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Fostering a Sustainable University in Germany – Setting, Infrastructure and Perspectives

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Abstract. Today, circumstances have changed across Europe and the world, sustainable development engagement in politics unfortunately steps back for military investments and more protective and defense spendings. The world is experiencing a rollback in terms of climate protection, sustainable development and scientific freedom. The consequences could have very negative impacts on todays and future generations. Hence universities worldwide have to concentrate harder and broader on future focused and science based sustainable solutions. So the concept of the Environmental Campus Birkenfeld is not only to instruct and talk about sustainability. We practice very consequently what is taught in the lectures every single day with an advanced infrastructure. Students, lecturers, labs and institutes study and work successfully with a professoral experience in these fields of almost 30 years, researching, testing and installing new environmental engineering technologies, teaching state of the art sustainable business and advanced environmental law. This paper focuses examples of the campus setting regarding facilities and buildings that are equipped technologically on a high level – as the Environmental Campus is Germany's first zero emission campus and a model site of Trier University. Finally, the 'UI Green Metric family' must foster and maintain advanced sites to convince people, politicians and third-party funds to assure the endowment of universities further on. Reducing or even stopping the admission of resources for science and education like in the U.S. 2025 is not acceptable – nowhere. This is a challenge for universities worldwide.

Keywords:

Advanced infrastructure, Environmental Campus Birkenfeld, green setting, smart building technology, sustainable facilities, infrastructure, zero emission university.

1. Introduction

The Environmental Campus Birkenfeld (ECB), a site of Trier University of Applied Sciences, founded in October 1996 focusing directly on advanced environmental and

sustainability studies and research fields [3, 5]. It is located at the Hunsrück-Hochwald National Park in the State of Rhineland Palatinate, Germany showing a distinct green campus concept surrounded by the verdant landscape of the park with mountains, hillocks, woodlands and rivers [1]. The Nahe river is flowing by directly near the campus. Before, the estate and its facilities opened in 1952. It had been used as a reserve military hospital for the US Army until 1994 and includes an area of 440,000 square meters. The site was converted to a residential campus that combines the concept of learning, researching, living and working sustainably at one place completely planned as a flagship project. There are eight residential properties providing housing for students (see fig. 1).

Figure 1. Environmental Campus Birkenfeld, Site of Trier University, Germany [4]

Despite ECB's rural setting it is well connected to all major European cities such as Frankfurt, Berlin, Paris, Luxembourg or Brussels by all opportunities of transportation including a railway station directly at the south side of the campus [3]. Since the beginning of the planning phase the infrastructure and all facilities of the campus were completely concentrating on extremely low emissions. So, it received site wide renewable energy and heat production with a biowaste fed power plant and a bundle of modern environmental technologies. In every feature of all buildings there is smart heat and water use, light motion management, carbon free cooling and much more installed. Today with about 1.700 students, 250 employees as stuff and 58 professors accommodating 777 students directly in campus apartments up to date the campus has been a model site for sustainability in Germany since its start – as Germany's first zero emission campus [3] .

Summarized, the ECB's comprehensive infrastructure, spanning a mix of natural and built environments (entrance area see fig. 2), provides a unique setting for sustainability-focused education offering currently 43 study programs [3]. With its rich history, connection to natural landscapes and strategic location, the campus stands for a model of sustainable development and educational excellence.

Figure 2. Central building, north entrance to audimax with wetland pond and some fruit trees.

2. Scenario of Campus Setting and Infrastructure

Step by step wide-ranging newest infrastructure elements were added to the initially environmentally equipped lecture halls, seminar rooms and currently 22 laboratories. All academic departments, libraries, staff rooms and the kindergarten are endowed in the same way. So below some of the broad variety of advanced environmental and zero emission technologies will be highlighted.

This reflects the Environmental Campus Birkenfeld's long-term development into a Zero-Emission Campus, where ecological building standards and modern sustainable technology are systematically integrated into campus infrastructure. The campus follows an ecological construction strategy complemented by renewable energy sources and highly efficient building systems covering heating, electrical power, cooling, and resource-saving utilities [4, 6].

All buildings and infrastructure are being upgraded to keep their state-of-the-art zero-emission status regarding electrical energy, cooling, lighting, warm water, grey water, heating and waste.

3. Implementation

Due to the extensive utilization of sustainable and zero-emission technologies, ECB has become the first Zero-Emission Campus in Germany, where both heat and electrical energy are supplied by neighboring biomass combined heat and power station which uses regionally available waste wood and biogas as primary energy sources. This zero-emission energy concept is central to the campus's ecological strategy and has been documented in technical

reports and sustainability documentation of the campus, showing the use of biomass cogeneration and biogas in supplying CO_2-neutral heat and power to the site [7]. Innovative building standards and environmental technologies legitimize the claim of being a real Zero-Emission Campus [3]. In early 2025 the campus replaced 200 elder photovoltaics modules (PV) and solar panels by highly performing new ones with an efficiency improvement of about 25% compared to the old modules [4]. On all roofs of the campus, every square meter is covered with solar energy production to deliver electricity in addition to the power plant in all kinds of modern solar cell variations. Besides, there is intense research about the best performing technologies not only under energy production and installation types but also under life cycle aspects with broad system boundaries cradle to cradle [2]. ECB integrates sustainability research into campus operations where students and faculty jointly explore renewable energy systems and ecological building technologies as part of academic programs and applied research [8]. The performance of different photovoltaics (PV) module types and mounting systems are continuously monitored, displayed for visitors and employed as a subject for practical teaching – the campus becomes a living lab for student education and research [4]. The intensive ise of PV technology to generate electrical energy, including PV on roofs and facades, is a documented characteristic of the campus's hands-on sustainability approach, combining research, teaching, and applied technology deployment [7]. The broad use of solar energy is completed by various installations of thermosolar water production with a total power of 135 kW. It uses a collector area of 270 m^2 augmenting the heating system during the cold months managed and regulated in the technical center (see fig. 3) [4]. Solar thermal systems complement the campus's renewable heat strategy as part of the diversified energy portfolio [8].

Another installed technology is the climatization for the lecture rooms: For air conditioning the campus uses so-called ground collectors (see air absorbers shown in fig. 4) pulling fresh air from outside into three concrete tunnel tubes of 55 m length each with a diameter of 1,5 m and submerged in 5 m under the surface, filtered with a capacity of 25.000 m^3/h. In the ground there is a constant temperature of about 10° C. So, in summer the tunnels cool down warm air from outside and climatize the lecture halls to a comfortable temperature and humidity. In winter outside air is taken just as well but then to be warmed up in the tunnels to support the CO_2 free heating of halls and seminar rooms with the help of geothermal energy. The advanced air heating, ventilation and air conditioning system (HVAC) is located beneath in the cellar [4].

Another smart technology applied is the fully automated daylight regulation and guiding system for all relevant windows and glass roofs of the campus. With daytime, sun position and wind room temperatures, shadowing and lighting in summer and winter is optimized (see fig. 5). If the sun shines brightly the sun blinders are regulated to shadow south rooms without reducing daylight too much. Indoor the entire lecturing area, restrooms, corridors and labs etc. are equipped with motion detectors so as you enter an area lamp are switched on. When you leave they switch off.

Of course, all lecture rooms, corridors and offices in all buildings and even the promenades and walkways outside around the campus area are LED lights. Right now, research is conducted for an even better LED lighting alternative outside to optimize on the one hand light protection for a darker night sky above the campus and simultaneously on the other hand to reduce light pollution for insects by not attracting them – as insects prefer certain light colours resp. frequencies that can be avoided with advanced LED technology [4].

Figure 3. Some examples of ECB's roof photovoltaics, CO_2 neutral technical center below [4]

Figure 4. Air-intake for the central building

Figure 5. Daylight regulation, motion sensors, greened lecture rooms [4]

An additional feature to save heating energy is when someone opens a window -at virtually all rooms with sensors- the heating will stop immediately all radiators and heating devices there. So, all heating elements in all rooms have remote electrical valves that are steered by the campus wide heating management system. This gives everyone the opportunity to manage all room temperatures everywhere, individually, besides lecture rooms for professors, assistants, lab employees, staff and social rooms. You just tell the facility management your presence time profile during the week etc. and your convenient temperature in your office will be regulated in time. This intelligent programming system is very effective and still being optimized avoiding wasted or dissipated energy. Any way you can also regulate and program your room at the entrance door. So, in the evening it shuts down automatically unless you forgot to do so and if you stay longer, you can reprogram the temperature management in your room. Plug sockets at every room are also mounted in three types: normal 220 V, 220 V stabilized for computers and lab experiments etc. buffered for unexpected blackouts and switchable sockets that can be switched off remote by the facility management e.g., overnight to save energy losses of beamers, coffee machines etc.

For water protection and saving the campus also takes measures and has installed a bundle of technologies. First of all, a vegetated rain water pond is used for student recreation and in case as a reservoir to fight fire. But the campus does not only harvest water at the pond: from the beginning the architects established about a dozen retention basins allocated on the whole campus for birds, amphibians and other small animals and also water plants providing small wetlands. Besides, rain water is collected and used to flush all of the toilets with a huge rain water tank. In addition, all urinals in all buildings are waterless used with oil as closing and sealing liquid to avoid any kind of smell [4, 9].

The zero-emission concept of the ECB is extended towards biotope and biodiversity management. It creates and maintains protected areas and also uses greened rooftops with plants on it [3]. This approach is part of the campus's broader sustainability agenda, which includes biotope and biodiversity management as integral elements of its zero-emission strategy. The campus deliberately designs and maintains vegetated surfaces to foster habitat diversity and ecosystem services. Green roofs not only contribute to biodiversity by providing food and shelter for insects and birds, but also improve thermal performance and retain rainwater at the source, reducing runoff [10]. Parts of the rainwater are collected after a mechanical purification in tanks and used for various greywater applications as mentioned like toilet flushing, irrigation and as a coolant [4].

A main technology component to establish a zero-emission campus like Environmental Campus Birkenfeld is the neighboring completely carbondioxide emission free driven waste wood chips and biomass power plant for electricity and heating. In cooperation with the local

energy provider this plant was built in 1997 parallel to the early beginnings of the campus [1]. This power station was inaugurated with an installed thermal capacity of 28 MW utilizing annually 65,000 tons of low contaminated waste wood from forestry, agriculture, landscape gardening and industry to produce up to 8 MW heat, 37.5 tons per hour of steam for a neighboring plant and in case up to a capacity of 8.3 MW electricity for the Campus.

In addition, ECB uses heat exchanger and heat recovery elements at several points of the main buildings, the data center and major labs [3]. So up to date we are legitimated to claim that we are really Germany's first and only zero emission university campus driven with 100% renewable energy concerning heat and electricity. The campus is frequently described as one of Europe's first "Zero Emission University" campuses, with renewable energy systems covering 100% of its thermal and electrical energy demand [11].

A further example of efficiency is the often-visited communication hall (see fig. 6) built 2012 with a capacity of 400 guests e.g., as a meeting platform for student and university festivities, ceremonies, scientific congresses and conferences [4, 12]. This hall is an energy plus building being isolated and air conditioned so extremely that if there is an event the campus calculates the number of participants in advance because all visitors together support significantly the heating of the building while a fully automated climatization regulates the air conditioning. This showcase also produces energy with another roof completely covered with PV. Through the years, this building serves as an ideal example what smart architecture, engineering and advanced facility management by interdisciplinary working together can achieve today paying back the investment. Often international guests are hosted in this building with its main hall and full of diverse rooms to meet various needs also for culture like cinema events oder music in rehearsal rooms, a free gym for fitness and recreation and a meeting area with the student's tea parlor and green office.

Figure 6. Communication hall – A highly isolated energy plus building [4]

The newest addition to ECB's major building stock is the rebuilt sports and gymnasium areal. The gym features an intermittent ventilation technique revolving 10.400 m^3/h driven by the photovoltaic system on the roof and using rainwater for most water needs, too - besides showering [4]. In addition, a huge shadowing system at the south side cools the

building in summer an collects heat in winter due to the seasonal solar incidence angle. The gymnasium and the kempt adjacent sports grounds for e.g. running track, tennis court, soccer and basketball fields offer a variety of sports activity outside and inside - in a remarkable architecture (see fig. 7). The sports areal was planned and built in an inter-communal cooperation between ECB and in association with regional municipalities. All sports facilities are available for students and staff of the university as well as to regional sports club members.

Figure 7. Multifunctional Gymnasium with smart shadowing and air conditioning [4]

4. Future Perspectives and Conclusions

Universities have a special responsibility for sustainable development, as they educate the decision-makers of tomorrow. It is therefore particularly important that universities fulfil their social obligations. This requires a holistic approach (whole-institution approach) that incorporates all areas of the university: Teaching, research, transfer, governance and operations. In order to fulfil this responsibility, the Environmental Campus Birkenfeld is not standing still, but is continuously developing into a real laboratory (living lab) in which the infrastructure is used for the education of students and for research purposes.

An innovative hydrogen project is currently underway at the Environmental Campus, which was planned together with the municipality of Birkenfeld, the Institute for Applied Material Flow Management (IfaS) and the Fuel Cell Competence Centre. Over the next few years, 4.6 million euros will be invested in the development of a regenerative hydrogen infrastructure with an electrolyzer, fuel cells, storage facilities, a hydrogen refuelling station and a hydrogen bus using funds from the National Climate Protection Initiative. As a model climate protection project, it is planned to supply the site with locally produced renewable energy all year round. The basis for the production of ‘green’ hydrogen is the existing PV potential and additional PV systems, which will be built as solar carports on almost all car parks on the Environmental Campus, financed by the Rhineland-Palatinate state construction company. The solar power can be stored using the hydrogen produced and converted back into electricity if required. The hydrogen will also be used as a climate-neutral fuel for a bus service in the Hunsrück-Hochwald National Park. The oxygen produced as a by-product during

electrolysis is to be used to increase the efficiency of the fuel cells on the one hand and to save energy in the municipal wastewater treatment plant, which also purifies the university's wastewater, on the other.

In addition, a nature trail biodiverse is intended to show visitors climate-friendly and resource-efficient technology in practice in connection with the regional natural environment and its animal and plant diversity in an estimated 32 stations using information signs with additional QR-codes for more detailed information. This project is realized with the Hunsrück-Hochwald National Park Authority (e.g., erecting the signs, building a log pile) and with the support of the Rhineland-Palatinate Nature and Environment Foundation.

In June 2024 the Environmental Campus Birkenfeld has had the honor of being invited to Federal President Walter Steinmeier, highest representative of the nation, for a exclusive exhibition called ‘week of the environment’ in his residence Bellevue Castle in Berlin where flagship institutions exhibited their environmental research results, successes and activities. Another highlight in 2025 is the World Exhibition in Osaka, Japan: Professors of Environmental Campus Birkenfeld advised the environmental features and the sustainable design of the german pavilion for the exhibition ground.

Finally, the campus is proud of having thousands of university graduates educated with an ecological conscience in different fields of all study programs. At ECB every technical installation is designed and added to augment the green campus concept based on zero emissions. The unique combination of academic excellence and technological innovation makes ECB an outstanding example of sustainable development and environmental stewardship. The campus's continuous evolution ensures that it remains at the forefront of green technology, inspiring future generations to consider and pursue sustainable solutions. In 2026 the Environmental Campus Birkenfeld will celebrate its 30th anniversary.

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Conflict of Interest

The authors declare that there is no conflict of interest in any aspect regarding the publication of this paper.

Authors Contribution

The concept, methodology, data collection and analysis of this contribution was initiated and realised by **K.R** as main author, reviewed and supervised by **K.H**, manuscript written by **K.R**. There was no funding acquisition necessary for this contribution.

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