Green roofs and living walls meet sustainable energy and building technologies

Buildings equipped with green roofs and living walls combined with solar architecture and renewable energy technology need an intense interdisciplinary planning process.

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Abstract

The building industry identified an increasing need for professional knowledge, especially when renewable energy and construction technologies are combined with green roofs and living walls. During the construction phase of buildings a variety of professionals and highly specialised disciplines have to interact. But aims and demands of different involved technologies may come into conflict – a professional coordination is necessary. An interdisciplinary planning process provides remedy.

Introduction

Using sustainable building technologies combined with green roofs and living walls are in line with the actual trend. Professional know-how is needed for sustainable, efficient and green solutions.

Building physical, constructive and static conditions of roofs are crucial for their loading capacity. Depending on that selected green roof types (e.g. reduced extensive green roofs with vegetation mats or intensive greened roof gardens) can be applied. All involved trades like carpenters, roofers, tinsmiths and gardener have to be coordinated with architects, landscape architects or building physicists. An insufficient coordination leads to construction defects and dissatisfied costumers. The same applies to living walls: professionals for metal construction, façade construction, static, building physic elaborate together with landscape architects, gardeners and irrigation technicians solutions for efficient living walls.

The need of know-how and additional coordination increases rapidly if technologies of sustainable construction and greening is complemented with renewable energy production technologies like solar technology. A high sensitivity for the other trade’s demands is recommend if e.g. passive houses or plus energy houses are equipped with green roofs, living walls and solar power systems. Combined interfaces (e.g. anchoring of living wall on a passive house wall, installing of a green roof on a wooden roof truss) have to be identified and technically solved.

But how can the optimal solution be found?
One recommended problem-solving approach for the complex task of combining energy efficiency, , green infrastructure (as green roofs and living walls) and energy production technologies is an interdisciplinary, integral planning and construction process. Within a creative planning process experts of different disciplines pursue a defined planning objective like the solution of a technical building problem (Figure 1). During this iterative process together several variants of solutions will be developed

Key messages:

- Integral, interdisciplinary planning is essential to cope with complex planning processes.
- Investing in the planning phase helps to reduce building costs by identifying synergies in the processed and avoid design errors and associated additional costs in the realization phase.
- Living walls and green roofs need experts with special know-how in planning and construction.
- Green design elements like living walls and green roofs are sensitive constructions and need coordination with other building trades involved in building processes.
- Multilateral and building trades overarching knowledge transfer and exchange lead to sustainable, green buildings.

Figure 1. During an integral, interdisciplinary planning process experts of different disciplines generate together an efficient solution for a technical constructive problem.

as long as the planning objective is accomplished. In a following implementation phase using detailed building inspections the compliance of the targeted objective will be verified (Ackermann, 2014).

Additional to this described interdisciplinary process the Austrian Standard OENORM B 1801-1:2009 'Building costs – Cost breakdown' (ASI, 2009a) provides a detailed planning system for building projects with six identified project phases starting with developmental and preparing phases, preliminary draft and draft phases up to a construction phase and a finalization phase. For each phase the scope of quality, costs and time schedule can be fixed and controlled.

Kovacic (2014) explains integral planning plays a key function in complex planning processes. However this system isn't yet common in the planning reality. Methodological know-how is still missing and building contractors or investors don't accept high cost for planning in contrast to traditional planning processes. Whereas an intensive planning process pays well: Currently 20 % of life-circle costs of buildings are calculated for planning and construction. The Austrian official scale of fees for services by architects and engineers regulates the planning costs with 10 to 15 % of the construction costs. That corresponds to 3 % of life-circle costs. Kovacic (2014) concludes from that that 3 % planning costs essentially influence the remaining 97 % life-circle costs of buildings. This comparison shows clearly that the best time to influence the development of costs and building quality is the planning phase. In later phases optimization steps will be more expensive and less realizable.

Thus the approach of integral and interdisciplinary planning has to be promoted, especially for complex architectonical solutions like buildings with renewable energy technology and sustainable construction techniques combined with green roofs and living walls. New know-how has to be generated and provided for planning specialists as well as professionals of the building trades in order to minimize construction defects and to enhance the quality of building.

A new interdisciplinary network including a variety of competences

2012 a new consortium and network – named GruenAktivHaus – of economic specialists and researcher initiating by the Institute of Soil Bioengineering and Landscape Construction of the University of Natural Resources and Life Sciences, Vienna (BOKU) was founded with the aim to increase and exchange knowledge of solar architecture, energy technology, building physics and greening technology needed for sustainable and greened buildings. Together a new qualification training curse was developed and tested: Know-how in the fields of living walls, green roofs, indoor greening, irrigation technology, control technology, illumination technology, permeable road construction, metal construction, photovoltaic and solar technology, energy technology, solar architecture, timber technology, building physic, landscape architecture, architecture, landscape construction and gardening was intensively exchanged. Aim of this new training course is to involve all needed trades for a building, which combines sustainable, renewable construction and energy technology as well as green infrastructure elements like green roofs or living walls. Within an integral working process the 16 consortium partners identified the demands of their own trade and become informed and comprehend the other trade's requests.

The first part of the new training course was designed as a theoretical exchange and generation of knowledge in form of lectures and excursions. Additionally in the second part the participants were asked to use and test their new know-how by means of a real planning and construction process of a GruenAktivHaus-lighthouse project. The used integral and interdisciplinary planning process allowed a detailed identification of several interfaces between different for the construction of the lighthouse project necessary trades and an optimal coordination of them.

Introduction of the GruenAktivHaus-lighthouse project

The named lighthouse project acts not only as training element. It should help to promote the interdisciplinary approach. As potential location the research and competence centre for construction and energy Sonnenwelt in Grossschoenau, Lower Austria could be identified. Sonnenwelt (2015) distributes know-how about energy efficient and sustainable construction and sanitation technologies.

A building complex composed of three different buildings named lens, hall and interlink provides space for entrance, exhibition, rooms for events, conference rooms, office, merchandising shop and buffet. The whole complex is built with passive house technology. A photovoltaic power plant is installed on one roof and produces the electricity needed at Sonnenwelt.

Within the training course the participants of the consortium identified the southeast faced wall of the exhibition hall and the interlink building as ideal locations for testing their new knowledge in a real planning and building project. In a first step a general vision was identify: A lighthouse project should be planned and built with the aim to present innovative synergies and usage of green infrastructure, solar energy technology, LED technology and solar architecture.

Architects and landscape architects of the consortium implemented this vision in their draft and detailed planning. The joint project presents the different trades of the consortium and their new and innovative collaboration. The historical development of façade greening is presented in six frames (each 4 x 3 m) illuminated by LED technology and photovoltaic panels alternated arranged in a gently zigzag line along the hall wall. The project shows interested people the variety of innovative technologies (Figure 2). The first three frames display classical façade greening with espalier fruits, climbers supported by steel cables and trellis or self-clinging climbers. Frame 4, 5 and 6 hosts three different innovative living wall systems, two Austrian and one German product. Each frame has a metallic subconstruction established on point foundation. An anchorage towards the sensitive wall in passive house technology using special threaded rods allows to minimize the loss of insulation effects. The metallic subconstruction serves as anchorage element of the different façade greening systems. Finally like a picture frame wooden elements have been fixed on the subconstruction and put the living walls into focus.

All façade greening systems are equipped with an sensor based irrigation using drip irrigation or subsurface irrigation allowing an irrigation according to the water demand of the plants in the differnet greening systems.
The solar power plant is conceptualized to produce 1.100 kWh electric energy per year, enough to run the irrigation system and LED illumination. A way paved with a water permeable surface consolidation method leads along the living walls and photovoltaic panels and ends at four small wooden huts of the Sonnenwelt's adjacent playground. The steep roofs of these huts were equipped with extensive green roofs using vegetation mats fixed with a special technology for steep roofs.

Identification of interfaces

During the integral and interdisciplinary planning process of the descripted lighthouse-project the consortium identified a huge amount of interfaces between the involved building trades. Under the control of a sensitive and experienced project management solutions for each interface could be developed. In a several weeks lasting process with many planning and discussion meetings in different constellations of experiences and disciplines step by step construction details, processes, a chronological order of acting, time schedules, cost and financing plans were developed, discussed, scraped and decided (Figure 3).

Figure 2. The GruenAktivHaus-lighthouse project at Sonnenwelt, Grossschoenau, Lower Austria, Austria. Participants of the new developed training course used their new learned knowledge to plan und construct this building project presenting innovating synergies and usage of living walls and green roofs, solar energy technology, LED technology and solar architecture.

Figure 3. Specialists of the GruenAktivHaus consortium are working on an efficient solution for a technical detail under the control of the project management.

Table 1. Identified interfaces during the interdisciplinary planning process of the lighthouse project GruenAktivHaus

no	involved trades	interfaces
1	architect, landscape architect	coordination of vision, draft and planning
2	architect, landscape and all other trades	coordination of draft concerning technical and vegetation technical feasibility
3	earthworks, building construction	identification of existing building foundation for dimension of earthworks
4	earthwork, road construction	coordination of excavation and substructure
5	earthwork, metal construction	coordination of excavation and dimension of founding of the metallic subconstruction
6	earthwork, building services	coordination of existing supply line plan
7	road construction, building construction	coordination of consolidation of house entrance
8	metal construction, building construction	coordination of anchorage subconstruction towards house wall
9	metal construction, landscape construction	coordination of dimension of subconstruction, facade greening systems (assembling)
10	metal construction, wood construction	coordination of assembling (wooden frame, trellis)
11	metal construction, energy technology	coordination of assembling the PV-panels on subconstruction and supply lines
12	wood construction, landscape construction	coordination of trellis and demand of plants
13	wood construction and landscape construction	coordination of static properties of the huts' roofs - roof construction
14	irrigation technology, landscape construction	coordination of irrigation system, water demand of plants and greening systems
15	irrigation technology, building services	coordination of existing water supply system
16	energy technology, irrigation technology	coordination of demand and supply lines
17	energy technology, illumination technology	coordination of demand and supply lines
18	energy technology, lightning protection	coordination of assembling in existing lightning protection system
19	illumination technology, building services	coordination of assembling in existing supply system

Table 1 structures with respect to involved building trades and illustrates the high variety of identified interfaces. Figure 4 helps to understand the complexity of the descripted planning process.

The most intensive discussion work was needed for an assembling detail on the metallic subconstruction. This small assembling detail should provide space for the wooden frame fixed with a carriage bold, for different façade greening systems, for indirect LED illumination, for supply lines (electricity and water) as well as for assembling points of the photovoltaic panels. All involved specialists created together a solution elaborating planning details. At the end only a 1:1 scaled plan helped to find for all demands an appropriate assembling solution (Figure 5).

The participants of the training course learned that by complex building tasks like greened, sustainable and energy efficient buildings a range of interfaces exist. They are specific to each building task, but some of them could be use in general. Crucial is to identify the interfaces timely. For the participants the planning phase was the ideal point of time to react and find satisfying, efficient solutions.

Conclusion

An intensive exchange between all members of the interdisciplinary planning group allows to find solutions for all addressed interfaces of the lighthouse project. A major challenge of this planning process was to find a joint terminology. Each trade has it's own technical terms. To make them understandable for the others 'translations' have to be found.

Especially in the following building phase of the lighthouse project not only an understanding between the different trades using a joint terminology was challenging also different mother tongues need a sensitive joint social interaction. On the construction site German, English, Hungarian, Slovakian, Czech, Polish and Romanian was spoken. If the linguistic barrier was too large sketches and plans helped. Hence, plans are absolutely necessary

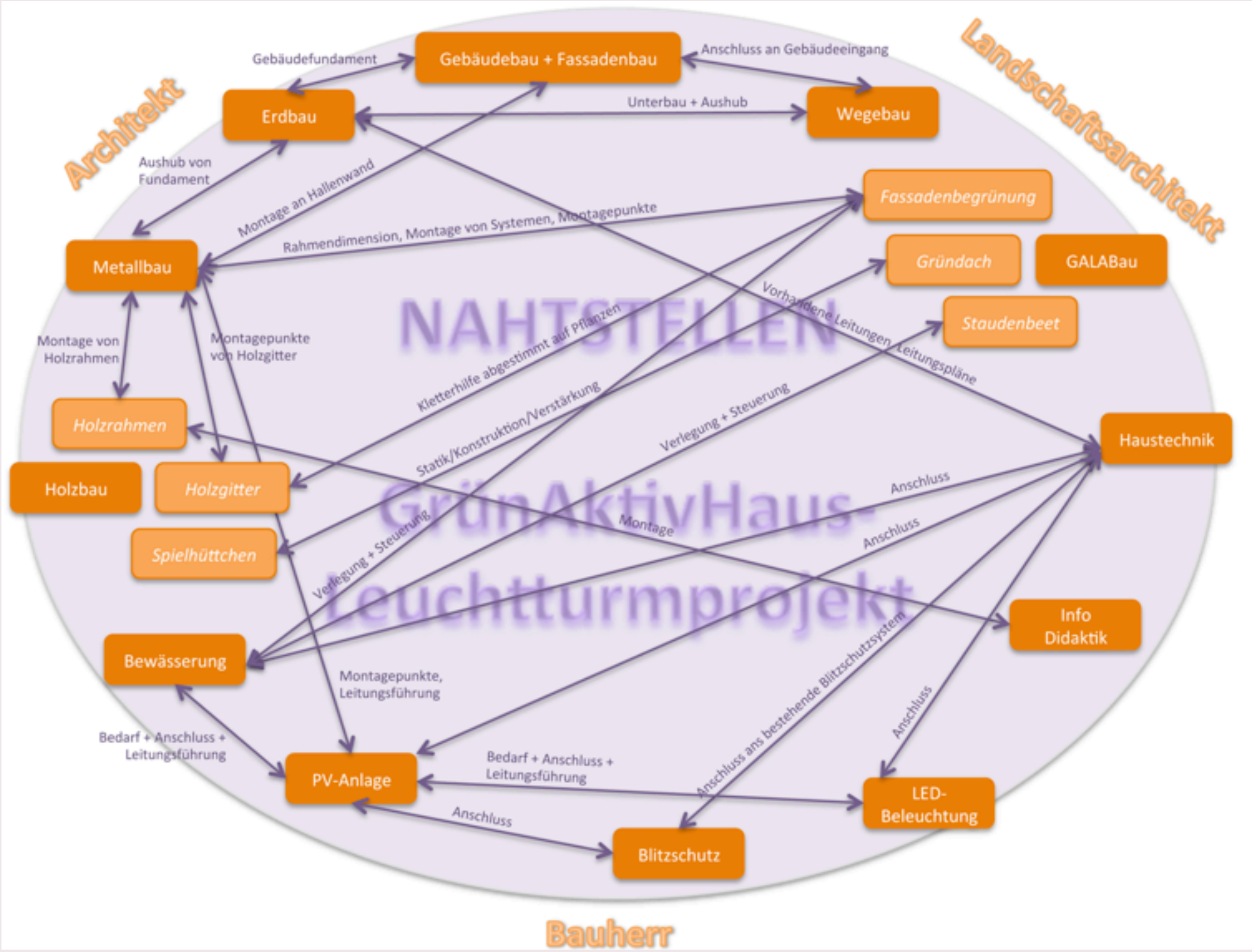

Figure 4. The complex interface diagram of the lighthouse project GruenAktivHaus

instruments for finding solutions of interfaces in the planning phase, but also to have a clear documentation of them for the following phase at the construction site. But a plan is not like another! Trades use different methods to map technical and constructive details. Some trades communicate without plans. In this situation a high competent project management is essential to coordinate all persons involved and to avoid misunderstandings.

An also interesting aspect of the interdisciplinary planning process was to get new insights of companies, their internal processes, communication strategies and mission statements. Additionally people have different characters and represent different personalities. This fact has also to be managed and coordinated.

At the end the participants of the training course evaluated clearly that the integral, interdisciplinary planning process of the GruenAktivHaus-lighthouse project and its higher effort was worth it. Especially complex technical and architectonical design of buildings with a combination of solar architecture, renewable energy production and green architecture with living walls and green roofs need such interdisciplinary work already in the planning phase. Creativity, spontaneity and flexibility but also soft skills like empathy, identification of the other trade's needs and an open communication will lead to best practices. Therefore specialists are needed who have an open mind about interdisciplinary knowledge transfer and new life-long-learning qualification methods.

Integral, interdisciplinary planning processes fix time, personal and cost resources, but leads to building objects with a high quality. This benefit should convince investors, decision makers, planners and companies of the building industry to invest more in planning phases in order to generate sustainable, energy efficient and green buildings with satisfied residents or users.

General information

Façade greening is quite common in Europe. Self-clinging climbers on houses have a long tradition as well as fruit trees trained as self-supporting espaliers. Modern façade greenings favour climbers supported by steel cables or trellis made of vertical and horizontal elements. Climber species developed different strategies of climbing: There are self-supporting woody plants trained as wall shrubs, climbers and plants that need support (rambles with and without thorns), true climbers with methods of attachment to supports (self-clinging climbers, climbers with aerial roots or suckers), twining climbers and climbers with specialized leaves for attachment (Dunnet and Kingsbury, 2010).

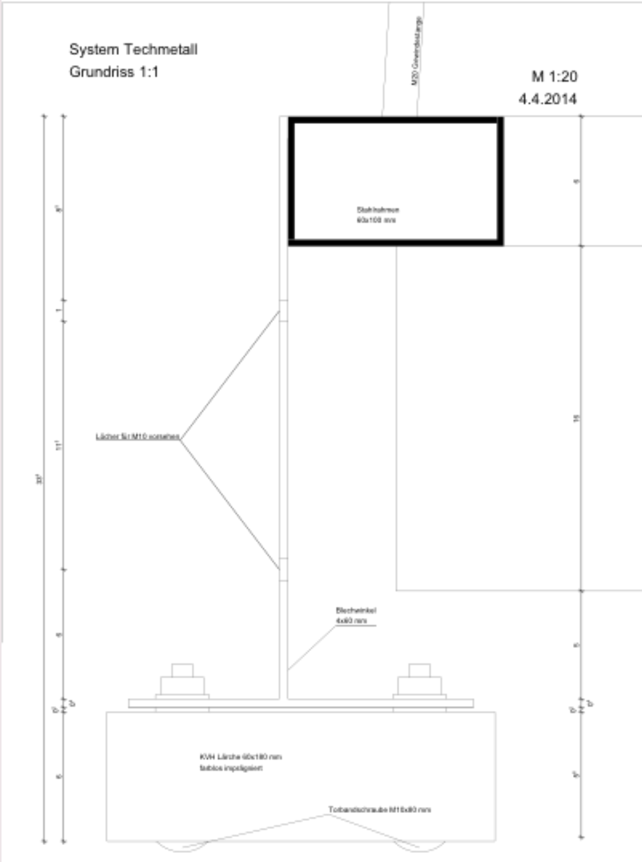

Figure 5. After several meetings the participants of the training course agreed on the above showed solution of a technical detail of the metallic subconstruction, an interface of five different trades.

Living walls represent a new type of covering walls with vegetation. Different form the descripted type of traditional façade greening with climbers rooting in surrounding soil or growing medium at the base of the wall, living walls allow plants to root totally within the living wall structure (Dunnet and Kingsbury, 2010). Shrubs and small woody plants grow vertically in retaining structures made of geotextiles, mineral wool or three-dimensional growing elements filled with specific growing medium or soil. Living walls are green high-tech systems with special needs.

But not only vertical walls of buildings can be greened. In Europe more and more roofs are greened. Modern Green roofing technology allows greening a broad variety of roof types. Plan roofs are suited as well as inclined roofs with an inclination of more than 40% (ASI, 2009a). Reliable constructions with different layers (soil layer, filter layer, drainage layer, protection layer) allow to plant roofs. Depending on the amount of maintenance two types of green roofs can be derived – intensive and extensive green roofs.

Intensive green roofs are more like roof gardens quite similar to gardens at the ground level. Shrubs and woody plants can be arranged additionally to recreation areas, sitting and rest areas and way structures. Soil depths in a range of 20 to more than 80 cm are required. The other type is an extensive green roof with thin soil layers (8 to 20 cm) made of light weight substrate materials and planted with moss species, sedums, grasses, herbs or small shrubs (ASI, 2009a). Extensive green roofs look like grasslands, are more ecological due to less maintenance and cheaper construction.

For further information about façade greening, living walls and green roofs please see:

- OENORM L1131 (2009-08-26): Quality assurance in green spaces – Green roof – Directives for planning, execution and maintenance, Austrian Standard Institute (ASI, 2009b)
- Leitfaden Fassadenbegruenung – A guideline for façade greening and living walls (2013), City of Vienna (OekoKauf Wien, 2013)
- Dachbegruenungsrichtlinie – A guideline for Green Roofs (2008), Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL, 2008)
- Richtlinie Fassadenbegruenung – A guideline for façade greening (2000), Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL, 2000)

GruenAktivHaus - Green roofs and living walls meet sustainable energy and building technologies

- aim and scope of the project: The aim of the GruenAktivHaus project was to initialize an economic and scientific multilateral exchange of know-how in the fields of solar architecture, energy technology, building physics and greening technology needed for sustainable and greened buildings. Therefore a new, all trades involved in sustainable and greened building design overarching training course with theoretical and practical course elements was developed in an participative process. In the practical course units the consortium members used their new learned knowledge to realise the GruenAktivHaus-lighthouse project in Grosschoenau, Lower Austria. This lighthouse project presenting an efficient combination of the above named specialist fields is open to public and can be visited at Sonnenwelt, Sonnenplatz 1, Grosschoenau, Lower Austria, Austria.
- time frame, ~dates of beginning and ending: 1.10.2012 – 30.9.2014
- country (town) the project is done in: Vienna, Austria and Grossschoenau, Lower Austria, Austria

- initiating organization: University of Natural Resources and Life Sciences, Vienna; Institute of Soil Bioengineering and Landscape Construction
- website: https://www.gruenaktivhaus.at

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