overall view of the buildingH .


1

79.3 kWp
441m^2



47° 34 N



COMPONENTS

Cell Type: Monocrystalline & Thin-Film
Module: SANYO HIT-H250E01

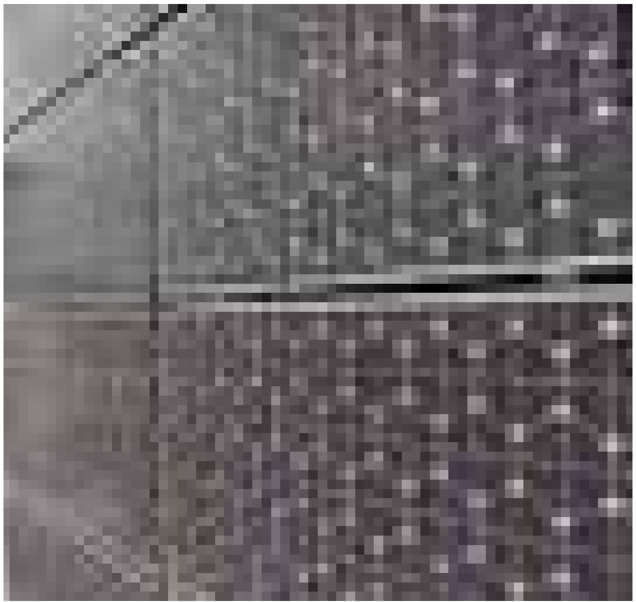
PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 5-10%
Energy Production: 89,700 KWh/year

5%



2

3h

4

2. Close up view of the PV cell and module installation.
3. & 4. Exterior overal views of the PV modules integrated into the building facade.

For more information visit: www.holinger-solar.ch; www.viriden-parten.ch

Opaque
Residential

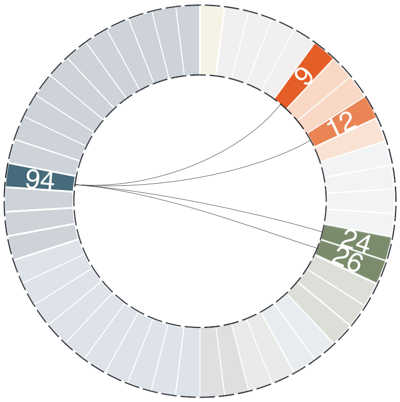
Pitched
Roof

WEIBEL FAMILY HOUSE

RYCHENER PARTNERS AG
HORGEN, SWITZERLAND
2013

Located in the Village of Horgen, Canton Zurich; this private family residence has been renovated per the Minenergy standard. Winner of the Swiss Solar Prize in 2013. The renovation included the energy retrofitting (building envelope and replacement of windows). The goal was to achieve a complete new architectural language.

The facade is cladded with horizontal wood slats (larch). And the existing gabled roof receives a new roofing membrane that includes the PV modules, directly attached to the waterproofing membranes of the roof. The north facing roof receives a green roof, protecting the building of overheating and increasing acoustic insulation. The retrofit energy saving measures account for up to 86% of the building energy demand.



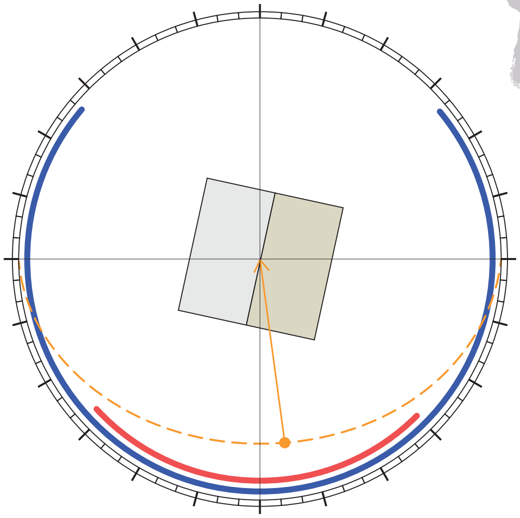
94	*Weibel family house*
9	Crystalline silicon cells
12	Types of integration
24	Opacity
26	Colour

1. Overall view of the building .

1

6.5 kWp
37 m²

47° 34 N



COMPONENTS

Cell Type: Monocrystalline
Module: -

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 5,525 KWh/year

20%

2


4


3

2. View of the sloped roof PV installation
3. Building within the natural surrounds.
4. View of the north faacing gable roof (green roof)W

For more information visit: www.rychenerpartner.ch; www.gae.ch

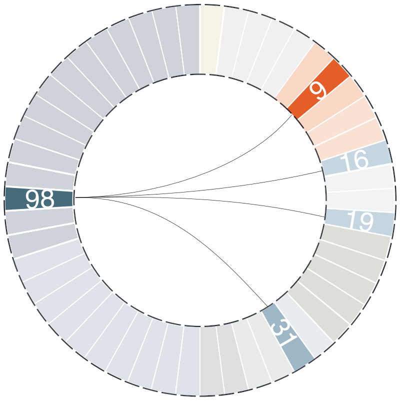
Opaque
Sports Facility

Pitched Roof

BENTEGODI STADIUM

VERONA, ITALY
2009

As the largest PV plant installed in a sport facility structure in Italy, and one off the largest in Europe. The Stadium stands as an example of BIPV. The old roof was renovated completely according to energy standards. More than 13,000 solar modules with about 1MWp power, the PV plant avoids 550 tons of CO2 and covers the energy supply of approximately 400 single family homes, when not in self demand operation.

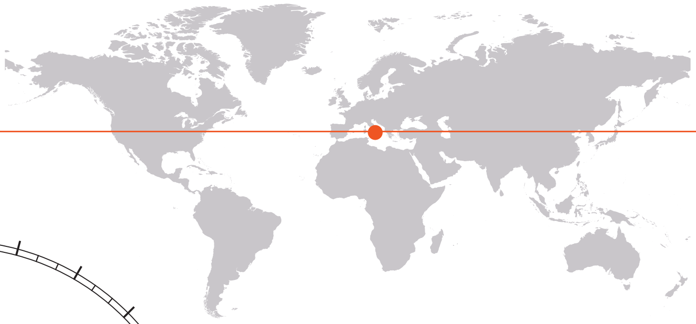


98	*Stadio Bentegodi*
9	Thin-film cells
16	Efficiency
19	Temperature dependant
31	Payback time

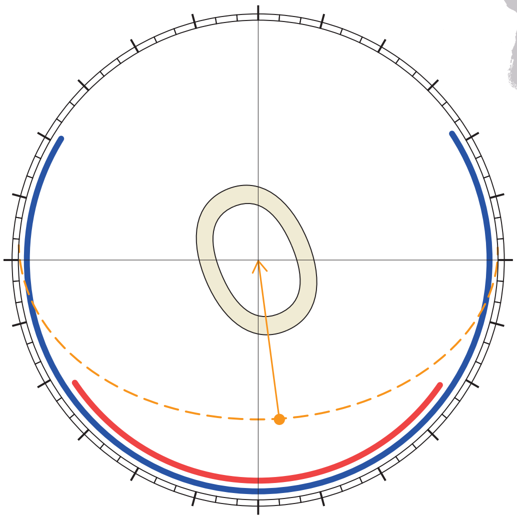
1. Overall view of the building roof.


1

999 kWp
9,600 m^2



45° 26 N



COMPONENTS

Cell Type: Thin-Film
Module: 13.321/First Solar FS-275

PV OPTIMAL TILT

Summer: 68.5°
Winter: 21.5°

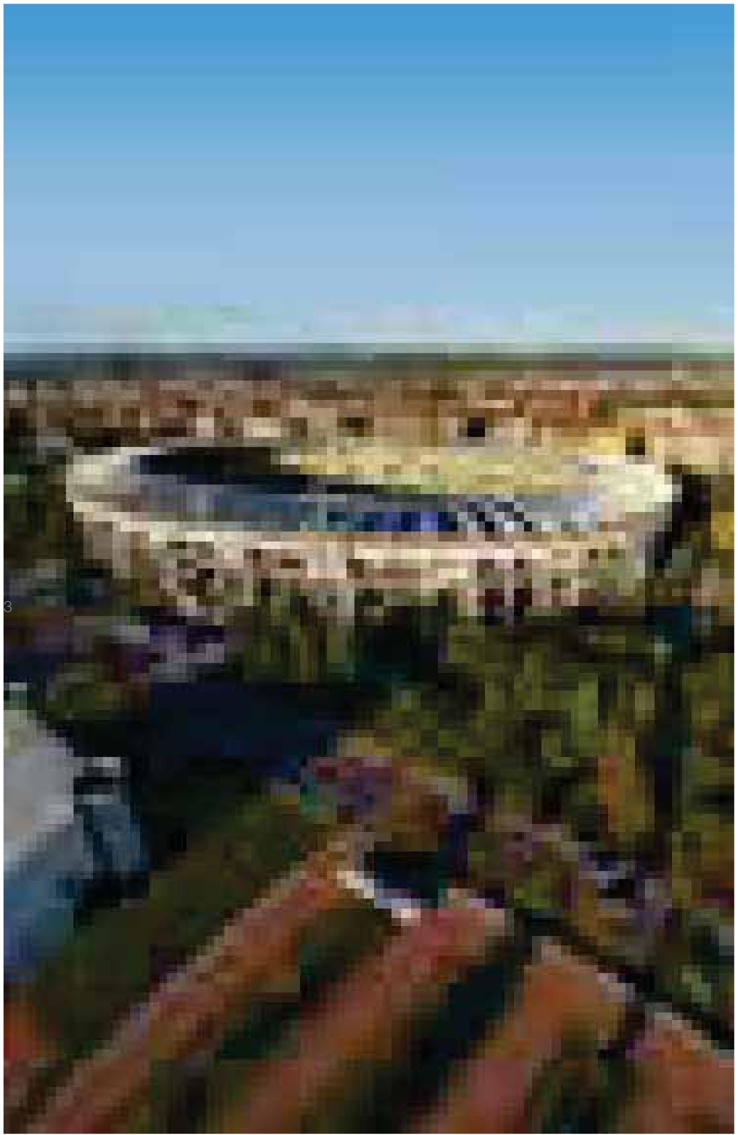
ENERGY

Cell Efficiency: 15%
Energy Production: 929,000 KWh/year

15%

2

3



4

2. View of the sloped roof PV installation
3. Building within the natural surrounds.
4. View of the sports complex.

For more information visit:www.juwi.it

Opaque
Commercial

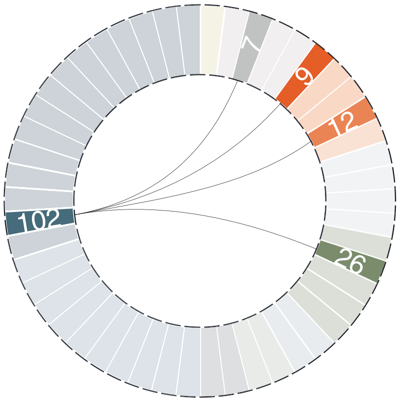
Cold Facade

Flat Roof

V-ZUG LOGISTIC CENTER

Arch. BETRIX & CONSOLASCIO ARCHITECTS AG
ZUG, SWITZERLAND
2009

The logistic center V-Zug serves as docking site for trucks. It is conceived to achieve high efficiency due to a dense shape and double skin facade, which is used to maintain low temperature fluctuations in winter and summer.
The PV plant in the south facade, with laminated insulating safety glass module is oriented to maximize solar exposure while engaging the rest of the building components in a cohesive geometry. In addition, the roof PV plant complements the solar energy system. This PV system arranges the modules to maximize power area, ensuring optimum utilization of the roof surface. Energy production surplus is enough to supply energy demand to 50 families.

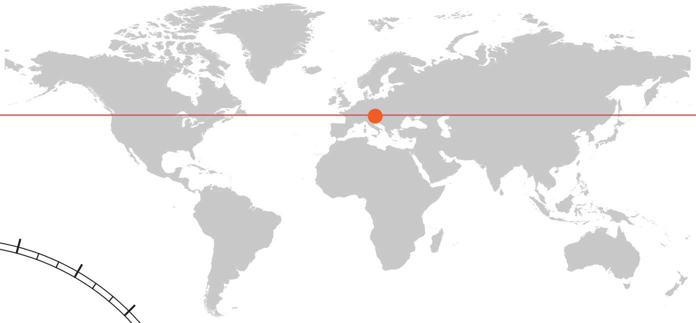


102	*V-Zug Logistic Center*
7	Orientation
9	Crystalline silicon cells
12	Types of integration
26	Colour

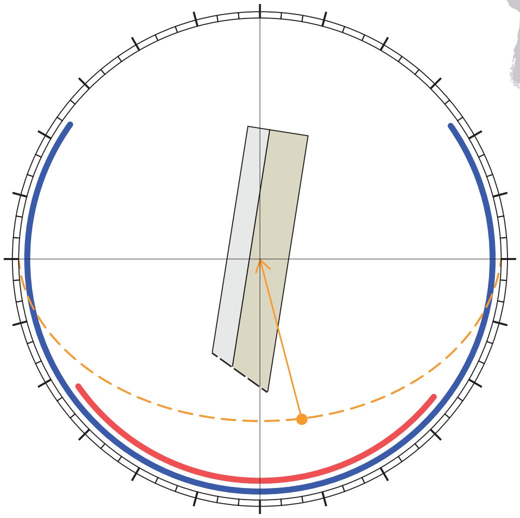
1. Overall view of the building roof.

1

271 kWp
1,800 m^2



47° 10 N



COMPONENTS

Cell Type: Polycrystalline
Module: Sunpower cells

PV OPTIMAL TILT

Summer: 66.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 230,350 KWh/year

20%

2


3


4

2. Closed up view of the cerrated BIPV facade.
3. Building roof mounted PV Plant.
4. Side view of the facade.

For more information visit: www.suntechnics.ch

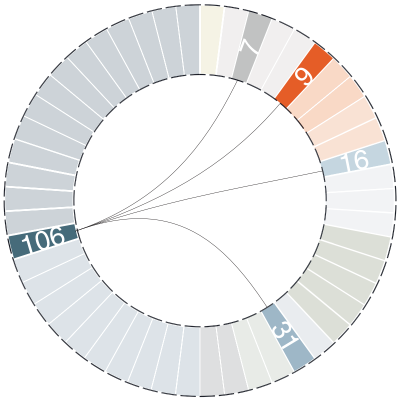
Semi-Transparent
Cultural

Cold
Facade

SANYO SOLAR ARK

BETRIX & CONSOLASCIO ARCHITECTS AG
ZUG, SWITZERLAND
2009

From scrap pile to stunning example – Solar Ark is the architectural equivalent of turning lemons into lemonade.
Sanyo Solar Ark stands as a massive solar collecting plant with over 5,000 solar panel. More outstanding is the fact that most of the panels were factory rejects -in line to scrap. Next to Sanyo's semiconductor factory in Gifu, Japan the Solar Ark stands as an example of BIPV. More than 75,000 red, green and blue computer-controlled LEDs lit up between the PV panels of The Solar Ark's 315 meter (1033 foot) long facade in various images and characters.
Stationed at the center of the Solar Ark is the Solar Lab, a museum of solar energy. A hands-on, outdoor light exhibition was planned for opening in 2005. The Solar Ark was an enterprise partner with the 2005 World Exhibition, Aichi Prefecture, Japan. It is one of the largest solar buildings in the world.

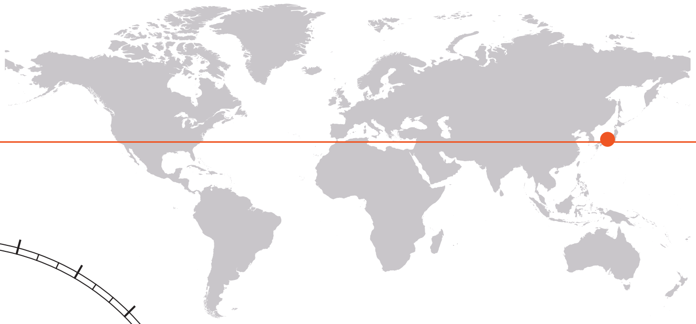


106	*Sanyo Solar Ark*
7	Orientation
9	Crystalline silicon cells
16	Efficiency
31	Payback time

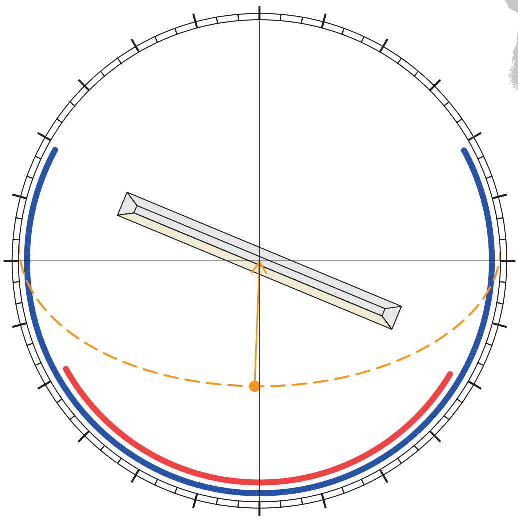
1. Night view of the Solar Ark Complex.

1

623,529 kWp
3,450 m²



35° 33 N



COMPONENTS

Cell Type: Monocrystalline
Module: -

PV OPTIMAL TILT

Summer: 78.5°
Winter: 31.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 530,000 KWh/year

20%

2

3

4

2. Side view of the BIPV modules.
3. Building overal elevation
4. Interior view of the structure.

For more information visit: www.solaripedia.com

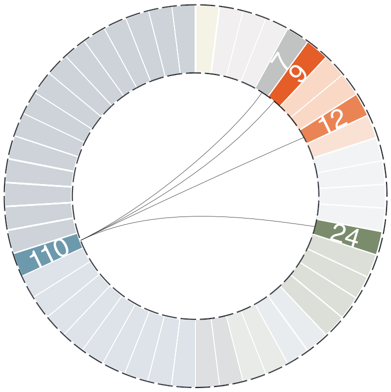
Semi-Transparent
Cultural

Glass Roof

NOVARTIS CAMPUS

Arch. GHERY PARTNERS LLC.
BASEL, SWITZERLAND
2008

The project consists of a group of volumes with a mixed use program, it inlcudes a restaurant and an underground auditorium.
A completely glazing envelope made out of curved shingle surfaces gives shape to the complex. The facade, with triple glazing and sun shading device within the window glass sandwich panes scurve along the volumes. The entire glazing roof is made out of semi-transparent photovoltaic modules. Not only the cells but also the modules were custom made. A punched pattern and a special color give the PV plant unique aesthetic qualities.

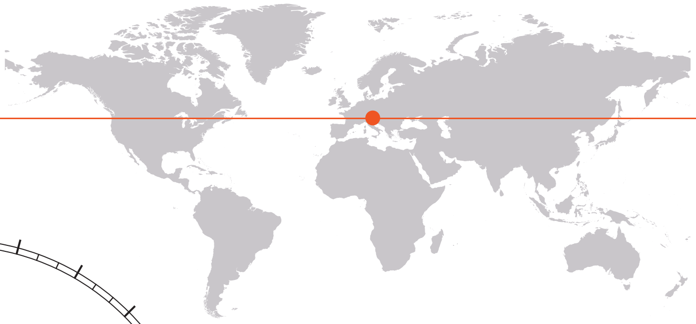


110	*Novartis Campus Gehry Building*
7	Sun path
9	Crystalline silicon cells
12	Types of Integration
24	Opacity

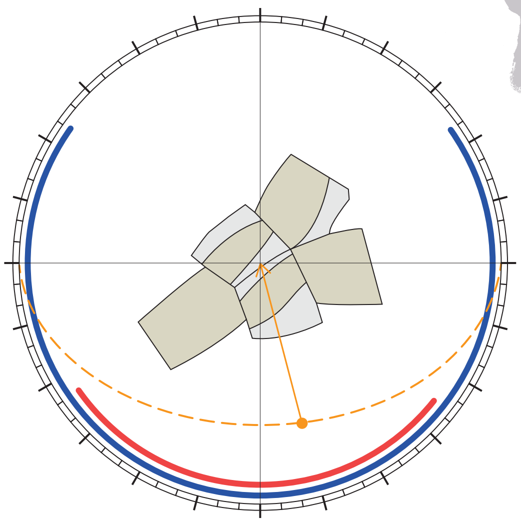
1. Night view of the Solar Ark Complex.

1

92.75 kWp
1,300 m^2



47° 34 N



COMPONENTS

Cell Type: Monocrystalline
Module: Schüco & Sunways

PV OPTIMAL TILT

Summer: 69.5°
Winter: 19.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 78,837 KWh/year

20%

2

3

4

2. Interior view of the PV modules.
3. View of the site & building complex
4. Side elevation of the building -night view.

For more information visit: www.tritec-energy.com

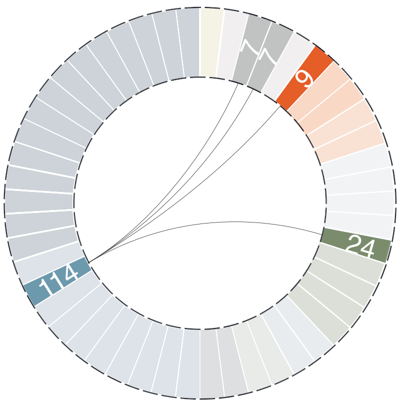
Semi-Transparent
Commerical

Glass
Roof

ALAN GILBERT BUILDING

Arch. METIER3
MELBOURNE, AUSTRALIA
2001

Glass laminated polycrystalline cells are distributed in order to allow some of the incident daylight to pass through the façade. The polycrystaline cells are embedded in the layered glass sandwich. The selection of this type off cells is due to cost in comparison with monocrystalline and to the added value offered by the aesthetic aspect, as they match the appearance of the building. All the cells were produced in Sydney by BP Solar. The modules were installed with structural silicone glazing. Every fifth module is externally framed with a pressure plate, which creates a pattern on the façade reflecting the internal primary structure of slabs and columns The plant generates energy surplus that is sent to the grid network when not used by the building demand.



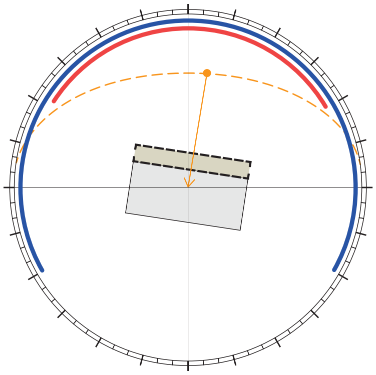
114	*Alan Gilbert Building*
7	Orientation
7	Angle tilt
9	Crystalline silicon cells
24	Opacity

1. Side view of thefacade holding the PV modules.

1

46 kWp
426 m^2

37° 48 S



COMPONENTS
Cell Type: Polycrystalline silicon
Module: Schüco & Sunways

PV OPTIMAL TILT
Summer: 69.5°
Winter: 19.5°

ENERGY
Cell Efficiency: 20%
Energy Production: 40,000 KWh/year

20%

2

3

4

2. Interior view of the PV modules.
3. View of the site & building complex
4. External view of the Alan Gilbert Building
showing the PV in the two top storeys only.

For more information visit: http://www.bp.com: www.arup.com

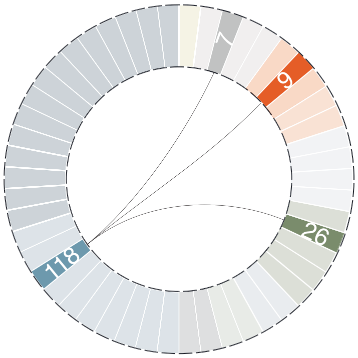
Semi-Transparent
Residential

Warm
Facade

14-UNIT HOUSING DEVELOPMENTT

Arch. HAN VAN ZWEITEN FT, KISS + CATHCART
IJSSELSTEIN, NETHERLANDS
2002

The 14-unit housing project in Ijsselstein became an example of integration between space and energy. Integrated solar power presented an obvious solution. Architects opted to focus on the aesthetics of PV, so decided to implement thin-film solar panels. The main characteristic of the homes is multi-level atrium enclosed by PV modules. Some bands are left unused by the PV panes for operable windows to let in natural light and fresh air. The PV system provides about 30 % of each house's energy demand.



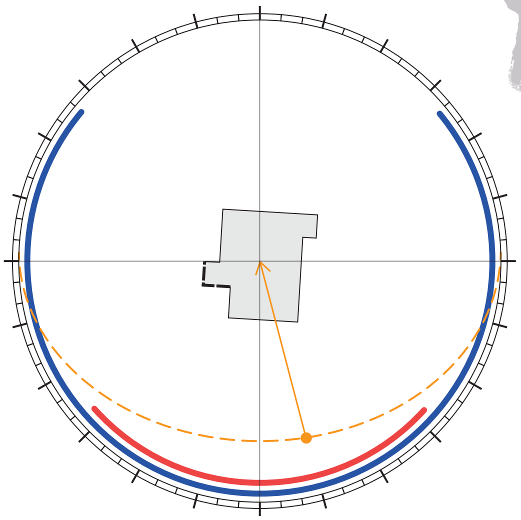
118	*14-Unit Housing Development*
7	Orientation
9	Thin-film cells
26	Colour

1. Side view of the facade holding the PV modules.

1

1.8 kWp
30 m^2

52° 10 S



COMPONENTS

Cell Type: Thin-Film
Module: EPV

PV OPTIMAL TILT

Summer: 61..5°
Winter: 14..5°

ENERGY

Cell Efficiency: 5-10%
Energy Production: 1,530 KWh/year

5%

2


3

2. Interior view facing the PV modules opposite.
3. View of the site & building complex

For more information visit: www.terrasolar.com

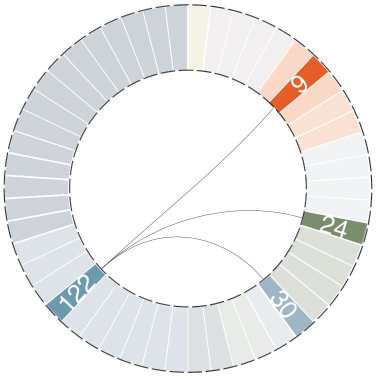
Semi-Transparent
Transportation

Glass
Roof

BEIJING SOUTH RAILWAY STATION

Arch. TERRY FARREL & PARTNERS
BEIJING, CHINA
2008

The project stands out as an upgrade to the 109 years old station. The Beijing South Train Station, is one four Asia's largest railway stations. The oval-shaped morphology, that looks like a giant stingray, is characterized by three parts: a large elliptical central roof and two symmetrical side canopies. Natural ventilation and solar system are key features of the building. The main roof is a 30,000m2 skylight and provides daylight into the stations halls. Over the perimeter, thin film PV glazing modules with CIS technology complete the PV system. A pattern is created by alternating the modules. In addition to generating electricity, the system acts as a giant shading system. Which contributes to reduction of the internal cooling loads.

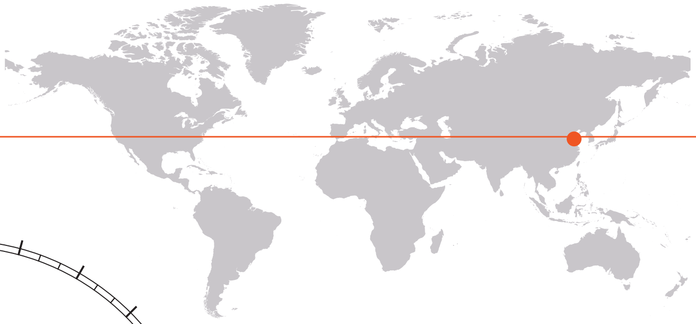


122	*Beijing South Railway Station*
9	Thin-film cells
24	Opacity
30	Cost

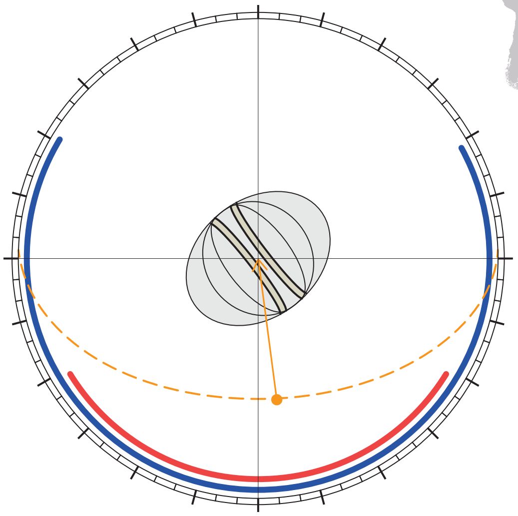
1. Side view of thefacade holding the PV modules.

1

390 kWp
3,750 m^2



39° 55 N



COMPONENTS

Cell Type: Thin-Film
Module: CIGS modules Würth Solar

PV OPTIMAL TILT

Summer: 74.5°
Winter: 27.5°

ENERGY

Cell Efficiency: 10%
Energy Production: 180,000 KWh/year

10%

2

3

2. & 3. Interior view of the giant atrium covered by the PV shading modules.

For more information visit: http://www.bp.com: www.arup.com

Semi-Transparent
Museum

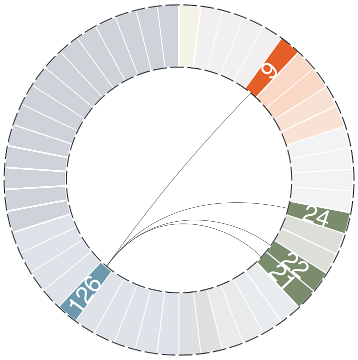
Glass
Roof

CALIFORNIA ACADEMY OF SCIENCE

Arch. RENZO PIANO & STANTEC ARCHITECTS
SAN FRANCISCO, CA. USA
2008

The California Academy of Science, located on the Golden Gate Park, combines research, exhibition, educational and office spaces. The architectural design creates a “living roof ” covered with 1,700,000 selected autonomous plants. Determined to achieve a Platinum LEED (Leadership in Energy and Environmental Design) rating. All aspects in the building considered sustainable and energy conservation and production strategies.

The main roof of the Academy is undulating in form and mostly covered with planting. The PV plant is located as part of the extended roof undulated canopy around the full perimeter of the roof. Monocrystalline silicon cells are laminated into bespoke glass-glass modules and used in a band of the canopy. The pattern of the opaque cells is “printed” in a friting pattern in the plain glass glazing on either side. This canopy constitutes the largest PV glass canopy in the United States.



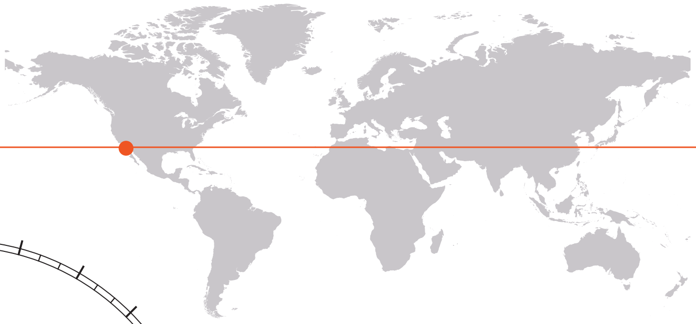
126	*California Academy of Science*
9	Crystalline silicon cells
24	Opacity
22	Size
21	Form

1. Close-up view of the onndulating roof and interiors of he Academy of Science Building.
2. Aerial view of the site complex.

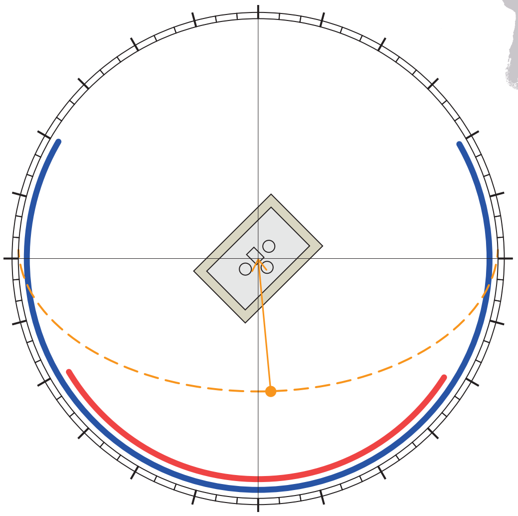
1

2

172 kWp
190 m^2



37° 47 N



COMPONENTS

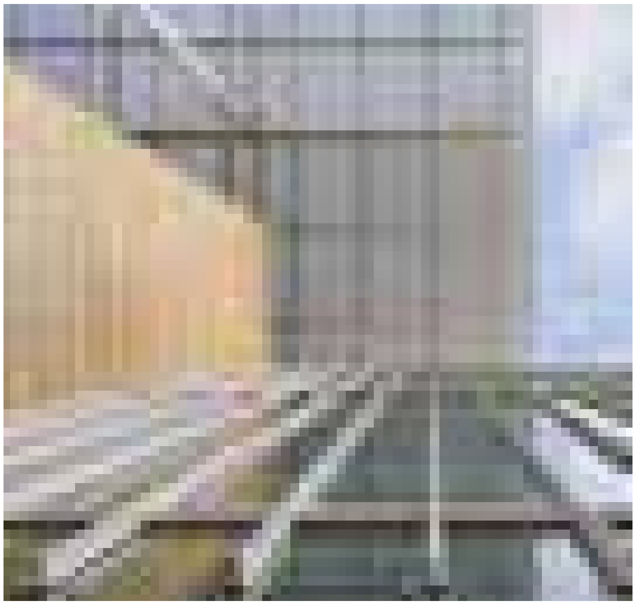
Cell Type: Monocrystalline Silicon
Module: Microcrystal PV cells

PV OPTIMAL TILT

Summer: 76.5°
Winter: 29.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 213,000 KWh/year



3


4


5

2. View of the PV shading canopy from below.
3. PV canopy.
4. Colonnade of the canopy, entrance to the building.

For more information visit: www.arup.com; www.rpbw.com

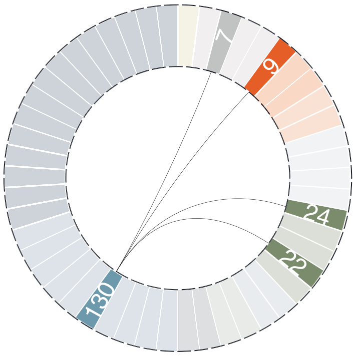
Semi-Transparent
Institutional

Glass
Roof

FIRE DEPARTMENT

Arch. SAMYN & PARTNERS
HOUTEN, NETHERLANDS
2000

The glazed shell incorporates semitransparent PV glasses with silicon cells, allowing for optimal daylight in the fire fighters garage area. The choice of a parabolic form for the roof is the result of the search for optimization of the structure. This hall is intended to serve as a climatic buffer zone, both in winter and in summer.



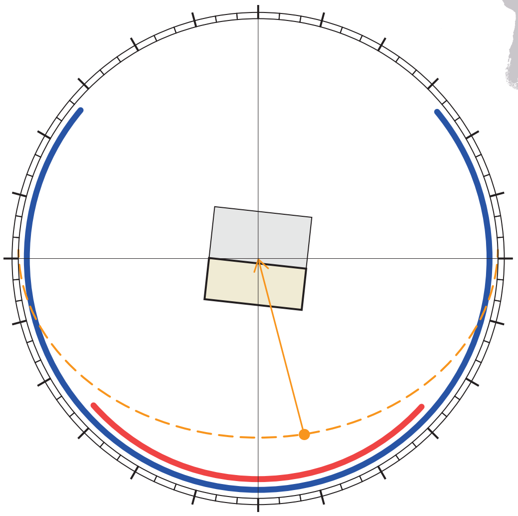
130	*Fire Department*
7	Orientation
9	Crystalline silicon cells
24	Opacity
22	Size

1. Night view of the Fire Department shading canopy.

1

23.9 kWp
400 m²

52° 2 N



COMPONENTS

Cell Type: Polycrystalline Silicon
Module: Shell Solar transparent laminate

PV OPTIMAL TILT

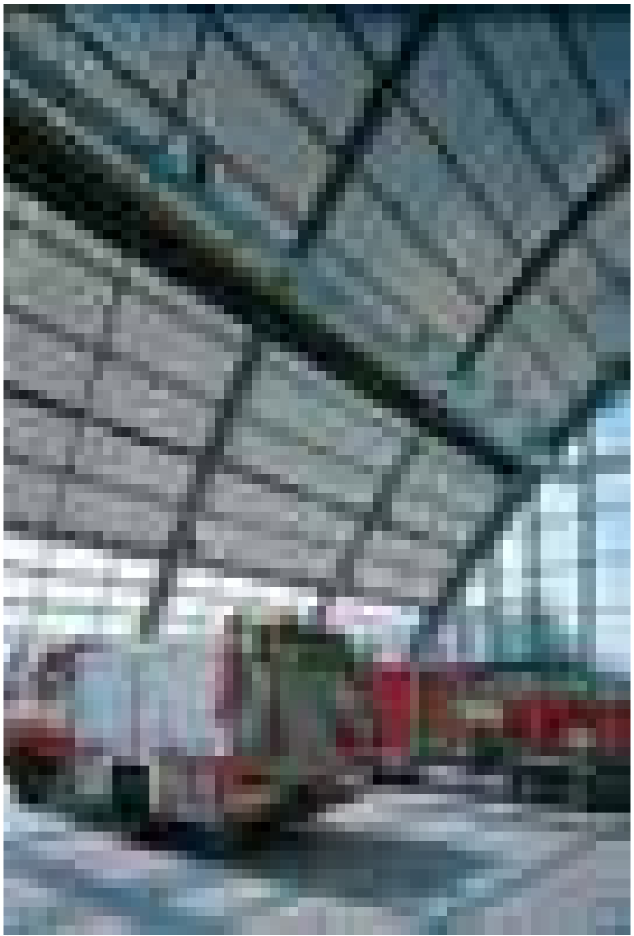
Summer: 61.5°
Winter: 14.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 30,000 KWh/year

20%

2


3


4

2. View of the PV shading canopy.
3. PV canopy from inside.
4. Overal exterior view of the building.

For more information visit: www.stroomwerk.nl

Semi-Transparent
Commercial

Louvres

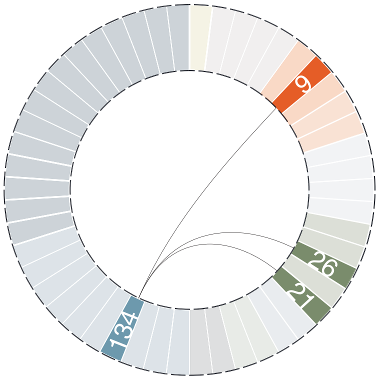
PURE TENSION VOLVO PAVILLION

Arch. SYNTHESIS DESIGN + FABRIC IMAGES
Location Not applicable (nomad installation)
2013

The Volvo pavilion is a lightweight, free-standing tensioned structure. It serves as portable movable charging station for vehicles. The structure form and function, as well as the PV integration are part of an experimental exercise. The structure and integration of the PV modules are the result of a development process between design, engineering and fabrication.

The structure for the pavilion is composed of a tensioned HDPE Mesh skin with embedded PV panels and a perimeter ring made of carbon fiber rods. The effect of the structure's organic form, perforated mesh, and PV transparent panels provide a striking language that engages the visitor and encourages interaction.

The fabric embedded Photovoltaic panels are light collectors from the sun or indoor artificial lighting, the power generated not only supplies energy for the operation of the pavilion but also charges the vehicle. The car will 'plug' directly into the pavillion's envelope, charging its battery with the energy collected over the day.



134	*Pure Tension Volvo Pavilion*
9	*Thin-film cells*
26	*Flexibility*
21	*Form*

1. Pure Tension Solar Pavillion iin display

1

3.6 kWp
30 m²

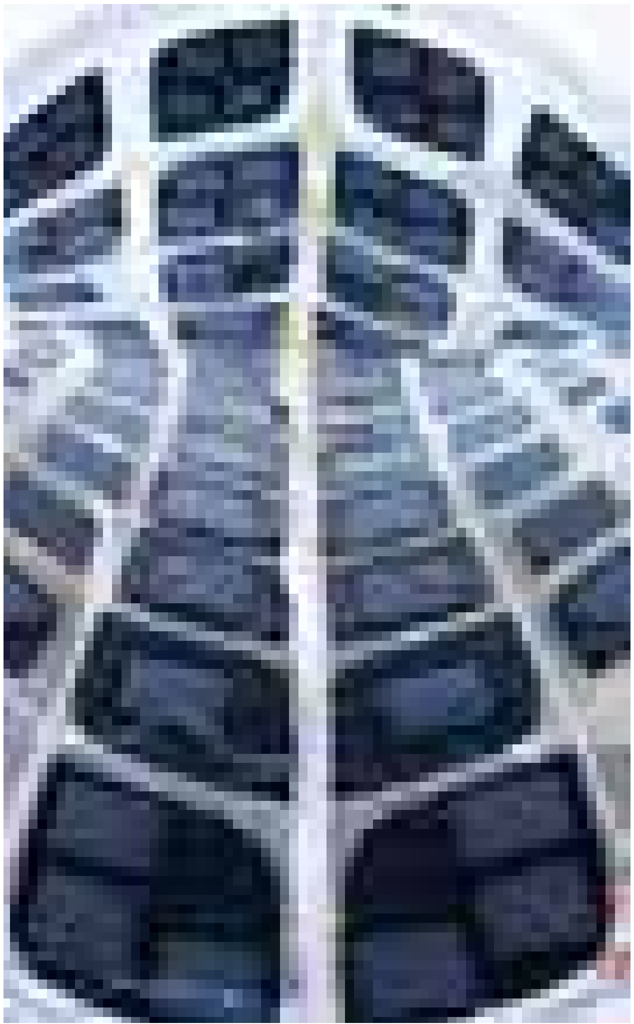
Not Applicable

COMPONENTS
Cell Type: Thin-Film
Module: Vynil Mesh Pattern

PV OPTIMAL TILT
Summer: Not applicable
Winter: Not applicable

ENERGY
Cell Efficiency: 5%
Energy Production: 3,060 kWh/year

5%



2


3


4


5

2. View of the different PV modules and electrical connections
3. Close up of the tensioned fabric and the PV modules
4. Overal view.
5. Side view.

For more information visit: www.synthesis-dna.com

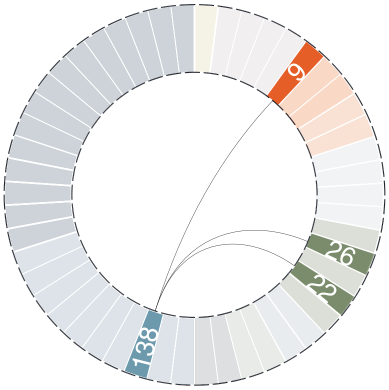
Semi-Transparent
Commercial

Cold
Facade

GREENPIX MEDIA WALL

Arch. SIMONE GIOSTRA & PARTNERS
BEIJING, CHINA
2008

The curtain wall system, called GreenPix Media Wall, is a digital media facade applied to the Xicui Entertainment Complex in Beijing. The facade is an interactive skin system with more than 2,000 color RGB-LED light points. It is the first photovoltaic system integrated into a glass curtain wall in this country. The LED lights are interactive and organically are coordinated to generate images. The wall absorbs solar energy during the day and illuminates in the night the 2.200 m2 screen using the same power.
The layout of the PV cells is coordinated with natural light interior requirements. At the same time it reduces overheating acting as shading. The PV cell are laminated in the translusccent curtain wall glass. All the components are supported by a steel substructure anchored to the rear load bearing building skin.

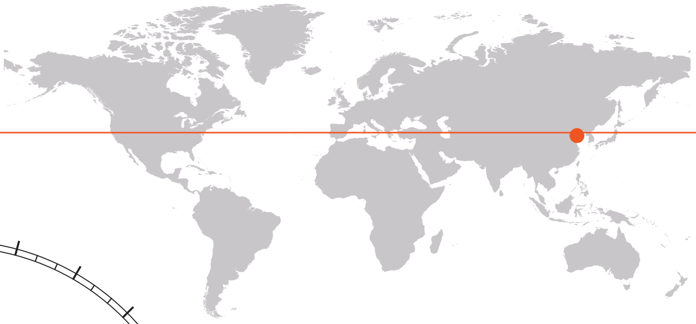


138	*GreenPix Media Wall*
9	Crystalline silicon cells
26	Colour
22	Size

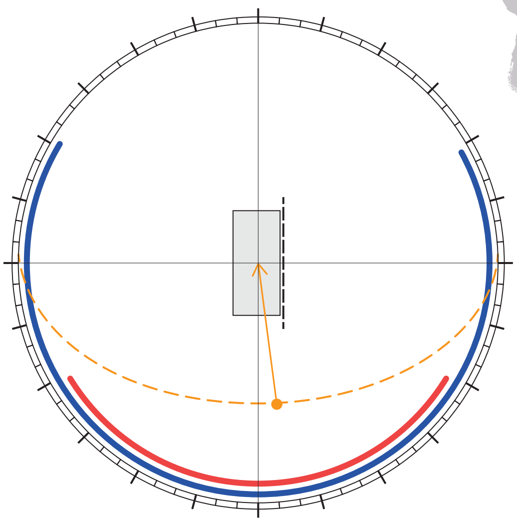
1. An example lighting pattern at night of the LED array.

1

79 kWp
534 m^2



39° 55’ N



COMPONENTS

Cell Type: Polycrystalline Silicon
Module: Lam. Frameless Glass

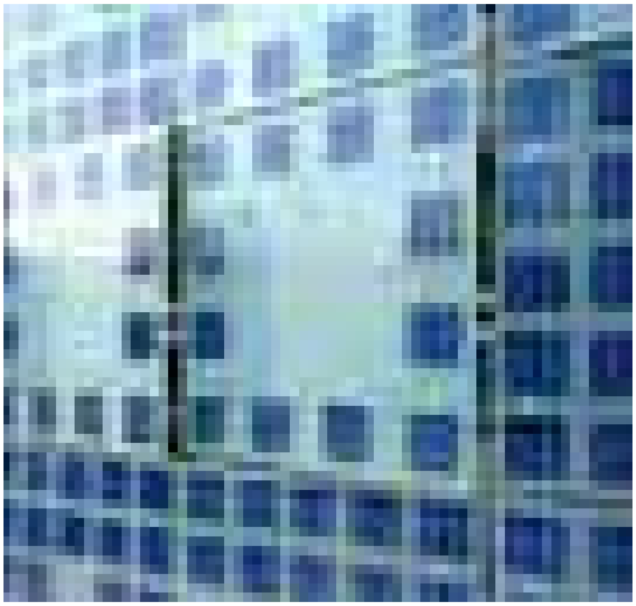
PV OPTIMAL TILT

Summer: 74.5°
Winter: 27.5°

ENERGY

Cell Efficiency: 20%
Energy Production: 38,929 kWh/year

20%



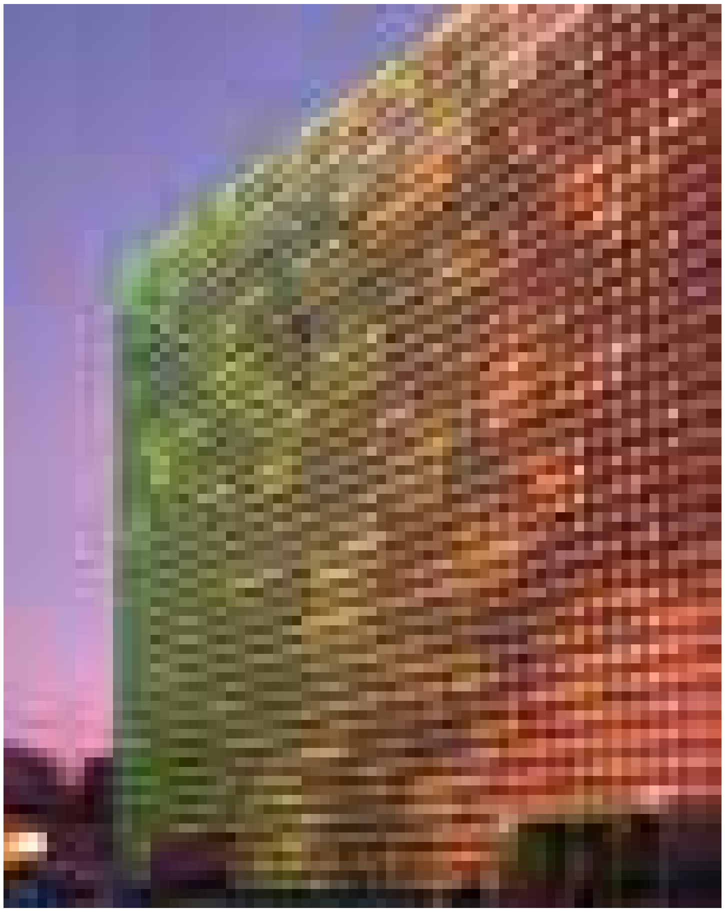
2

3

4

LEGEND

1. LED Mounting-support plate
2. Slotted holes in two directions for horiz. adjustment
3. LED mounting bar
4. LED
5. PV mounting bar
6. Shims to accommodate tolerances
7. Fabricated stainless steel brackets
8. PV Module



5

PV cells are laminated within the glass and placed with changing density on the entire building's skin.
The facade skin interacts with the building interiors and exterior public space, transforming the building into a responsive system for entertainment and display with zero energy cost, serving as example of energy efficiency. The photovoltaic arrays on the facade capture twice as much energy from the sun as the lighting facade consumes.

For more information visit: www.sgp-a.com; www.arup.com

2. Different types of glass laminate PV modules.
3. Modules side view
4. Plan detail for mounting LEDs and PV modules.
5. An example lighting pattern at night of the LED array.

Semi-Transparent
Commercial

Warm Facade

Flat Roof

CITE DU DESIGN

Arch. LIN ARCHITECTS
SAINT-ETIENNE, FRANCE
2014

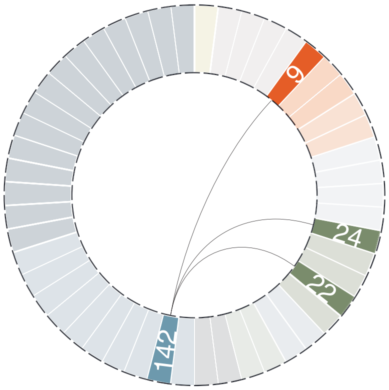
Situated in an obsolete arms manufacturing facility in Saint-Etienne, the recently unveiled Cité du Design is a stunning international center for design. Designed by LIN, the project completely renovated the historic complex and integrated a new facility made out of triangular scaffolding. Powered by solar energy and supplemented by an efficient heating system, the energy efficient Cité du Design is a world class design center that lives up to its name.

A latticed 3D structure forms the walls and roof of the complex, and the interior of the hall is left open without any supports or beams to get in the way. The 200-metre long building primary structure is a series of steel trusses that span the width of the building, allowing for a open space interiors.

The skin of the building is composed up of 14,000 equilateral triangles which are filled with eleven different modules . made from different materials that help to control light, temperature and air flow according to environmental conditions. The triangles either absorb or transform it into energy. Further, the facade triangles modules can exchange location and some are operable, supporting the fresh air intake of the building.

The combination of photovoltaic’s panels with under floor heating and cooling, thermally active pilings and filed containing 24 probes guarantees the energy supply.

The building envelope also provides a opportunity to experiment with technological innovation; at the moment, photosynthesis modules are being tested.



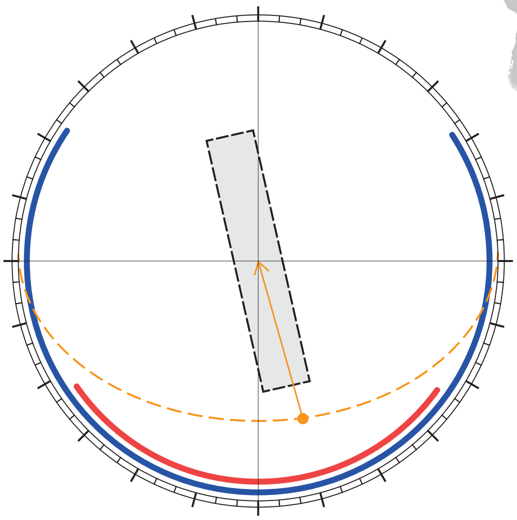
142	*Cite du Design*
9	Crystalline silicon cells
24	Opacity
22	Size

1. Aerial view of the site and building complex.

1

258 kWp
1725 m^2

45° 26’ N



COMPONENTS

Cell Type: Monocrystalline Cells
Module: Framed Laminated

PV OPTIMAL TILT

Summer: 68.5°
Winter: 21.5°

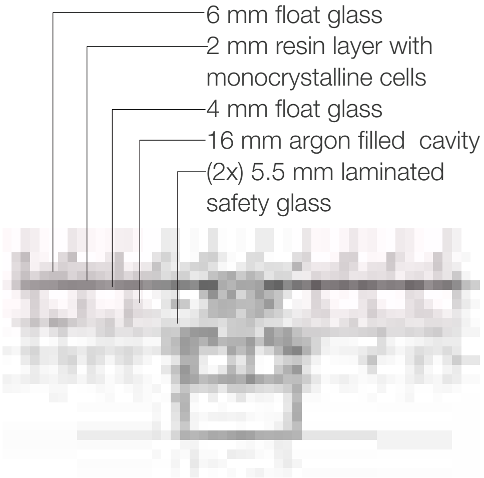
ENERGY

Cell Efficiency: 20%
Energy Production: 219,937 kWh/year

2

3

4



5

2. View of the different triangle modules
3. View of the roof
4. Interior view of the tPV cells in the riangulated modules
5. Photovoltaic Module detail section view .

For more information visit: www.schueco.com

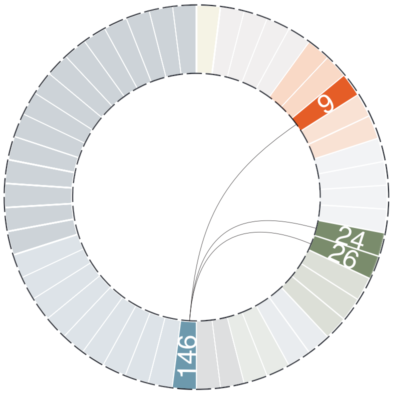
Semi-Transparent
Commercial

Warm
Facade

SWISSTECH CONVENTION CENTER

Arch. RICHTER DAHL ROCHA & ASSOCIATES
LAUSSANE, SWITZERLAND
2014

The SwissTech Convention Center, located in the Northern quarter of the École Polytechnique Fédérale de Lausanne (EPFL), in the area of the Lake Geneva Region, is a building of the new EPFL campus including housing for 516 students, retails and service areas and a hotel organized around a main public plaza. The Convention Center is the key protagonist thanks to its formal and expressive identity. The anodized aluminum roof, shaped like a catamaran, contrasts with the lightness of glassed façade below. This project is the first application of multicolored dye photovoltaic cells (Grätzel technology). The panels, installed as horizontal shading system in the western facade, are arranged in 65 colored columns, with 5 different shades of red, green and orange, providing a unique color tone to the light transmitted into the interior hall. The solar facade passively prevents overheating the of the entrance hall and actively produces renewable electricity from sunlight.



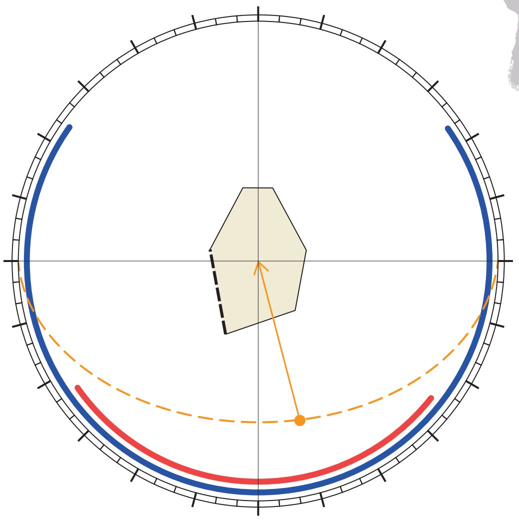
146	*Swisstech Convention Center*
9	*Nano cells*
24	*Opacity*
26	*Colour*

1. Corner view of the PV facade.

1

2.35 kWp
300 m²

45° 31' N



COMPONENTS

Cell Type: Dye Sensitized Cells
Module: Solaronix

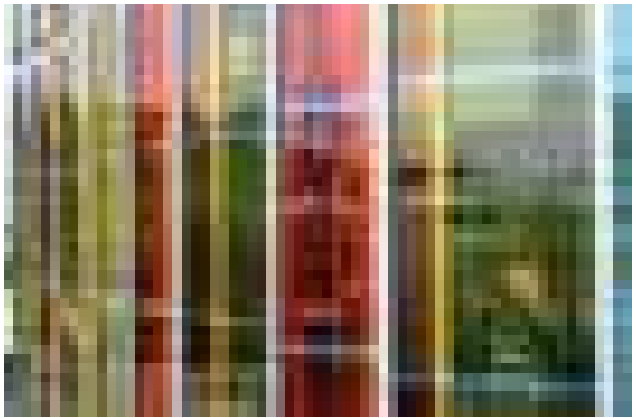
PV OPTIMAL TILT

Summer: 67.5°
Winter: 20.5°

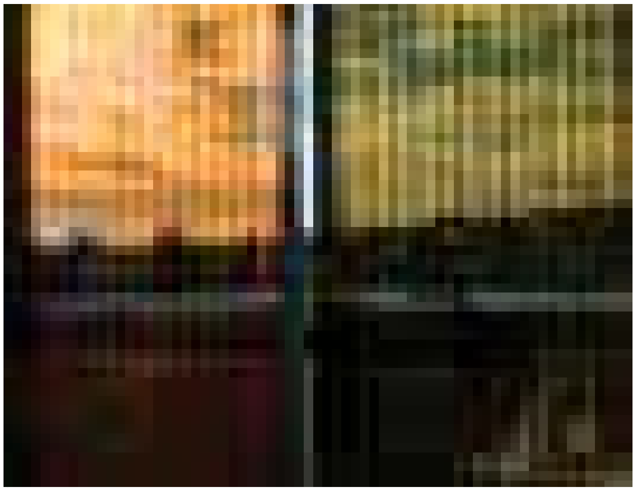
ENERGY

Cell Efficiency: 5%
Energy Production: 2,000 kWh/year

5%

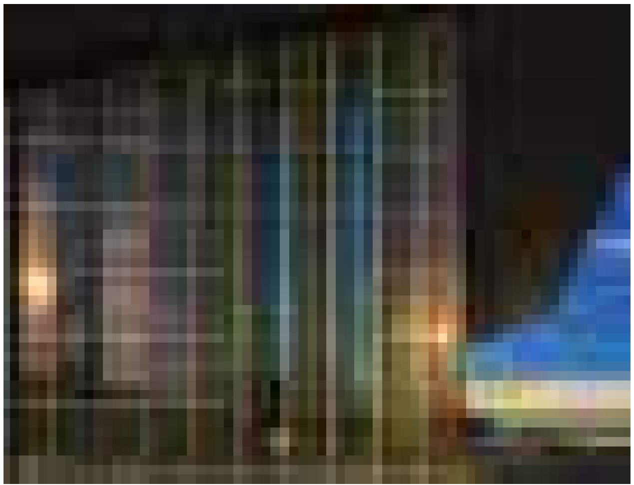


2



3

4



5

2. Close up view of the colored PV facade.
3. PV cells
4. Interior view of the PV facade.
5. Exterior view of the PV facade.

For more information visit: www.romande-energie.ch

Design Examples Statistics

General

This manual includes twenty-five case studies, which exemplify a varied selection of BIPV solutions. We have compiled a set of data on these systems. In this table we present specific information ina comparative manner that illustrates comparison of their energy output and performance.

How to Use the Table

The table objective is to depict in a comparative manner each case basic data associated with BIPV, this done by reviewing the performance of the design examples. Since one of the most important aspects that reflects performance is the output of a project, the table lists the projects in order from smallest to largest energy producer.

Case Study Name	Latitude	Annual average Solar Irradiance [kWh/m²·y]	Geographic Location	Cell Type	Degree of Transparency	Optimal Tilt Winter	Optimal Tilt Summer	PV Area	Peak Power kWp	Annual PV output [kWh/y]
IJsselstein Housing	52	700 - 1000	IJsselstein, Netherlands	Thin Film	Semi-transparent	14.5	61.5	30	1.8	1,530
VOLVO	N.A.	Not Applicable	Not Applicable	Thin Film	Semi-transparent	N.A.	N.A.	30	3.6	3,060
Weiber family house	47	1000 - 1300	Horgen, Switzerland	Mono	Opaque	19.5	66.5	37	6.5	5,525
Soft House	53	700 - 1000	Hamburg, Germany	Thin Film	Opaque	13.5	60.5	124	5.9	5,040
Kraftwerk B	47	1000 - 1300	Bennau, Switzerland	Mono	Opaque	19.5	66.5	261	32.0	32,000
Swisstech convention center	46	1000 - 1300	Lausanne, Switzerland	Poly	Transparent	20.5	67.5	300	2.4	2,000
Hofberg 6/7	47	1000 - 1300	Wil, Switzerland	Mono	Opaque	19.5	66.5	344	50.8	55,300
Fire Department	52	1000 - 1300	Houten, Netherlands	Poly	Semi-transparent	14.5	61.5	400	36.0	30,600
Paul Horn Arena	48	1000 - 1300	Tubingen, Germany	Poly	Opaque	18.5	65.5	420	43.7	37,145
Alan Gilbert Building	37	1600 - 1900	Melbourne, Australia	Poly	Semi-transparent	29.5	76.5	426	46.0	40,000
Heizplan Solar Park	47	1000 - 1300	Gams, Switzerland	Mono	Opaque	19.5	66.5	440	68.8	124,400
Romanshorn PlusEnergyBuilding	47	1000 - 1300	Romanshorn, Switzerland	Mono & Thin Film	Opaque	19.5	66.5	441	79.3	89,700
GreenPix	39	1300 - 1600	Beijing, China	Poly	Semi-transparent	27.5	74.5	534	79.0	38,929
Flumroc Headquarters	47	1000 - 1300	Flums, Switzerland	Mono	Opaque	19.5	66.5	816	146.9	117,504
California Academy of Science	37	1600 - 1900	San Francisco, USA	Mono	Semi-transparent	29.5	76.5	920	172.0	213,000
LA Cub	44	1000 - 1300	Bordeaux, France	Poly	Opaque	22.5	69.5	1250	225.0	191,250
Novartis Campus Gehry Building	47	1000 - 1300	Basel, Switzerland	Mono	Semi-transparent	19.5	66.5	1300	92.8	78,838
Cite du Design	45	1000 - 1300	Saint-Étienne, France	Mono	Semi-transparent	21.5	68.5	1725	258.8	219,938
Logistic Center V-Zug	47	1000 - 1300	Zug, Switzerland	Poly	Opaque	19.5	66.5	1800	271.0	230,350
Sanyo Solar Ark	35	1300 - 1600	Anpachi, Gifu, Japan	Mono	Semi-transparent	31.5	78.5	3450	623.5	530,000
Beijing South Railway station	39	1000 - 1300	Beijing, China	Thin Film	Semi-transparent	27.5	74.5	3750	390.0	180,000
Umwelt Arena	47	1000 - 1300	Spreitenbach, Switzerland	Mono	Opaque	19.5	66.5	5342	736.0	625,600
Riedel Recycling	52	700 - 1000	Morse, Germany	Thin Film	Opaque	14.5	61.5	9500	837.0	750,000
Stadio Bentegodi	45	1300 - 1600	Verona, Italy	Thin Film	Opaque	21.5	68.5	9600	999.0	929,000
Kaohsiung National Stadium	22	1300 - 1600	Kaohsiung, Taiwan	Poly	Opaque	44.5	91.5	14155	1341.2	1,140,000

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Image References

Part 1

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Part 2

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