Woodscraper - highrise according to the circular economy

J Finkbeiner¹, K Günter¹, J Meissner¹, C Merz², F Stahl³, D Kruse⁴ and M Ernst⁵

¹ Partner und Partner Architekten – Reichenbergerstr. 124D/ D-10999 Berlin
² Merz kley partner ZT GmbH, Sägerstraße 4/ A-6850 Dornbirn
³ IFB Ingenieure GmbH, Wielandstraße 2/75385 Bad Teinach-Zavelstein
⁴ Dehne, Kruse GmbH & Co. KG, Major-Hirst-Straße 5-11/ 38442 Wolfsburg
⁵ Hochschule Ostwestfalen-Lippe (HS-OWL) Emilienstraße 453/2756 Detmold

mail@partnerundpartner.com

Abstract. shortages, climate change and population growth with associated urbanization pose immense challenges to the construction industry. The question of sustainable building construction raises the need for innovative concepts, which address the increasing scarcity of raw materials, energy efficiency as well as space efficient construction to protect our climate. strategies become more and more the focus also of social interest So far, buildings are usually built and operated according to the take-make-waste principle[1]. This means that finite resources are no longer available for new uses through downcycling processes. The Woodscraper examines by way of example how far fully circulatable buildings are already possible today. Therefore the concept of Woodcrapers is based on the principles of Cradle-to-Cradle, Circular Economy and AktivPlus. As part of the “Deutsche Bundestiftung Umwelt (DBU)” -funded project, strategies for circular construction have been developed and implemented in the project through an integrated planning process, involving the competences of a planning team, the early involvement of the authorities, as well as specialist planners and manufacturers. Synergies between construction, materials and building services have been identified and implemented meaningfully. A life cycle analysis ran in parallel, to quantify those potentials. The Woodscraper visualizes this added value in the construction and makes it perceptible through comprehensive lifecycle analysis during operation over its entire life cycle.

Keywords: Circular Economy-Principles, Building as Material Bank, design for disassembly, resource-positive approach, BIM/Lifecycle analysis.
1. Introduction

1.1. State of the art
State of the art in relation to the question of sustainable construction, and innovative concepts that meet the growing scarcity of raw materials, the energy efficiency against climate protection, are increasingly in the focus of social interest. However, many approaches are currently focused solely on the numerical reduction of energy consumption in building operation, which may, for. This means a considerable expansion of the cost-oriented building technology in passive house construction and also ignores the space requirement and thus the space consumption, the energy and indoor air quality. With a similar focus, the EnEV aims to reduce energy consumption in building operations by continuously increasing insulation standards. From this it can be concluded that the already developed efforts are not yet sufficient to answer the challenges of the construction industry in an economically attractive way.

1.2. The research Project - Woodscraper
For the WOODSCRAPER project in Wolfsburg, a strategy was developed to design a building from the early planning stages ecologically but also cost-effectively. The WOODSCRAPERS are aiming to offer the potentials as the holistic, integral planning approach addresses the resource question through the topic of renewable raw materials, as well as the comprehensive planning for disassembly and reuse of individual components and building materials for the sorted recovery of the resources used. Various studies, aiming to streamline and simplify building technology, looking for solutions that reduce the negative impact of buildings on climate change. Skyscrapers as a building typology tackles the need to reduce land consumption through compact construction.

1.3. The main construction material
Wood as an essential construction material is suitable for a resource-positive approach for a variety of reasons. As a renewable building material, it can be provided promptly and in sufficient quantity. Due to the light weight as well as the provision of dry connections, wood constructions are in general more suitable for direct reuse, non-destructive dismantling or homogenous recycling that can be returned into the biological cycle. The technical feasibility of wooden high-rise buildings has been proven in Europe with a few research and pilot projects [2]. Likewise, the use of ecological, as well as renewable building materials demonstrating economic benefits, become more and more feasible.

However, the high-rise typology must legitimately meet stringent regulations regarding fire protection and statics. In addition, sound insulation (cause by the lightweight construction), maintenance during operation and increased weather conditions still represent challenges. Sustainable building construction is therefore not particularly widespread in the field of this typology. Economic issues and certain reservations in the construction industry often hinder the implementation of such buildings in practice.

2. Methodology

2.1. Procedure
The aim of the WOODSCRAPER research project presented in this study is to use the example of WOODSCRAPER to develop a strategy that ensures the cost-effective implementation of complex, resource-optimized buildings from the beginning of the planning process.

The strategy requires that investment costs, lifecycle costs as well as life cycle assessment of the WOODSCRAPER as an ecologically optimized building are compared to a conventionally planned building. By means of the commercially available LEGEP software [3]. These two case studies can be compared and evaluated taking into consideration all design-specific components and elements. The results of this evaluation, enables the intelligent combination of components and elements in such a way that ecological optimum and efficiency are balanced, which in turn represents the planning result, as planning is the anticipation of future action. Prerequisite for this strategy is an integral planning process with all stakeholders including all required consultants and experts to check new materials, and material
combinations regarding feasibility at the beginning of the design process to minimize negative path dependencies in the further course of the project. Using the example of WOODSCRAPER, a strategy of an comprehensive planning approach has been developed to integrate a holistic economic analysis including life cycle assessment for the planning of ecological buildings already in the design process, since the possibilities of influencing these questions are greatest at the beginning of each project. Construction methods, not widespread but preferable due to environmental reasons, are usually difficult to implement, as they have to withstand the argument of lack of experience in addition to concerns regarding the lack of economic viability. In this study, a method is developed to address and clarify these questions at an early stage. The anticipation of subsequent work phases is inevitable, therefore an integrated planning process involving all project participants is a prerequisite.

2.2. Starting situation
Timber construction has undergone a renaissance in recent years, and has developed into a highly innovative industry through research and new manufacturing techniques, among other things. Multistorey buildings, up to high-rise buildings erected in wood represent no longer a technical problem. This is proven by the examples ranging from the Wood Cube in Hamburg [4] to the 24-storey wooden tower in Vienna [5] and the 18-storey student residence in Vancouver [6]. Despite these examples, timber construction in Germany still faces the deep-rooted prejudices of fire protection and feared additional costs. Questions of fire safety have already been examined in detail, which is reflected in the amendment of the building code in Baden-Württemberg [7] and the aspirations of other federal states such as North Rhine Westphalia [8], Hamburg [9] or Berlin [10].

Many approaches are therefore currently focusing solely on the numerical reduction of energy consumption in building operation, which usually results in a significant expansion of the building technology, ignoring both the additional construction and operating costs, and the additional space required thereby. The operating energy and the consequences on the indoor air quality are not adequately taken into account. With a similar focus, the EnEV aims to reduce energy consumption in building operations by continuously increasing insulation standards. From this it can be concluded that the already developed efforts are not yet sufficient to answer the challenges of the construction industry in an economically attractive way. Likewise, there are detailed studies on structural U-values, improvement of indoor air quality, room humidity control properties and much more [11]. Thanks to responsible forestry, Europe's tree population has increased in recent decades. According to calculations by the expert group "Life Cycle Assessment" of the German Sustainable Building Council, between 2003 and 2042 about 78.2 million cubic meters of raw wood are felled each year [12]. 8% of this amount would therefore be sufficient to build the entire volume of new housing construction (20 million m² in 2012) from solid wood. These investigations as well as the further development of the processing techniques prove that wood, as a high-tech building material of the future, is already particularly suitable for high-rise buildings today. However, when assessing the cost of construction, there is still some need for investigation, since the square meter of wooden wall is actually currently more expensive than that of a conventionally constructed wall (for example a masonry-wall or a wall made out of concrete). In practice, the higher quality standards for the indoor climate and the ecological performance. In a fundamental reassessment of the wooden wall are generally accepted only in the case of owner's own needs. At the same time, wooden walls can be made considerably slimmer, which would have to include a considerable gain in area and, in fact, a realistic economic analysis considering all costs that include a real estate project in addition to the pure construction costs. Construction, there are also enormous saving potentials for the following aspects, which must be examined in detail, so that the cost arguments against wood construction and ecological construction can be rebutted:

- Reduction of construction area
- Streamlining the building technology through passive measures, as well as alternative installation techniques and intelligent electrical systems
- Variants of fire protection in high-rise buildings
- Possibilities of local power generation at the building and storage in the building
• Reduction of construction costs by shortening the construction time and pre-elementation
• Alternative financing models. For example: Consideration of valuable

These examinations are intended to provide exemplary proof that environmentally sound construction is already possible and affordable even on a large scale today. It will be the first wooden high-rise buildings in Germany, where all today realistically usable ecological innovations are used economically and sensibly. The aim is for the houses to serve as a model for new, circular planning and construction, which can massively reduce the consumption of resources and create a healthy living environment with drastically reduced negative impacts on people and nature.

2.3. Task Methodology
Using the example of WOODSCRAPER in Wolfsburg, a model with proven construction practices for the economical construction of resource-positive buildings for high-density living space is to be developed. From a holistic point of view, savings potentials of individual components are examined and evaluated in a macroeconomic way by methods of economic and life cycle analysis. The results are comprehensibly summarized and documented in a brochure for specialist planners and builders. It may be necessary to create a website with results of the investigation in order to intensify the public relations work. An early involvement of all project participants in an iterative planning process ensures the detail sharpness in the holistic view.

The aim of this project, using the example of WOODSCRAPER, is to investigate holistically whether these savings potentials can be presented in a positive overall economic sense. The innovation of this project lies in the proof resources to build positive buildings cost-neutral. The following questions will be examined together with the partners in the requested DBU-funded project.

• Plot "J": 1.630m², plot "N": 1.814m², together 3.444m²
• 2 wooden high-rise buildings, each with 11 upper floors, a half-storey and a common underground car park
• WHP: approx. 15,462 m² including underground parking
• BGF building: approx. 12,655 m²
• BGF underground car park: approx. 2,806 m²
• Rentable area: approx. 8,683 m²
• about 90 apartments (house J and N)
• approx. 83 parking spaces
2.3.1. Façade columns. On the outer facade, on the one hand, high transparency and, on the other hand, the greatest possible flexibility with respect to the arrangement of the windows are desired. The resolution of the wall in columns for vertical load transfer and in non-load-bearing wooden frame elements as a building shell is therefore obvious. Wooden columns are advantageous in terms of carrying capacity and cost and are also an important identity-creating element for the design.

2.3.2. Load-bearing interior wall. The depth of the building from the facade to the core with 10 m requires an intermediate support. In contrast to the façade, where a great deal of transparency and flexibility with regard to openings is required, the central axis corresponds in many parts to the room delineation. A wall is crowded around it. A load-bearing wooden wall can be made relatively narrow even with high fire requirements. Columns, as on the façade, are thicker and lead to a large loss of living space when flushed or complicate the furnishing, built between the columns, partitions.

2.3.3. Non-load-bearing interior wall. As non-load-bearing interior walls drywall walls are proposed. Practice shows that walls of metal stands and gypsum boards have an unbeatable value for money. If there is a cost game they could of course be replaced by wooden frame walls. In that case, the metal stands would be replaced by wooden frames.

Figure 1. The buildings were designed according to a clearly systemic design principle. Nonrenewable building materials were reduced to the necessary parts of the building.

Figure 2. The floor plans follow the optimized construction principle.
Figure 3. Visualization of the buildings, systemic modular design approach

Figure 4. Visualization of the building inside, unenclosed wooden construction
2.3.4. Balconies. To form the balconies, the ceiling elements project over the load-bearing outer wall. In order to protect the construction from outside moisture, it must be completely sealed. In addition, special attention must be paid to the airtightness of the element joints in order to avoid any damp damage from convection. A cost-effective alternative would be to imagine a self-supporting reinforced concrete structure that could be stiffened by means of punctual brackets over the main building body.

2.3.5. Detailing. From a static constructive point of view, it is above all the transmission of the vertical loads of the columns and walls on the floor slab and the connection of the ceiling to the core that are critical and relevant for the costs. The corresponding details are shown schematically in Figures 14-16. It was sought after to avoid cross-pressing in the wood and to minimize the use of steel junction.

3. Results
The building can be adapted to address changing needs, and enables the recycling of expended resources. The operator also benefits from the economic potential inherent in the circular economy. A holistic cost analysis during the planning process evaluates all medium and long-term added value for users, operators and investors, as a foundation to enable meaningful, future-oriented decisions. Due to the slight crossing of the high-rise building by 4 storeys, the economy, regardless of the ecological construction method, shows that enormous additional costs are incurred to fulfill the legal requirements of this typology. It is therefore certainly interesting to examine in perspective how the economy is under the high-rise boundary.

4. Conclusion and Outlook
After a comprehensive life cycle analysis, we can conclude that a resource-positive building is fundamentally possible (Fig. 5, 6). The problem of a concrete implementation is not due to lack of technical solutions or building materials. More problematic is an overall system that is not intended for a circular future: path dependencies, established planning and construction processes and, if well-intentioned, legislation prevent genuine innovation. The transformation from a linear to a cycle-oriented system is fundamental and comprehensive and poses great challenges to our society and to the building as a whole. It affects planners as well as building material manufacturers, disposal companies and legislators. Because in addition to a cycle-capable design, recycling cycles must be developed and established, and new business models must be developed for this purpose. This requires a holistic planning culture that works integrally.
Figure 5. global warming potential. Observation period 25 years

Figure 6. totally renewable primary energy and totally non-renewable primary energy. Observation period 1 years

5. References
[1] Cradle to Cradle: Remaking the Way We Make Things (April 2002, ISBN: 8580001060248)
[2] Pilot Projects:
  www.creebyromberg.com/de/detail/lct-one-der-erste-lifecycletower-der-welt,
  www.zueblin-timber.com/news/baustart-fuer-deutschlands-erstes-hochhaus-aus-holz.html
[3] LEGEP WEKA MEDIA GMBH Co KG (Titel-Nr.: CD7266, Version 08/2017),
[4] https://www.iba-hamburg.de/fileadmin/Slideshows_post2013/02_Wissen/01_Whitepaper/14-04-04_White_Paper_WOODCUBE.pdf
[5] www.hoho-wien.at,
[6] www.detail.de/artikel/18-geschosse-in-holz-studentenwohnen-in-vancouver-30117/
[7] www.landesrechtbw.de/jportal/?quelle=jlink&query=BauO+BW&psml=
  bsbawueprod.psm&max=t%20true&aiz=true
[8] https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=58200311069233838
[9] http://www.landesrecht-hamburg.de/jportal/page/bshaprod.psm?doc.id=jlr-BauOHA2005rahmen&st=lr&showdoccase=1&paramfromHL=true#focuspoint
[10] http://www.stadtentwicklung.berlin.de/service/gesetzestexte/de/bauen.shtml
[11] www.b-house-project.eu/
[12] https://www.forstwirtschaft-in-deutschland.de/forstwirtschaft/forstwirtschaft-in-deutschland/waldbesitz-holzeinschlag/

Acknowledgments
This project has received funding from the Deutsche Bundesstiftung Umwelt (DBU) No. 34252/01-25.