CASE STUDY

LIVE IN POSITIVE ENERGY

The TU Wien (Vienna University of Technology): Award-Winning Plus-Energy Retrofit of a High-Rise Office Building

The Plus-Energy Office High-Rise Building of the TU Wien (Vienna University of Technology), completed in 2014, is the first example of a sustainable renovation of an office tower building, which generates more energy than it consumes. It is also a great example of successful interdisciplinary collaboration, simultaneous, integrated planning, as well as a well-developed usage concept.

In addition to drastically reduced energy consumption (by up to 88%), the building produces electricity directly through a photovoltaic system integrated into the facade and mounted on the roof and via energy recovery from the elevator. Energy recovered from the server's waste heat is the main source of heating for the building.

This building proves that renovation with a plus-energy concept is not only technically possible but also commercially feasible.

Author: Joanneum Research

Background image on case study title page: [Source: © Schöberl & Pöll GmbH]

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The PEB in its Local Context

The Plus-Energy Office High-Rise Building is located in the center of Vienna and is one of 8 buildings within the TU Wien Getreidemarkt Campus. The original building, built in 1970s, was dilapidated and consumed a lot of energy - around 803 kWh/m²y (primary energy, non-renewable). The owner of the building, the Federal Real Estate Company - Bundesimmobiliengesellschaft or “BIG” - and its tenant, the university, decided on a complete renovation as part of the “TU Univercity 2015” project: Modification and refurbishment of the infrastructure of TU Wien.[1]

Since legal restrictions did not allow the construction of a new high-rise building on the same site, renovation seemed to be the best option. However, ambitious scientists and engineers intended not only to reduce the energy consumption of the building, but also to make it energy positive, which was a challenge for a building of such height, being located in a confined space. Enthusiasm, integrated planning, and an interdisciplinary team passionate about innovative strategies and technologies, made it possible to turn the old building into the world's first-ever 'Plus-Energy' office tower block.[1]

The Plus-Energy office building itself consists of two buildings - the actual eleven-story tower block and the adjacent building. The total area of the building is about 13,500 m², and it contains office spaces, classrooms, a library, an auditorium, an event hall and ancillary spaces. After the renovation, it houses the Faculty of Mechanical Engineering and it is a workplace for about 800 people, with a total capacity to accommodate up to 1800 people.[2]

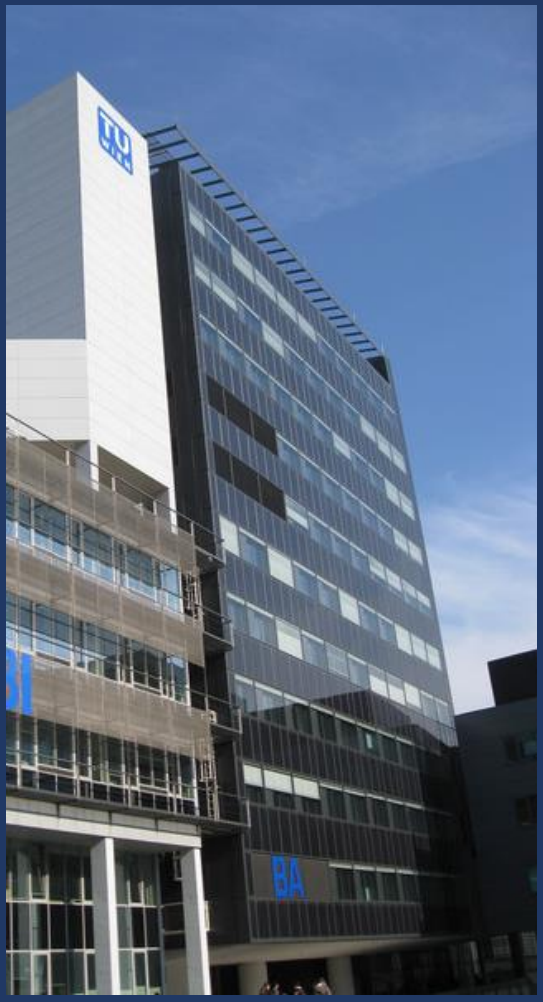

Image 1
Cropped photograph showing the building’s façade
[Source: © TU Wien | Alexander David]

The Building’s Special Features

The energy consumption of the building is divided into two categories: A) "Building operation" - amount of energy needed to operate a building in general (heating, cooling, lighting, etc.). B) "Building usage" – with the energy consumption resulting from the use (computers, telephones, equipment in common spaces, etc.). The team behind the renovation, points out that their building is a 'plus-plus energy building', as it covers not only ‘the operation’ part of energy consumption but also 'the usage' part of energy consumption caused in the office area.

“Enthusiasm, integrated planning and an interdisciplinary team passionate about innovative strategies and technologies …”

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As TU Wien uses a number of high-performance computers for its research activities, that are typically not being found in office buildings, the energy consumption increases from 56 kWh/m²y to 108 kWh/m²y, which exceeds the building's own energy production set on 61 kWh/m²y. Still it falls under typical plus-energy building definition, which states that the building's own energy production must cover the 'operation' part of the energy consumption.[3]

The building's primary energy consumption is covered by the photovoltaic system placed on the roof and integrated into the façade (largest photovoltaic system ever integrated into any facade in Austria), and energy recovery from elevators, while the heat demand is delivered by the energy recovered from the servers placed in the basement. When the produced energy is higher than the building's current energy needs, the surplus is used by neighbouring buildings at TU Wien. If not enough energy is produced, the required energy is taken from the power grid or Vienna's district heating network. The cooling required in the server room and in the building in the warmer months is obtained with hybrid cooling towers and an automatic night ventilation system using the ambient air.[3]

Selected Performance Indicators

Categorization of Energy Consumption

Heating: 14.45 kWh/m²y

Cooling: 11.22 kWh/m²y

Renewable Energy Generation

Photovoltaic: approx. 60.0 kWh/m²y

Building Envelope Performance:

Sheet metal façade: 0.097 W/m²K
Flat roof: 0.065 W/m²K
Air Tightness Value: n50 ≤ 0.09 1/h, q50 ≤ 0.6 m³/(h m²)

To what Percentage is the PEB Energy Positive? 109%

Greenhouse gas emissions for building:
20.0 kgCO_2/m²

Total Primary Energy Supply, Austria, OECD, 2017:

Oil 35%, Natural Gas 23%, Biofuels & Waste 20%, Hydro 10% and Coal 9%

However, to achieve the green plus-energy standard, energy consumption had to be completely reduced for all parts of the building, for heating and cooling, as well as for office computers and smaller electrical components. In the project, the scientific team registered, optimized and approved 9,300 components from 280 categories. In all offices small computers (components of a notebook) are used. These hardly emit any heat because the computationally intensive processes are "outsourced" via the network to the central server room. As a result, and thanks to the storm-proof shading and LED-lighting, the offices can be passively and comfortably temperature-controlled in summer via free night-time cross ventilation. The waste heat in the server room is used in winter and dissipated in summer.[2]

Key Technologies Installed

- Photovoltaic system integrated into the façade (façade + roof, total 2,199 m², efficiency 17%) with a total capacity of 328.4 kWp (and an 8.5 year payback period).
- The energy recovered from braking the lifts is used. The cabin's kinetic energy is converted into electricity.
- Energy recovery from server's waste heat.
- Cooling by natural night ventilation and hybrid cooling towers.

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Non-Exhaustive List of Involved Stakeholders

Owner
Bundesimmobiliengesellschaft
Federal Real Estate Company
https://www.big.at/

Building User
TU Wien Rector's Office – TU Wien Buildings & Technology
https://www.tuwien.at/

Main Contractors
ARGE Architekten Hiesmayer, Gallister und Kratochwil
http://www.ae30.at/

Building Physics & Research
Schöberl & Pöll GmbH
https://www.schoeberlpoell.at/

& Prof. Bednar – Research Unit Building Physics team, TU Wien
https://www.bph.tuwien.at/

Various Specialists & Consultants

Catalysts, Challenges & Results

The general conditions of the Getreidemarkt campus buildings, as well as urban regulations that prevent the construction of a new building of the same height on the premises, led TU Wien and BIG to take on the engineering challenge, to retrofit the building to a 'plus-plus energy' standard by harnessing technological innovation. The project was financed by BIG, and its realization cost less than an entirely new construction. The final amount was slightly below the cost limit applicable to university buildings. In addition, public research funding programs covered all the research and planning costs. The overall cost of the building was 19.4 million € (excl. VAT, as of June 2014, for 13,500 m² of usable space, 1,437 €/m² usable area), and it included the photovoltaics and the IT infrastructure like server boxes. The cost breakdown is as follows:

Façade	**Construction works**	**Interior fittings**	**Heating, air-conditioning, sanitation**
2,946,000 EUR	4,151,043 EUR	3,363,150 EUR	1,714,722 EUR
E-technology	**Ventilation**	**Photovoltaics**	**Measurement, control & regulation tech.**
2,040,000 EUR	1,494,951 EUR	825,000 EUR	760,944 EUR
Lighting	**IT infrastructure**	**Elevator**	**Roof construction** (incl. steel for PV)
724,400 EUR	586,000 EUR	485,000 EUR	313,200 EUR

The renovation required simultaneous, integrated planning, continuous knowledge sharing and maintaining a clear overview, from the very beginning of developing the building concept. All involved partners had to communicate well, apply their advocacy skills in practice and to have a proactive approach to project management.[1] Building users were consulted even before the building planning started and were asked about their needs, in order to create the building programme, and based on that, the energy usage concept.

Overall, the building generates approx. 5 kWh/m^{2}y more energy than its office space consumes in total, which reflects the definition of a 'plus-plus-energy building'. Also, a comfortable and healthy space has been created for over 800 users.[1]

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Building awards and achievements include the ‘klimaaktiv GOLD-Plakette‘ from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, achieving 1,000/10,00 points, first place in the Austrian Sustainable Building Council‘s TQB rankings (with 986/1,000 points), ‘2015‘s most innovative building‘ – ‘Innovative Gebäude (building)‘ platform.[3]

The building is not only a successful pilot project with regard to the technology and construction, but also the software developed for it (planning, control, monitoring) has been the basis for further development in other research projects. Thanks to a common platform for all planners developed in this project, it is now possible to work together interactively from the start and any building can be optimized in the preliminary design phase. All special programs can be docked to the software SIMULTAN. Thereby optimizing the planning process, the building erection and the operation of the building is possible. This should make many successor projects of the same quality possible.

Replication Potential

So far, no other plus energy office tower has been constructed, but the acquired skills and tools have been used for some renovation of other TU Wien buildings. The findings of the research project set the standard for future projects and construction activities of the university and are already applied to all 5500 employees, e.g. through more efficient computers, switching off technical equipment overnight, etc.

Conclusions & Lessons Learned

Through various schemes, Austria has been financing sustainable and energy-efficient construction technologies at the national level for years, making it one of the world's leading countries in this field. Moreover, its ambitious climate and energy policies give good signals for experimentation and real testing of such unique solutions. However, quality control should be taken more seriously compared to conventional buildings, starting with airtightness, elevator testing and others.

The Plus-Energy Office High-Rise Building is a particularly good example of an innovative model of cooperation in the sustainable renovation of old building structures. Combining basic scientific principles, research on applications and concrete implementation resulted in tailour-made solutions that enhanced building performance added social value.[4] The actors involved definitely paved the way for further PEB projects, primarily by transferring their knowledge, as well as by providing the possibility of visiting the building.

Image 2

Exterior view of the façade with PV modules
[Source: © TU Wien | Alexander David]

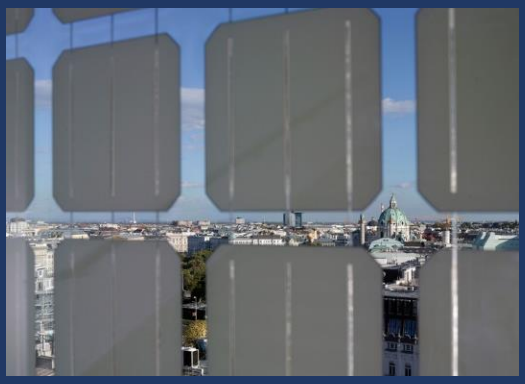

Image 3

Inside view of glazing with integrated PV modules
[Source: © TU Wien | Alexander David]

“…a particularly good example of an innovative model of cooperation in the sustainable renovation…”

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Acknowledgements

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- For all the involved companies for permitting the use of their logos.
- Thomas Bednar, Alexander David, Ernst Heiduk, Institute of Material Technology, Building Physics and Building Ecology, Research Unit Building Physics, TU Wien, for contributions to the case study text and Alexander David for the permission to use photographs.

Selected References

[1] https://www.tuwien.at/en/tu-wien/campus/tu-univercity/locations/plus-energie-buerohochhaus/building-concept/

[2] https://www.sauter-controls.com/wp-content/uploads/2019/02/Bildung_Facts33_Technischen-Universit%C3%A4t-Wien-%C3%96sterreich_EN_S22_23.pdf

[3] https://www.tuwien.at/fileadmin/Assets/tu-wien/Campus/TU_univercity/plusenergiebuerohochhaus/Broschuere-Plus-Energie-Buerohochhaus_ENG.pdf

[4] https://www.tuwien.at/en/tu-wien/news/news-articles/news/tu-wien-opens-austrias-first-energy-plus-office-building-1/

[5] https://www.pvaustria.at/wp-content/uploads/Sanierung-Weltweit-erstes-Plus-Energie-B%C3%BCrohochhaus-Beschreibung.pdf

Local Information

Address: Getreidemarkt 9 , 1060 Vienna, Austria

Approximate Geographic Coordinates [Google | EPSG:4326 – WGS 84]: 48.20° N, 16.36° E

Local Government: City of Vienna

Population: 1,897,000 (2019)
Total Area Administered: 414.6 km²
Municipal Budget: https://www.wien.gv.at/finanzen/budget/
Total annual GHG emissions: 9,194,000 tCO_2e [2018]

Climatic Zone [Köppen]: Cfb - Temperate oceanic climate | Temperate | Without dry season | Warm

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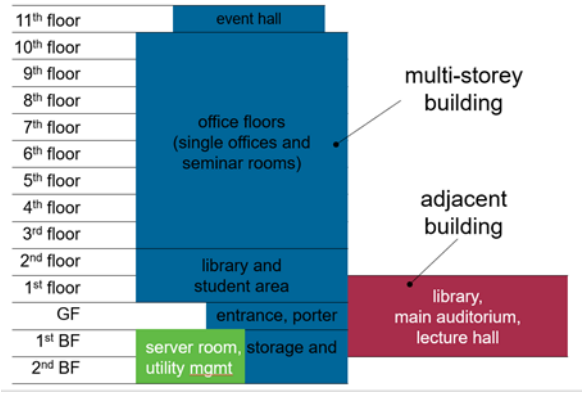
Further Images & Visuals

Image 4

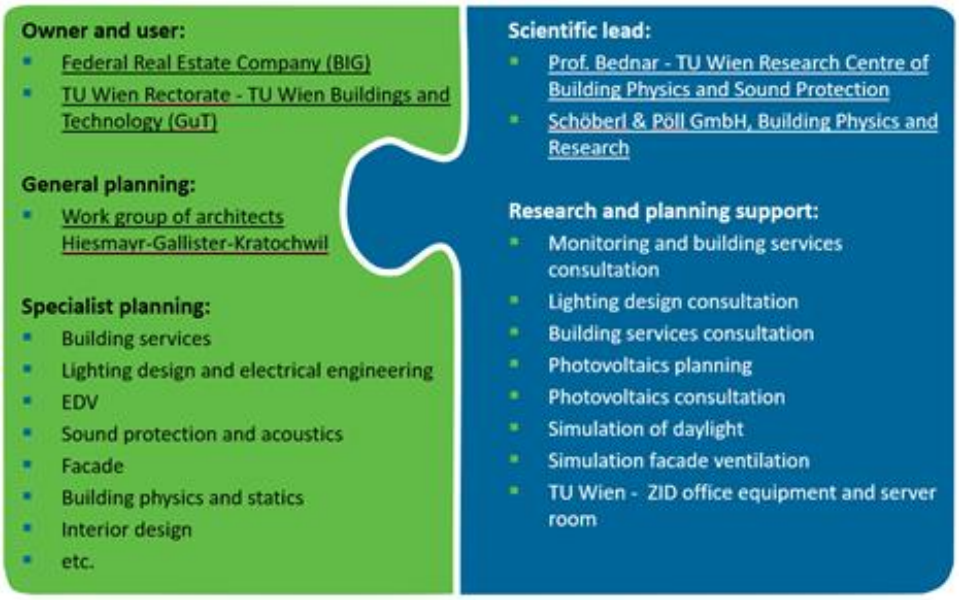
Building before renovation [Source: TU-Wien]

Image 5



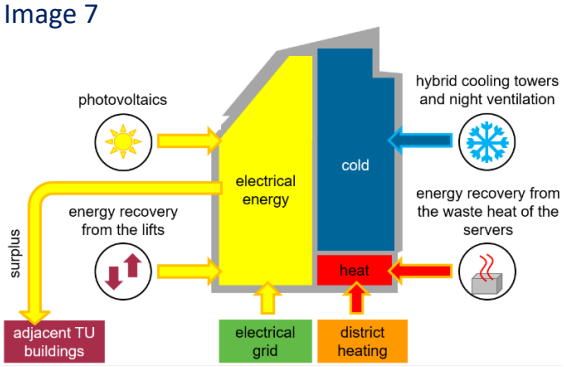
Section [Source: TU-Wien | Alexander David]

Image 6



Project Partners [Source: TU-Wien | Alexander David]

Image 7



Used Energy Sources and Sinks [Source: TU-Wien | Alexander David]

Image 8

Office computer

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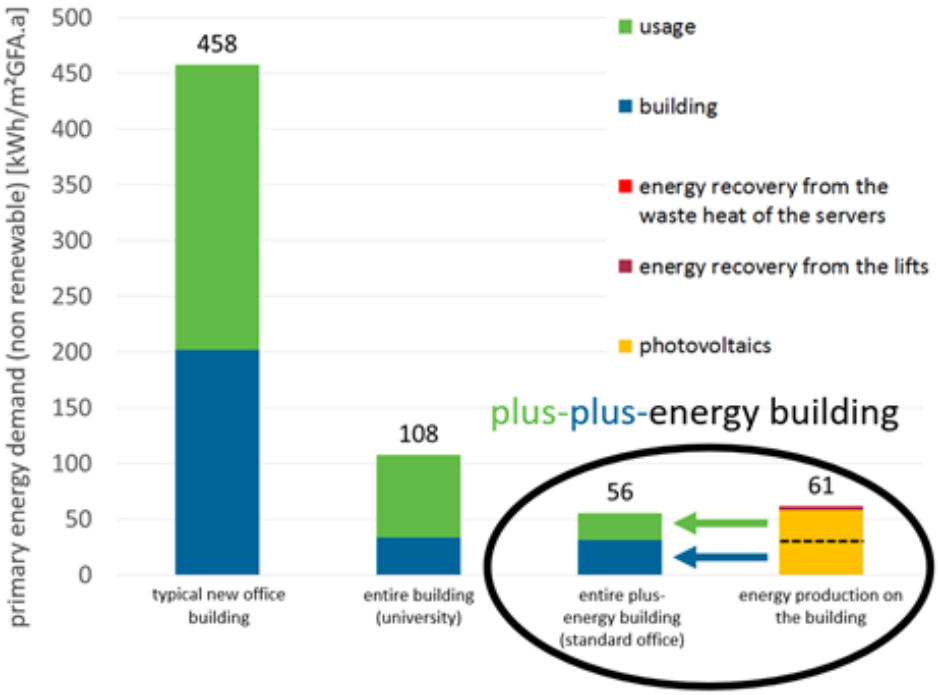
Image 9



Energy balance [Source: TU-Wien | Alexander David]

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