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The Solar Government Quarter in Berlin

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- Renewable Energy System
- Federal Chancellery
- Lower House of Parliament
- Federal Ministry of Justice

Astrid Schneider

From Vision to Reality

THE SOLAR GOVERNMENT QUARTER IN BERLIN

Despite being barely noticed by the public, a Solar Parliamentary and Government Quarter has been built in Berlin. When the German Chancellor, Gerhard Schröder or his fellow ministers look out from the cabinet room towards the Reichstag, the building where Germany's Bundestag meets, they see the flat roofs of the Federal Chancellery which are themselves fitted with over 1000 m² of photovoltaic modules. To either side of the Reichstag they see other roofs which are also covered with arrays of solar panels.

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A new glass dome designed by the British architect, Lord Norman Foster, rises from the center of the Reichstag's roof. The design of the now famous dome was determined by its functions, which include providing natural light and ventilation to the debating chamber of the Bundestag - the German Parliament - below. The southern roof of the historic Reichstag building is equipped with a solar power plant. The famed British architect's integration of the photovoltaic panels into the southern part of the roof has been so successful and unobtrusive that without a signboard, visitors are hardly likely to be aware of the presence of the innovative technology.

The elegant blue shimmer of solar cells on the glazed vaulted roof of Berlin's new main railway station can be seen from the balcony of the Chancellor's office. Opposite the Federal Chancellery is the Paul-Löbe-Haus which houses the offices of many members of the Bundestag. The Paul-Löbe-Haus is one of a number of new government buildings criss-crossing the river Spree and straddling the formerly divided sectors of Berlin. A huge glazed atrium, spanned by a roof which bears the world's largest power plant using amorphous solar cells integrated into the system of shading louvres above it forms the main axis of the building. The central Spree is bridged not only by a ribbon of governmental buildings, but also by a string of solar power plants.

An underground energy system links the government buildings; connecting them is a network of heating, cooling, and electrical pipelines as well as connections to an aquifer storage deep underground. Decentralized combined heat and power plants running on biodiesel produced from rapeseed oil provide most of the energy requirements of the government quarter and, taking all renewable resources into account, more than 80% of the overall energy demand in the new governmental quarter is met from renewable energy sources.

Political and NGO activities leading to a 'Solar Government Quarter'

On September 28th 1992 the symposium 'A Solar Government Quarter' was held in the Reichstag building. This conference was organized by the European Association for a Solar Age EUROSOLAR (Membership Corporation) and was one of the starting points for the development of a Solar Government Quarter.

Aerial photograph of the government district near the Reichstag (Photo: Luftbild und Pressefoto, Berlin)

Photo credits front page:
top: Photovoltaic system on the roof of the Federal Chancellery,
Photo: Astrid Schneider, Berlin
left: Photovoltaic shading system on the Federal Ministry of Justice, Berlin,
Photo: Colt International GmbH, Kleve

The vision of supplying the planned governmental buildings with renewable energy sources was presented to and discussed by a number of the politicians involved in the planning process. The regional EUROSOLAR Berlin representatives saw the opportunity to influence the plan, and successfully took it. The vision of a Solar Government Quarter showed potential. Political initiatives by Herrmann Scheer, a member of the German Parliament who is also the chairman of EUROSOLAR, resulted in the Bundestag laying down fundamental requirements for efficiency and the use of renewable energy in the new government buildings:

- At least 15% of the energy demand should be produced from renewable energy sources
- Low-energy building standards were set at 25% below those specified in regulations that were due to come into force in 1995
- A budget was set at 18 million DM (9.2 million Euros) for solar electrical and 2 million DM (1.02 million Euros) for solar thermal power plants for the government buildings

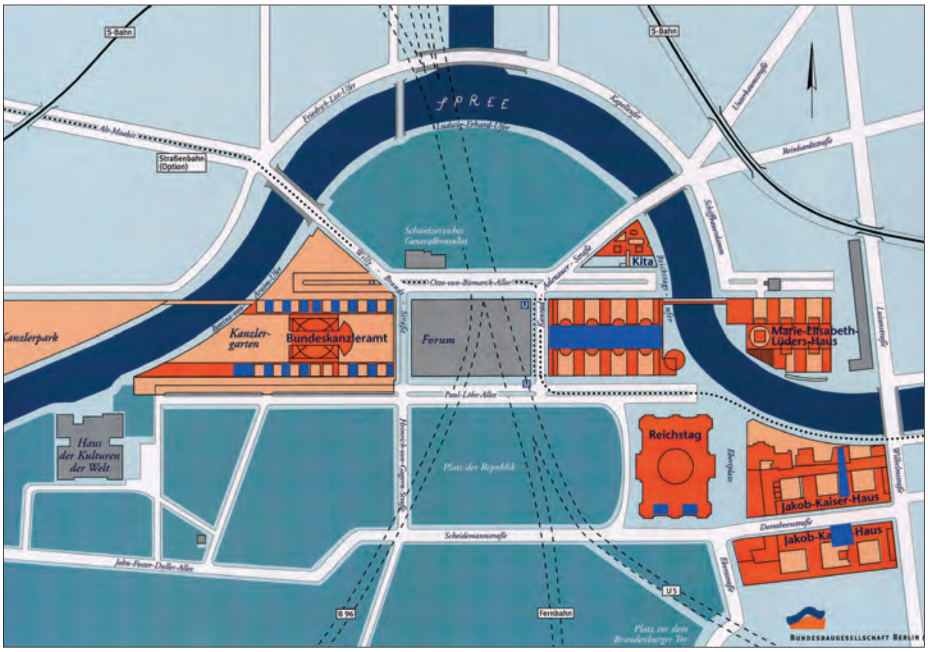
The Renewable Energy System using Aquifer Cold and Heat Storage in the 'Spreebogen'

The regenerative energy system for the Spreeside government complex on the Spreebogen, (a bend in the Spree river), became an innovative project implemented by the 'Bundesbaugesellschaft Berlin' (Federal Building Association Berlin). The energy system is based on the combination of heating and power units (CHP) fuelled with rapeseed-derive biodiesel. The CHPs are located in the Federal Chancellery, the Reichstag building, and the Paul-Löbe-Haus.

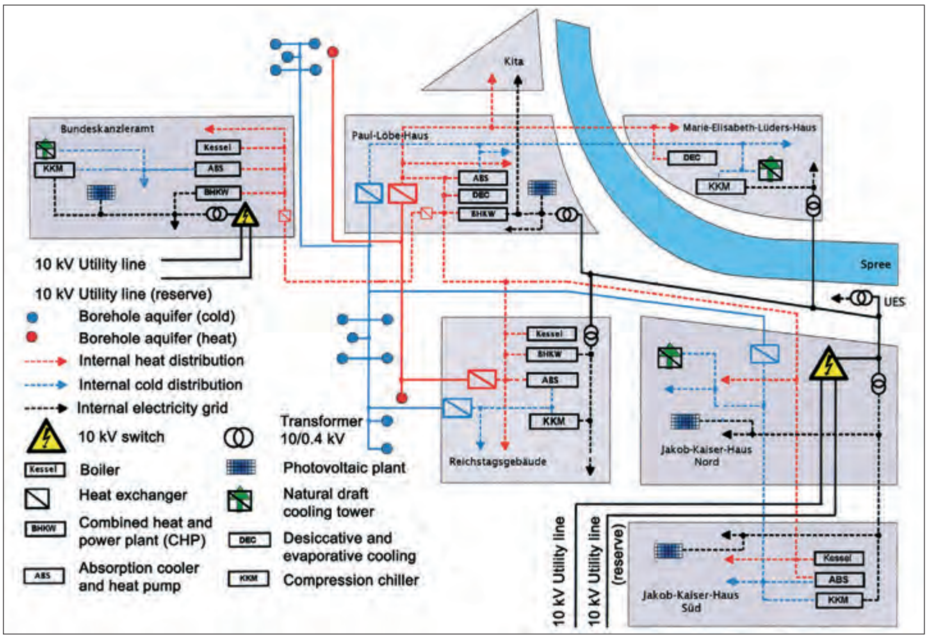
In order to achieve optimal conditions for efficiency, safety and economic viability the buildings are all interconnected with heating, cooling and electricity lines. The CHP plants are powered-up according to electricity demand; excess heat can be absorbed and stored in an aquifer storage facility during the summer and retrieved for use in winter, when heat is needed. There is an additional seasonal aquifer storage unit for storing cold from the environment during the winter, which can then be used for cooling during the summer.

Aquifer storage:

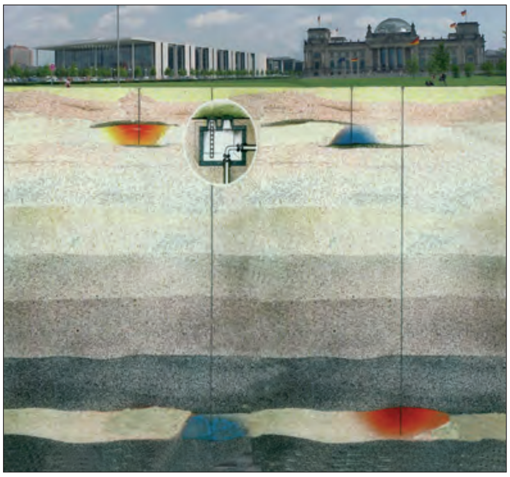
1. The heat storage unit consists of a layer of porous sandstone permeated by salt water at a depth of 200 m – 300 m. The brine is pumped to the surface where it absorbs excess heat from the CHP. The heated brine is then pumped down a second borehole. In the wintertime the aquifer circulation is reversed and supplies brine at approximately 65° C for heating purposes.



Map showing the location of Spreeside government buildings and photovoltaic plants (blue)



Energy systems in the Spreebogen



Seasonal aquifer storage for heat and cold

(All illustrations: Bundesbaugesellschaft Berlin mbH)

2. The cold is stored in ground water beneath a clay layer at a depth of 60 m. During the winter cold months the ground water is cooled down to 5° C in natural draught 5 megawatt cooling towers by the cold outside air and then stored. In the summer the cold water is recovered and used in cooling ceilings.

The heat storage is the first underground thermal storage system in Germany with heat storage temperatures as high as 70° C. The seasonal heat and cold storage system is regarded as having been highly successful, particularly because there has so far been no observable damage to either vegetation or the natural environment.

To increase the efficiency of the energy system, it includes absorption coolers utilizing some of the waste heat produced by the CHP units. The absorption units can also function as heat pumps to bring heat from the aquifer to a higher temperature if required. Under average conditions heat and cold from the aquifer can directly be used for heating and cooling purposes at the temperature delivered. The water circulating ceilings allow heating and cooling with a smaller temperature difference than do conventional air-conditioning or radiator heating systems.

Results of the Energy Consumption in the Government Buildings

Due to energy being supplied by biodiesel (rapeseed derived fuel), CO_2 emissions from the governmental district have been reduced by 70%, compared to what would be expected from a conventional system. The combined heat and power plants supply about 35% of the peak power demand, and produce in approximately 5,000 hours 80%, of the government quarter's annual power requirement. The waste heat produced by the CHP generators supplies some 90% of the yearly heat required for space and water heating. Up to 40% of the cooling demand is supplied by absorption coolers and desiccant cooling systems driven by the CHP waste heat in summer. Another 55% of the cooling energy is taken from the aquifer storage. The cold water is used for the water-fed cooling ceilings, which cool the concrete building structures. Only 5% of the cooling energy is produced by electric compression coolers.

The government buildings' photovoltaic power plants installed in the Spreebogen have a capacity of 357 kW_p and a yearly solar power production of 263,000 kWh. They supply about 1.1% of the government quarter's electricity requirement from solar energy. However, it must also be borne in mind that the Reichstag's photovoltaic plant is very small in relation to the building's size. More

View towards the Reichstag from the cabinet room in the Federal Chancellery (Photo: Astrid Schneider)

roof area could not be utilised because of the building's historic character and the use of the roof as visitors' terrace.

Integration of Solar Power

Taken together, the photovoltaic power plants installed in the new Berlin government buildings have a total capacity of 798 kW_p. This includes the buildings close to the Reichstag as well as others further away at various sites in the central city area. The total surface area covered by solar cells incorporated into the 14 government buildings is about 9,500 m^2, and the annual solar electric output is 630 megawatt hours.

Interestingly, several different photovoltaic technologies and systems have been used. The installations include photovoltaic/shading louvre systems, insulating glazing with solar cells, and inclined and flat roof integration. An additional 1,500 m^2 of solar collectors has been installed producing about 570 MWh of solar thermal energy per year. The solar thermal collectors not only supply heat; they also include two solar cooling systems, which use heat to drive absorption chillers.

The Integration of Solar Power Systems into Architectural Design

Several designs for the governmental buildings were submitted by well-known architects. However, none of them had any hands-on experience with solar architecture, or with the challenges involved in integrating active solar technologies into buildings. Only one of the architects showed particular interest in these innovative approaches.- Lord Norman Foster and Partners' proposals in their competition entry included these features as a characteristic aspect of their planning.

In order to ensure that the Bundestag's building commission's aims of:

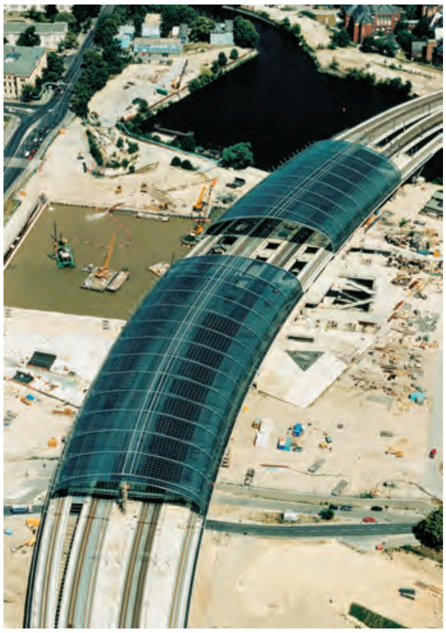
- an energy-efficient building design
- an innovative and renewable energy supply
- integrated solar power systems

could be achieved and implemented, the at that time Federal Minister of Transport, Construction and Housing Klaus Töpfer, who was responsible for the new government buildings, appointed an energy consultant, Dr. Uwe Römmling from IEMB, the former East German Building Academy. His job was to ensure that all the energy contractors and architects would comply with the set criteria at every single stage of planning; his job turned out to be fairly demanding.

The architects who won the competition insisted that the solar modules should not be visible. For example, the Federal Chancellery and the 'Paul-Löbe-Haus' have huge south-facing facade areas, an ideal opportunity to integrate photvoltaic cells. However, the architects involved refused to consider making solar modules a highly visible feature of their work, preferring instead concrete walls and white stone facades. The solar power plants were integrated into roofs, a shading system above an atrium, and on flat-roofed office spaces.

Federal Ministry of Economics and Labour: Solar cells integrated into insulated glazing (Source: Scheuten Solar Technology GmbH)

Chancellor Schröder and his visitors can look at photovoltaic panels on the flat roof of the Federal Chancellery and see the solar roofs of the new main station and the Ministry of Economics and Labour at the skyline. (Photo: Astrid Schneider)



Aerial photo of Berlin's new main station north of the government quarter with it's solar roof (Source: Scheuten Solar Technology GmbH)

In the early nineties, when the competitions for the government buildings were held, solar architecture was not a priority. The general aims were described in the competition invitation; however, neither the architects nor the jury gave them a very high priority. The competitions were won on the basis of the general form and architectural design of the buildings. The winning designs were first altered to be more energy efficient and to integrate solar energy after the design had been approved. The Bundestag's policy decision to integrate solar and renewable technologies had to be met in details point by point. The creative process leading to the development of the German government buildings shows that an overall aim will not automatically result in solar architecture, but rather that energy-efficient and solar technologies can be incorporated in a number of different architectural styles.

The following two pages show the most interesting photovoltaic installations in the new government buildings.

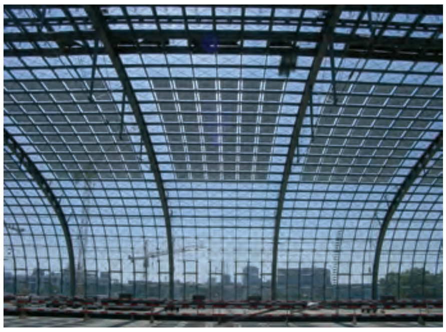
The photovoltaic systems include integrations of high architectural value:

- Photovoltaic louvre shading and daylight system installed above atrium
- Solar cells integrated in glass roof
- Photovoltaic roof integration
- Solar cells integrated into tilted insulation glass of a reception area facade

Solar Systems on Government Buildings

Building	**Area in m²**	**Capacity in kW_p**	**Type of photovoltaic installation**
Foreign Office	181	23	Flat roof installation
Federal Ministry of Health and Social Security	177	18	Flat roof installation
Federal Ministry of Transport, Construction and Housing	328	35	Flat roof installation
Federal Ministry of Transport, Construction and Housing	170	17	Flat roof installation
Federal Ministry of Consumer Protection, Food and Agriculture	63	8	Photovoltaic roof integration
Federal Ministry of Education and Research	163	17	Photovoltaic roof integration
Moabiter Werder housing	991	130	Flat roof installation
Total (including government buildings next 2 pages)	9,425	798	

(Source: IEMB)



Solar cells with an capacity of 189 kW_p are sandwiched in glass-glass-modules produced by Scheuten for Berlin's new main station (Photo: Astrid Schneider)

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– Dipl. Ing. Bernhard Lützke, Bundesbaugesellschaft Berlin mbH
– Dr.-Ing. Uwe Römmling und Dipl. Ing. Jens Dittrich (IEMB),
– Dr. Jörn Bartels, Geothermie Neubrandenburg GmbH
– Andreas Heinz, IER-Uni Stuttgart; Prof. Günther Baumbach, ALS Uni Stuttgart; Gerd Hitzler, FKFS Stuttgart (www.iemb.de)

Reichstag
(Lower House of Parliament)

Address: Spreebogen – Platz der Republik 1

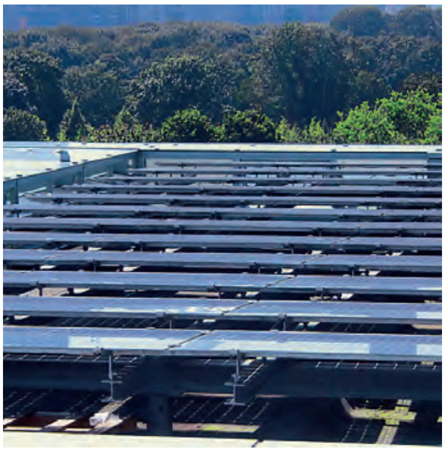
Architect: Lord Norman Foster and Partners

Producer: Scheuten Solar Technology GmbH / RWE-Schott Solar GmbH (cells)

Solar system: Photovoltaic roof integrated on the south roof with glass-glass modules

Capacity/Size: 37.5 kW_p, 296 m^2

Photos: Astrid Schneider



Federal Chancellery

Address: Spreebogen – Willi-Brandt-Straße 1

Architect: Axel Schultes und Charlotte Frank Architects

Producer: Scheuten Solar Technology GmbH

Solar system: Flat roof installation on metal supporting structure

Capacity/Size: 149 kW_p, 1,271 m^2

Photos : Astrid Schneider

Paul-Löbe-Haus
(Parliament offices and resources)

Address: Spreebogen – Platz der Republik 1/ Konrad-Adenauer-Straße

Architect: Stephan Braunfels Architects

Producer: Solon AG / RWE Schott-Solar GmbH (cells)

Solar system: Photovoltaic louvre shading and daylight system with amorphous solar cells above glass atrium

Capacity/Size: 123 kW_p, 3,239 m^2

Photos: Astrid Schneider (left); Solon AG, Berlin (right)

Jakob-Kaiser-Haus
(Parliamentary offices)

Address: Spreebogen - Dorotheenstraße

Architect: Busmann and Haberer Architects (part of building with photovoltaic)

Producer: Solon AG / Ado Solar GmbH

Solar system: Photovoltaic louvre shading system installed above glass atrium and integrated in pergola

Capacity/Size: 29 kW_p, 301 m^2 (atrium) and 17 kW_p , 120 m^2 (pergola)

Photos : Astrid Schneider (left); Solon AG, Berlin (right)

Deutscher Bundesrat
(Upper House of Parliament)

Address: Leipziger Str. 3-4

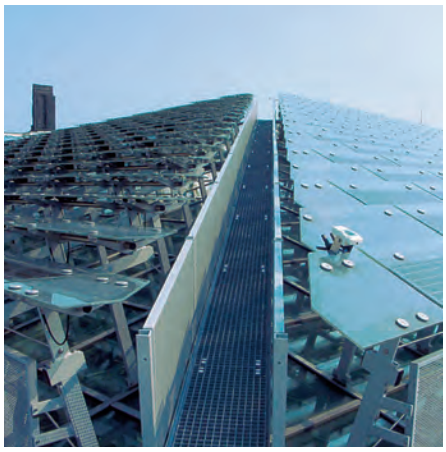
Architect: Schweger und Partner Architects

Producer: Saint-Gobain Glass Solar GmbH / Bomin Solar GmbH

Solar system: Photovoltaic louvre shading and daylight system installed above conference hall

Capacity/Size: 21 kW_p, 324 m^2

Photos: Deutscher Bundesrat, Berlin (left) / Astrid Schneider (right)



Federal President's Office

Address: Spreeweg 1

Architect: Huber und Kleine-Kraneburg Architects

Producer: Solon AG

Solar system: Flat roof installation

Capacity/Size: 40 kW_p, 380 m^2

Photos: Solon AG, Berlin

Federal Ministry of Justice

Address: Mohrenstraße 37

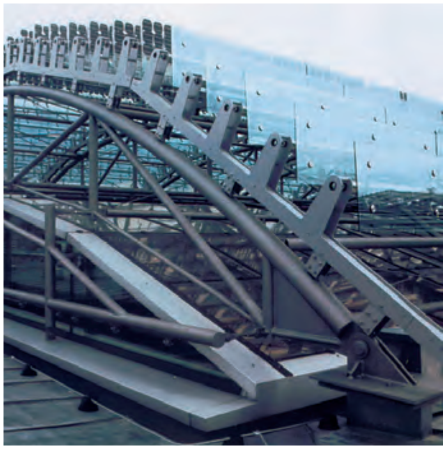
Architect: Eller & Eller Architects

Producer: Colt International GmbH / Saint-Gobain Glass Solar GmbH

Solar system: Photovoltaic louvre shading and daylight system installed above glass atrium

Capacity/Size: 25 kW_p, 345 m^2

Photos: Astrid Schneider (left); Colt International GmbH, Kleve (right)



Federal Ministry of Economics and Labour

Address: Scharnhorststraße 34-37

Architect: Baumann und Schnittiger Architects

Producer: Scheuten Solar Technology GmbH

Solar system: Solar cells integrated into tilted insulation glass of a reception area facade

Capacity/Size: 102 kW_p, 1,076 m^2

Photos: Astrid Schneider

Astrid Schneider

The Lower House of the German Parliament: Powered with Renewable Energy

Rebuilding the Reichstag with Solar Energy

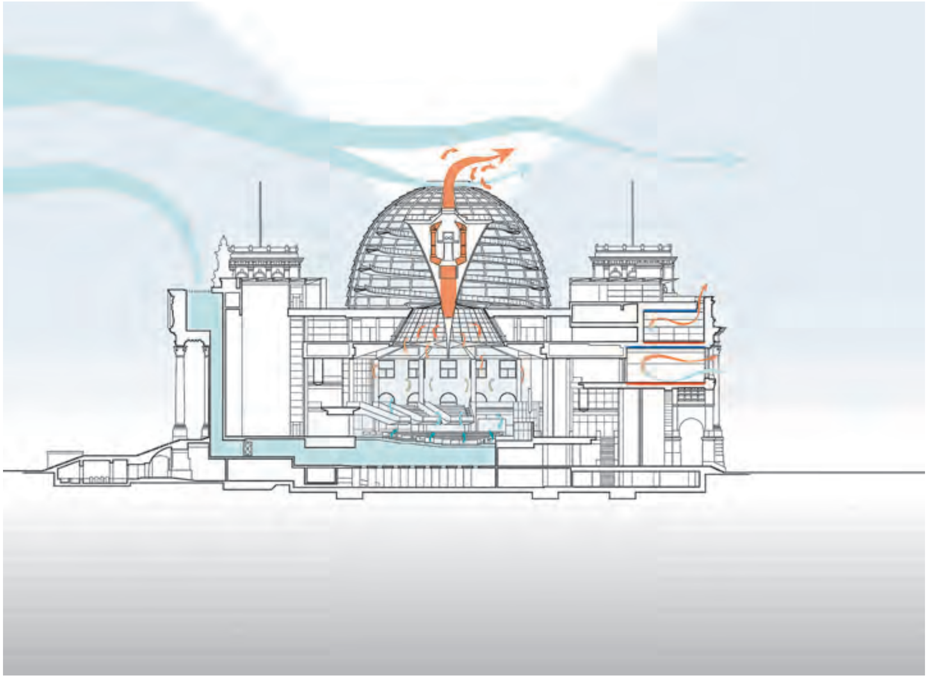
After the reunification of Germany the Reichstag building was reconstructed as the seat of the Lower House of Parliament by the architects Lord Norman Foster and Partners. The main ideas incorporated in the planning included its reconstruction as a democratic forum - the most important and public place of Germany's open democracy - while at the same time paying attention to historical associations and integrating an ambitious energy concept. While its dome, which attracts more than 3.5 million visitors every year, has impressed itself on the public mind, the new Reichstag, as well as becoming a landmark and symbol of the new Berlin, incorporates innovative energy concepts which are much less well-known.
This article describes the building's unusually efficient energy system, which is powered by biofuel and solar energy. The system has reduced CO_2 emissions by some 94% compared with pre-rebuilding emissions.

Shortly after the opening of the competition for the design and reconstruction of the Reichstag the symposium 'A Solar-powered Government Quarter' was held in September 1992 in the Reichstag building itself. Lord Norman Foster and Partners' architects took up the vision of renewing the historical structure with innovative technical systems, which included the use of solar energy technology. The firm was one of three teams of architects which reached the final round of the competition.
The original design by Lord Foster envisioned a huge new roof asymetrically spanning the entire Reichstag and surrounding green areas, providing a new public level, and affording new views of the Reichstag and the city. The new roof would have fulfilled a range of functions, symbolising the new character of the Bundestag, while taking account of tradition. The roof would also have incorporated a number of different energy functions such as daylight technologies, solar electricity generation, and natural ventilation. After the parliamentary building commission's reduction of the required floor area, Lord Foster won the final round of the competition. His winning design included a smaller, centrally-placed modern roof for the building. In the next stage of design development, Lord Foster proposed a 'Lighthouse'. Finally, in the summer of 1994, following numerous proposals by the architects, the Bundestag voted to include a modern variation of the historic dome. The innovative ideas of the original proposal for utilising solar energy and allowing public access to the roof were adapted to fit the new, final concept.

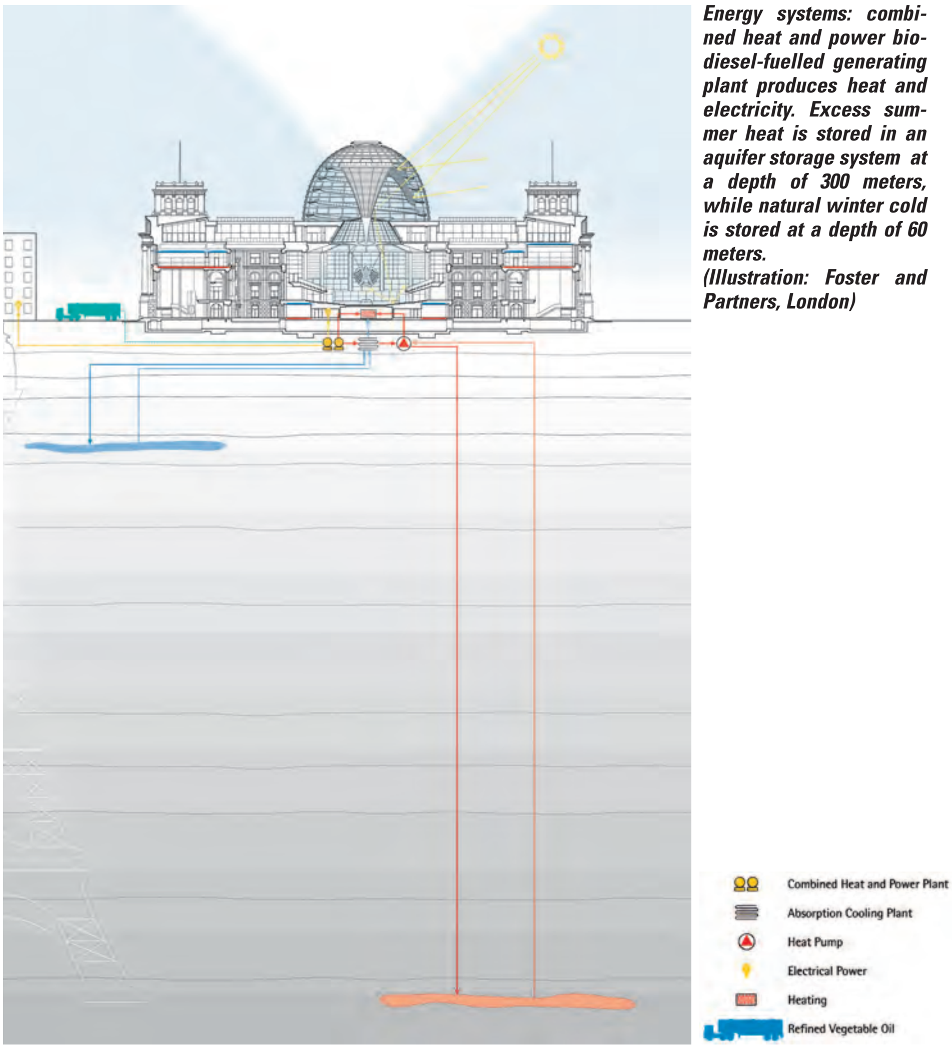
Rebuilding the Reichstag: Demolition, Reconstruction and the New Design

The Reichstag building was originally built as the first seat of the German Parliament, completed in 1895 to the plans of Paul Wallot. It was sited just to the north of the Brandenburg Gate, which marks the entrance to the historic city centre. Following the famous fire of 1933 and the Second World War, the building suffered severe internal damage. The massive stone walls of the outer facade, however, survived. Following the war, the building was in the western sector of the divided city, directly beside the Berlin wall.
In the sixties the building was reconstructed according to plans drawn up by Paul Baumgarten in 1957, which made extensive use

The Reichstag from the west (Photo: Astrid Schneider)



Ventilation system: fresh air is drawn into the building through a large opening above the portico. The air enters the debating chamber through a pressurised underfloor system. The natural draft causes the air rise into the dome, where used air leaves the building via a heat exchanger.
(Illustration: Foster and Partners, London)



Energy systems: combined heat and power bio-diesel-fuelled generating plant produces heat and electricity. Excess summer heat is stored in an aquifer storage system at a depth of 300 meters, while natural winter cold is stored at a depth of 60 meters.
(Illustration: Foster and Partners, London)

of air-conditioning systems and artificial lighting – with the resulting high energy consumption. During the reconstruction work, which took place under the direction of the Federal Building Corporation (Bundesbaugesellschaft) Berlin, acting as the public developer, the installations from the Baumgarten reconstruction were completely removed, and the building's historic structure was reconstructed.

Natural Ventilation Concept

Surprisingly, in the course of reconstruction it was found that historic installations for the ventilation of the debating chamber could be re-utilised. Following the removal of structures from the Baumgarten era, the planners took advantage of ventilation shafts and ducts from the time of the original construction. In 1883 David Grove, an American whose engineering skills allowed him to develop a very advanced energy concept, won the competition for a novel heating and ventilation concept for the Reichstag.

Today, Grove's generously-dimensioned shafts and ducts are again being used to draw fresh air from an opening above the Reichstag's west portico into the debating chamber. The size of the shafts allows a highly energy-efficient movement of the ventilating air. After passing through a heat exchanger, the warmed air enters the debating chamber through a pressurized underfloor system. Following the natural thermal gradient the air slowly rises, and is drawn into the conical daylight element in the center of the dome. Another heat exchanger and a ventilator are concealed in the cone's interior. The ventilation of the debating chamber functions efficiently and effectively, providing a high level of comfort because of heat recovery and the utilisation of the principle of natural draught ventilation.

The building is, to a large extent, equipped for natural ventilation. Most rooms have windows which can be opened, allowing cool air to come in at night for natural cooling. To serve this purpose the windows are multi-layered, having an outer element of safety glass and an inner element of insulating glazing. The spacing of the exterior safety glazing from the wall allows air exchange rates of from 0.5 to 5 times an hour. The inner glazing can be operated manually or automatically. While paying attention to security requirements, this system allows for individual ventilation as well as centrally-operated nocturnal ventilation. In addition, a shading system in the space between the elements reduces heat loads.

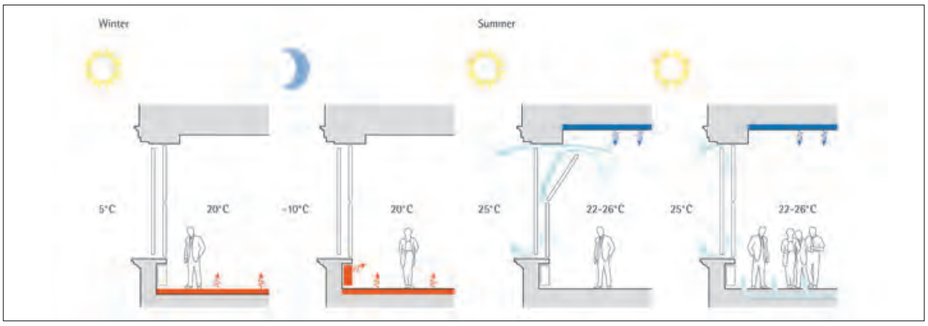
The New Dome

The new dome is a multifunctional re-interpretation of the historic cupola. The shape of the curve follows the outline of the original dome. Although the base of the former dome was rectangular, Lord Foster decided on a circular base for the new dome. Like the old design, the space within the new dome does not open onto the debating chamber but follows functional requirements. In the center of the dome is a transparent skylight, which allows daylight to enter the chamber below. This skylight is penetrated by a conical element, which is an important component of the new construction.
A fan and heat exchanger incorporated in the structure of the new dome extract air from the debating chamber. The used air leaves the building through a large opening in the upper visitors' platform at the top of the cone. Protected by the dome, used air can be discharged even during bad weather. The space within the dome is completely open to the outside air, as the skin of the dome itself is of scale-like glass panes. The dome is set on the new Reichstag's flat roof which functions as a large visitors' terrace. From the terrace visitors can walk up two ramps forming a elliptic double helix leading up to an upper sight-seeing platform allowing fine views of the surroundings and the city center.

Facade double window: safety glass with open joints to the frame (outside) and insulating glazing (interior) to permit natural ventilation. (Photo: Astrid Schneider)

Daylight Systems

The outer shell of the cone is made up of mirrors which are part of the debating chamber's natural lighting system, redirecting diffuse horizontal light downwards into the chamber. In order to protect the hall from direct sunlight, a moving shield follows the sun. The cone provides natural lighting which supplements the light from the facade windows surrounding the assembly hall; supplementary artificial lighting is, however, also required, particularly for television work.
A number of conference and meeting rooms which are lit through skylights are located in the four corner towers of the building and under the tilted roofs of the upper level. The flat, inclined glass roofs between the towers are equipped with a special daylight system developed by Bartenbach Lichttechnik (light technologies) and Thomas Herzog to provide natural light. The system utilises a plastic grid incorporated in the insulating glazing which is designed - according to the solar orientation of each roof - to reflect direct sunlight and allow the entrance of diffuse light only. All vertical windows are equipped with aluminium blinds for solar shading mounted in the gap between the different elements of the glazed panels.



Underfloor heating and cooling ceilings maintain comfortable temperatures (Foster and Partners, London)

Photovoltaic Power Plant

Lord Norman Foster originally intended to integrate a solar energy system in the new dome's solar shading system. However, technical difficulties, and the client's requirement that the dome be light and transparent, led design work in a different direction, resulting in a 37.5 kW photovoltaic system being integrated in a part of the south roof between the two south towers. Module oriented inverters compensate for the partial shading caused by the two towers.
Although the solar power plant can be seen directly from the adjacent visitor's terrace, their integration has been so sensitively handled by Lord Foster and Partners that only specialists who knew that it was there would recognise the photovoltaic power plant. The solar modules cover a roof area of 300 m^2, forming a rainproof shelter inclined at 15° above the concrete roof, fully integrated into the overall roof design, following the same grid as the glazed stairwell skylight in the middle of the roof. This required high stress-resistant photovoltaic glass panels, the largest of which have a length of 3040 mm. The production of these highly resilient custom-sized glass-glass modules was carried out by Pilkington Solar - now known as Scheuten Solar Technology GmbH - a company which specialises in compound photo-

The dome with its interior cone (Photo: Astrid Schneider)

Photovoltaic power plant on the southern part of the roof: 3040 mm x 1095 mm PV-modules produced by Scheuten Solar Technologies GmbH, a company which specialises in compound PV-glasses, each generate 412 watts. (Photo: Foster and Partners, London)

voltaic panels. Monocrystalline,100 mm x 100 mm solar cells with 15% efficiency producing 1.5 watts per cell were used for the photovoltaic modules.
The rectangular cells are anthracite-coloured. Due to the dense packing of cells in the modules the available roof area could be used to optimal effect. The uniformly dark colour of the solar modules makes it difficult to differentiate between pure glazing and photovoltaic area, maintaining the uniform appearance of the roof.

Because people must be able to walk on the roof for cleaning and maintenance purposes, each module is made up of a 12-mm single pane of toughened glass on the upper side, and an 8 mm tempered glass layer on the lower; the solar cells are embedded in cast resin. The resulting modules, which are comparable to a compound safety glass, are installed on a metal frame above the concrete roof and are interconnected with rubber profiles. To minimize gaps, the front panes of the solar modules have chamfered edges to provide an optimal fit with the rubber profiles. The result is a homogeneously flat roof that meets the high architectural standards set by Lord Norman Foster and Partners.

Energy Supply

The massive stone walls of the Reichstag function as a temperature buffer to maintain a balanced indoor climate. The energy concept builds on this, regarding the building as a homogeneous environment, which can be given additional slight warming or cooling according to the users' needs and the outdoor temperatures. The heating is based on different types of systems. The basic temperature is maintained by underfloor heating and ceiling cooling systems. Additional radiators have been installed, depending on the requirements arising from the use of space. While most rooms are naturally ventilated, conference rooms have forced ventilation and are equipped with re-circulating air coolers. The fresh ventilating air can be heated if necessary.
Four combined heat and power generating units (CHP) supply energy to the building. Each CHP unit has an electric and thermal capacity of 400 kilowatts. To meet peak heating demand there is a 750 kilowatt boiler; a separate boiler produces steam for the humidification of the fresh air supply. All the generators are fuelled with rape seed-derived biodiesel. The generating plant is coupled with the government quarter's energy system and the seasonal heat and cold storage aquifers. The system includes an 850 kilowatt absorption device to provide cooling during July or August if it will be needed. The absorption device uses waste heat from the CHP units to produce cold. During the winter it can function as a heat pump, bringing heat drawn from the aquifer storage up to a higher temperature if necessary.
Compared with the condition of the Reichstag before reconstruction, increased energy efficiency, the use of biofuel, and the solar generating plant mean that CO_2 emissions can potentially be reduced by approximately 94% from 7,000 to 400 tons per year.

Astrid Schneider

Photovoltaic Shading System above the Glass Atrium

Federal Ministry of Justice in Berlin

The Federal Ministry of Justice is an example of the environmental strategy implemented during the move of Germany's capital from Bonn to Berlin. This strategy was proposed by Klaus Töpfer, former Federal Development Minister, and now the head of the United Nations Environmental Program (UNEP). He emphasized that the environmental quality of the new government buildings should be demonstrated not only by the use of renewable energy sources, but also by the utilisation of existing buildings. This approach required that at least half of the government's institutions would be relocated in old buildings. The goal of the program was to recycle existing buildings, avoiding demolition and new construction. An example of how this strategy was implemented is the transfer of the Federal Ministry of Justice to a block made up partly of old, and partly of newly-built sections. The architects Eller and Eller were responsible for the development of the site. Two courtyards have been roofed over with glass roofs. An intelligent solar shading system consisting of glass louvres with solar cells provides natural daylight and shading from direct sunlight.

The architects, Eller and Eller, won the competition to rebuild the block of buildings; their task was, however, not an easy one. The block where the ministry was to be located is in the baroque quarter of the historic heart of Berlin in the former eastern sector of the city. It is close to the well-known Gendarmen Markt, where the first judicial administration was located in 1877, and adjacent to Hausvogteiplatz, the site of the former royal prison and law courts.

The building complex is between the Mohrenstrasse, Jerusalemer Strasse and Kronenstrasse. Four existing buildings - all of different dates - occupy the 117 m by 77 m site. The Mohrenkollonaden were built by the famous Berlin architect C. G. Langhans. Also on the site are an industrial building from the end of the 19th century, and a prefabricated concrete building from the communist era. The baroque Mohrenkollonaden, dating from 1787, were part of a bridge between the old historic city around the former Berliner Schloss (Hohenzollern palace) and Friedrichstadt, a newer district built during the reign of King Friedrich. Another part of the Ministry of Justice building is the Stern house, which was used as an East German national press office before reunification, the press office where Günther Schabowski 'accidentally' announced the immediate authorisation of free travel which led to the fall of the Berlin wall on the 9th November 1989.

This mixed historic locale was earmarked for transformation into a functioning ministry building with accessible space. A further challenge was to improve the buildings' efficient use of energy while complying with the restrictive building codes covering a number of the various buildings' features. The architects therefore proposed covering two of the courtyards with glass to provide a greater degree of cohesion between the different buildings. At the same time, covering the courtyards made the renovation of the facades, which are scheduled as protec-

Court yard with glass atrium (Photo: Astrid Schneider)

Glass louvre system with solar cells (Source: Colt International GmbH)

Shading system of glass louvres with and without solar cells (Source: Colt International GmbH)

ted monuments, easier. The glass roofs, which reduce heat losses as well as providing shading, have facilitated the restoration of the facades to their original historic appearance.

The Glazed Atrium: a Daylight and Shading Concept

An interdisciplinary team - involving not only the architects but building services engineers, facade designers, and contractors - undertook the glass atrium design work. The goal was for the glass roofs to provide and optimize all the functions of the building's envelope:

- Allowing access for daylight
- Allowing views to the exterior
- Providing sun protection
- Producing power from photovoltaic cells
- Conserving heat
- Providing natural ventilation

The clients expressed an interest in generating electricity from photovoltaic cells. The contractor, Colt International, proposed three different systems, which would have combined photovoltaic cells and shading. The chosen method was a sun-tracking glass louvre system. Photovoltaic panels have been integrated into the glass louvres above the curving glass roof, enabling them to function at the same time as shading elements, while the lateral areas of the roof, above the courtyard facades, have louvres of colourless, high-transparency solar shading glass.

Construction

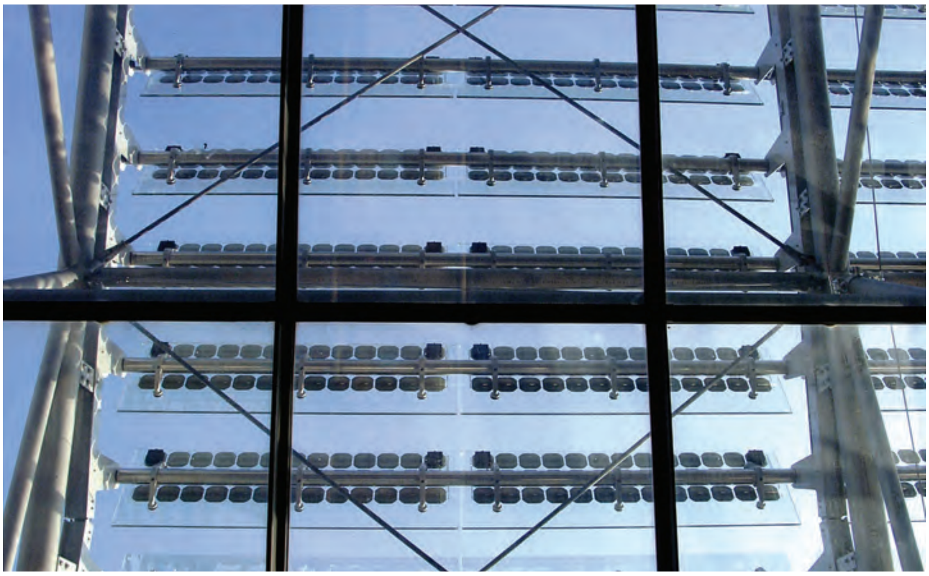
The barrel vault glass roofs cover the historically protected Prausenhof (courtyard). A glass wall with walkways intersects the opening to the neighbouring open courtyard. The architects decided on an exterior steel construction in order to keep the courtyards free and uncluttered. Curved lattice girders which span the courtyards support the free-standing steel atrium roof structure. The prefabricated girders were delivered in one piece. The framework of steel tubing and cables was erected on site. The steelwork, which is exposed to the elements, is protected with a multi-layer anti-corrosion coating. The glass roof is made up of insulating glazing. Steel cables attach it to the underside of the lattice girders. The supporting framework for the louvre shading system is above the curved lattice girders. The supports of the louvres are polygonal, allowing them to be moved by a motorized system, the computer-controlled actuators of which rotate the louvres according to the position of the sun. Colt International worked together with the architect and façade designer to produce a custom-made shading system. In accordance with the CAD-generated drawings, the substructure of the movable stainless steel axis for the louvres was machined from 8 mm aluminum with a water jet saw. Two of these profiled sub-elements were joined together to form the girder which holds the adjustable torsion tubes on which the louvres are mounted. Stainless steel tubes span the 4 m distance between the girders. Two 1.9 m long glass louvres are attached to each stainless steel tube at 6 points.

Photovoltaic system

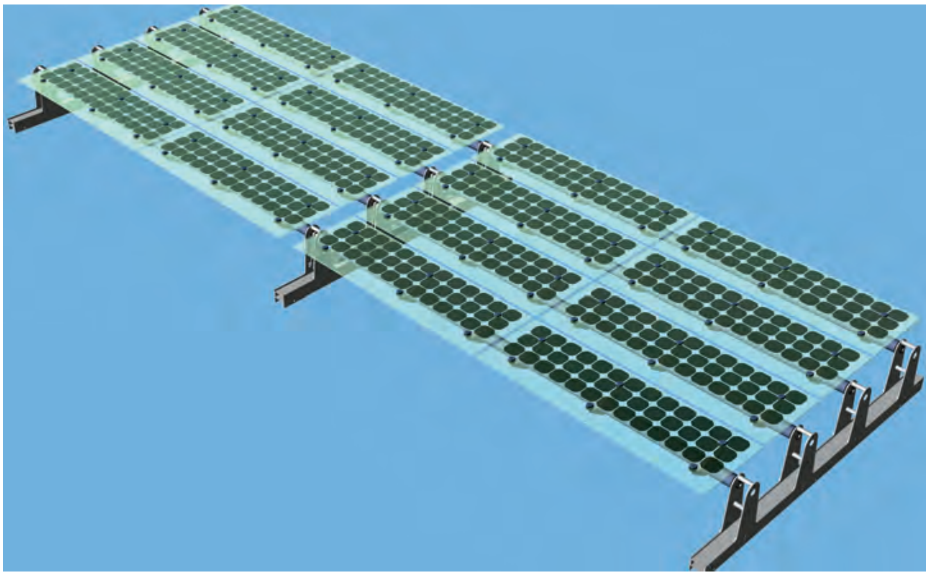
The photovoltaic louvres are made up of two high-transparency panes of glass glued together with cast resin. Mono-crystalline solar cells are sandwiched in the compound glass modules, which have borings for point-fixing. The solar cells do not, however, occupy the full area of louvre glass, which minimises shading effects as the lower parts of the louvres are not covered with photovoltaic cells. The electric cabling is concealed in the stainless steel torsion tubes. The cabling is then led down to the floor of the atrium through conduits integrated in the aluminium structure where it ultimately feeds into the inverter room. In 2002 a solar electricity output of 724 kilowatt hours per installed kilowatt was generated. In a total 308 photovoltaic louvres with an capacity of 25 kilowatts have been installed.

Natural Lighting Concept

The glass louvres that support the solar cells are made from high-transparency glass which allows enough daylight to enter between the cells. The pure glass louvres installed close to the facades are made from a special colourless sunlight-blocking glass. The glass louvres can be controlled separately from the photovoltaic louvres, thus allowing daylight penetration to be optimised according to the actual weather conditions. To achieve optimisation the intensity of the sunlight is continuously monitored; when the automated system calculates that shading is required all louvres are directed towards the sun. When there is a need for more daylight, the non-photo-voltaic glass louvres are rotated sunward, allowing more daylight to enter. Simultaneously, the angle of the solar louvres is optimised for the generation of photovoltaic electricity.
When radiation is less than 100 kW/m^2 the photovoltaic louvres rotate to allow sunlight


Movable glass louvres with monocrystalline solar cells (Photo: Astrid Schneider)


Insulating glazing attached to the underside of the lattice girders with steel cables (Photo: Astrid Schneider)


Water jet saw substructure with mouvable louvres (Source: Colt International GmbH)

Interior view atrium (Photo: Astrid Schneider)

pass into the building, thus maximising the natural lighting. This ensures that artificial lighting is not required so long as there is adequate natural daylight.

Lightning Protection

The builders originally intended to include a concept for lightning protection, which would have avoided damage from lightning strikes. This would have involved placing steel rods above the roof in order to attract lightning before it reached the building. However, the size of such lightning conductors would have caused shading of the photovoltaic system. A study found the risk of lightning strikes to be minimal, since the higher neighbouring buildings would be more likely to be struck. The chance of lightning strikes was, in fact, found to be so small that the risk would have been outweighed by the effects of permanent shading on the photovoltaic system.

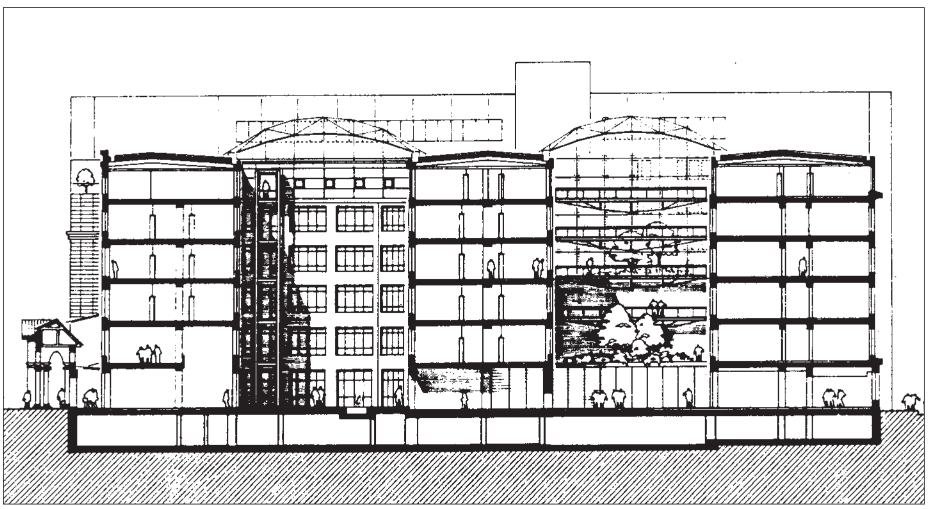
Other measures were therefore taken. The solar modules have been subdivided with over-voltage circuit breakers. If lightning were indeed to strike any particular louvre, damage would be limited to that element alone. The steel roofing support structure was earthed and connected to the building's overall lightning protection system.

Cost

Because both glass louvres and glass/photovoltaic louvres have been used it is possible to illustrate the cost differences arising from the installation of a custom-made photovoltaic system. The Institute for Building Renovation and Modernisation (IEMB e.V.) has calculated that the substructure costs are identical for both a shading and a shading/photovoltaic system.

The glass louvres cost an additional 447 € per m^2 when equipped with solar cells, giving a total of 5651 € per installed kilowatt capacity, to which must be added the cost of inverters and mountings. Thus, while it is clear that the integration of a photovoltaic system is more expensive than a standard module system, its appearance and multi-functionality make it a very attractive solution. Furthermore integrated photovoltaic systems consume less incorporated energy for production, what makes them more environmentally friendly. Meanwhile the costs of solar modules have continued to decline as solar cells are being mass-produced. This will allow dramatic reductions in the cost of photovoltaic building integration in the near future.

Section through the courtyards with atrium roofs (Eller & Eller Architekten, Düsseldorf)



Federal Ministry of Justice in Berlin: Parties involved:

Client:
Federal Ministry of Justice, Bundesrepublik Deutschland

Architects:
Eller & Eller Architects, Düsseldorf Berlin

Facade Consultant:
Michael Gödde, Neuss

Civil Engineering:
Schmidt Reuter und Partner, Köln

Design and Realisation Louvres System with Photovoltaic:
Colt International GmbH, Kleve / Berlin

Producer Solar Modules:
Saint-Gobain Glass Solar GmbH, Aachen

Project Data:

Atrium 1 -Casinohof:
352 Glass louvres with sun protection glass
176 Photovoltaic louvres
Solar cells 125 x 125 mm Power Max
Module power: 77,5 W_p
Installed solar capacity: 13,64 kW_p
Inverters: string-concept with 6 SMA/SunnyBoy

Atrium 2 - Repräsentationshof:
264 Glass louvres with sun protection glass
132 Photovoltaic louvres
Solar cells 125 x 125 mm Power Max
Module power: 83,64 W_p
Installed solar capacity: 11,04 kW_p

Inverters: string-concept with 6 SMA/SunnyBoy

Installed capacity: 24,68 kW_p
Solar electricity production in 2002: 724 kWh/kW_p
(The annual solar electricity output is 15% below maximum, because the louvres are directed to let the sun in for daylight use, when solar radiation is below 100 kW/m^2)

Astrid Schneider

Federal Chancellery, Paul-Löbe-Haus and Reichstag in the central Spree area (Photo: Scheuten Solar Technology GmbH)

From Vision to Reality

The new Government buildings in Berlin have been equipped with efficient energy systems supplied with renewable sources. The Lower House of Parliament, the Federal Chancellery and the buildings for members of the Bundestag (see picture right) are supplied to more than 80% with renewable energies. The innovative technologies include:

- The installation of 798 kW_p of photovoltaic plant with a solar module area of some 9,500 m^2
- The installation of 900 m^2 of solar thermal collectors
- An aquifer heat and cold storage
- Biodiesel-fuelled combined heat and power plants
- A decentralized energy network for the main government buildings
- Solar cooling systems
- Energy-efficient building design to low-energy standards, high insulation, natural airing and daylighting systems

About the author:
Astrid Schneider is an architect and author, who lives and works in Berlin. She is specialist for photovoltaic building integration. She is active in the design, product development, and consulting fields. In 1992 she initiated, as the voluntary head of the Berlin group of EUROSOLAR the conference 'A Solar Government Quarter'. Part of her work is the internet publication and dissemination of information about solar building integration:
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Photovoltaic shading system on the Federal Ministry of Justice, Berlin (Photo: Colt International GmbH, Kleve)

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