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From U.S. Army Installation to Zero Energy Community: The B&O Bad Aibling Park Looks to the Future

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ABSTRACT

The B&O Bad Aibling Park, located in Bavaria, Germany, occupies a 173-acre (70 ha) facility that originally served as an airbase. Although the site buildings were in good repair, their thermal quality was poor. The district heating system was in good condition, but the scale of heat generation was too large. This project described in this paper designed a development plan that could be easily replicated and that could ultimately become a model for a zero energy city. The B&O Bad Aibling Park project employed a rich diversity of technologies that may be scaled up for application in larger urban areas. A biomass-fired boiler and a number of decentralized solar thermal facilities feed heat into an existing district heating grid in combination with grid-fed heat pumps that generate hot water individually in buildings and that use central and decentralized hot water storage tanks. This configuration allows the system to operate with low grid temperatures, and makes use of optimized energy efficiency measures while intensively harvesting solar energy. The B&O Park model project is a test bed, small enough so that it can address questions and problems in a purposeful way, yet large enough to set a standard that can be readily used in other urban areas or military installations.

INTRODUCTION

The B&O Bad Aibling Park is located in Bavaria, Germany some 35 miles (56 km) southeast of Munich. The 173-acre (70-ha) facility, which was built in the 1930s, originally served as a German airbase with neighboring barracks. After World War II, the U.S. Army converted the site to an intelligence base that monitored radio communications behind the Iron Curtain. For six decades, some 1,400 American military personnel and their families lived and worked at the base. Typical for an American base, the park-like site was largely self-sufficient. An oil-fired district heating station supplied the buildings at the site with 66,536 MBtu/h (19.5 MW) of heat. After the end of the Cold War and the shift in eastern/western bloc borders, the base lost its importance, and in 2004 it was returned to the Federal Republic of Germany. In 2006, the B&O real estate management and construction company acquired the grounds for high-quality development.

When the Bad Aibling Station was taken over from the American Army, its 52 building complexes contained some 774,720 ft^2 (72,000 m^2) of living space and usable area. Most residential buildings dated from the 1930s; their style of construction was clearly more German than American. Although buildings were kept in good repair, their thermal quality was poor. The district heating system for the grounds had been thoroughly modernized in the mid-1990s and was in good condition. However, the scale of heat generation was much larger than the site required (Figure 1). Since at the beginning of the project, some buildings had to be torn down and the purpose of others was not yet clear, the plan referred only to the enclosed area indicated on the overview map (Figure 2). Buildings include residences, a hotel complex with conference facilities, offices, businesses (manufacturing), a kindergarten, schools, a gymnasium, and a large hall for social events. Future plans are to join larger residential buildings already in place with low-energy detached house, row houses, and some low-energy apartment buildings constructed of wood.

The northern part of the site will mainly be the focus of retrofit projects involving buildings to be used as residences, a hotel, offices, and schools. New buildings will be constructed in the

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middle section of the grounds around the small lake. The original plan shows some detached houses. An architectural competition has proposed a new vision for a "city of wood" in this middle section. The southern part of the site contains businesses, sports facilities, and offices, which will mainly be the focus of retrofit projects.

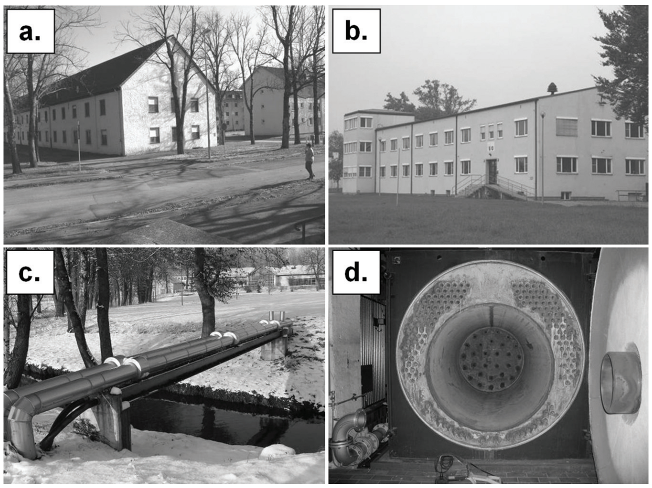

Figure 1 *(a and b) Buildings were constructed soundly, but had poor insulation and inefficient heating; (c) district heating pipes were in well maintained condition, but (d) boilers were oversized (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

Figure 2 *An aerial view of the grounds. At lower right is the former main access road, at upper right is the residential area, and in the green and wooded area to center right is a landscaped park; a sports park will be opened at lower center to right, and to the left and center there will be a business complex (B&O) (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

PROJECT GOALS

The guiding principle underlying this conversion project was to design a development plan that could be easily replicated, and that could ultimately become a model for a Zero Energy City. Goals were to be attained by the following:

- applying high energy efficiency standards,
- using innovative technologies,
- using modern methods of project management and modern planning tools in a consistent and integral planning process,
- networking the energy generation and consumption areas of the grounds, and
- methodically monitoring the entire energy recovery system of the district.

ENERGY EFFICIENCY IN BUILDINGS WHEN THE PROJECT BEGAN

Calculations made according to EnEV standards show that a typical residential building in the project area had a primary energy demand of 145.6 MBtu/ft^2·yr (459 kWh/m^2·yr). (The Energieeinsparverordnung, or EnEV, is Germany's energy conservation ordinance that sets energy efficiency standards for new construction and the retrofit of existing buildings.) Office buildings were shown to have similar energy demands. The buildings used to house the gymnasium and event hall had originally been built as airplane hangars in the 1930s. Heating for these subsequent uses was makeshift, and primary energy demand was estimated at 87.2 MBtu/ft^2·yr (275 kWh/m^2·yr). Because the energy efficiency of all buildings was so poor, retrofitting them to meet EnEV or better standards for new construction would result in savings in primary and supplied energy of well over 50%.

THE PLAN FOR USAGE

The site development plan was based on the existing building plan, which dated back to the original layout of the old military airfield in the 1930s. The project area was divided into three usage areas. The northern section is being converted into a residential area that consists mainly of apartments but also includes a conference hotel (Figure 3), a wellness center, offices, a design exhibition, a Waldorf school, and a soccer boarding school.

The landscape park in the center of the project adjoins the residential area to the south. Some of the residential blocks in this section along the old access road have already been demolished and more will follow. Some new single-family and duplex houses will be built here to meet Passive House energy standards. The first of these has already been completed. In the near future, several four- and eight-story

Figure 3 *The old officers club was retrofit as a conference hotel (left); 1930s vintage multifamily house retrofit to use solar energy (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

buildings will also be erected to form a "city of wood" using innovative, largely prefabricated wooden components (Figure 4). Two of these buildings have already been completed. The special feature of these buildings is their load-bearing wood construction, which is considered very innovative in Germany. These prefabricated structures are extremely cost-efficient and have very low heating requirements. The high degree of prefabrication is considered an advanced feature that promises lower building costs; even the processes used to manufacture their components are designed to consume little energy and are environmentally friendly.

A sports park is under construction at the south end of the project. Two former airplane hangars on this site will be converted into a gymnasium and a place for public events. Next to these buildings are several large outdoor sports fields. The old airport tower and fire brigade building, now being used as office space, are also planned for energy retrofits.

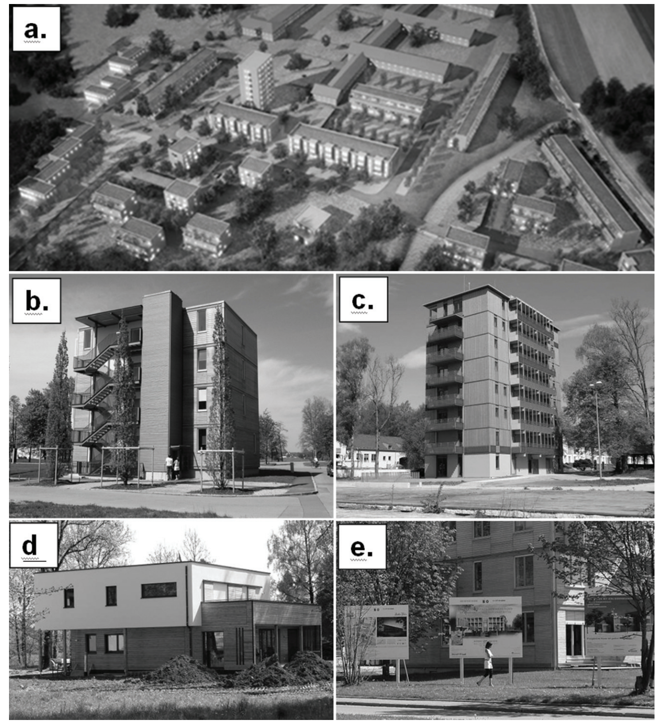

Figure 4 *New vision for the middle section of the Net Zero Energy (NZE) project area: (a) architectural of the "city of wood," (b) a four-storey and (c) an eight-storey house built with prefabricated wooden elements and wooden load-bearing construction; (d and e) detached houses that meet the Passive House standard (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

ENERGY STANDARDS, ANNUAL LOAD DURATION CURVES, AND HYDRAULIC ANALYSIS OF THE DISTRICT HEATING GRID

Energy standards for buildings in the project are targeted to fall within the following ranges:

- New building standards are determined to range from 5.1 to 13 MBtu/ft^2 (16 to 41 kWh/m^2).
- Retrofitted building standards are determined to range from 7.9 to 24 MBtu/ft^2 (25 to 76 kWh/m^2).

GEF Ingenieur AG (an engineering consulting firm) determined the annual load duration curve for the 27 buildings to be serviced by the district heating grid based on the energy efficiency goals. Calculations clearly showed that the base load for hot water is relatively low. More important, an analysis of all buildings within the model project area showed a large difference in the level of needs between the north and south areas, which are separated by the Moosbach stream flowing from west to east. In the northern area, highly efficient new buildings are being constructed applying ambitious energy modernization standards. This allows for low supply temperatures of about 131°F (55°C). In the southern area of the grid, which services the model project area as well as other buildings on the site, annual load duration curves are being largely determined by high swings in seasonal temperatures. Supply temperatures are at a low, but conventional, level between 149°F–167°F (65°C–75°C). This temperature range suggests that it may be beneficial to divide the grid so that each area can be serviced with its own supply temperature. This would isolate the northern area so it could achieve a zero energy balance, while still allowing the southern area to separately achieve an energy-efficient conversion (Figure 5).

OPTIONS FOR HEATING SUPPLY SYSTEMS AND POLIS SIMULATIONS

The POLIS simulation tool was used to develop and assess several options for the northern NZE grid supply system (Figure 6). The decision was made to use a Central Solar System, which is now being implemented. The system operates as follows. With enough sunshine, buildings with solar thermal panels will meet their own primary heating needs. A decentralized buffer tank in each building absorbs excess solar energy (more than is needed for heating). When a buffer tank is heated

Figure 5 *Separation of the district heating grid into a northern and a southern grid with different temperature profiles according to demand (image used courtesy of Schankula Architects).*

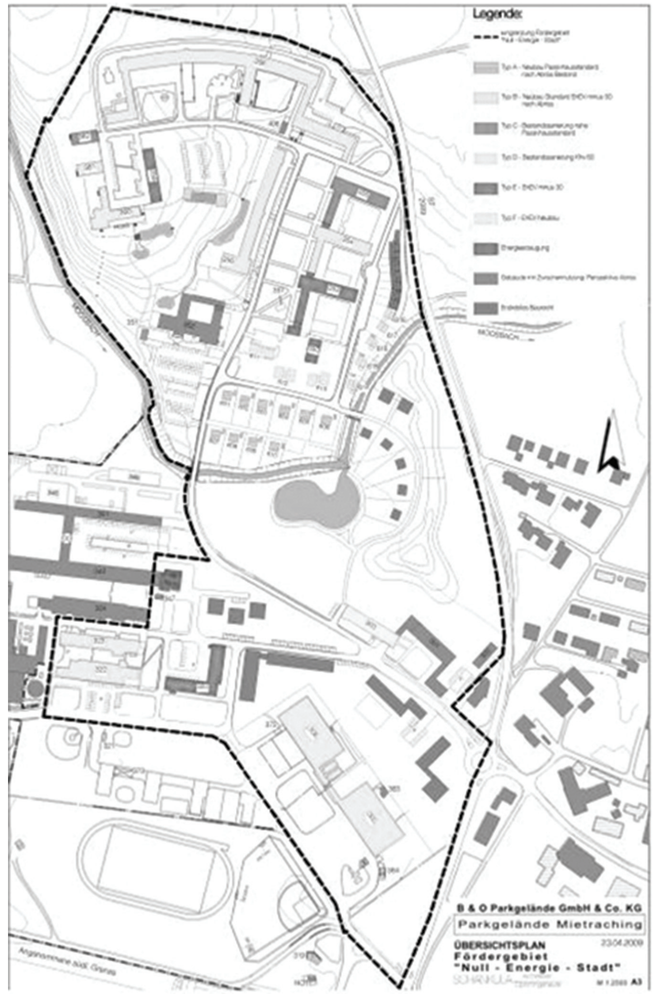

Figure 6 *Overview map of the zero energy city funded project area in 2009 (image used courtesy of Schankula Architects).*

to capacity, the surplus heat is fed into the grid to supply heat to other buildings. During the hot summer months, when heat yield peaks, excess solar energy is transferred to a 15,852 gal (60-m³) central storage tank in the heating plant (Figure 7).

In any season, grid temperature will vary with the amount of solar energy available. If solar energy is insufficient for hot water generation, heat pumps integrated in the buildings will reheat water in the decentralized storage tanks. Low temperature differences contribute to the heat pumps' high performance factors. If heat pump performance factors fall below 4, a woodchip-fired boiler is activated; this supplementary boiler also ensures that demand for heat is met in winter. The woodchip-fired boiler is sized fairly lean to ensure that the system exploits solar energy to the maximum extent possible, either directly or through the storage tanks. Finally, the system is also augmented by a conventional gas-fired boiler to ensure a secure energy supply in case the system must meet unusual peak loads.

A WELL-DESIGNED CONTEMPORARY BOILER HOUSE

The 28.5-MBtu/min (500-kW) woodchip-fueled boiler house, which can be easily replicated elsewhere, has been completed (Figure 8). This biomass-fueled heating plant was designed to be ecologically sound, attractive, and adaptable to an urban setting. Special filters and a sophisticated woodchip supply technology make the system appropriate for urban locations. The boiler house, conceived by architect Matteo Thun, was built near the lower hotel parking area and has been in operation since early spring of 2012. In the near future, it will be connected to a large heat storage tank in the basement of a nearby building. This buffer tank will be added to the existing 2119 ft^3 (60 m^3) central solar storage tank located in the old gas-fired heating plant, which now serves as peak load supplier.

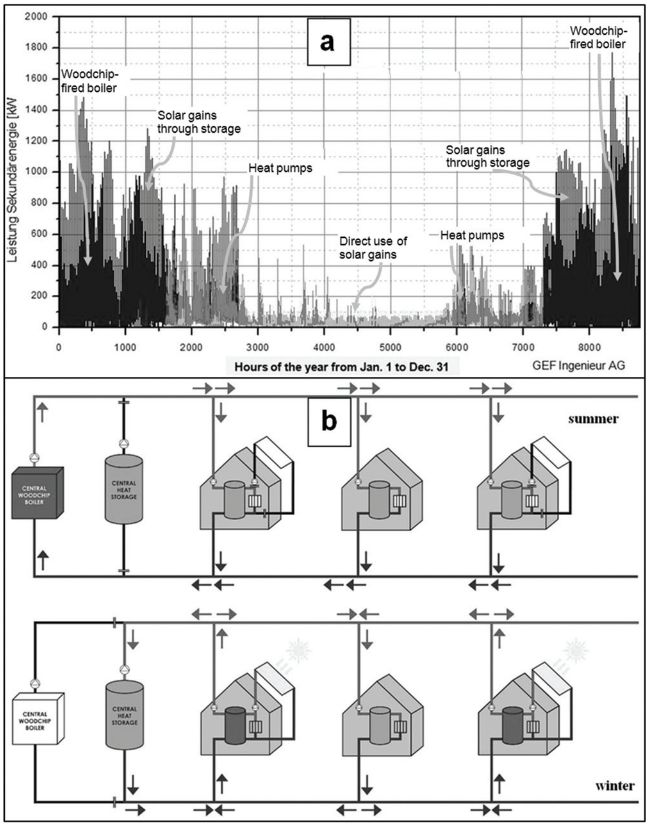

Figure 7 *(a Operation schedule of the central solar grid and (b) POLIS simulation of heat demand coverage by different generation systems throughout the year (image used courtesy of GEF Ingenieur AG).*

SOLAR THERMAL FACILITIES

Solar heat plays a major role in providing the buildings with hot water and heat. Plans are to join the ~8608 ft^2 (800 m^2) of flat solar panels currently in operation with another 29,052 ft^2 (2700 m^2) of (mostly flat) panels, some evacuated tube solar collectors, and hybrid modules (for simultaneous heat and power generation). All solar facilities are located on buildings in the residential area and are therefore connected to the northern grid.

RENEWABLE ENERGY GENERATION WITH HYDROPOWER

Molz engineering consultants researched the feasibility of building a small hydropower plant using the Moosbach stream on the grounds of the northern grid area. In the 1950s, a weir system was built near Building 350 to dam the stream. The Molz study showed that a small plant was technically feasible, would produce slightly less than 170,650 MBtu/yr (50,000 kWh/yr), and would provide a return on capital of about 5%. B&O intends to implement this project.

RENEWABLE ENERGY GENERATION WITH PHOTOVOLTAICS

An open field west of the large halls in the conversion project area that previously contained antennas offered an ideal space for setting up photovoltaic arrays. Different photovoltaic array systems were investigated (e.g., stationary systems, tracking modules, etc.). For economic reasons, a simple stationary photovoltaic array system was selected. The 161,400 ft^2 (15,000 m^2) of PV arrays, which were completed in the summer of 2010, have a peak capacity of 7029 MBtu/h (2.06 MW) and an estimated annual yield of 630 MBtu (2150 MWh/a). Another 3228 ft^2 (300 m^2) of PV installed on the roofs of two hangars have increased the solar electric yield up to 644 MBtu (2200 MWh/a).

ENERGY BALANCES

Energy balance calculations are performed only on the northern grid, the Net Zero Energy (NZE) area of the project. A balance calculation was done to compare primary energy delivery (renewable heat generation and solar electricity generation) with primary energy consumption (room heating, hot water, and electricity consumption—including all the plug loads). Since primary energy delivery to the grid was more than 878 MBtu (3,000 MWh/a) and primary energy consumption was 70 MBtu (240 MWh/a), it was found that the NZE-project delivers 10 times more primary energy to the state grid then it consumes from outside its boundary (Figure 9).

The results of the balance calculation show that the project is not only a NZE, but also a net plus energy project. The balances were done using monitored values, where they were available, but also some statistical average values (e.g., for electricity consumption of different usages). Because the energy balance is so skewed in favor of energy generation, it is very likely that the net zero energy will remain a net energy exporter, even if future measured values show slightly lower gains or higher consumption. Note that the calculations did not consider cooling because Bad Aibling climate conditions do not require cooling.

OTHER SPECIAL AND INNOVATIVE FEATURES OF THE PROJECT

The B&O Bad Aibling complex has incorporated other innovations to enhance the overall plan for modern, energy-efficient heating supply systems and to advance the concept of the energy-efficient city.

Retrofitting—Prefabricated Wood Elements with Integrated Panel Heating

Retrofit of occupied apartment buildings normally creates noise and stress for the residents. However, the amount of work to be done inside an apartment can be kept to a minimum by using innovative wooden façade elements

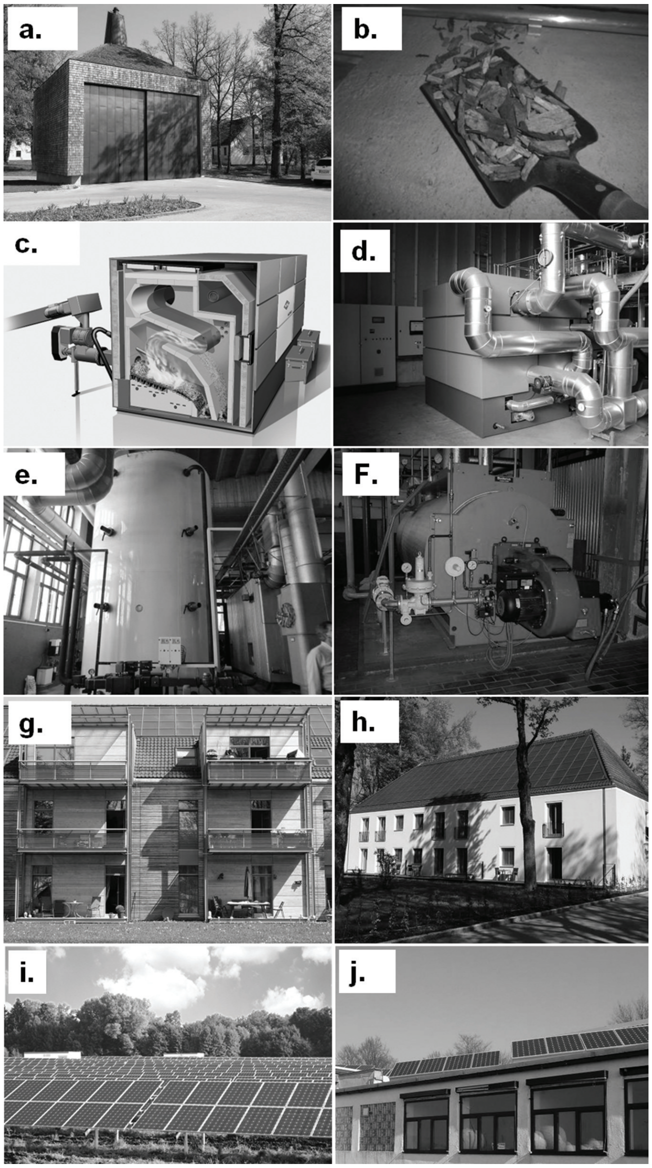

Figure 8 *Innovative technologies: (a) new woodchip-fueled boiler house designed by Matteo Thun; (b) dried woodchips as fuel; (c) operation scheme of woodchip boiler (HDG Bavaria); (d) 28.5 MBtu/min (500 kW) woodchip boiler in Bad Aibling (HDG Bavaria); (e) the first 2,119 ft³ (60 m³) central solar buffer tank; (f) 3MW natural gas-fired peak load boiler in the old heating plant, which also supplies heat for the southern grid; (g) flat solar panels on the south-facing roof of Building 353; (h) Flat solar panels on the south-facing roof of Building 362; (i) 161,400 ft² (15,000 m²) PV arrays on the former antenna field (KOCO AG); (j) 3228 ft² (300 m²) roof-mounted PV modules (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

that are mounted from the outside and that have integrated insulation and new built-in windows. This method can incorporate HVAC components into outside wood elements that would otherwise be installed from inside. A special feature of this technology is that irregularities in the old façade are first measured to ensure that the new elements fit exactly to the retrofitted building. One large multifamily house was retrofitted in 2009 using this technology, with panel heating mounted on the inside of some of the insulation elements (Figure 10).

Retrofitting—Pore Ventilation Façade Made of Natural Materials

The Deutsche Bundesstiftung Umwelt (DBU) (German environment foundation) funded two test façades with pore ventilation mounted on another multifamily house. By drawing fresh air in through the pores of the exterior insulation, this technology can recover heat transmission losses. The test façades in the B&O Park are made almost entirely of natural

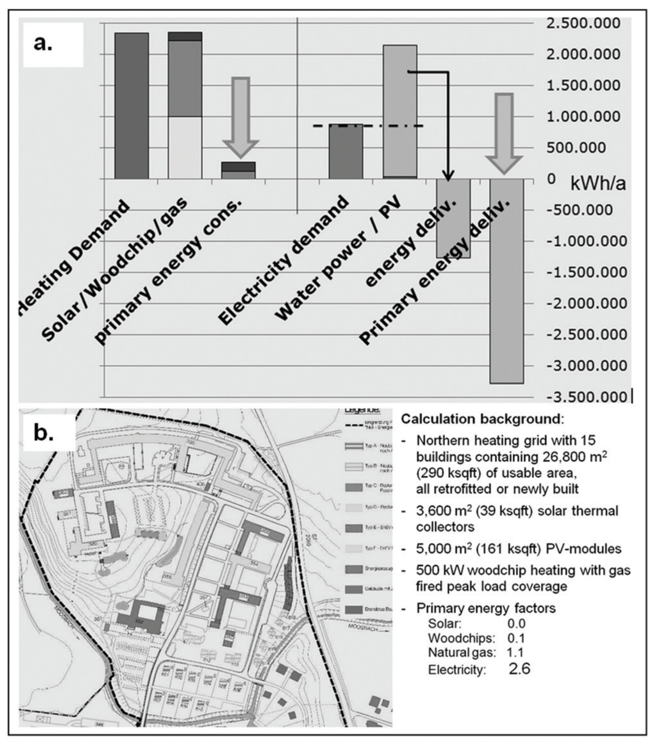

Figure 9 *(a) Primary energy balance for the 15 buildings of the northern grid, which defines the NZE area. More than 10.2 million MBtu (3 million kWh) are delivered to the state grid, but only 819,120 MBtu (240,000 kWh) of fossil fuel are consumed; (b) NZE-area of the project and calculation background for the energy balances (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

materials. Fiber boards made of hemp were used as porous insulation material.

Rosenheim University's Solar Decathlon Home

The Rosenheim University of Applied Sciences assembled its Solar Decathlon Home on the B&O Park grounds in the spring of 2011. The house, which was designed by university students, was awarded second prize at the 2010 European Solar Decathlon competition in Barcelona.

Innovative HVAC—Various Ventilation Systems and Methods for Generating Hot Water

B&O is using the Bad Aibling model project to gain experience with a wide range of innovative building services that can be used in many other projects. In this way, B&O, the leader in a highly competitive retrofit industry, hopes to secure further market advantages. This has synergetic effects—B&O can use the model project to compare various ventilation systems that all meet the most up-to-date standards. The project is similarly testing and evaluating a variety of innovative and energy-saving methods for heating water.

Smart Metering and Consumer Guidance

The model project has also incorporated smart metering into the vacation apartments in one of the large multifamily houses. Smart metering can track heating and electricity consumption on an hourly, daily, or continuous basis to give households an easy overview of their energy consumption behavior and resultant costs (Figure 11). This technology was provided primarily by integrating internet-like services.

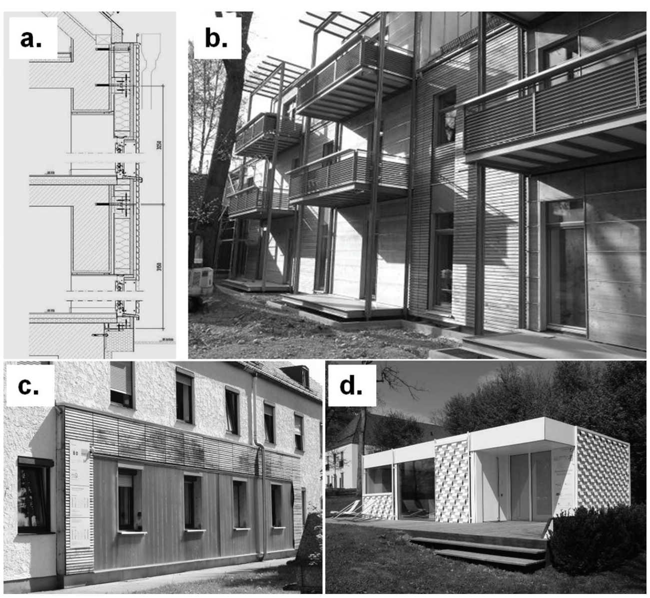

Figure 10 *(a) Vertical cut through prefabricated wooden element for façade retrofit (Huber&Sohn); (b) completed façade retrofit; (c) pore ventilation test façade at a multifamily building; (d) solar Decathlon Home at the B&O Park grounds (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

IMPLEMENTATION OF THE PROJECT

Deep retrofit of nine buildings (107,600 ft^2 [10,000 m^2] usable area) is complete, and three more buildings are partly refurbished. Four new buildings (21,520 ft^2 [2000 m^2] usable area) were erected, all of which meet an energy standard close to the Passive House standard. Construction of some 86,080 ft^2 (8,000 m^2) in the buildings of the "city of wood" was completed in 2012, as was installation of 164,628 ft^2 (15,300 m^2) of PV arrays and ~8,608 ft^2 (~800 m^2) of solar thermal collectors. Thermal collector area enlargement continues. The woodchip-fired heating plant has been in operation since early spring 2012, a 2119 ft^3 (60 m^3) central storage tank has been used to cache the surplus solar energy since 2010, and further implementation is planned.

MONITORING

A comprehensive monitoring system was developed in 2009. It is currently being commissioned to evaluate the energy efficiency of the entire project and to identify possible improvements. The Rosenheim University of Applied Sciences is working on this task in a separate EnEff:Stadt-funded project. Rosenheim's monitoring plan has identified as many as 1500 measuring points across the entire grounds (Figure 12). Most of the sensors are (or will soon be) in operation. The emphasis of this part of the project is to measure not only building performance, but also the performance of the

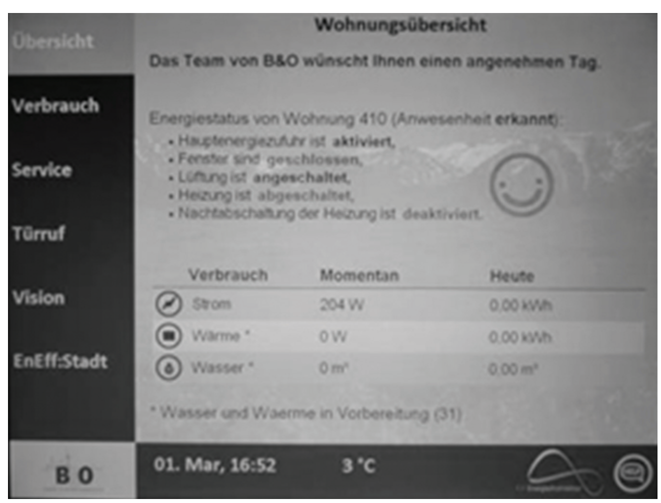

Figure 11 *Smart metering displays help the tenants to get an overview of their energy and water consumption and the resulting costs (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

Figure 12 *Measuring points in the heating grid of the NZE northern grid (image used courtesy of RK-Stuttgart Architecture and Energy Design).*

heating grid with its different heat sources and complex operating schedule.

DEGREE OF INNOVATION, EASE OF REPLICATION, POTENTIAL FOR FUTURE PROJECTS

The B&O Bad Aibling project resolved a number of complex energy issues by using a diverse mix of technologies that may be scaled up for application in larger urban areas. This project went beyond business-as-usual innovations by using an extremely innovative heating plan that possesses the quality of new high-level research. A biomass-fired boiler and a number of decentralized solar thermal facilities feed heat into an existing district heating grid, in combination with grid-fed heat pumps that generate hot water individually in buildings and that use central and decentralized hot water storage tanks. This configuration allows the system to operate with low grid temperatures and makes use of optimized energy efficiency measures while intensively harvesting solar energy.

Experts know that the decentralized feed-in of low heat to local or district heating grids will play an important role in developing plans for heating in the medium and long term when fossil fuels must be gradually replaced. The Bad Aibling model project demonstrates the enormous amount of research and development needed to make such large and complex grid structures a reality. The B&O Park model project can be seen as a testbed, small enough so that it can address questions and problems in a purposeful way, and large enough to set a standard that can be readily used in other urban areas or military installations.

Partners

Partners in the B&O Bad Aibling model project include:

- Government funding: German Ministry of Economics and Technology
- Funding administration: Project Management Jülich (PtJ) at the Forschungszentrum Jülich
- Funding recipient and project manager: B&O Wohnungswirtschaft GmbH und Co. KG (real estate management and construction company)
- Technical and scientific coordinator: RK-Stuttgart Architecture + Energy Design
- Simulation and analysis of options for heating supply systems: GEF Ingenieur AG
- Innovative HVAC, Solar Grid test network: Enwerk, PEWO
- New wood façade elements and retrofitting: Huber + Sohn
- Hydropower: Molz engineering consultancy
- Construction physics and monitoring: Rosenheim University of Applied Sciences.

Links

RK-Stuttgart Architecture and Energy Design. 2013. Our focus: Energy efficiency in Buildings. www.rk-stuttgart.de/index.php?id=20&L=1.

Hochschile Rosenheim University of Applied Sciences. 2013. www.bo-wohnungswirtschaft.de.

Hochschile Rosenheim University of Applied Sciences. www.fh-rosenheim.de.

EnEff: Stadt/EnEff: Warme. 2013. EnEff: Stadt/EnEff: warme research iniative. www.eneff-stadt.info

REFERENCES

Alfred Kerschberger. 2011. From US Army Installation to Net Zero Energy Community—Bad Aibling and other Examples. Conference on Energy Efficient Technologies for Buildings and Communities. January 26–28, 2011, Las Vegas, NV.

Alfred Kerschberger. 2012. Net Zero Energy (NZE) Communities—Concepts, Methods, Implementations. Army Net Zero Energy Installations Conference. January 18–20, 2012, Chicago, IL.

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