Award-Winning New City Hall of Freiburg: The World's 1st Public Net-Plus Energy Building

The New City Hall in the City of Freiburg is a highly energy efficient public building that has received national awards and international recognition. The municipal building, which was completed in 2017, is an example of how local government commitment and vision, the effective collaboration of specialist firms and a careful balancing act between economic considerations and environmental sustainability ambitions can result in a modern and future-proof administrative building. In addition to benefits such as lower maintenance and running costs, the working environment of local government staff has improved and citizens benefit from the concentration of administrative functions and services in one central location.

Constructed over a 33-month period and costing 82.5 million Euro, the 24,215 m² building provides office space for 840 local government employees. The distinctive curved design features a highly insulated building envelope with integrated photovoltaic panels (PV), an expansive array of rooftop PV and hybrid panels. Heating and cooling are achieved via a ground-water coupled heat pump system and groundwater heat exchanger.

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The Positive Energy Building in its Local Context

The new municipal building is located in Freiburg im Breisgau – a university town in the south-west of Germany that is home to just under 230,000 inhabitants (2019). Freiburg is renowned for its visionary approach to sustainable urban development and for being the sunniest city in Germany. The site of the new development is found in the city's district Stühlinger, approximately 1km to the north-west of Freiburg's historical core. The 24,215 m² administration building provides space for 840 local government staff who, up to the building's completion in 2017, had worked in 16 separate locations across the city.

At ground level, the building accommodates an expansive open-plan, naturally lit public service centre and a smaller building erected on the site houses a day nursery (1,900 m²). An additional administrative building is due to be completed in 2024 and a third development phase will see the administrative campus expanded further (pending City Council approval) whilst also incorporating residential buildings.

Designed by the Düsseldorf-based architectural practice ingenhoven architects and constructed over a period of 33 months, the new City Hall spans six floors above ground and is characterised by a curved floor plan as well as a distinctive vertical timber-aluminium façade. Reflecting the local government's green credentials, the municipal building was commissioned, planned and constructed to be highly energy efficient.

Image 1

View of the City Hall's PV-system on the rooftop [Source: ingenhoven architects / HGEsch]

Image 2

View of the PV-System installed on the façade of the City Hall [Source: ingenhoven architects / HGEsch]

The Building's Special Features

The municipal administration building functions as a decentralized power plant, incorporating a range of interconnected technologies to maximize energy efficiency and renewable energy generation. The building's mullion-transom façade consists of staggered, vertically projecting modules that feature local sustainably sourced timber.

Further, it incorporates triple glazed windows, highly insulated panels and natural ventilation elements that are equipped with PV-modules in areas exposed to the sun (the U-value of the entire façade is approximately 0.9 - 1.0 W/m²K). At rooftop level, the building is equipped with an array of photovoltaic and hybrid photovoltaic-thermal collectors to provide both electricity and thermal energy. The PVT elements principally provide domestic hot water for the canteen.

"… the new City Hall […] is characterised by a curved floor plan as well as a distinctive vertical timber-aluminium façade."

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Electrical energy generated by modules on the roof and façade is converted from direct to alternating current through 22 inverters and supplied to the building and the electricity grid.

Heat derived from a ground-water coupled heat pump system and cooling, extracted via a groundwater heat exchanger, is distributed across the building by means of thermal activated concrete slabs and an air handling unit. Heating and cooling of slabs takes into account weather forecast data in order to maintain the air temperatures of 20°C in winter and 26°C in summer. The building's ventilation system is equipped with a highly efficient heat recovery system, to reduce energy losses. A simulation-based energy management system is used to measure and optimize the building's plus energy performance. With regard to artificial and natural lighting, the building uses energy efficient LED technology and an automated sunshade system to manage solar gains.

Selected Performance Indicators

Energy Demand

Annual thermal
energy demand: 55 kWh/m^{2}y

Annual electrical energy demand of building (includes lighting but excludes user-specific consumption): 23 kWh/m^{2}y

Breakdown of Energy Generation

Photovoltaic: 557.4 MWh [2018]

U-value of the entire façade:
approx. 0.9 - 1.0 W/m²K

Local Energy Mix: The City of Freiburg only uses certified green electricity.

Going beyond energy related features, the building also incorporates sustainable design elements such as showers and lockers for cyclists to promote low-carbon mobility.

Key Technologies Installed

- 880 photovoltaic modules with a total peak output of approx. 220 kW (custom glass-glass panels from Sunpower) are integrated into the building façade. The vertically projecting modules (3.5 m long x 0.6 m wide) weigh almost 100 kg and have an output of 253 Wp per module. The 7 mm distance between the solar cells creates a high degree of transparency to the wooden element behind. In order to maximize the forecast amount of energy of 91.6 MWh/y, each module was equipped with a power optimizer.

- An approx. 465.8 kWp photovoltaic system (also Sunpower) with an inclination of approx. 10% covers the building's roof. The flat roof was designed to maximise the amount of surface area for renewable energy generation (no elevator shaft protrusions or building services modules). In order to further maximize the amount of energy generated from the roof photovoltaic system each module was also equipped with a power optimizer.

- The building draws heat and cooling from a groundwater well. For heating purposes, the well is connected to 2 heat pumps, each with a capacity of 150 kW. A gas condensing boiler covers peak loads. Pleasant temperatures in summer are ensured by groundwater cooling, without the aid of the heat pumps.

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- Thermal energy is stored in a 1,810 liter stratified storage tank (SOLVIS Strato), which is fed by 22 SOLVIS PVT combi-collectors on the roof with an aperture area of 2 m² each.

- The Energy Management System (developed by Drees & Sommer) monitors and continuously optimizes the building's energy performance using, amongst others, simulation-based approaches. The system was already used during the commissioning phase, monitoring over 9,500 data points and over 875 million values (in 2020).

Non-Exhaustive List of Involved Stakeholders

The following list includes some of the key actors involved in realizing the PEB. It should be noted that the architectural practice ingenhoven architects was also involved in activities such as site supervision, landscape planning and the interior design of special areas. Responsibilities of the company DS-Plan included the energy concept, photovoltaics, building services as well as façade design work.

Client
City of Freiburg
www.freiburg.de

Architect
ingenhoven architects
www.ingenhovenarchitects.com

General Technical Planner
Energy Design & Energy Management
Drees & Sommer
www.dreso.com

Structural Planning
MOHNKE I HÖSS Bauingenieure PartGmbB
www.mh-bauingenieure.de

Project Management
THOST Projektmanagement
www.thost.de

Lighting Design / Planning
Tropp Lighting Design
www.tropp-lighting.com

Fire Protection / Safety
Brandschutz Planung Klingsch
https://bpk-fire.de

Landscape Planning
BBS Landscape Engineering
www.bbs-landscape.com

Catalysts, Challenges & Results

The principal enabling factor for the realisation of a PEB at such a big scale was the vision and commitment of the client, the City of Freiburg, which is striving to become carbon neutral by 2050. Whilst the building was initially envisioned to meet the Passive House Standard, project partners calculated that a positive energy building was technically feasible as well as economically viable and the client ultimately embraced a more ambitious goal. This city-driven project does not appear to have been enabled or otherwise influenced significantly by provincial, national or European policies or programs. With project costs totaling approximately 82.5 million Euro (which equates to about 3,400 €/m²) local government decision-makers embraced a lifecycle approach as opposed to cutting costs in the short-term. Total costs included manufacturing and construction costs, ancillary costs, fees, equipment, furniture as well as VAT.

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By specifying in the design brief that the building should integrate low-tech concepts where possible, the client ensured that the building would not only perform well in terms of environmental sustainability, but could also be maintained and operated cost-effectively.

The decision to fix the PV-panels to the façade - as opposed to making these movable to maximise exposure throughout the day – is just one example of how carefully investment decisions and environmental performance were weighed against one another. The projects costs, which increased from 78.3 to 82.5 M€ as a result of construction delays, are to be partly recouped through the sale of government-owned property and savings associated with renting fewer premises. Bringing on board experienced architects, project managers and specialist firms also clearly contributed to the success of the project. Further, the effective collaboration of project partners was imperative to manage a project of such scale and complexity. Looking back at a twenty year long history of collaboration, ingenhoven architects and the general technical planner DS-Plan were well-suited partners for planning the PEB.

Public participation at the project conception stage should be highlighted as another enabling factor for the project as it helped planners understand challenges and potentials from the perspective of citizens and increased overall acceptance of the project.

Funded by the Federal Ministry for Economic Affairs and Energy, the Fraunhofer Institute for Solar Energy Systems monitored the building's performance over a one-and-a-half-year period and developed energy management tools. In 2019, the Institute confirmed that during the first full year of building use in 2018, a nearly zero-energy balance could be achieved and optimisation potentials existed to improve the performance further. In addition to the building's excellent energy performance, project realization has also brought co-benefits including: (1) efficiency gains for public administrative processes resulting from the spatial proximity of previously dispersed departments; (2) a more centralized point of contact for citizens' services; and (3) clear improvements to the wellbeing of staff, resulting from an improved working environment.

The building's environmental sustainability credentials and positive impacts have been recognised by award nominations such as the 2019 DGNB Sustainable Building award for outstanding implementation of ecological and architectural standards (winner) and the 2018 Balthasar Neumann Preis (nominated).

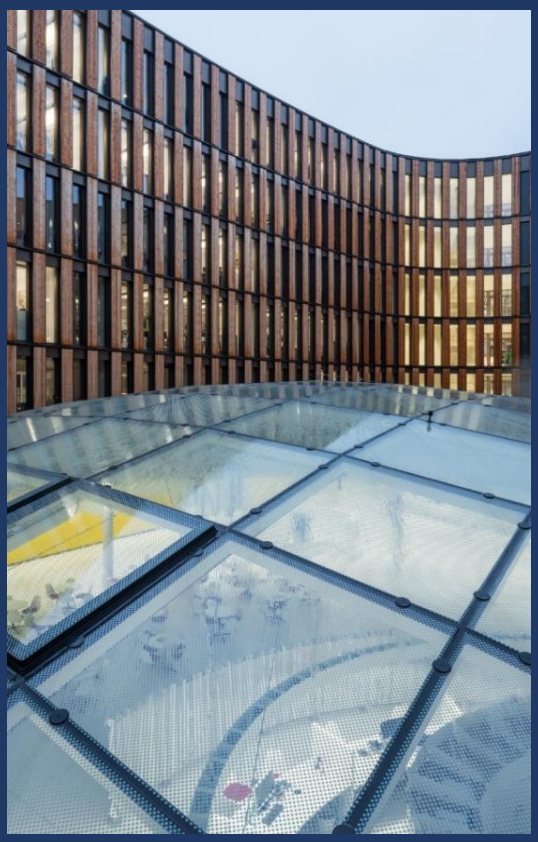

Image 4
The City Hall's courtyard and glass-domed service centre [Source: ingenhoven architects / HGEsch]

Awarded for "outstanding implementation of ecological & architectural standards"

EXCESS

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Replication Potential

A key condition for replicating an energetically ambitious municipal building such as the New City Hall is the commitment and vision of local government decision-makers. Cross-party consensus and public acceptance of a proposal must be ensured for the project as well as a clear and demanding public procurement process and contract management from the start. On the subject of stakeholders, it is clear that bringing together a team of specialist firms requires the strong leadership of a project manager as well as trust and effective communication within the project consortium. For large-scale PEBs like the New Town Hall of Freiburg, it is therefore prudent to work with companies with proven experience of working in larger teams, preferably having already worked together in the past.

Furthermore, the significant costs associated with an ambitious design may prove to be too high for local governments whose budgets are more limited and creative financing options such as research grants and/or energy cooperatives may have to be explored to finance large-scale PEBs. The potentially longer planning and construction time for a complex building project must also be considered by the client.

With regard to technological solutions, the PEB uses established and market-ready solutions, which can be replicated for various uses and contexts. Their integration would, however, have to be calibrated to site-specific conditions (e.g. climate, local renewable energy potentials, etc.) and in some cases quite different technology packages may be required altogether. Placing an emphasis on low-tech solutions to keep building maintenance costs low is a commendable approach that should be replicated.

Conclusions & Lessons Learned

In order to pave the way for the commissioning of more public PEBs across Europe, multiple existing barriers must be overcome. Whilst the technological solutions used in this case study have been tried and tested, private sector partners that have the necessary experience and technical knowledge must be engaged to integrate these effectively. Furthermore, the higher upfront costs of installing energy efficiency and renewable energy generation technologies are likely to be insurmountable for many authorities and national governments as well as the European Union would need to strengthen financial incentives for such projects, if broader replication is to be achieved. Measures could include grants, no-interest loans as well as energy performance contracting schemes.

In light of the longer planning and decision-making processes associated with the commissioning of municipal buildings, it is also clear that political stability and broad support for environmental sustainability are key factors that enable the realisation of public PEB. The architectural design for the New City Hall in Freiburg was chosen in 2013, construction work began towards the end of 2014 and the building was completed in 2017. Over this time period the project experienced some delays as well as cost-overruns, which could have derailed construction had the client not been sufficiently committed and demanding.

Lastly however, it should be emphasised that the project has delivered multiple benefits to municipal staff as well as the city's residents, and the result achieved has been recognised as a success at national and international level. The City of Freiburg has already given a green light for the second development stage, which will see the existing structure joined by an additional administration building of similar size, design and energy performance.

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- Drees & Sommer for providing technical details and suggesting corrections.

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Local Context Details

Address: Fehrenbachallee 12, 79106 Freiburg im Breisgau, Germany

Geographic Coordinates [Google | EPSG:4326 – WGS 84]: 48.000552, 7.832402

Local Government: City of Freiburg

Population: 227,090 [31.12.2019]

Total Area Administered: 153.04 km²

Municipal Budget: 1,029,525,059 € [2020]

Total annual GHG emissions: 1.65 M t [2016]

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

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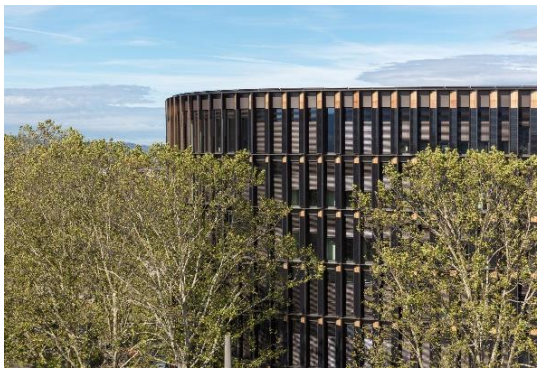
Further Images & Plans of the PEB

Image 5

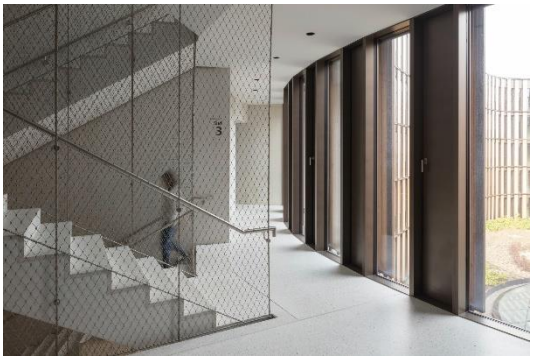
Panoramic view of the new City Hall in its context
[Source: ingenhoven architects / HGEsch]

Image 6



Building façade with integrated PV-panels and sun shades
[Source: ingenhoven architects / HGEsch]

Image 7



The first construction phase of the City Hall
[Source: ingenhoven architects / HGEsch]

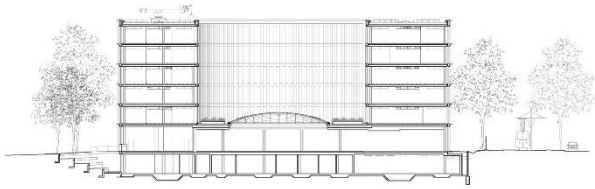
Image 8

The naturally lit citizens' service centre at ground-floor level
[Source: ingenhoven architects/ HGEsch]

Image 9

Plan of 1st phase development, showing main building and day nursery
[Source: ingenhoven architects]

Image 10



Cross-section of building, showing 6 floors above ground and 1 below
[Source: ingenhoven architects]

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