Fifteen years ago, German solar energy company SOLON SE started in Berlin. Only a dozen years later, the firm installed the world’s largest solar array of its kind in Springerville, Ariz. This global supplier of photovoltaic systems for large-scale solar power plants required a headquarters in Berlin that showcased innovative energy design, while providing administrative offices and manufacturing facilities for the firm.

SOLON formed a team early in the planning process to find an integral approach to designing the new headquarters in the Adlershof science and technology park in Berlin.

Project Goals, Development
The project goals included constructing a sustainable building with a high level of energy efficiency and indoor environmental quality. The final building needed highly efficient and flexible spaces (at ≤25 m² [269 ft²]) gross floor surface per workspace). Also, the office workspaces required lots of natural lighting and natural ventilation as well as wireless information technology (IT).

Two ambitious energy goals were set for the site during the planning stage. Planners set an annual primary energy requirement for heating, cooling, ventilation and lighting for the office building of less than 100 kWh/m² (9 kWh/ft²) (net floor surface), which is more than 50% below the minimum requirements stipulated by the German Energy Savings Ordinance.

Also, a target was set for achieving a heating requirement of less than 40 kWh/m² (4 kWh/ft²) annually. Planners set another goal to operate the entire site (not including energy for production facilities) as largely CO₂ neutral in combination with a biogas CHP plant, starting in 2010. During the concept development phase, the architects, energy designers and planners worked closely together to take an in-depth look at the site conditions, production requirements and the various building uses. They invited manufacturers of individual systems and components to participate in the process. This early involvement led to incorporating wood architecture into the façade (unusual for office or administrative buildings) as largely protective and prefabricated wood panels.

Siting and Layout
The entire complex of office and production buildings is situated on a site that extends across approximately 36 000 m² (387,500 ft²). The office building, with its total space of around 10 000 m² (107,639 ft²) (net floor surface), provides work spaces for about 350 employees. The construction costs of the office building totalled approximately 2450 €/m² ($305/ft²) (gross floor surface), with 34% of this total spent on building services (HVAC, lighting, electrical installation, and building automation).

SOLON’s production and administration buildings are linked by bridges. While the production building was essentially designed as a large hall to meet the needs of manufacturing, the office building was structured with an open interior landscape that flows around five inner courtyards under a roof sloping to the south. Facing the street, the building forms a straight line with...
softer, rolling transitions extending to the park behind the building.

A glass atrium serves as the entrance to the administrative building and as a central corridor between the two parts of the complex. From the atrium, the office building can be seen in its entirety, connecting the four floors and the transparent courtyards.

Vertical connections also are designed into the atrium with several stairwells and two elevators to connect the entire complex. The strategic combination of glass, insulated steel and wood in the enclosure creates an open and inviting atmosphere, which is enhanced by views of the accessible green roof. Stairwell entrances of Cor-Ten steel rise up like cliffs in a sloping green meadow.

The Globe is the central meeting and presentation area of the building. Every floor includes environments such as fixed working areas, meeting rooms and thinking pods to meet staff needs and facilitate rapid exchange of information.

The ground floor of the production building houses facilities for manufacturing photovoltaic modules, including material storage and access. This is also where the research and development facilities are located.

Offices and meeting rooms are found on the upper floors next to the exterior façades on the southwest and southeast sides, with a direct line of sight to the production areas on the lower floors. In addition to housing primarily offices and conference rooms, a restaurant and an area for holding events are on the ground floor of the office building.

Each of the building’s five courtyards has a different theme and is accessible to occupants.

A landscaped park behind the building comes to an end at Kopenickerd Straße (Street), where there is also a solar charging station for electric scooters. Batteries with charging sockets built into the wall are connected to large moveable solar panels (solar movers) on the park premises and are evidence of the future potential of solar-powered transportation in Berlin.

Creating an Innovative Façade

For the façade, the team set a goal to minimize the energy required to produce the façade materials. Additionally, the decision was made to mostly dispense with conventional heating and cooling technology by lowering the cooling and heating loads from the outside.

Prefabricated Façade. To meet both requirements, a completely prefabricated wood beam façade was created in close cooperation between the architect, energy designer and the company responsible for implementation. All of the necessary functions are integrated into the façade element including heat and cold protection through triple-glazed insulated windows and vacuum insulated opaque panels.

ENERGY AT A GLANCE (OFFICE + PRODUCTION FACILITY)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Produced kWh/m²</th>
<th>Exported kWh/m²</th>
<th>Difference kWh/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (PV on site)</td>
<td>9.2 kWh/m²</td>
<td>38.6 kWh/m²</td>
<td>29.4 kWh/m²</td>
</tr>
<tr>
<td>Electricity (CHP)</td>
<td>71.3 kWh/m²</td>
<td>80.7 kWh/m²</td>
<td>9.4 kWh/m²</td>
</tr>
<tr>
<td>Heat (CHP)</td>
<td>146 kWh/m²</td>
<td>146 kWh/m²</td>
<td>0 kWh/m²</td>
</tr>
</tbody>
</table>
performing vacuum buildings

The vacuum insulation panels (VIPs) have a total thickness of approximately 47 mm (1.85 in.) to achieve a U-value of approximately 0.25 W/m²·K (0.04 Btu/h·ft² ·°F). The VIP manufacturer considerably improved the long-term durability of the elements for this building project. By combining a high proportion of fixed high performance glazing with high performance VIP elements, a good U-value was reached for the façade of 0.68 W/m²·K (0.12 Btu/h·ft² ·°F). The entire façade has an acoustic insulation factor of about 43 dBA.

Motorized Shading. Outside of the glass façade is a rail-guided, wind-resistant shading system made up of motor-controlled 20 mm (3.15 in.) blinds. The system achieves a solar reduction factor (F₀) of approximately 0.2. To minimize the electricity needed for artificial lighting, the shading system is designed with a daylight function, i.e., the upper one-third of the blinds can be independently opened, allowing light to enter while the lower part may be closed to provide shade.

Meeting Heating, Cooling Needs

The design of the building shell considerably reduces the heating and cooling required for the office building and allows for simple heating and cooling technology. A coil system in the concrete ceilings (thermally activated components) provides heating and moderate cooling. Heat convectors are integrated into the façade to cover peak heating loads when outside temperatures are extremely cold and for individual temperature adjustment. The heat convectors in front of the full height glass facing the inner courtyards are integrated into the floor.

The heating and cooling load is largely met by the thermal activation of the concrete ceilings: water with moderate supply temperatures (cooling: 16°C to 18°C [61°F to roughly 15°C met by conditioning incoming ventilation air.

Mechanical Ventilation. A mechanical ventilation system with heat recovery (designed for an air exchange rate of 1.2 to 1.4 ach) provides comfortable room temperatures while simultaneously minimizing the energy required. Air is supplied to and from the building through ventilation pipes visibly suspended from the ceiling. The mechanical ventilation system is operated in winter and summer because using natural ventilation at those times leads to occupant discomfort and heat losses. Otherwise, ventilation is supplied only through the manually operable windows in the façade.

Biogas-Powered CHP Plant. A central mechanical hub supplies the office and production buildings with heating and cooling. A biogas-powered CHP plant (waste biomass satisfies the basic heat load and has been located in the technical control center of the nearby power plant of the local energy supplier (BTR) for maintenance reasons.

The heat emitted from the CHP plant is used in winter for heating and to operate an absorption chiller in summer. A biogas production

Energy-Efficient Glazing. In addition to the exterior sun protection, a color-neutral sun protection glass with a g-value of about 0.32 and a light transmission of 0.57 were used. The triple-glazed insulating glass is designed for reflection (Level 2) and has a low-energy coating (Level 5); it is argon-filled with thermoplastic spacers to achieve a Ug-value of 0.6 W/m²·K (0.11 Btu/h·ft² ·°F). The profiles of the façade are made of laminated timber (European fir) with attention given to creating a design that reduces thermal bridges.

The vacuum insulation panels (VIPs) have a total thickness of approximately 47 mm (1.85 in.) to achieve a U-value of approximately 0.25 W/m²·K (0.04 Btu/h·ft² ·°F). The VIP manufacturer considerably improved the long-term durability of the elements for this building project. By combining a high proportion of fixed high performance glazing with high performance VIP elements, a good U-value was reached for the façade of 0.68 W/m²·K (0.12 Btu/h·ft² ·°F). The entire façade has an acoustic insulation factor of about 43 dBA.

Motorized Shading. Outside of the glass façade is a rail-guided, wind-resistant shading system made up of motor-controlled 20 mm (3.15 in.) blinds. The system achieves a solar reduction factor (F₀) of approximately 0.2. To minimize the electricity needed for artificial lighting, the shading system is designed with a daylight function, i.e., the upper one-third of the blinds can be independently opened, allowing light to enter while the lower part may be closed to provide shade.

Meeting Heating, Cooling Needs

The design of the building shell considerably reduces the heating and cooling required for the office building and allows for simple heating and cooling technology. A coil system in the concrete ceilings (thermally activated components) provides heating and moderate cooling. Heat convectors are integrated into the façade to cover peak heating loads when outside temperatures are extremely cold and for individual temperature adjustment. The heat convectors in front of the full height glass facing the inner courtyards are integrated into the floor.

The heating and cooling load is largely met by the thermal activation of the concrete ceilings: water with moderate supply temperatures (cooling: 16°C to 18°C [61°F to roughly 15°C met by conditioning incoming ventilation air.

Mechanical Ventilation. A mechanical ventilation system with heat recovery (designed for an air exchange rate of 1.2 to 1.4 ach) provides comfortable room temperatures while simultaneously minimizing the energy required. Air is supplied to and from the building through ventilation pipes visibly suspended from the ceiling. The mechanical ventilation system is operated in winter and summer because using natural ventilation at those times leads to occupant discomfort and heat losses. Otherwise, ventilation is supplied only through the manually operable windows in the façade.

Biogas-Powered CHP Plant. A central mechanical hub supplies the office and production buildings with heating and cooling. A biogas-powered CHP plant (waste biomass provides the source of the biogas) satisfies the basic heat load and has been located in the technical control center of the nearby power plant of the local energy supplier (BTR) for maintenance reasons.

The heat emitted from the CHP plant is used in winter for heating and to operate an absorption chiller in summer. A biogas production

Energy-Efficient Glazing. In addition to the exterior sun protection, a color-neutral sun protection glass with a g-value of about 0.32 and a light transmission of 0.57 were used. The triple-glazed insulating glass is designed for reflection (Level 2) and has a low-energy coating (Level 5); it is argon-filled with thermoplastic spacers to achieve a Ug-value of 0.6 W/m²·K (0.11 Btu/h·ft² ·°F). The profiles of the façade are made of laminated timber (European fir) with attention given to creating a design that reduces thermal bridges.

The vacuum insulation panels (VIPs) have a total thickness of approximately 47 mm (1.85 in.) to achieve a U-value of approximately 0.25 W/m²·K (0.04 Btu/h·ft² ·°F). The VIP manufacturer considerably improved the long-term durability of the elements for this building project. By combining a high proportion of fixed high performance glazing with high performance VIP elements, a good U-value was reached for the façade of 0.68 W/m²·K (0.12 Btu/h·ft² ·°F). The entire façade has an acoustic insulation factor of about 43 dBA.

Motorized Shading. Outside of the glass façade is a rail-guided, wind-resistant shading system made up of motor-controlled 20 mm (3.15 in.) blinds. The system achieves a solar reduction factor (F₀) of approximately 0.2. To minimize the electricity needed for artificial lighting, the shading system is designed with a daylight function, i.e., the upper one-third of the blinds can be independently opened, allowing light to enter while the lower part may be closed to provide shade.

Meeting Heating, Cooling Needs

The design of the building shell considerably reduces the heating and cooling required for the office building and allows for simple heating and cooling technology. A coil system in the concrete ceilings (thermally activated components) provides heating and moderate cooling. Heat convectors are integrated into the façade to cover peak heating loads when outside temperatures are extremely cold and for individual temperature adjustment. The heat convectors in front of the full height glass facing the inner courtyards are integrated into the floor.

The heating and cooling load is largely met by the thermal activation of the concrete ceilings: water with moderate supply temperatures (cooling: 16°C to 18°C [61°F to roughly 15°C met by conditioning incoming ventilation air.

Mechanical Ventilation. A mechanical ventilation system with heat recovery (designed for an air exchange rate of 1.2 to 1.4 ach) provides comfortable room temperatures while simultaneously minimizing the energy required. Air is supplied to and from the building through ventilation pipes visibly suspended from the ceiling. The mechanical ventilation system is operated in winter and summer because using natural ventilation at those times leads to occupant discomfort and heat losses. Otherwise, ventilation is supplied only through the manually operable windows in the façade.

Biogas-Powered CHP Plant. A central mechanical hub supplies the office and production buildings with heating and cooling. A biogas-powered CHP plant (waste biomass provides the source of the biogas) satisfies the basic heat load and has been located in the technical control center of the nearby power plant of the local energy supplier (BTR) for maintenance reasons.

The heat emitted from the CHP plant is used in winter for heating and to operate an absorption chiller in summer. A biogas production
PV Company Uses PV

The CHP plant provides electricity, but a second power grid is available for redundant, reliable electricity supply for the manufacturing operation. Building and site integrated PV systems generate about 236 MWh/year of solar electricity that is fed into the grid. Excess heat is returned to the district heating network. Integrated design involving the builder and the design team led to a decision to restrict photovoltaics to the outer edges of the roof to support a large green roof area.

Building Automation

Raumtalk software is used for building automation. It is user friendly, responds flexibly to changing floor plans and supports monitoring of energy consumption and building operation. All devices connected to the Raumtalk installation communicate on the basis of open, standardized Internet protocol (IP) standards. In addition to DALI, EnOcean, KNX and LON applications, IP-capable functions also could be integrated for security, facility management, multimedia, infotainment, etc. The systems are connected to one another through the open OPC standard.

SOLON employees can control lights, sun protection and heating via programmable operating elements on PC monitors and touch panels (soft controls). In addition, switches and other sensors with battery-free wireless technology are used for control.

Monitoring Energy/Operations

The performance of the building as a whole is being evaluated during operation. The Institute for Building Services and Energy Design (IGS) at the Technical University of Braunschweig developed a comprehensive planning and monitoring concept to support continuous evaluation and integrated it into the building automation system. SOLON uses the data for ongoing adjustments and operational optimization.

Analyzing Building and System Performance

Roughly two years after construction was completed, the data show that the SOLON office building consumes less energy than the initial energy targets. The annual primary energy consumption (with balance limits stipulated by the energy savings ordinance) is approximately 86 kWh/m² (7.98 kWh/ft²) (net floor surface). This means that energy consumption is more than 15% less than the annual value set during the planning stage of 100 kWh/m² (9 kWh/ft²) (net floor surface).

An energy balance for the entire site was roughly calculated from October 2009 to September 2010 in accordance with the balance limits set by the energy savings ordinance to take into account renewable energy production on site (PV, biogas), but to exclude energy consumption of the manufacturing-related facilities.

The final energy consumption was 1,131 MWh/year of heat and 1,137 MWh/year of electricity. This is offset by energy from renewable sources of 4,025 MWh/year of heat and 1,943 MWh/year of electricity from the biogas CHP plant, and 258 MWh/year of electricity from photovoltaics.

The site achieves a considerable net energy plus status. The CO₂ emissions that would have been created using district heating and grid electricity were reduced by approximately 85%.

Achieving High Indoor Environmental Quality

Another essential goal for a high performance office building is excellent indoor environmental quality to ensure the physical comfort of the occupants and to support a high level of work effectiveness. The thermal comfort in the SOLON building was
The sloping green roof, which is sometimes used for employee meetings, is surrounded by a 210 kW photovoltaic system. The green roof absorbs most of the rainwater that falls onto the roof’s surface. The overflow is collected in a cistern and used to refill decorative fountains and to irrigate the landscape, or is diverted to the landscaped cascade of drainage basins.

An intensive analysis of the structural, functional and technical options, it was possible to develop the best possible design and engineering approaches for the SOLON SE headquarters.

After one year of commissioning in the office building and in the manufacturing facility, the building went into regular operation. The fully instrumented and measured building reveals a workplace that is a net energy exporter, achieving high thermal and lighting quality and occupant satisfaction.

About the Authors

M. Norbert Frisch, Dr.-Ing., is professor of Architecture and head of the Institute of Building Services and Energy Design (IGS) at the Technical University of Braunschweig, Germany. Mr. Frisch is president of EGS-plan Engineers, Stuttgart, Germany, and was a member of the planning team for the SOLON project.

Stefan Pieszer is head of the Measurement & Verification Research Group at IGS and managing director of EnergyDesign Braunschweig Engineers.

Henrik Langeheinrich is research member of the Measurement & Verification Research Group at IGS.