IEA PVPS TASK 7
Activity 1.2 “Case studies”
Activity leader: Cinzia Abbate

Reporting Format

- Title of project: New Premises for Fraunhofer ISE, 20 kWp
- Typology of project: Office
- BIPV or retrofit application: Retrofit
- Team of project:

Client:
Fraunhofer Gesellschaft für Angewandte Forschung e.V.
Leonrodstr. 54
D- 80636 München
Email: info@zv.fhg.de
Website: http://www.fraunhofer.de

Project architects:
Dissing+Weitling Arkitektfirm,
Overgarden neden Vandet 45
DK-1414 Kopenhagen

Engineers:
Rentschler+Riedesser, Stuttgart;
Group „Solar Building Design“, Fraunhofer ISE

Contractors:

Raw structure construction:	Züblin AG
Steel constructions including shed roof PV:	Winterhalter Metallbau
Facade including PV of “Magistrale“:	Schneider Metallbau

PV electrical design: Fraunhofer-Institut für solare Energiesysteme ISE

User:
Fraunhofer-Institut für solare Energiesysteme ISE
Heidenhofstr. 2
79110 Freiburg
Germany
email: info@ise.fhg.de
web: www.ise.fhg.de

PV manufacturers:

Gobain Glass Solar GmbH
Jülicher Str. 495
D- 52070 Aachen
Germany
mail@SGGSolar.Vegla.de
Fax. +49-(0)241-9667-241

Flabeg Solar International
Muehlengasse 7
D- 50667 Koeln
Fax: +49-(0)221-2581117
mail@flabeg.com

BIPV installer(s):

Winterhalter Metallbau, Freiburg, Germany

Schneider Metallbau, Germany

Solarmarkt Freiburg, Freiburg, Germany

Time for design process:

Design of the various PV systems was done as part of the overall building design. It lasted therefore some 3 years.

Time for construction:

Building construction started in May 1998 and was completed in June 2001.
BIPV installation: 2 weeks, 4 weeks, 3 weeks for the different subsystems at different stages of the building process.
Total time: about 2 years

Figure 1: The new premises seen from south-east (photo: Guido Kirsch).
Source: Fraunhofer ISE, photo by Guido Kirsch
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Contact details for source: Hermann.Laukamp@ise.fhg.de

Information regarding the project

1. Brief of project:

Fraunhofer ISE is a research institute working on solar energy (www.ise.fhg.de). For many years its facilities were spread over some six buildings in an area of about 0,5 km². The new building brings these parts together and provides a modern research facility with up-to-date energy efficiency features and a healthy and pleasant atmosphere for its employees.
The building site is located on the northern edge of the central area of the City of Freiburg. It is a narrow lot extending in north/south direction.
Gross floor area of the building is 13 000 m², net use area is 6 500 m². One third of the latter area is used for offices, the remaining two thirds comprise laboratories and workshops. Cost of building construction and building services equipment is about 11 million EURO (1700 EURO/m²).
The building was completed in July 2001.

The building combines a high-quality working environment and a high functionality with a low energy consumption and a high design quality.
Most of the building complex is three storeys high. It consists of three parallel building wings connected by an access tract, which is adjacent to a technical prototype laboratory. The comb structure and the interior zoning were deliberately chosen to achieve south-orientated offices for maximum daylighting.
Thermal insulation, solar control, lighting and ventilation technology have been designed for a minimal energy demand. Energy demand for the offices is planned to stay 35 % below the current building code requirements.

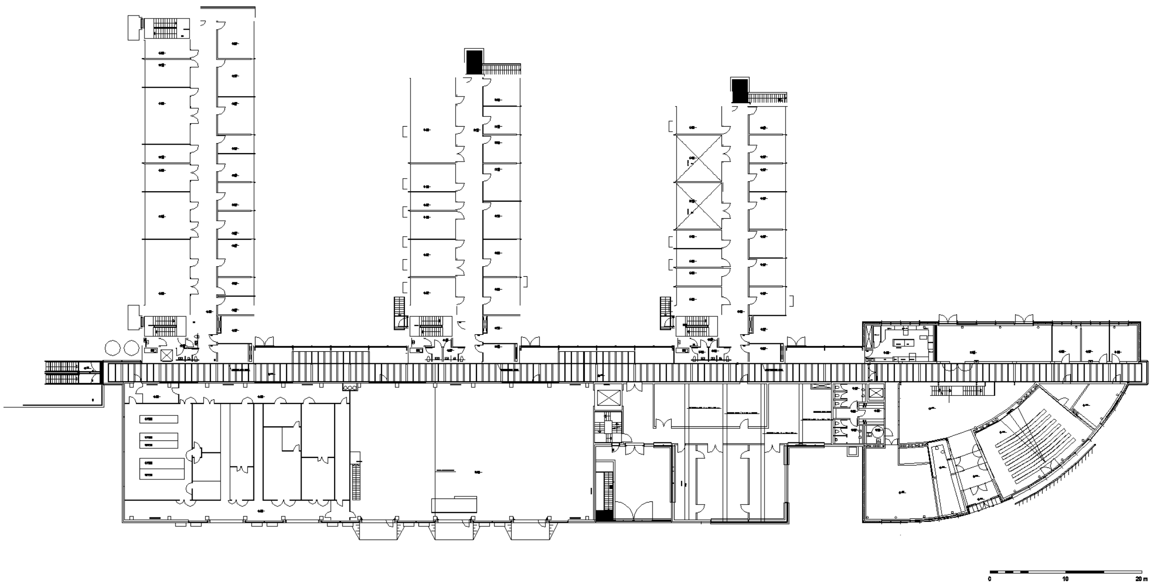

Figure 2: Horizontal section of the building´s ground floor.
Picture title: horizontal section of the building´s ground floor.
Source: Dissing + Weitling
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SOLAR DESIGN FEATURES

The comb-like ground-plan (see figure 2) and the separation between the wings were chosen on the basis of minimal shading, good daylighting conditions, comfortable summer temperatures, passive cooling, passive use of solar energy and, last but not least, a pleasant indoor atmosphere (pronounced horizontal transparency). The main entrance foyer is dominated by an atrium with a saw-toothed roof and integrated PV modules.
External venetian blinds with a light-redirecting function provide solar energy flux control.
An underground heat exchanger cools or pre-heats the inlet air for ventilation of the entrance block. The building mass is cooled down in summer by active nocturnal ventilation.

Selection of the »wings« as the basic design approach was done after an evaluation of three different concepts. The evaluation was guided by the aims of energy efficient building and high indoor comfort. The evaluation scheme is given in table I.

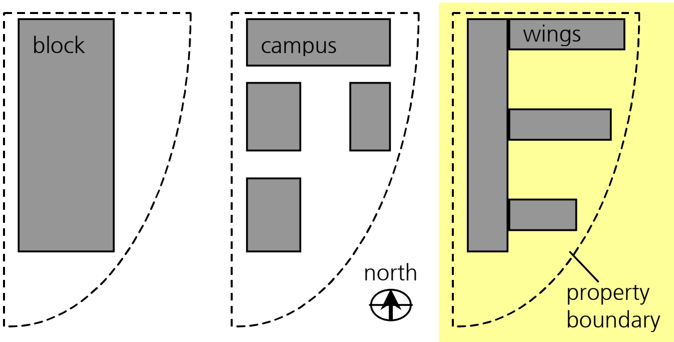

Figure 3: The three evaluated design concepts.
Source: *Fraunhofer ISE*
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Table I :Matrix for evaluation of building concepts

criterion	block	campus	wings
indoor climate	-	0	+
daylighting	-	0	+
energy consumption	+	-	0

The chosen concept has proven its value in similar applications and is appropriate to the pronounced north/south orientation of the lot. The three building wings are oriented east/west and are widely separated to allow daylighting. The offices, which are not air-conditioned, are located on the sunny side, while the air-conditioned laboratories are on the shady side. The flat roofs of the wings have been designed to function as outdoor test areas. The wing structure and the internal distribution of zones combine passive use of solar energy for heating in winter (sun low in the sky) with low over-heating loads in summer (sun high in the sky). A central access tract extends more than 130 m in the north/south direction and protects the inner courtyards and the wing facades from the summer afternoon sun. An entrance block at the southern end of the access tract houses the administration and central services. The technical prototype laboratory, clean room and workshops adjoin the access tract to the west and educe heat gain into offices from westerly sun.
In the context of an energy efficient building the PV systems produce as much electric power as needed to light the offices on an annual basis.

The building structure consists of a steel-concrete frame with ceilings/floors and vertical supports. The functional and design concept for the facades reflects the planners' reaction to the building purpose, orientation and cost parameters:
• Curtain walls as a dominant design element of the entrance block and the southern facades of the wings, with steel facing panels. The construction material is wood, with compound

wood/aluminium window frames. The thermal insulating material in the spandrel areas is 160 mm thick.
• Continuous window and spandrel bands on the northern wing facades and the entire technical prototype laboratory. Compound wood/aluminium window frames and combined external insulation and finish panels are applied here.
• Glass facade with wood/aluminium framework for the access tract.

The overall approach to the project is based on the respect for the environment. All the materials used for the construction are either recycled or recyclable and non-toxic. Aluminium as facade cladding material was abandoned, because of its high embodied energy and low recycling fraction.

The PV generators demonstrate different aspects of building integration (see figure 4 and table II).

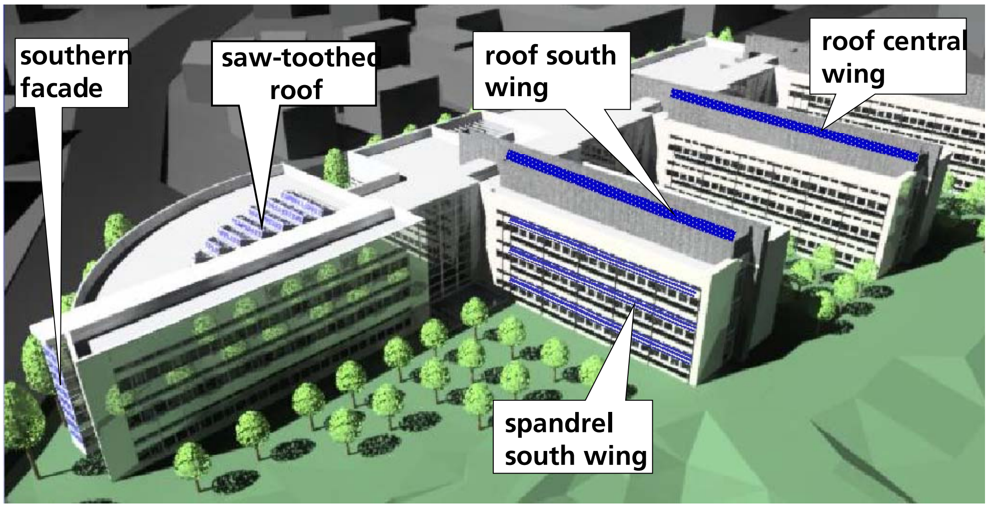

Figure 4: Computer animation of the new building with its five photovoltaic systems .
Source: Fraunhofer ISE, computer animation by Peter Apian Bennewitz
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Table II: Position and rated power of the PV systems

Position	**Power [kWp]**	**mounting**
Facade access tract	2.4	heat insulating glazing
Saw-toothed roof	5.0	heat insulating glazing
Spandrel south wing	3.9	vertical + inclined spandrel (in planning)
Roof southern wing	4.5	flat roof
Roof central wing	4.8	flat roof

In the southern facade and the saw-toothed roof, the solar cells are encapsulated within double glazing. They reduce the heat gain to the building and support the efforts to dispense largely with conventional air conditioning. The generator on the facade of the southern wing will demonstrate the application of photovoltaic modules as spandrel elements in vertical and tilted configurations. This array is still (November 2001) in the procurement phase. The generators on the roofs of the southern and central wings serve as cladding for the ventilation shafts behind them.
In the context of an energy efficient building the PV systems produce on an annual basis as much electrical power as needed to light the offices, about 15 MWh.

2. Description of the area, and its urban context:
(How the site analysis has influenced the project, its morphology, and so on...)
The building site is a narrow lot extending in north/south direction. The urban surrounding is of mixed use. To the north another research institute is located, to the south apartment buildings along a road are situated. To the east a railway rack limits the lot and to the west a road, followed by residences and a distribution center for a soft drink company.
The shape of the lot is reflected in the building´s shape (fig. 2).
Surrounding buildings are mostly limited to a height of three storeys, which was set as limit for the new building.

3. Climate considerations and energy demands of project:
Latitude: 48 ° north
Longitude: *7*.5° east
Altitude: *275* meters above sea level
Climatic type: moderate (Temperature: January av. = 1,8 degrees; July av. = 19,5 degrees)
Sunshine hours: Yearly average = 4.8 hours; 1100 kWh/m² horizontally

The aims of the energy concept, which combines energy saving and efficient energy supply, are to achieve a heating demand which is 40 % lower than that required by the legal regulations for building insulation. Furthermore, we wanted to prevent an increase in the total demand for primary energy compared to the present situation, although the equipment and functionality of the laboratories and workshops have been upgraded significantly. In the new building, much of the process cooling will be integrated into a central cooling system rather than using mains water and air cooling as at present.
The investment costs are almost twice as high as for a conventional energy. However, the annual costs for energy supply are lower due to the consumption costs being 15 % lower. The amortisation period is expected to be eight years.

Because of the high electricity demand throughout the year for the clean room, laboratories and workshops (including electric diffusion ovens with 300 kW power rating), the choice of an in-house, heat/electricity co-generation plant was obvious. A pre-requisite for its success is that the waste heat can be used throughout the year. This is achieved by combining a gas-powered heat/electricity co-generation plant with an absorption cooling machine to form a power/heat/cooling complex (fig. 5): Whereas the waste heat is used in winter for room heating, it can also be converted to cooling power for air-conditioning as needed. An auxiliary compression chiller and a gas-heated boiler allow the system to respond to power demand fluctuations. Despite the favourable operating conditions, the system only becomes economically viable once the high priority of protection against power failures is taken into account: The co-generation plant operates during a grid black-out as an emergency power supply and reduces the investment that would otherwise be needed for this function.

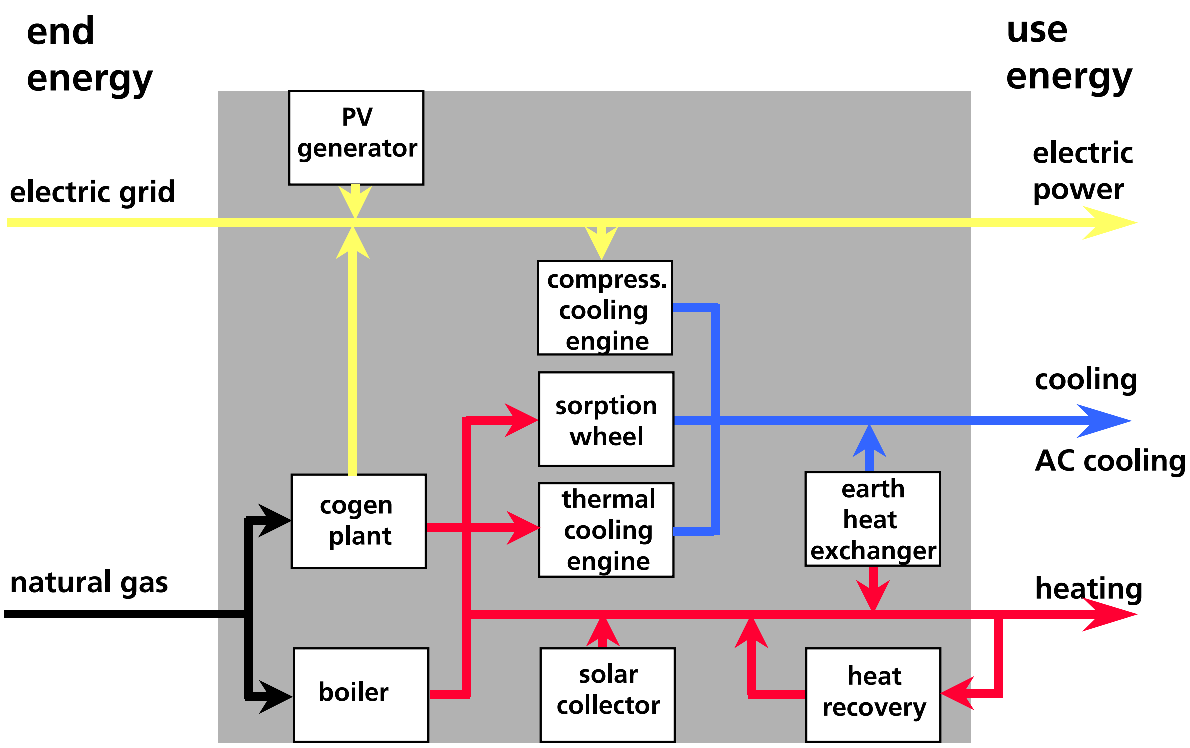

Figure 5: Energy concept of the new building.
Source: Fraunhofer ISE
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Contact details for source: Hermann.Laukamp@ise.fhg.de

The photovoltaic systems, with an annual yield of around 15 MWh, will meet about the entire demand for office lighting in the new building. Electricity for lighting is planned at 7.7 kWh/(m²a). For 2000 m² office area this amounts to 15 400 kWh annually.

Fig. 6 illustrates this relation from the perspective of the primary energy. It lists primary energy demands for a conventional new office building in Germany and for Fraunhofer ISE´s new buildings. The loads included are those to be planned beforehand, occupant specific loads are not considered.

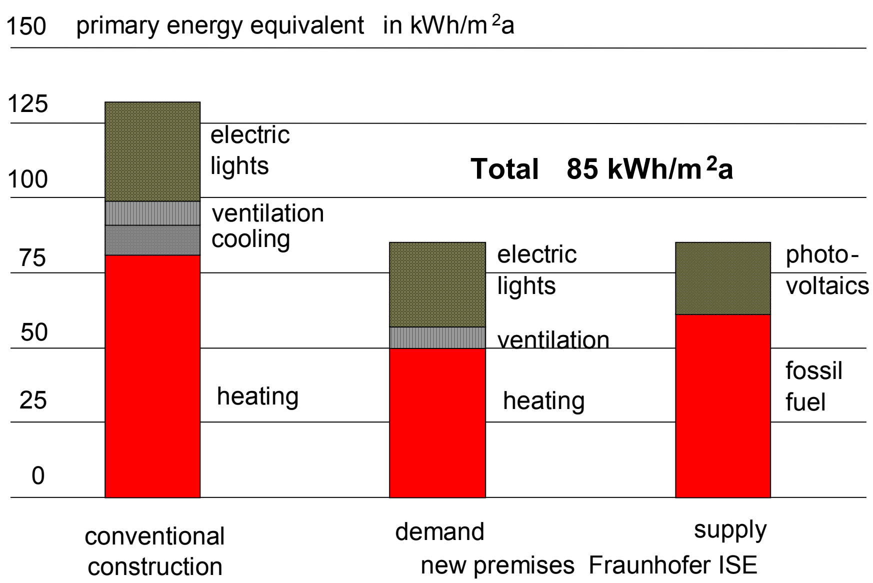

Figure 6: Specific energy consumption and supply of the new building (center and right column) in relation to the energy consumption of a conventionally planned German office building (left column) from the perspective of the primary energy.

Assuming a conversion factor for primary energy to electric power of 0.33 the PV systems will contribute a significant amount of the offices primary energy consumption despite their moderate size.

4. City restriction, code or regulation:
The process for approval was the standard. The height was limited to three floors above ground. For the PV installation regular standards for glazing were applied.

5. Short description of the bureaucratic procedure phased to obtain the building permits:
In the preplanning phase a detailed planning with detailed budget plan had to be developed, because the building was financed by state and federal government. These governments require a budget plan, which they have to approve.
The building permit followed the standard process, the city building department and fire department were involved. Because of the public character with many occupants and visitors high safety requirements are posed and the fire department had to be involved.

6. Client requests:
The client wanted to demonstrate PV on its new building. He wanted to demonstrate various methods of building integration. And he wanted to demonstrate a holistic approach to integration covering architectural, functional and energetic aspects. Especially PV modules as part of heat insulating glazing and as part of a overheating protection scheme should be demonstrated.
In the southern facade and the saw-toothed roof, the solar cells were encapsulated within heat insulating (double) glazing. They reduce the heat gain to the building and support the efforts to dispense largely with conventional air conditioning. Saw toothed roof and south facade employ effects of translucent PV modules and use the shadow of the solar cells in the building interior as an architectural element.
The generator on the facade of the southern wing will demonstrate the application of photovoltaic modules as spandrel elements in vertical and tilted configurations. This section of the generators is still (July 2001) in the planning phase.
The PV arrays on the roofs of the southern and central wings serve as cladding for the ventilation shafts behind them.

7. Describe the project team:
The client was Fraunhofer Society, which was the legal partner in all contracts.
The building department of the Fraunhofer Society is responsible for the overall project management. They especially oversee the budgets and the compliance to federal and state budget controlling regulations. The future user, Fraunhofer ISE, worked closely with the client to ensure that its needs were met.
The architect co-ordinates the work of the engineering experts. He has full power with regard to the design (»Gestaltung«), the appearance, of the building.
The engineers specialising in the different aspects, including those from Fraunhofer ISE for energy, building science and indoor comfort, have direct commissions from the building owner.
A building specialist representing the users is involved in the whole planning process.
The contractors have received contracts for a certain part of the whole building work, usually defined along trade boundaries. Among their responsibility was the procurement and mounting of the PV modules and wiring including the respective array junction box. This is a crucial feature, to achieve well defined limits of liability. Thus, there is one party responsible for the quality of the facade and the shed roof, respectively, including the PV array.

Realisation of the building was controlled by the architects who also had the supervising role for all trades.
Fraunhofer ISE was closely involved in the overall planning as well as the building services design through its »solar building design« group. Structural engineering, landscaping, building services planning and clean room planning were performed by external companies.
During construction the design team met at least once a week to discuss progress, problems and solutions.

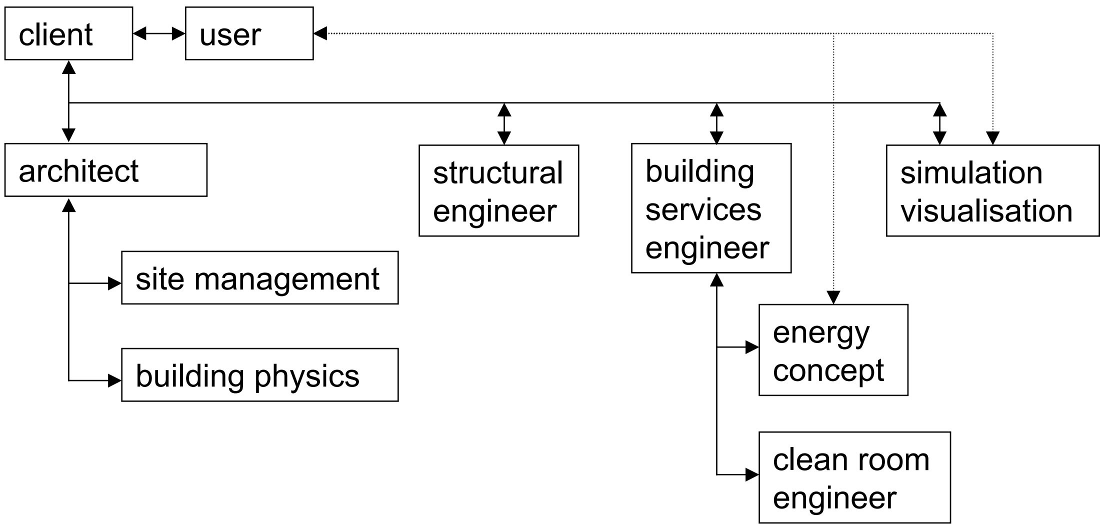

Figure 7: The project team and its relations.

8. Functional and technical issues:

8.1 Facade of Access Tract

This PV generator serves as an »eye-catcher« for visitors coming from downtown. It employs EFG cells with their rather homogeneous appearance in a large area module. The cells reduce the heat gain of the south facing glass facade.

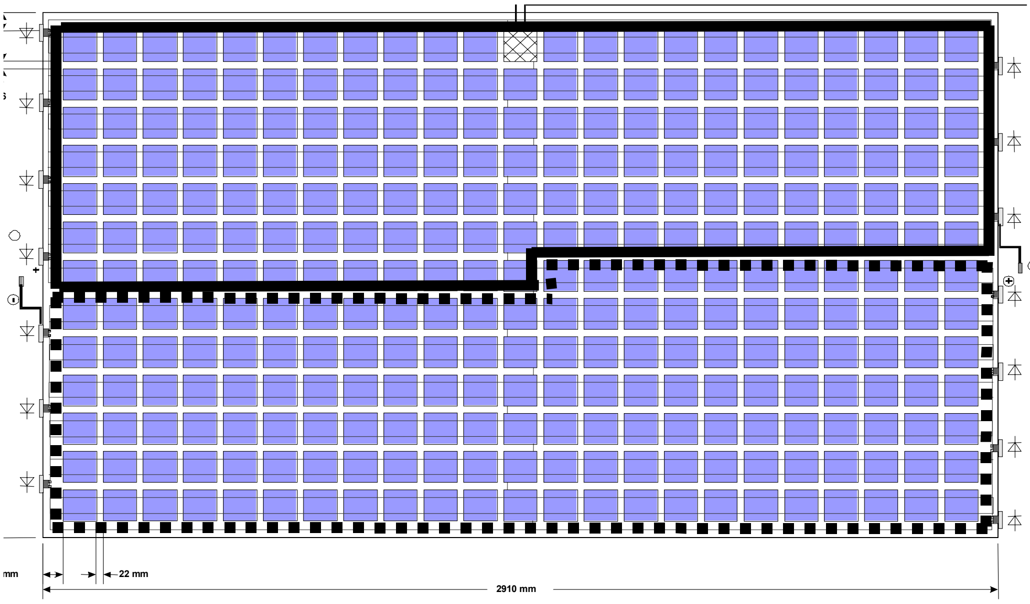

Figure 8: Drawing of the facade module, 299 cells, 400 Wp, 2 x (87 V, 3 A). The electrically independent submodules are marked for better distinction. Uneven numbers of rows and columns demanded an asymmetrical internal wiring. The cell in the upper row, center column is a sensor cell for irradiance measurements.tract.

Picture title: Drawing of the facade module. It is a 299 cells, 400 Wp module.
Source: Flabeg Solar International
Copyright issues: ok
Contact details for source: helau@ise.fhg.de

The cells were chosen as a compromise between the homogeneous, dark appearance of mono-crystalline cells and the lower cost of poly-crystalline cells. Additionally, the manufacturer, RWE Solar, claims a lower embodied energy compared to other wafer technologies.

The facade is subject to shading from nearby trees and a building on the other side of the street. Therefor we designed the module in close co-operation with the manufacturer, Flabeg Solar International, as well as the string wiring to minimise shading losses.
Each module consists of two horizontal submodules (fig 8), thus reducing the area simultaneously affected by partial shading Three submodules are connected to form one string of 260 V Voc (fig. 9). The lower and the upper part of the facade form two independent subsystems with one inverter (SMA, 1100 W) each.
Due to the architects wish of uneven numbers of columns and rows, a special asymmetric wiring was developed to utilise all cells. A vertical partition – not indicated in Figure 8 - was necessary to limit the number of cells per bypass diode.
The wiring is run in a vertical duct at the eastern edge of the construction on the building outside. Inverters are mounted in the basement below the facade.

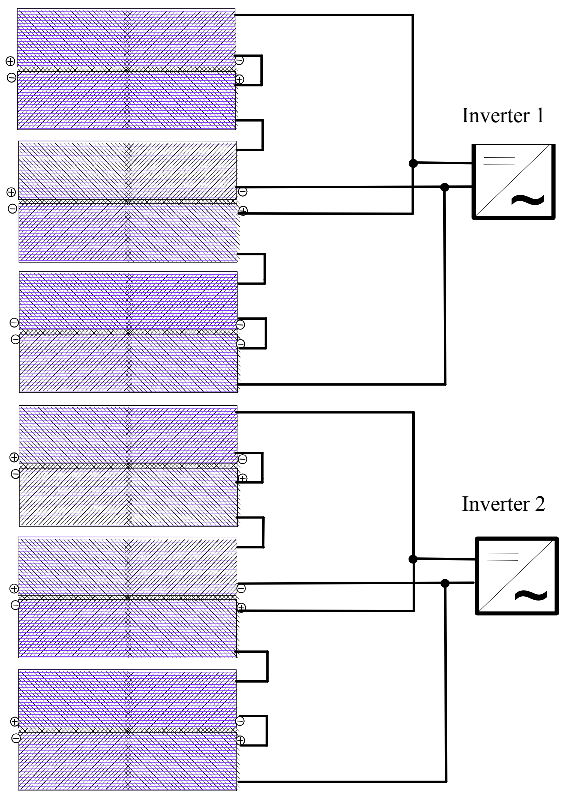

Figure 9: Wiring and position of strings in the access tract facade.
Source: *Fraunhofer ISE*
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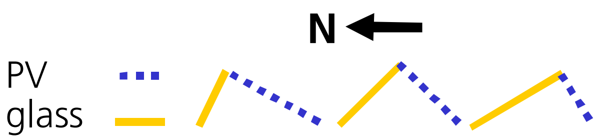
8.2. The saw-toothed roof of the atrium

The saw-toothed roof over the atrium offers some 70 m² of area for PV modules. It is a good example to illustrate the design process. The table in the following figure illustrates the optimisation of the saw-toothed roof geometry as part of the building concept.
Good daylighting conditions are essential for the use and the aesthetic effect of an atrium. On the other hand, enormous overheating would arise in summer, if transparency is high and there are no shading elements. We carried out simulations for the indoor thermal and daylighting conditions to take into account both aspects. Electric power generation, daylighting and protection from overheating in summer were balanced. This optimisation was mainly driven and carried out by Fraunhofer ISE´s design team.
The first geometry of figure 14 was chosen yielding an inclination of the shed-skylights near the optimum of 35 degrees.



electric power	+	0	-
daylighting	-	0	+
indoor temperature	+	0	-

+ = favourable, - = unfavourable, 0 = neutral

Figure 14: **Evaluation of different geometries of the shed roof structure. The slope of the photovoltaic generators on the saw- toothed roof is adapted to the energy concept of the building. Electricity generation, daylighting and reduction of heat gains to the atrium in summer were taken into account when optimising the construction.**

Picture title: Evaluation of different geometries of the shed roof structure
Source: *Fraunhofer ISE*
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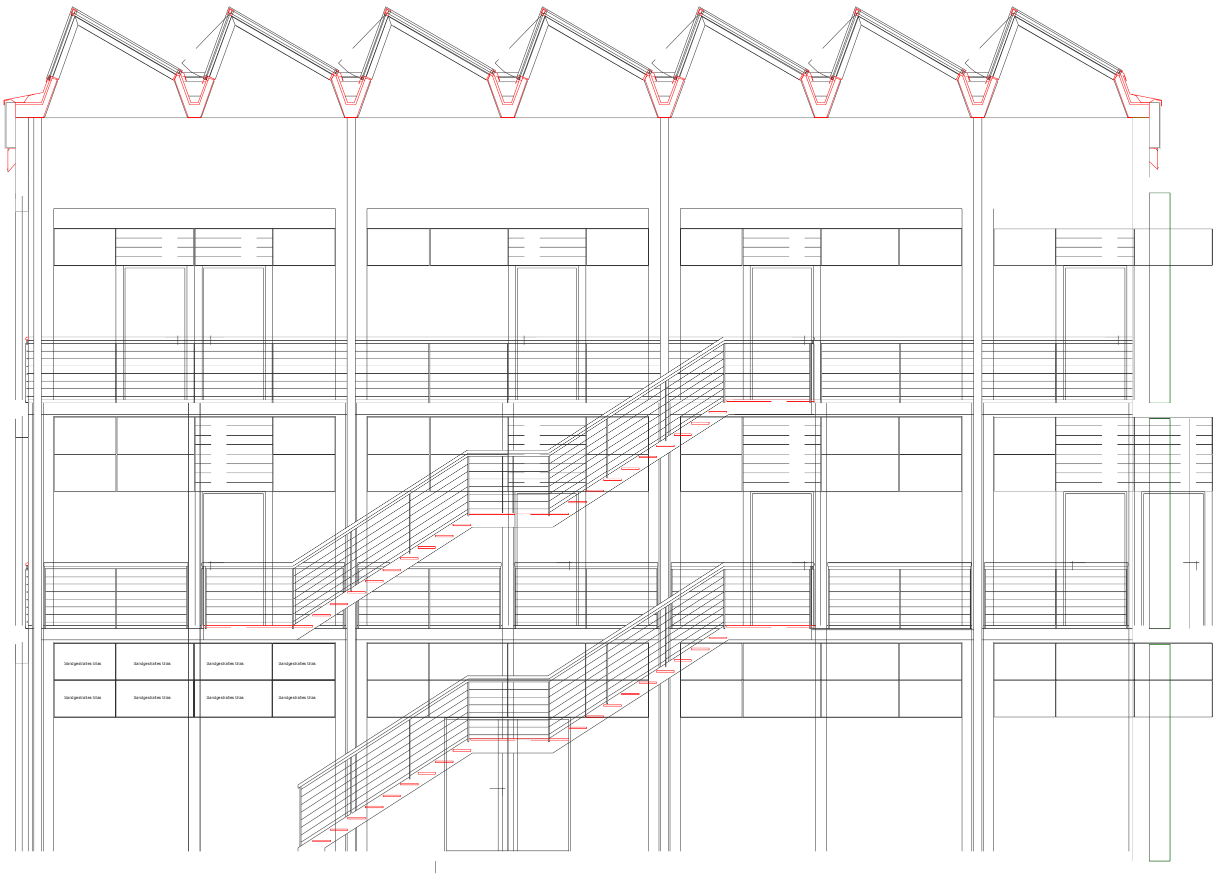

Figure 15: Cross sectional view north-south through the atrium. The building design grid with its base dimension of 625 mm and the geometry of the »saw teeth« determine the module dimensions.
Picture title: Cross sectional view north-south through the atrium..
Source: *Dissing + Weitling*
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Glazing is born by a steel support structure which holds a sort of mullion/ transom stick construction. Modules are placed on sealing rubber stripes and fastened by a screwed cover profile (see figures 27 ... 33)

Figure 17: view from above on the saw –toothed roof. The blue areas mark the PV modules. Between the module rows the north facing glazing can be seen.
Picture title: view from above on the saw –toothed roof.
Source: *Fraunhofer ISE*
Copyright issues: ok
Contact details for source: helau@ise.fhg.de

Module design
Module design was guided by :

- architectural design considerations
- electric power production
- heat gain reduction
- daylighting

The building design grid and the geometry of the »saw teeth« determine the module dimensions. The basic shape of the structure had been fixed according to the optimisation illustrated by figure 14
From that, the basic dimensions were set to be about 590 mm by 1900 mm.
Further requirements for the modules were: cells from a partner company, a TSET value below 30 % and light transmission above 15 %. The cell type was not important, but the rear view was, since the cells are visible from below and not from the front.
After the basic dimensions had been defined, modules were designed.
Initially 3 drafts were discussed (Figure 18). Eventually the cell “SHELL”, 125 x 125 mm² was chosen and then the lay-out and the electrical circuit was designed.

The architects opted for large gaps between cells for transparency and the design was fixed as shown in figure 19. A TSET value of about 30 % was achieved

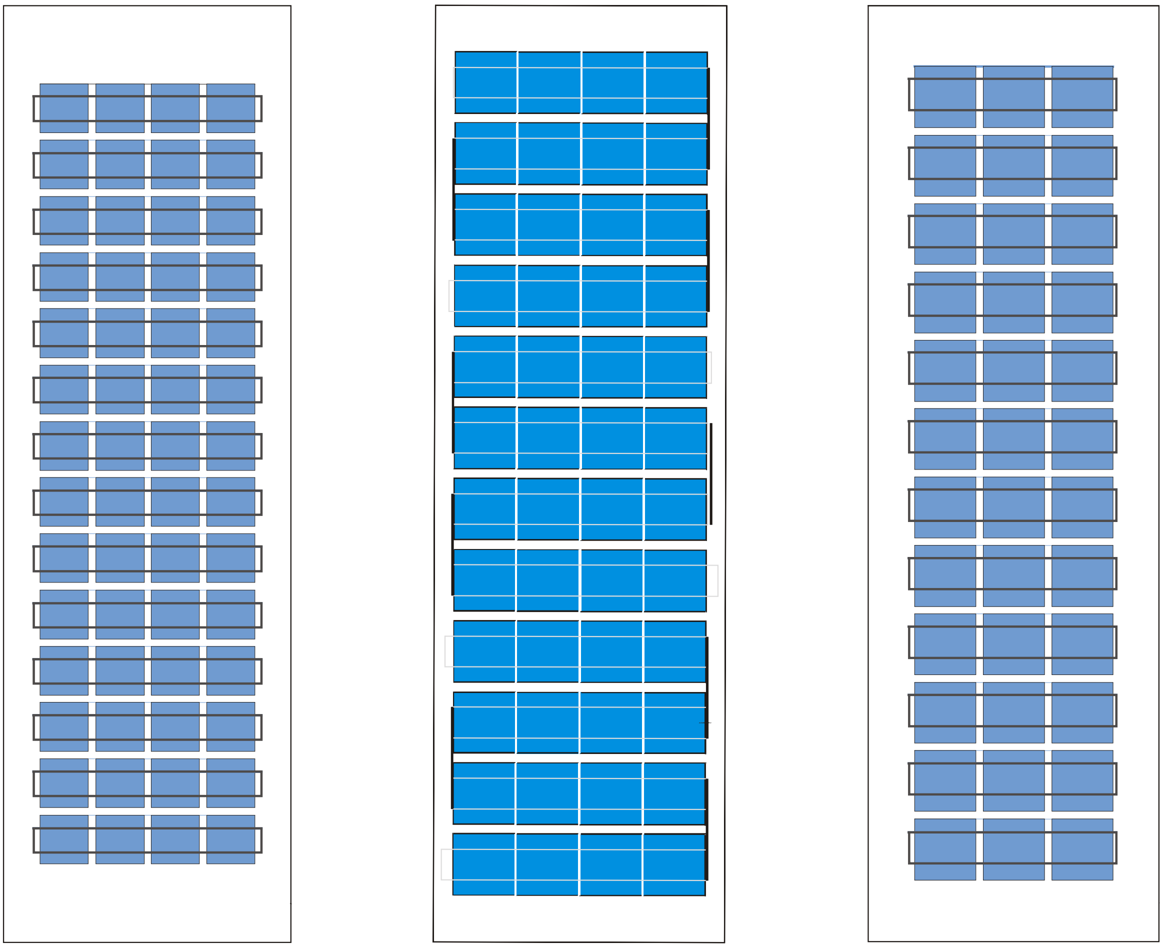

Figure 18**: Various module designs considered; left: 100x100 cm2 cells, center: 125 x 125 mm² cells, densely packaged, right: 125 x 125 mm² cells, 20 mm distance between cells**

Picture title: *Shed roof* - Various module designs considered
Source: *St. Gobain Glass Solar*
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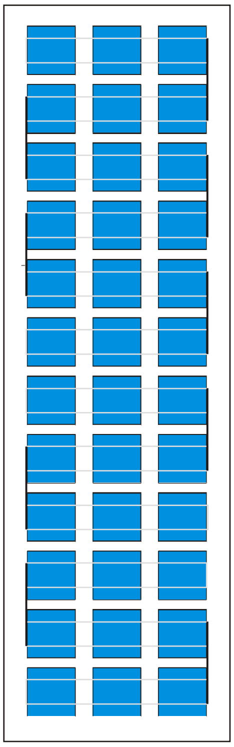

Figure 19**: This was the final module design.**

Picture title: *T*he final module design.
Source: *St. Gobain Glass Solar*
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Contact details for source: helau@ise.fhg.de

Optimising the electrical design

After optimising the geometry of the PV modules the design of the electrical circuits including the PV modules was optimised to take into account the partial shading by the southern sheds. (Figure 20). Following a proposal by the module manufacturer, St. Gobain Glass Solar, the modules were split in three submodules (figure 21). The submodules were designed according to the rule of thumb for open field arrays – at winter solstice noon the shadow of the front row shall just fall below the rear module´s lowest cells.

The module is constructed as heat insulating glazing with a gas filled space between front and rear pane (figure 22).

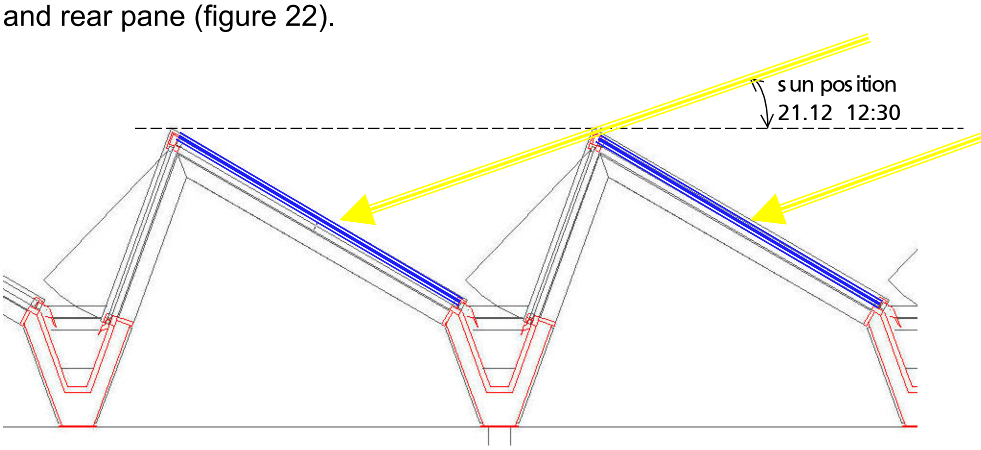

Figure 20**: Shading of the rear rows by front rows. The upper half of a module is not shaded at winter solstice.**

Picture title: Shading of the rear rows by front rows.
Source: *Fraunhofer ISE / Dissing+ Weitling*

Copyright issues: ok
Contact details for source: helau@ise.fhg.de

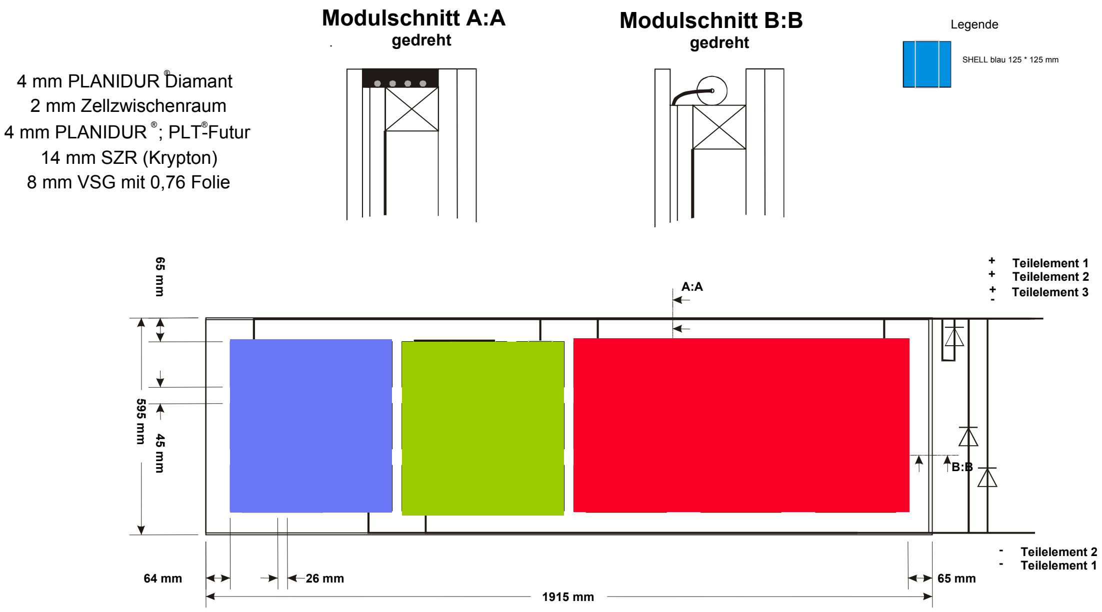

Figure 21**: Construction of the modules. The submodules are marked by different colours. Bypass-diodes for each submodule are mounted at the upper edge. The modules need a special two-layer back pane, because they are mounted »overhead«.**

Picture title: Construction of the modules.
Source: *Fraunhofer ISE*
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String Wiring

The module lay-out as well the wiring was designed to allow a flexible inverter concept (figure 23). We can use string inverters as well as a central inverter. Slight asymmetries in the data of the strings due to differing numbers of cells in series are neglegible compared to the influence of turbulent winds and different natural ventilation.
Table 3 gives a summary of the electrical data of the array.

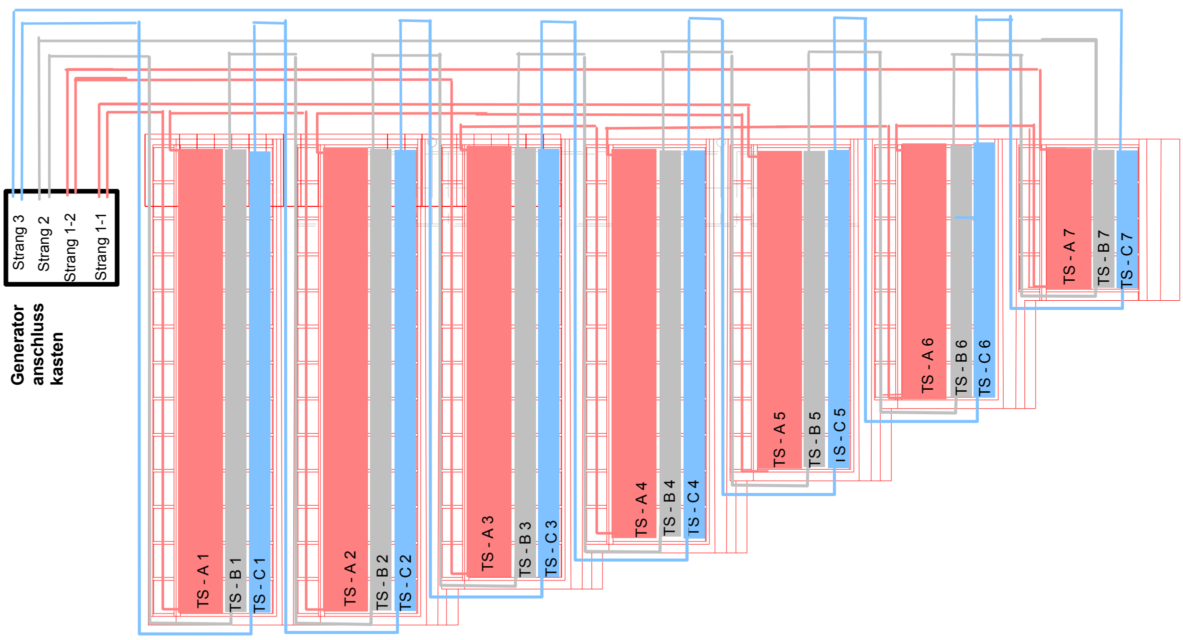

Figure 22: The wiring of the array. Despite the irregular structure of the shed roof an even distribution of modules per string could be achieved.
Picture title: Array wiring
Source: *Fraunhofer ISE*
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8.3 Cladding elements on the wings´ roofs

The PV arrays on the roofs of the southern and central wings serve as cladding for the ventilation shafts behind them. They employ standard modules in a standard mounting structure. These modules replace an initially planned sheet metal wall. The cost for the support structure is completely recovered from the saved sheet metal wall.
This idea was developed during the construction process after the north wing had been nearly completed. It had not been included in the original »call for tender«. Therefore, only the later parts of the building, central and south wing, benefited from this idea.

Support Structure

Concrete elements above the structural members of the building structure bear galvanised steel frames. These are inclined at 30°. On these frames a mounting structure Type »AluTec« is screwed which holds the modules of Type ASE - 100 -GT-FT in place (figure 8). This module was chosen by Fraunhofer ISE, because it employs the same cells (ASE EFG 100x100) as are used in the access tract facade and it also fits well into the available geometric boundaries.

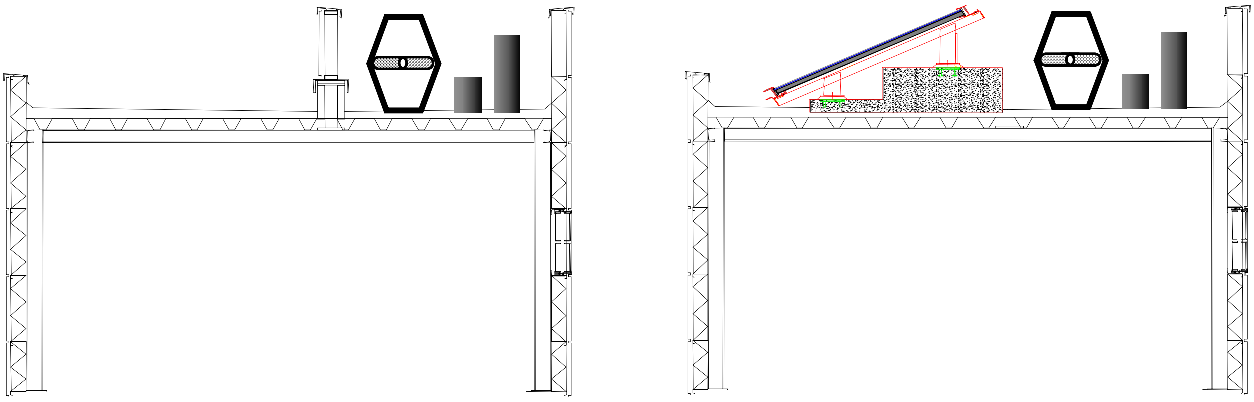

Figure 23**: Sectional view of the sheet metal wall on the wings and its replacement by a PV array.**

Picture title: The PV array replacing the cladding of the ventilation equipment.
Source: *Dissing + Weitling*
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Contact details for source: helau@ise.fhg.de

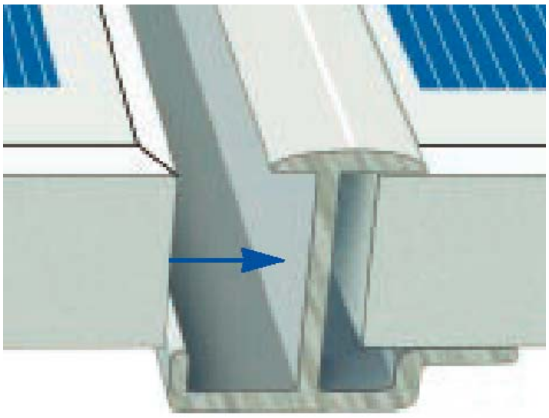

Figure 24**: Principal function of the AluTec profile. A module is slid between an upper and a lower mounting rail and kept in place by a protruding edge.**

Picture title: *Principal function of the AluTec profile.*
Source: *TESSAG*
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Contact details for source: ewald.koch@ase.tessag.com

9. Description of the PV structure as built:

9.1 Facade of Access Tract

Figure 25**: The south facade after completion**

Picture title: The south facade after completion
Source: *Fraunhofer ISE*
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Contact details for source: helau@ise.fhg.de

Figure 26**: View from inside through the south facade.**

Picture title: The south facade after completion
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9.2 Construction of the Saw-toothed Roof over Atrium

The installation followed standard glazing procedures.

Figure 27:

Modules were delivered in crates onto the roof by a crane. From there they were transported manually onto the shed structure...

Figure 28:

and placed on the sealings.

Each module weighs about 50 kg.

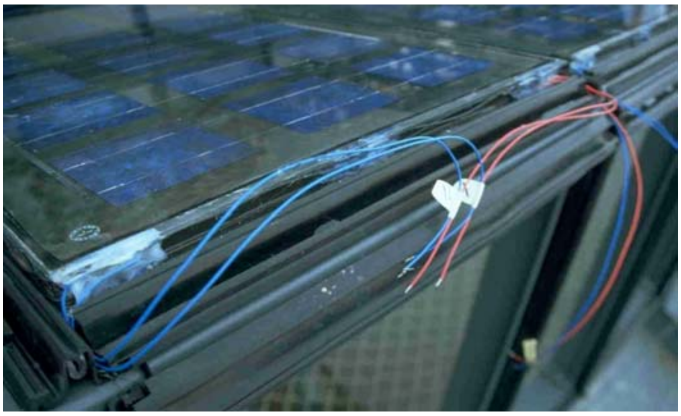

Figure 29:

A close view on a module after it had been placed onto the sealings. Connection wires of two sub-modules are clearly visible.

Figure 30:

Cover profiles are mounted to secure the modules against up-lift winds.

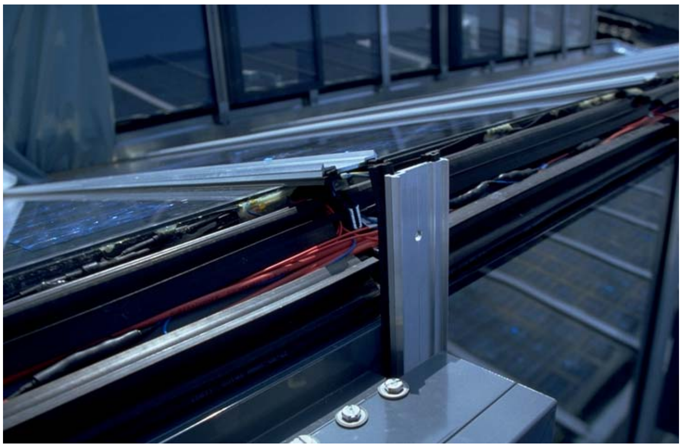

Figure 31:

Modules have been secured by a cover profile. The sub-modules have been connected using crimp terminals and a protective shrinkable tube.
The string wires are placed into a channel besides the top of the modules.
The northern glazing has been mounted and secured (vertical cover profile).
At the bottom of the picture the top of a ventilation flap is visible

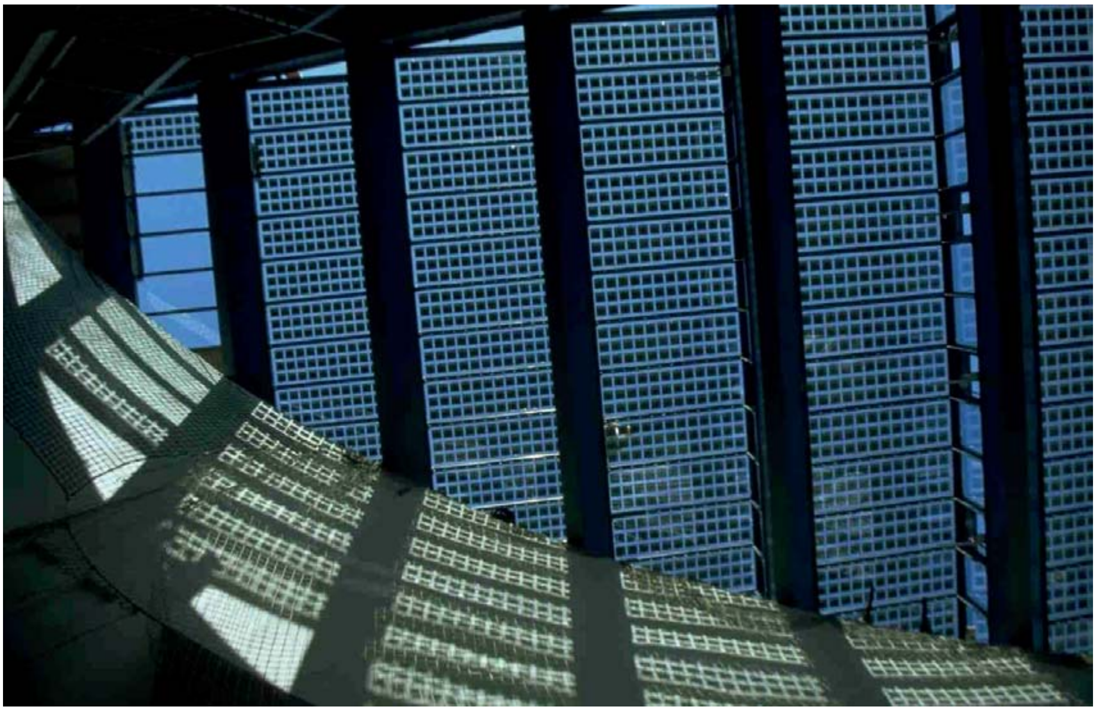

Figure 32: The roof is nearly completed.

Figure 33: light and shadow in the atrium: View into the atrium. The modules and the shadow of the cells on the curved wall are nicely visible. PV cells in the saw-toothed roof create a vivid and ever changing impact on the impression of the atrium

Figure 34: The sheds viewed from outside

Picture title: : Figures 27 to 34.
Source: *Fraunhofer ISE*
Copyright issues: ok
Contact details for source: helau@ise.fhg.de

9.3 The PV Cladding on the Southern and Central Wings

Figure 35: The PV generator on the flat roof of building C during mounting.

Picture title: The PV generator on the flat roofs
Source: *Fraunhofer ISE*
Copyright issues: ok
Contact details for source: helau@ise.fhg.de

9.4 Spandrel of South Wing

This section of the PV systems is still in the planning phase and will not be reported here.

9.5 Problems during realisation

Some modules showed water condensation in the insulating air gap between panes. Presumably, this resulted from sloppy work by the glazing manufacturer. The modules affected were taken out and resealed.

10. PERFORMANCE CHARACTERISTICS

Performance data are not yet available. We expect an annual yield of around 16 MWh for all PV systems, which shall meet the entire demand for office lighting in the new building.

11. PROJECT COST BREAKDOWN

Total building cost was about 26 million EURO including laboratory facilities and equipment.

Table 4: Cost breakdown for the PV subsystems [1]. All cost in EURO.

	Facade of access tract	Saw-toothed roof	Roof wings	Spandrel of the south wing
Rated power [kWp]	2.5	4.9	10	2.9
modules	20 000 1)	50 000	42 000	35 000 2)
mounting structure	0 3)	0 3)	4500 4)	n.n.
Mounting + array wiring labour	10 000	25 000		n.n.
DC main cable + inverter wiring incl. labour	1500	1800	8000 5)	n.n.
inverter	1600	2800	7000	2200 2).
Other cost				
Additional grid connection for feed into grid				3500
monitoring equipment incl. wiring + sensors				12 000

1) estimate 2) initial offer 3) included in building structure
4) Alutec mounting profiles 5) long cable runs to allow for flexible testing configurations

Specify if used any financial incentive:

The installation of these PV systems is part of a larger European “THERMIE” project called »TEAPUB«. The THERMIE program provided about 30 % of the total funding of the PV systems cost.

All electricity is fed into the utility grid at a rate of 0.50 EURO per kWh. This is according to the new German law for electric power from renewable Energies (EEG).

Originally, it was planned to feed the electricity into the building grid using distributed feeders for the inverters. After the law for a higher buy-back rate had been passed these plans were changed to feed all electricity into the utility grid. The utility did not wish distributed meters and requested a separate, additional grid connection for the feed-in meter.

Regular electricity supply is connected on the medium Voltage level of 20 kV.

12. Utility connection:

The utility demanded a separate 400 V connection aside from the main 20 kV connection only for feeding in the PV power. This demand is not covered by the legal framework, but to avoid a lawsuit and major delay to the project we accepted it.

Otherwise the procedure was standard. The utility was only notified on a special form after commissioning by our concessioned (He has got utility approval to work in their region.) electrician.

[1] cost for the Spandrel of the south wing are not yet known

13. Start up issues:
At the time of the compilation of this report the Children's Museum of Rome had not yet opened to the public and was not yet in operation.

14. Maintenance:
Modules are cleaned regularly with all glazing 2-3 times a year..

15. Building and system performance:
At the time of the compilation of this report only rough checks of the systems had been performed. No closer evaluation can be reported yet.

136 CONCLUSIONS
True integration of Photovoltaics into buildings demands a holistic design approach. It then offers new opportunities for aesthetically attractive solutions to daylighting and overheating prevention. It also offers opportunities to integrate PV into the building energy concept.
A careful design of the electrical systems minimises the effect of unavoidable shading.

REFERENCES

[1] H. Laukamp, E. Wiemken, Mismatch Effects and Inverter Sizing in PV generators with differently oriented sections, Proc. 14th EC, Barcelona, June 1997

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