TEACHING AND RESEARCH ON SUSTAINABLE ARCHITECTURE AT THE UNIVERSITY OF APPLIED SCIENCES VIENNA–FH CAMPUS WIEN

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INTRODUCTION

The University of Applied Sciences in Vienna has offered university degree programs in the field of construction for more than twenty years and has thus gained great expertise in developing its curriculum. Founded in 1996, the department of *Building and Design* consists of six university degree programs. A major strength of the department is the possibility to adapt to recent challenges in a timely manner. As shown in Figure 1, in the winter term 2008/2009, the master's degree program, *Sustainability in the Construction Industry*, was held for the first time; it was transformed into the master's degree program, *Architecture—Green Building*, in 2016. In 2013/14 the bachelor's degree program, *Architecture—Green Building*, started with the first students graduating in 2016. For ten years the department has focused on sustainability within the building, planning and designing processes.

KEYWORDS

curriculum development, sustainable architecture and construction, practical education and exercises, Construction Engineering Laboratory

This seems logical considering that the construction industry is responsible for 40 percent of the overall energy requirements in Europe. Therefore, the building sector plays a key role in sustainable climate protection and renewable energy. In order to take actions against climate change and to meet the challenges of the 2010 *Energy Performance of Buildings Directive* (*EPBD*), which obligates EU members to build only nearly zero energy buildings from 2020 on, a suitable education for future architects and civil engineers is crucial.[9] The university degree program

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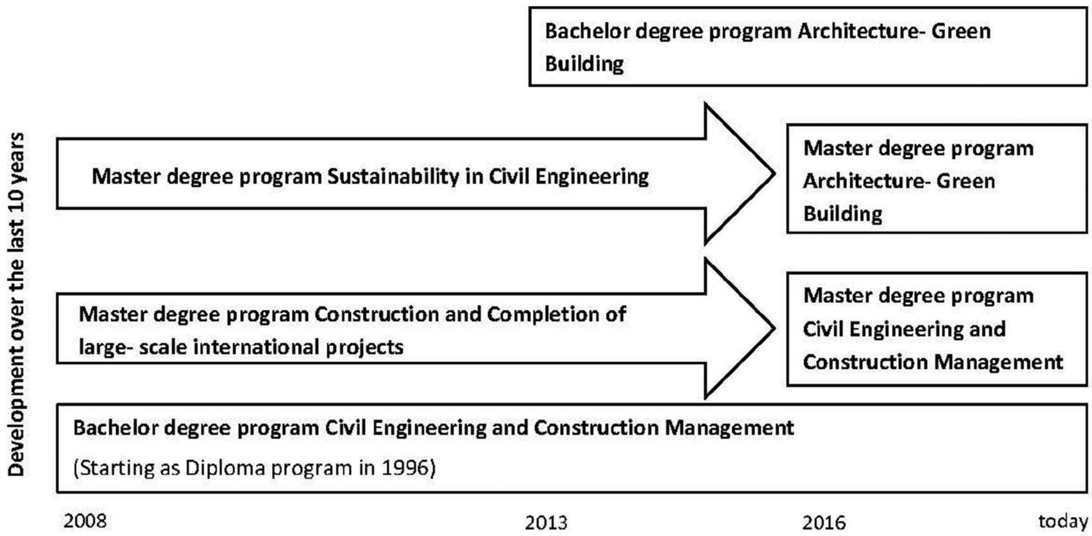
FIGURE 1. Development of the Department Building and Design from 2008–2018.



at Vienna, *Architecture—Green Building*, is the first university degree program in Austria that focuses on sustainability within the planning and designing process already on a bachelor's degree level. The emphasis lies with the planning of resource-friendly and energy-optimized buildings that meet high aesthetic demands and at the same time respond to sustainable needs. With the start of the master's degree program, *Architecture—Green Building* in 2016, the department *Building and Design* established a comprehensive education program in architecture. The accreditation of the study program *Architecture—Green Building* in February 2017, in accordance with EU directives on the recognition of vocational qualifications, confirms that the degree programs meet the demanded quality standards for architectural educations.[10]

Architectural education that focuses on sustainability is a necessary step towards a future in which the aspect of sustainability in the construction field will be self-evident. The first master students will graduate in September 2018.

SUSTAINABILITY—A MATTER OF ATTITUDE?

The term 'sustainability' often connotes negatively due to its extensive (mis)use in order to make products or services more interesting, more saleable or to add an ethical attribute. Sustainability should not be understood as an add-on or a current trend but as the basis of all future architecture. But what does the word sustainability mean in the context of architecture? To understand the sense and significance of the word in its entirety, we have to take a look at its etymology. In the Oxford English Dictionary from the 1960s (before the intense use of the word), the first part 'sustain' is listed as 'keep in being', 'to cause to continue in a certain state' or 'to keep or maintain at the proper level or standard'. The second part stands for 'having the means or skills or know-how to do something'. Looking at the history of the word, the term originally emerged due to the lack of wood in the past, when the survival and development of a country or

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN. p. 2f (2018-06.27)

10. Cf. Article 46 „Training of architects" In: EU directive of professional qualifications. Via: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2005L0036:20140117:EN:PDF (2018-06-27)

region directly depended on the continuity and maintenance of the health of the forests. If the American continent had not been discovered, Europe would have had an existential crisis caused by the lack of wood for building houses and ships, heating and energy generation in the age of industrialization. In this context we have never had the true necessity to think about the end of our resources; there has always been the possibility of bringing resources in. Albert Schweitzer once said: "Man has lost the capacity to foresee and to forestall. He will end by destroying the world."[11] Being confronted with current issues about climate change, global warming and the future lack of resources, Schweitzer's quote could not be more relevant.

To recap, the word sustainability can be paraphrased as the ability to preserve a current state combined with foreseeing and forestalling the needs of future generations.

In the process of creating a building, architects undertake the important role of designing the concept, combining the work of specialists and leading the whole building process to a (hopefully) successful end. Integrating sustainability into this process requires the consideration of various facets of ecological, economic and socio-cultural sustainability. Creating houses, cities and environments that allow future generations to experience the same or even better quality of life than we have at present should remain the main goal. In this sense, sustainability is an ethical issue.

The University of Applied Sciences aims at not only teaching (practical) competences but also functions as a space where students form their personalities and develop their points of view on the important issues of our age. One issue that architecture students are confronted with is the different approaches in sustainable architecture. During their studies, students are introduced to sustainable building materials, energy efficiency concepts as well as life cycle management and social concepts for housing. Sustainable architecture is often represented as technical requirements that are fulfilled by numerous separate measures. However, a holistic approach to the relevant aspects of design and planning processes is the main goal within architecture education. The different approaches should not be understood as separate trends but as a comprehensive concept. In the following passages specific courses of the bachelor and master degree programs are introduced, covering everything from building physics and innovative energy systems to integral planning and various design studios. All of these courses teach different aspects of sustainability with the students having to put them into practice within their design studios in each semester.

1.1 Energy efficiency

The bachelor degree program, *Architecture—Green Building*, is unique in its setting and overall approach towards a holistic and integrative understanding of architecture, where sustainability plays a key role. Including energy and resources into the planning process is one of the fundamental aspects of sustainable design. In this context, the full comprehension of the physical interaction of the built environment within its external and internal framework conditions is a fundamental pre-requisite. Designing and developing comprehensive and sustainable buildings thus necessitates a sound basis in building physics, technical systems and energy concepts.

During the first year of the bachelor program, students have to take the courses *Building Physics 1* and *Innovative Energy Systems 1*, both of which are continued in the following year. In the first year the focus is on the fundamental aspects of building physics and energy concepts, whilst the second year builds on the acquired knowledge and expands into more complex

11. Cf. Grober, Ulrich: Die Entdeckung der Nachhaltigkeit. p. 4 ff.

systems such as active and passive cooling and ventilation systems. Below, the overall setting, didactical approach and content of the first year lectures are described in more detail.

The first course on "Building Physics" is defined as a series of lectures over one semester, encompassing a total of 45 present hours. The course is divided into four main thematic blocks, including basics in buildings physics (1), heating protection (2), moisture protection (3) and summertime overheating (4). One of the key aims of this first course is to convey the basic principles of building physics with specific attention to aspects relating to energy and resource protection. The focus is thus on the passive design elements of the building defined by the architecture. This includes the building envelope, with its opaque and transparent elements, shading, greening of the building and thermal mass. Even though the course does not include any elementary design work, students are guided by practical examples in order to include the lessons learned into their accompanying design studios. From a didactical perspective, a variation of methods is applied in each of the four thematic blocks. Standard lectures are divided up by group work and single work exercises. These actions include short literature research tasks, debating exercises as well as quizzes, which the students can define themselves. After each thematic block, the students participate in an interactive self-evaluation test, where they can assess where they stand in terms of overall understanding and content. In addition, calculations and simulations form an essential part of this course. During the first semester, the focus is on the influencing parameters of the calculations and the analysis itself. The goal is for the students to understand the influencing parameters of the calculations and to be able to implement them manually, i.e. with a calculator only. At the end of the semester, a simulation tool is introduced into the course-work so that students can build on their acquired calculation skills and move towards more complex energy assessments. Previous experience in other courses has shown that students often cannot comprehend the key influencing factors if they step directly into simulation tools and omit the step of doing hands-on calculations. This follows the basic principle that one already needs to have a basic idea of the expected result when carrying out a complex simulation. If students cannot judge whether the inputs and outputs are meaningful and relevant, simulations can be overwhelming at such an early stage. The goal is for the students to gain a sound understanding of the analysis procedures and a good judgement of how various framework conditions affect the results.

During the second semester the course is followed by "Innovative Energy Systems." Whilst the first semester mainly focuses on the passive design elements of the architecture, this second course concerns itself with the building systems responsible for heating, cooling, lighting and ventilation. Structurally the course follows the setting of the first semester and is also divided into four thematic blocks, namely energy concepts (1), heating systems (2), electrical systems (3) and ventilation systems (4). With an approach toward sustainable architecture in mind, the topics focus on passive technical systems, low energy and renewable energy systems. At the beginning of the semester, within the energy concept block, students analyze various existing signature buildings that are known for their low energy design. At the end of the semester, the same buildings are analyzed again with a view to improving the systems, thereby applying the knowledge acquired during the course. From a didactical perspective, the methods match those of the first semester. The application of the simulation tool introduced in the previous course is deepened so that the students can use the software for the analysis of their energy concepts in future design studios.

The overall aim of these courses during the first year of the bachelor program is for the students to acquire a basic understanding of the energy and resource related to physical and technical interrelations of the building design within its external and internal framework conditions. On this basis, the students should be able to apply their knowledge in design studios and deepen their understanding of more complex energy concepts and systems in following years.

1.2 Connecting real sites to the work of students

Design and sustainability concepts need to be processed in an integral way in order to develop a sustainable building. By connecting student study work to real sites and by co-working with their civil engineering colleagues, the students gain a holistic picture of the construction work and knowledge, which prepares them well for future work as architects. This holistic and integrative approach not only improves the ecological impact of a building but also its architecture. At the University of Applied Sciences "FH Campus Wien," practical knowledge is a core element of all study programs. In civil engineering and architecture, this means that the students are taught by professionals who pass on their knowledge and practical experience, which the students can implement in real-life projects and competitions.

One example of the practical education at the University of Applied Sciences was the participation in the *pro Holz competition* in the winter term 2017/18. Within the course *Integral Planning 1*, the master degree students of architecture co-worked with their master colleagues in the civil engineering program and participated in a competition that aimed to build two halls in Lower Austria; i.e. an exhibition hall and one functioning as a warehouse and part-time exhibition hall. With the two new halls, the current usage of temporary tents for each new exhibition should end. "Permanently sustainable instead of temporary," was the motto of the competition.[12]

The warehouse had to be designed without any heating system. The focus was put on the construction's simplicity and cost efficiency. The choice of building materials should consider aspects of sustainability and the conservation of resources. The detailing and manufacturing should consider industrial and digital methods. Design loads could be found in the according standards. The payload should be determined in accordance with the categories of use. The task included planning the infrastructure of both halls.

1.2.1 Project: Triple Zero

The concept behind the project triple zero is shown in Figure 2 and is based on three aspects: the ecological footprint of the buildings, the sealing of the obstructed surface and the reduction of carbon dioxide.

The first zero refers to the ecological footprint, which is kept as low as possible by using building materials that make the recycling, upcycling or biological degradation of the building possible. The second zero stands for the greening of the roofs, which restores the natural surface that would otherwise be lost due to the building of the halls. Thirdly, the chosen building materials store carbon dioxide. Additionally, the planted roof transforms carbon dioxide into oxygen. So, the two halls are CO_2 neutral.

1.3 Merging topics of sustainability in design projects

Skills and methods are brought together in the project assignments that imitate parts of professional practice. At the beginning of every exercise and every design problem stands a detailed

12. Pro Holz Steiermark (ed.): Student Trophy pro:Holz 2018 [Wettbewerbskatalog]

FIGURE 2. Triple Zero.

analysis of the task, an examination of the task's different aspects and a thorough research of beacon projects of other architects.

One of the main criteria that need be considered when designing buildings is context. A good project evolves out of its cultural context and reflects the specific characteristics of the task and the place. A good project, however, needs more than contextual thinking and planning: a good project has an artistic dimension. It is a piece of architectural poetry.

The design studios follow a didactic concept and are held by lecturers who work within the architecture field. This is an important aspect of the practically oriented education at the University of Applied Sciences. Throughout the study program, Architecture—Green Building, the students not only learn practical tools but also values in order to meet the requirement for a future of green building. At the end of every studio the students present their project in front of a jury which consists of teachers and guest jurors who discuss and analyze the various aspects of their projects.

With the students' increase in design competencies in the course of their studies, the assignments in the design studios increase in complexity. They vary in size, regional context and social context, reaching from minimal buildings in the first year to hotel and school buildings in different climate zones in the second year and nursing homes and museums in the third year. A common ground for all design tasks is the aspect of sustainability that needs to be taken into account throughout the planning process.

1.3.1 Design studio 4: Regionally adapted building

During the 4th semester of the studies "Architecture—Green building" at the FH Campus Wien, an elementary school for New Bagan in Myanmar is developed. The history of Myanmar shows that there was a big educational problem during the military dictatorship, when many schools were closed. In 2010 the dictatorship ended and there was a general sense that a new era was about to dawn. So, the traditional Buddhist education, which includes rice cultivation and other crafts, was reinforced. Therefore, building new schools in Myanmar is very important to the society. New Bagan is a fast-growing town, which was built as a result of the revolution. The building site is located in the heart of Myanmar, next to the Irrawaddy River, in the western part of New Bagan. New Bagan is a city founded 1990 by relocating the village from the Old Bagan area. Between the grid-shaped streets there are clusters of buildings. The school is situated in one of these grids.

In the following passages two projects are described in greater detail.

Project: NEW BAGAN SCHOOL

The central concepts for the school as seen in Figure 3 are community and flexibility among the use of local building resources. The school is open to the whole community of New Bagan. Therefore, two different sections were planned: a main section and a smaller class section. The main section includes a library, a mensa, rooms for sports, seminars, school administration and side rooms. In the second section there are four classrooms each for 30 children. The classes are arranged in groups of two with flexible rooms placed between them. With sliding partitions, the classes can be opened to the additional room and the space can be used for events or as a break room. Additionally, a courtyard between the two sections was built, which can be used as a playground for the children. A significant water tank separates the courtyard from a little meditation park, from where children can reach the sports ground with the tribunes. The area will be irrigated intensively to sustain the rich vegetation, which provides fresh air.

Myanmar is a poor country, so expensive ventilation systems are not useful. The building is oriented north and south, i.e. the main wind directions. Big roofs protect visitors from the sun. The roofs were cut into three parts so that the wind can stream through it and carry away the jammed warm air under the roof. Instead of walls, bamboo lamella was used so that the

FIGURE 3. New Bagan School—Rendering.

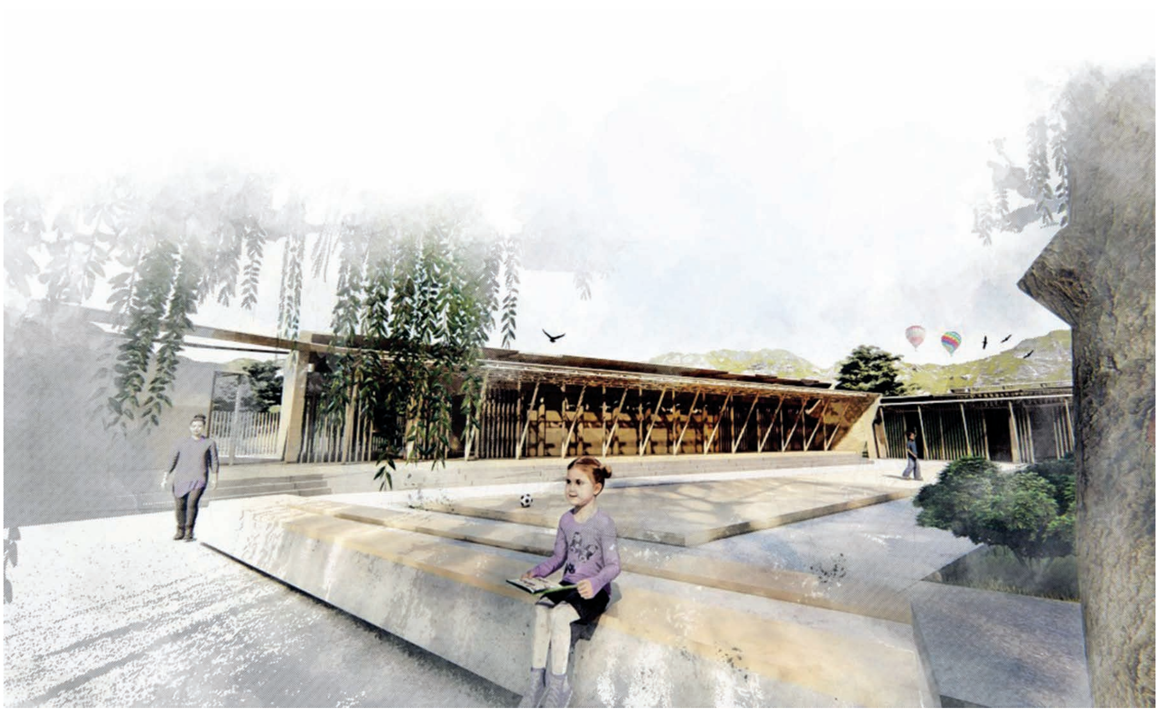
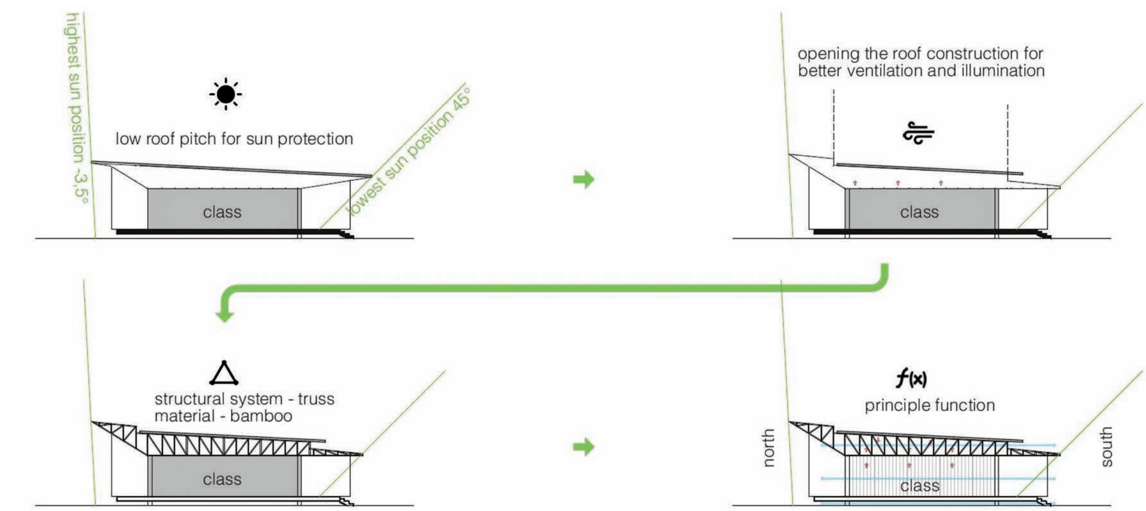


FIGURE 4. New Bagan School—Bioclimatic concept.



wind can pass through the rooms. The class section is elevated, so that not only the warm air under the roof can be ventilated but also the jammed air beneath the classes can be carried away by the wind. Due to the big roofs lighting might pose a problem, so the roofs were divided into varying lamella parts with polycarbonate panels and corrugated steel panels. Parts of the bioclimatic concept are shown in Figure 4.

From the perspective of statics, bamboo trusses were used in order to enable load derivation with the large spans. The force is then directed via beams and load-bearing walls into the ground. The main building material is bamboo, as it is fast growing, renewable, cheap and a well-known building material for construction workers in Myanmar. On the roof, corrugated steel and polycarbonate were used, which are not as renewable as bamboo, but these materials are available in large quantities and provide for a long-lasting building in Myanmar.

Project: Aasipanyar eat lam

The arrangement of the rooms shown in Figure 5 symbolizes the everlasting circle of life—the Samsara. As it runs in a nearly circular manner, it also represents the daily school schedule. A second, artificial pathway runs elevated on the second floor of the building and allows the students to get different perspectives not only of the area, but—in a symbolic manner—also of life. The eastern part of the campus is publicly accessible and supposed to be used by all the inhabitants of New Bagan.

The main goal was to develop a sustainable, long-lasting building to provide education for many years. Therefore, it was necessary to choose the materials carefully. It was decided to use mainly clay, bamboo and steel. The supporting walls are made of rammed clay with an inner bamboo structure to allow a flawless transmission of the forces involved. Steel is used for the structure of the outer enclosure, consisting of the truss and the corrugated roof. All structural connections are especially constructed to be reopened to allow easy maintenance and recycling after the building's lifespan. Showing children how to protect the environment by teaching in a sustainable school helps them to understand the concept of sustainability more easily. The main aspects are a long lifespan, using local resources, low energy consumption, and dealing with local climate conditions, which is illustrated in Figure 6. The school uses as little climate control as necessary. The low-tech building uses natural ventilation and operable shadowing to adjust the climate inside. Only the library and the administration office use mechanical ventilation. Direct sunlight is prevented from entering the building by protruding roofs and additional shading. The open building style allows wind to enter the rooms, which helps to adjust the inside climate. The corrugated roof drains all occurring precipitation fast and collects it in a tank for later use. Part of the sustainability goal was to start climate protection during the construction phase, by reducing transport and using local resources.

1.3.2 Design studio 6: Centre for architectural mediation

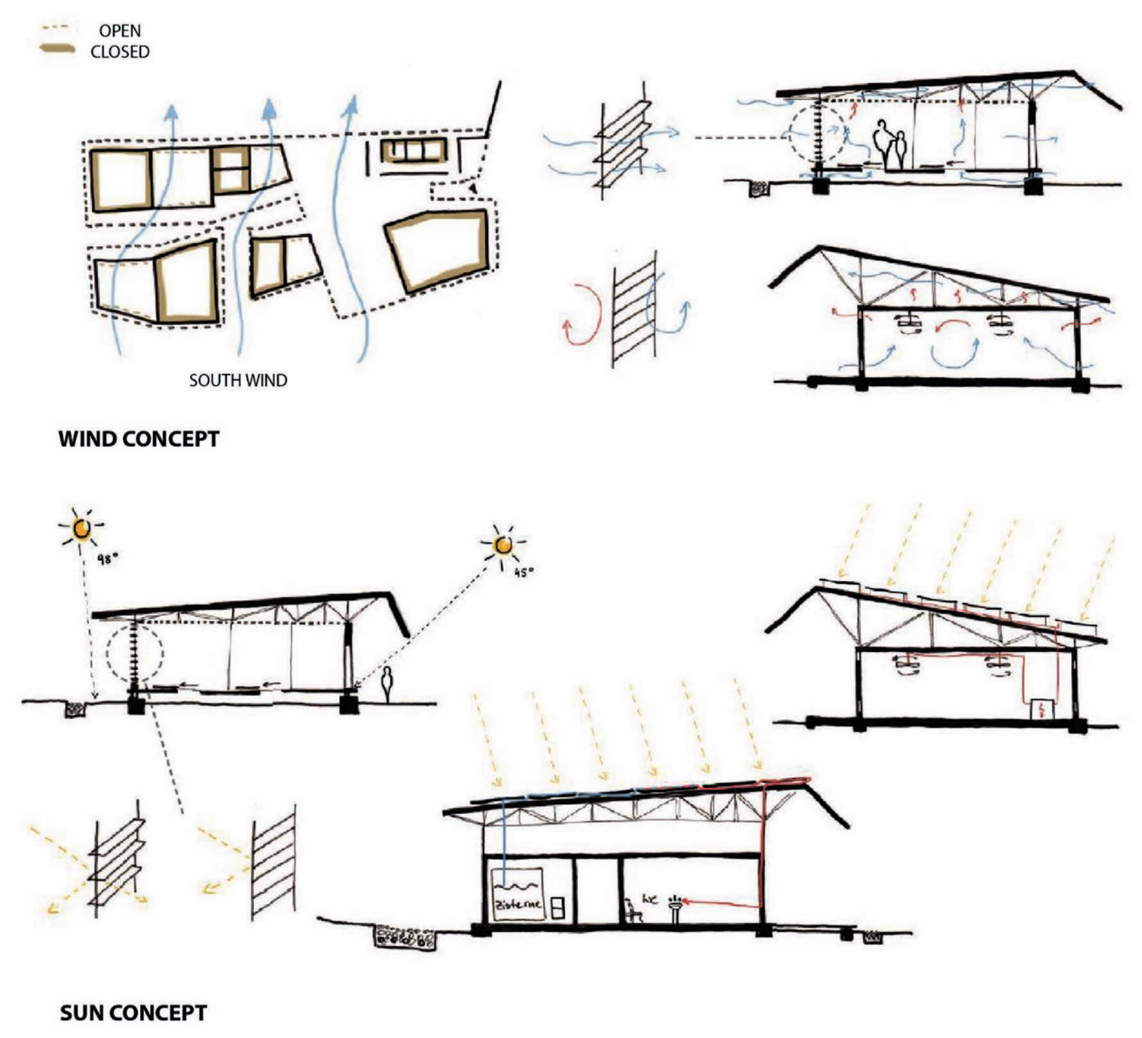
The main goal was to create a building with a highly efficient use of resources such as energy, water and materials while keeping the harmful effects on health and the environment very low. The selection of renewable and environmentally friendly materials is as important as the recycling and reuse of the construction.

Project: Cycle of Sustainability

The construction of the Cycle of Sustainability is completely pre-fabricated and consists of solid wood as seen in Figure 7. The vertical load is transmitted via spacers at a distance of 2 meters.

FIGURE 5. Aasipanyar eat lam—Rendering.

FIGURE 6. Aasipanyar eat lam—Bioclimatic concept.



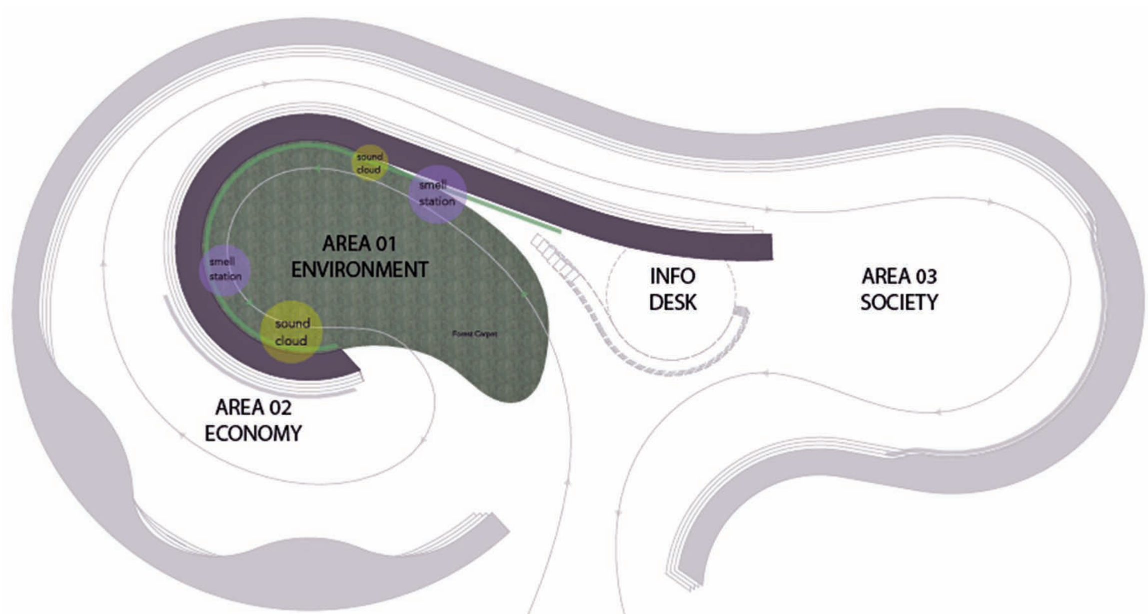
Here it is important that all spacers are on top of each other. An offset of the spacers would lead to a torque in the lower board. If the torque is too high it leads to a breakdown, which would cause the system to fail. The horizontal load is also transmitted via spacers at a distance of 2 meters, which is crucial for the reinforcement of the pavilion.

The exhibition concept, shown in Figure 8, is based on the completion of three areas: area 01—Environment, area 02—Economy and area 03—Society. All areas have a different perception and exhibition contents. Area 01 constitutes the beginning of the exhibition and is dedicated to the environment, a considerate handling of resources and the planting of building structures. Area 02 contains two different exhibition concepts. The first is the physical part with a variety of exhibits and the second part is the visual part, where visitors get virtual-reality-glasses to get through the economy tunnel. In the first part different statistics about energy consumption, global warming gases and their effects are shown. The second part is a walk through the

FIGURE 7. Cycle of Sustainability—Rendering.

tunnel with virtual–reality-glasses. Area 03 is the end of the exhibition and is designed as a theater. It aims to foster interaction between the participants and different speakers, who will hold public lectures about various topics relating to sustainability, green building and the impacts on our society. A small cafeteria has also been integrated in the info-desk. The type of

FIGURE 8. Cycle of Sustainability—First floor plan.



perception in this area is auditory. The different types of perception aim at reaching a constant level of attentiveness throughout the whole exhibition.

1.3.3 Master degree program Design Studio 1

A new extension for the Department of Transportation should be built on the site of the historical University of Agricultural Sciences and Natural Resources in the 19th district in Vienna.

Project: STEP UP!

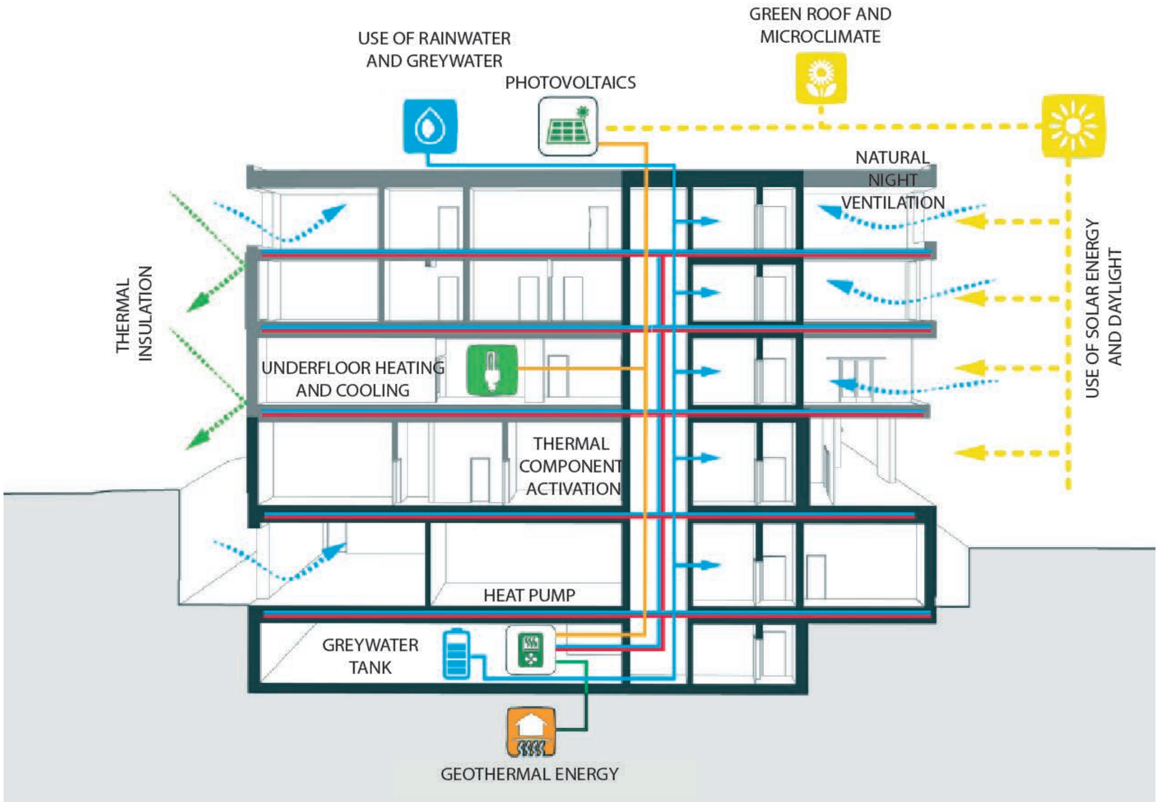
The project shown in Figure 9 "STEP UP!" primarily provides a respectful distance to the existing Schwackhöfer-building and also conveys an openness of the inner courtyard. Due to the stepped stories, daylight can reach the new extension, and a maximum number of light and visual axes is established. The greened, stepped rooftops not only serve an ecological purpose, they also make the greening area visible and noticeable for the user.

The building's structural system is ordered around two stiffened reinforced concrete cores and serves as an access and supply point for the stories. The external walls were structured in individual panes by floor-to-ceiling windows in order to use the building material in a resource friendly way. The walls and the ceiling consist of CLT elements and are thermally enclosed by wood fiber insulation. Internally, the CLT walls were arranged in a way that allows gutting of the building at a later time.

A mixture of conventional reinforced concrete (cellar- and ground floor) and pure timber construction (upper floors) was established for cost reasons. A major priority was the flexibility

FIGURE 9. Step up!—Rendering.

FIGURE 10. Step up!—Bioclimatic concept.



and convertibility of the rooms. Bearing wall structures in aisles and non-bearing wall elements as room dividers should allow dismantling and a change of the structure at a later time. The bioclimatic concept is shown in Figure 10. The building is equipped with a sole water heating pump whose electricity demand is covered by a photovoltaic system. During summer, night ventilation is possible through window ventilation. This ensures that cool summer air can be stored and serve as a buffer for the room climate.

RESEARCH ON SUSTAINABILITY

There are three main research areas at the department of Building and Design: construction economy, structural engineering and sustainable architecture and smart buildings. What combines the three topics is the focus on life cycle and sustainability.

1.4 Improvement of the carbon footprint of infrastructure and construction engineering

The strategy of Vienna for research, technology and development, which operates as "Innovatives Wien," defines possibilities for the reduction of the general energy consumption and emissions of its metropolitan area.[13] In this respect, the quality of life in and around the city of Vienna should be conserved or even improved. Previous examinations declare that the currently emitted amount of CO_2 and other heat-trapping gases has to be reduced. In addition, an intact infrastructure is indispensable for a city's economy, but it is associated with high costs and a large carbon footprint over a building's lifespan. The massive amount of emitted carbon is caused by one of the dominant materials, in conjunction with the construction of infrastructure, is concrete.[14]

This material is primarily used in combination with steel as reinforced concrete or prestressed concrete. Due to its unique characteristics in durability and its forming and design possibilities, it is currently not replaceable for many applications. Nevertheless, concrete exhibits a massive drawback with regard to its eco-friendliness. Primarily, the production of the cement clinker, which is used as hydraulic binder in ordinary concrete mixtures, causes the bulk of the released CO_2. Therefore, a large spectrum of research work is being done on optimizing the cement clinker percentage in regular concrete mixtures.[15] This can happen if, for example, substitute materials are used instead. These substances often can be waste products of other production processes, for example flue-ashes.[16]

The University of Applied Sciences "FH Campus Wien" in Vienna is working on alternative approaches to make concrete a considerably eco-friendlier building material. This can happen if concrete is seen as a recyclable quality-product, which should not be landfilled at the end of a building's life cycle. Existing technical standards define specifications for recycling concretes, which means that it is practicable to replace natural aggregates in concrete mixtures by granulated break-off material. In addition to benefits by saving raw materials and leaving the natural environment and habitats untapped, there is a possibility to store CO_2 in granulated concrete aggregates.[17] This happens because during the production of the cement clinker high temperatures are used to calcine the raw mix. After the cement setting and the carbonation of the exposed areas, calcium hydroxide stays reactive inside a massy concrete component.[18]

Accordingly, recycling a concrete structure does not only mean producing secondary raw material out of break-off buildings, but also integrating this product into the production process of cement. Un-carbonated concrete granulates can act as a CO_2 filter for industrial emissions which contain high percentages of carbon dioxide. In that way, heat-trapping emissions from industrial processes can be reduced. Additionally, the carbon footprint of newly produced recycling concrete can be improved.

Research on a fictive concrete mixture with 50% natural aggregates replaced by the cured break-off granulates shows how much carbon dioxide can be cut down. Based on a common concrete mixture for engineering purposes, $86m^3$ of this material causes 10,000 tons of carbon dioxide emissions in conjunction with the contained binder. If the same amount of concrete is

13. MA23, Stadt Wien (ed.): Innovatives Wien 2020. Wiener Strategie für Forschung, Technologie und Innovation. 2015.

14. Vereinigung der österreichischen Zementindustrie (VÖZ) (ed.): Emissionen aus Anlagen der österreichischen Zementindustrie. Berichtsjahr 2016.

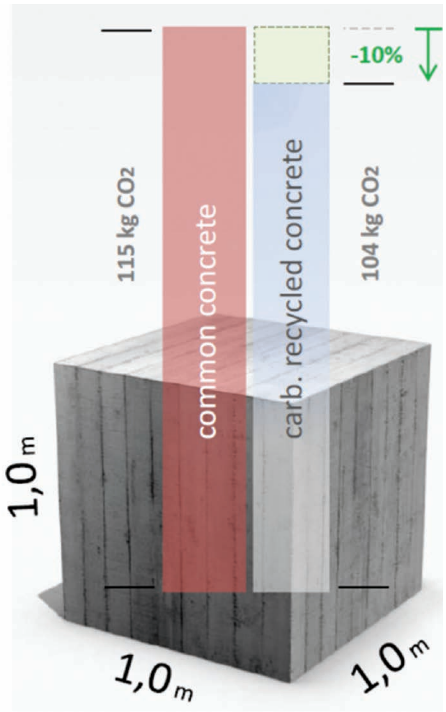
15. Higuchi,T., Morioka, M., Yoshioka, I., Yokozeki, K., Author, S.: "Development of a new ecological concrete with CO2 emissions below zero." In: Construction and Building Materials, 67/2014, Part C, p. 338–343.

16. Proske, T., Hainer, S., Rezvani, M., Graubner, C.-A.: "Eco-friendly concretes with reduced water and cement content—Mix design principles and application in practice." In: Construction and Building Materials, 67/2014, Part C, p. 413–421.

17. Seidemann, M., Müller, A., Ludwig, H.: Weiterentwicklung der Karbonatisierung von rezyklierten Zuschlägen aus Altbeton (2. Phase: Prozessoptimierung im Labormaßstab und Technologieentwurf). Bauhaus-Universität Weimar

18. Kommission "Carbonatisierung" des VDZ: "Carbonatisierung des Betons. Einflüsse und Auswirkungen auf den Korrosionsschutz der Bewehrung." In: Betontechnische Berichte 1972, S. 125–133. Beton-Verlag, Düsseldorf 1973.

FIGURE 11. Emitted CO_2 per m^3 unset concrete.



mixed with cured secondary granulates, around 10 percent of the polluting emissions can be absorbed. This leads to a reduction of approximately 1 ton of CO_2 compared to each $86m^3$ of newly used concrete. This relation is illustrated in Figure 11.

In other words: to compensate for 1 ton of CO_2 emissions a common spruce has to grow for nearly 80 years to metabolize the same amount of gas. This shows the still unused potential of an optimized recycling process. Besides, cement production has been growing exponentially and so has the associated air pollution. Currently, the cement industry is responsible for 3 percent of the human related carbon dioxide emissions. This data illustrates the importance of research on eco-friendly construction and related materials. This project is funded by the City of Vienna Municipal department 23 "Economic Affairs, Labour and Statistics.

1.5 Strategies of sustainability applied to contemporary architecture in Vienna

About 40% of energy consumption in the European Union is caused by the construction and maintenance of buildings including heating, cooling and ventilation systems.[19] This signals that sustainable climate change is highly dependent on the building industries.

Currently, the sustainability assessment of buildings is conducted primarily through building certification systems, quality labels or awards. The usual certification and rating systems focus primarily on building performance, energy and cost efficiency, and less on architectural concepts and location.[20] Many certifications, such as the "Green Building" program, are almost

19. Energieverbrauch und Baustandards. In: URL: https://www.baunetzwissen.de/nachhaltig- bauen/fachwissen/einfuehrung/energieverbrauch-und-baustandards-665901 (last checked: 2018-01-12)

20. T. Ebert, N. Eßig, G. Haser: Zertifizierungssysteme für Gebäude. Nachhaltig bewerten; internationaler Systemvergleich; Zertifizierung und Ökonomie. Edition Detail. München, 2010.

exclusively energy-related, and actually award homeowners who build or renovate a building with better energy characteristics than the applicable building regulations require.[21] Lower energy values than the regulations require, however, do not mean a comprehensive sustainable architecture. Sustainable architecture should be a connection of ecological and thus resource-efficient building materials together with economic and socio-cultural aspects, which altogether should provide a high living standard for every human being in every stage of life.

In the architectural discourse there are currently two main trends to build sustainable: low-tech and high-tech. Low-tech should be understood as building concepts that apply environmental conditions, where very little technology and mostly regional resources are used. On the contrary, high-tech buildings are associated with complex and expensive building services.[22]

Against this background the research project aimed to list and analyze strategies of sustainability of contemporary architecture in Vienna and its surrounding area independent of building certifications or awards. Guiding research questions in this context are as follows: Which sustainable strategies are applied to contemporary Viennese architecture? What roles do the building services or the architectural program play? The research project forms the basis for a further discussion on the development of sustainable architecture in Vienna.

Research method

For analyzing the sustainability of buildings, the aspects mentioned by the architects were listed. These aspects include energy concepts like the generation of energy, the conversion for heating or cooling functions and sustainable architectural concepts like site orientation, natural light, building forms, etc. The sustainability aspects refer to those mentioned by the specialist planners, architects and builders. Texts published by the architecture offices, plans and graphics, as well as publications about the projects provide the used sources.

Sustainability strategies

The most commonly used strategies are photovoltaic panels, followed by heat pumps, natural lighting and common areas. Strategies that affect social or ecological sustainability are used less often. One out of eleven projects indicated a concept for mobility like car sharing and the connection to local infrastructure.

The reason for this is on the one hand due to the fact that photovoltaic tiles and heat pumps have been subsidized by the City of Vienna for several years. On the other hand, they are extensively considered in building certifications and contribute to a large proportion to a building certification in the assessment.

Table 1 shows the conceptual classification of the strategies of eleven analyzed buildings in and around Vienna. The frequency of the strategies is as follows: a total of 32 building-technical strategies are mentioned; 23 times construction-related strategies and only 4 times social and 2 times infrastructural aspects of sustainability are stated.

The results reveal that building-service oriented aspects are the most frequently applied strategies, with social and infrastructural aspects being less frequently listed. The effectiveness of the respective strategies is often difficult to measure. For example, district heating is cited four times as a sustainability strategy in the projects under review. In urban areas and cities, this type

21. E. Haselsteiner et al: Low Tech–high Effect! Eine Übersicht über nachhaltige Low Tech–Gebäude. Berichte aus Energie- und Umweltforschung. Wien, 2017.
22. B. Cody: Technology, Architecture and Sustainability. Theorie der Technik in Architektur und Städtebau. In: Wolkenkuckucksheim—Internationale Zeitschrift für Theorie der Architektur, Jg.19, Heft 33. 2014. S.237-247

TABLE 1. Conceptional classification of sustainability strategies.

Sustainability strategies	Design	Building services	social	Infra-structural
Photovoltaic panels		5		
Heat pump		4		
Natural light	4			
Shared spaces, common spaces	4		4	
District heating		4		
Heat recovery system		4		
Geothermal energy		3		
Thermal activation of building units	3			
Buffer storage		3		
Solar thermal energy		3		
Natural ventilation	2			
Flexibility	2			
Heat exchanger		2		
Optimal use of site	1			
Rainwater infiltration on site	1	1		
Rainwater use		1		
Controlled LED-lighting		1		
Car Sharing				1
Local infrastructure				1
Passive use of solar energy	1			
Slope of roof for collectors	1			
Forms of buildings	1			
Protection against overheating during the summer	1			
Triple glazing insulating glass	1	1		
Materials of regional resources	1			

of heat generation is also more efficient than single gas or fuel oil power generation. However, in Vienna only 1–5% of the energy of district heating comes from renewable energy sources. In contrast to Salzburg (Austria), which uses almost 95% of regenerative energy for district heating, Vienna has a clear need to catch up.[23] Furthermore, building technology strategies are easier to measure than methods concerning room height, construction, etc. This is probably the reason why certifications prefer building technology strategies in their assessment. In addition, high costs are associated with building certifications. Thus, according to the fee rules of the ÖGNI and to DGNB, an amount between € 3,000 and € 10,000 for a pre-certification and an amount between € 4,000 and € 16,000 for the actual certificate has to be paid.[24] This does not offer equal opportunities for all projects but favors builder-owners of buildings with higher construction costs who can afford certifications.

Furthermore, technical devices are closely linked to technological progress and are therefore always short-lived. On the other hand, methods relating to construction methods or materials are more durable, but they require extra effort in the planning phase. Building technology accounts for approximately one third of the total cost of a construction project. If part of the costs associated with building technology were invested in the planning, sustainability strategies would be more durable and less expensive due to the lower maintenance and service costs. Such strategies include natural convection, room heights, and protection against overheating during the summer or open and shared spaces. This project was funded by the Hochschuljubiläumsstiftung of Vienna.

1.6 Teaching with hands-on experience: CE–Lab

In both educational programs "Civil Engineering and Construction Management" and "Architecture—Green Building," students show a deficiency in understanding and applying links between the STEM-fields. STEM is a term summarizing science, technology, engineering and mathematics. Students often struggle to link the subjects of mathematics, mechanics and structural engineering, which leads to high dropout rates. As a consequence, the department was looking for a solution that enables a deeper understanding of complex tasks in these subjects.

Based on this issue, a project funded by the Municipal Department 23 "Economic Affairs, Labour and Statistics", called "Building in Theory and Practice" a "Construction Engineering Lab," short "CE-lab" will be established, where theoretical content from specific courses is made tangible by practical exercises on experimental setups. The CE-lab will be situated at the University of Applied Sciences "FH Campus Wien" in Vienna and will be used by architecture and civil engineering students. By integrating the CE-lab into teaching, improved knowledge transfer and a stronger link between the individual disciplines, such as mathematics and statics, can be expected.

As shown in Figure 12, a possible set-up represents forces in a truss. Tasks can be solved while simulating at the set-up. The hands-on experience strives to involve students in the learning process. This method is also known as active learning and should transform students from passive listeners to active participants.

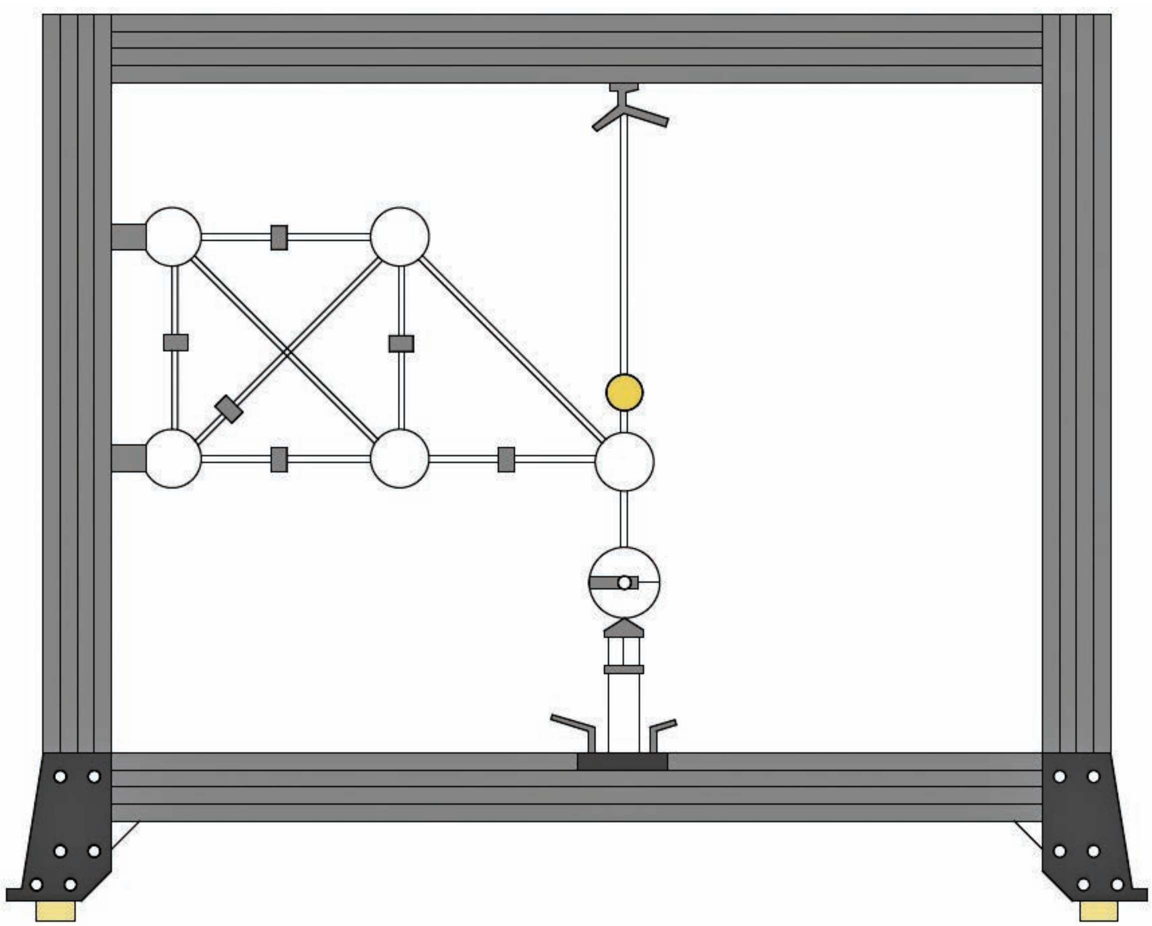
The implementation of the CE-lab takes place in four phases. The first phase "conception" includes the analysis of the courses, the selection of courses for applying the devices, the choice

23. Fernwärme aus Wind und Sonnenenergie. Via: https://derstandard.at/2000068743214/Fernwaerme-aus-Wind-und-Sonnenenergie-Erste-Anlage-der-Stadt-Wien (last checked 2018-01-12)
24. Zertifizierung. Via: http://www.ogni.at/de/zertifizierung/ (last checked: 2018-01-12)

of suitable teaching materials and the creation of a didactic design for the use of the CE-lab. The second phase "CE-Lab" deals with the procurement of teaching materials and the setup and commissioning of the CE-lab. The choice of devices is based on the didactic concepts developed in the first phase. Particular attention is paid to durability, flexibility, stability and long-term availability of parts, as well as the possibility of hardware extensions. Before regular use, selected students will conduct a test phase (Dry Run). During the third phase "teaching," the new technology and didactics concepts will be implemented in the selected courses step-by-step. Parallel with a student evaluation, a feedback option will be introduced in each session. In evaluating the CE-lab, students should assess methodological and content-related aspects, such as the provision of specific knowledge and preparation for later professional practice. Based on the feedback results, subsequent adjustments will be made. "Lessons learned," as the fourth phase of the project, reviews and a summing up of the output of the previous project phases. This is to obtain well-elaborated recommendations for curricula adjustments.

Currently, the first project phase is nearly finished and the didactic design is created. The didactics of the course will alternate between theory and application. In the theoretical phase the

FIGURE 12. Example of set-up (purchased from a specialized company for engineering education): forces in a truss.



concept of a "flipped classroom" will be applied. This means that students will prepare current topics at home, for example, watching a video or reading material. During the attendance period, lectures will be structured by topic. At the end of a block a multiple-choice test will be conducted. The results divide the students in two groups: instructors and attendees of the lab.

In the practical phase the students work on tasks where the students with better results act as peer instructors. The selected group of peer instructors and attendees will be reevaluated after every multiple-choice test at the end of a theory block. At the end of the course there will be a final project involving explorative learning.

CONCLUSION

The study program, Architecture—Green Building, is a result of the so-called *Hochschulmilliarde*, i.e. a 1 billion Euro set aside for universities to provide additional funding from 2013–2015. The universities were encouraged to develop new and innovative study programs. The bachelor degree program, Green Building, was one of these innovative curriculums. Starting in the winter term 2013, the Architecture—Green Building study program is a young program that due to regular evaluations continually improves in various aspects. Starting as a part-time study program, it became obvious that the work load on the students fits better to a full-time study. This change made the accreditation with the EU directives on the recognition of vocational qualifications possible in February 2017.

Regular evaluations are one of the key strengths of the University of Applied Sciences "FH Campus Wien" in Vienna. Students' feedback led to new subjects, such as *Visualization* in 2017, which is held in addition to the CAD courses in the first bachelor semester. One major change was made in regard to the bachelor's thesis, which used to be linked to the compulsory internship students have to take in the 4th semester. Currently, students can write their thesis in all subject areas linked to the curriculum's lectures. This allows students to deepen their knowledge in their specific areas of interest. Every year the department of *Building and Design* improves its curriculum in order to meet the high standards of the professional world and to adapt to recent changes. By doing so, the students are offered a practical-oriented education that prepares them for the recent challenges the construction industry and architects are facing concerning environmental changes, which make sustainable architecture inevitable.

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