Federal Ministry
of the Interior, Building
and Community

Federal Institute for
Research on Building,
Urban Affairs and
Spatial Development
within the Federal Office for
Building and Regional Planning

English Version

Zukunft Bauen

Digitale Bauwelt

Das Magazin der Forschungsinitiative
Zukunft Bau

Digital Construction World

The Magazine of the
"Zukunft Bau" research initiative

FORSCHUNGSINITIATIVE
Zukunft BAU

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Contents

Foreword

When it comes to research, enormous efforts are being made to make building simpler, quicker and more modern and, overall, to position the sector on a future-oriented, progressive and sustainable level. Digital methods and tools play a significant role in this context – and their importance continues to grow.

Since the Future Building research initiative was established in 2006, digitisation has had a firm place in the promotion of research. The advent of Building Information Modeling and the development of new production methods have lent additional dynamism to penetration of the building sector with digital technologies.

However, two areas of activity need to be examined in the interest of successful implementation:

Firstly, internal (in-house) organisation of digitisation is necessary. Media discontinuities should not lead to the loss of information. Setting of one's own standards is of particular importance in this respect if uniform processing of data and information is to be achieved. Significant added value can be generated here with comparatively little effort.

In addition, the Building Information Modeling (BIM) method is regarded as part of digitisation as it focuses on a specific building structure. Implementation must be transdisciplinary in this context, with cross-process use of building-related data. The BIM method delivers data consistency here and structured data storage and availability in the building data modelling process.

Digitisation therefore examines data consistency across in-house and inter-company processes. Internal organisation and the consistency of building-related information therefore provide the basis for successful digitisation of the building sector.

The current edition of the "Future Building" magazine presents a few future-oriented projects from the world of digitised building. It offers you an insight into current research projects in the Future Building research initiative and perspectives on upcoming developments in building.

Lothar Fehn Krestas

Deputy Director of the Department for Building and Construction at the Federal Ministry of the Interior, Building and Community

Robert Kaltenbrunner

Director of the Department for Building and Housing at the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

Digitisation – an opportunity for the building sector

Interview with Lothar Fehn Krestas

Deputy Director of the Department for Building and Construction at the Federal Ministry of the Interior, Building and Community.

***Question:** Building sector capacities are currently almost fully utilised. Are companies in the building industry currently investing in research and development? Is any advantage being taken of Federal Ministry of Building funding options?*

It's true, the building industry is busier today than it has been for a long time. That said, it is also taking steps to ensure its future. The demand for application-oriented programmes in the Future Building research initiative remains unchanged. A new record since the initiative was established in 2006 was achieved in November 2017, which underscores the attractiveness of this measure. When it comes to grant-funded research, the number of project outlines we have received has increased by almost one third over the previous year. This poses a real challenge for our colleagues in the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) who oversee implementation of the programme with enormous commitment and the highest degree of professional expertise.

***Question:** Greater federal investment in research and development! This is the demand we are currently hearing from the scientific and business communities. Will the Federal Ministry of Building react to this call?*

Taking the area of applied building research in particular, the Federal Ministry of the Interior, Building and Community (BMI) has not only long recognised the increased demand for research, but already reacted to it.

The Future Building research initiative has benefited in the last legislative period from additional funding for research and development from the cross-departmental high-tech strategy of the federal government.

This means that, with regard to grant-funded research, available funding has grown by 30% when compared to 2015. Specifically speaking, we are providing € 11 million in the current funding round for research projects in construction – a very real investment for the future in the building landscape.

***Question:** How exactly is the sustainability and innovativeness of the building industry promoted?*

Federal Ministry of Building research in building is aimed at ensuring the capability of small and medium-sized building enterprises to implement major socially relevant issues and strengthening them for the internal European market.

We have been pursuing this goal since the research initiative was established eleven years ago.

Research involves a combination of the building industry and scientific community. The Federal Ministry of Building expressly promotes an interdisciplinary approach.

Focal areas of funding are reviewed annually, with new questions and future issues being included in this. For example, the issues addressed by the current funding guideline cover a broad spectrum, ranging from the construction of affordable housing and building that is energy efficient, climate responsive and conserves resources to added value for architecture, urban space and design qualities. The question of digitisation in building is also an important focus at present.

Question: *The digital transformation process in industry is also increasingly affecting building. What opportunities would you identify for digitisation of planning and building processes?*

Greater punctuality with regard to deadlines, greater true-cost pricing, enhanced and early planning quality! In particular, when it comes to the challenge of achieving lower and affordable building costs and, simultaneously, greater quality, it is extremely important to promote this efficiency potential in planning and building processes. Digitisation can contribute to more affordable housing and building.

Question: *Can this be achieved solely through digitisation?*

Obviously this efficiency potential cannot be enhanced solely through the availability of information technology. In general, it can be said that the omnipresence of digital technologies is not the critical characteristic of digitisation, because this would mean that digital technologies are only auxiliary tools in the implementation of previously analog working methods. Instead, we will experience changed and new working procedures and processes that are supported by information and communication technologies. More intensive cooperation between project stakeholders will be a significant characteristic of the digitisation of planning and building processes.

Data models are the basis of this intensive cooperation. All relevant geometric and alphanumeric data for a specific project is input, updated and administered in these models. Project stakeholders can coordinate and examine all information in a transparent manner through comparison in a cross-project coordination model.

However, it also must be clearly shown that the BIM method, in other words Building Information Modeling, cannot guarantee good planning quality and an optimum project process on its own. Its application through qualified specialists continues to be decisive.

Question: *Lifecycle considerations are a significant feature of sustainable building. What impact does digitisation have on the lifecycle of a building?*

The use of digital technologies means that BIM opens up new possibilities with regard to the lifecycle of a building. Detailed (and in part automated) collision checks of different tasks can be conducted during the planning phase. Calculations of lifecycle costs and appropriate decisions are already possible during this phase. Detailed information on deadline dependencies during the erection of buildings, to give an example, is available in the building phase. And, at the end of the building phase, information required for operation of the building is available – quicker, clearer and with fewer losses of data. This means that digitisation addresses the areas where the cause of many project disturbances lie.

Question: *So, digitisation should help to eliminate information exchange deficiencies and, consequently, avoid project disruptions?*

Stakeholders in the building process have, in particular, optimised their internal processes for economic reasons in the past. This means that internal processes tended to be optimised so that interfaces to the outside could be satisfied to the minimum degree demanded by contractual agreements. This leads to major losses of data which is already available digitally at the interfaces and, thus, multiple "recreation" of this information. It needs to be demonstrated that a disclosure of information that goes beyond the minimum demanded contractually can lead to an increase in efficiency for all involved.

Question: *The success of digitisation requires the broad participation of all stakeholders. What is the prerequisite for this?*

It's quite clear – product-neutral solutions with data interfaces open to all systems. In other words, the 'Big Open BIM'. Nothing else can be considered for federal building construction, and the support of the Federal Ministry of Building is targeted exclusively on this.

We are focusing on a gradual, practice-oriented digitisation process to allow all stakeholders in the value chain to contribute to this development. Any other approach is unrealistic, as not every prerequisite for regular and comprehensive application of the BIM method has yet been achieved.

This also includes the area of standardisation and harmonisation. It's also important to take the right steps on an international level. The BMI is already involved itself and through the representation of the BBSR in standardisation committees and plans to intensify these activities in future.

Additionally, the BMI has joined forces with the Federal Ministry for Economic Affairs and Energy (BMWi) to initiate the "Digital Building" dialogue in the sector in which several chambers and associations are also involved. Our aim is to use this industry dialogue to contribute politically to the digital transformation process and lend it targeted support. The dialogue provides the opportunity for an exchange among stakeholders, creates synergies and is intended to provide targeted support for the digital development of planning and building.

Question: *Does the federal government also place its trust in BIM for its own building measures?*

When it comes to federal building construction, we have continuously gained experience relating to digitisation, albeit initially limited to project phases. This experience will be pooled and assessed in a "Digital Planning and Building" competence centre for federal building construction. The competence centre will commence its work in the first half of this year. Other tasks realised by the competence centre include the creation of BIM-specific work documents such as client information requirements and BIM schedules, support of BIM pilot projects and the advising of building authorities working for the federal government.

Question: *Digitisation of building will not be limited to planning and building processes. Is the Federal Ministry of Building also considering other areas of the building industry?*

Networked systems will establish themselves along the entire building sector value chain over the course of digitisation. Digitisation will have an impact on architects and engineers and the companies realising building. In addition to BIM as a digital planning method, digital manufacturing methods, to give one example, will establish themselves with both of these building on one another. Ultimately, an unbroken information flow will be created from planning to the physical building process and building operation to recycling. Architects and engineers will again be drawn closer to the building process through digital manufacturing methods. A lot of hopes are attached to digital manufacturing, including greater resource efficiency, material-appropriate design concepts and cost and time savings.

But there are still a lot of questions which remain to be answered. What effect will digital manufacturing have on the traditional separation of planning and realisation? Will digital manufacturing create a new working area for architects and engineers? How will digital manufacturing affect trades and site logistics?

A lot of innovation is still needed if digitisation is to meet the high expectations we have of it. Visionary entrepreneurs are needed in planning and both trade and building companies, and creative clients and innovative researchers and developers, will be needed to achieve this. And this is precisely where our Future Building research initiative comes into play. Through it, we are promoting applied research in the building industry and, also, research into questions relating to digitisation for the entire building value chain.

The federal government wants to organise a rapid transition to digitisation of building and, especially, encourage medium-sized planners and trade companies to recognise the opportunities this presents for them.

Highly insulated and recyclable solid timber construction

Solid timber structures which fulfil the constructive and structural-physical requirements of energy-efficient and sustainable building in design and form

Prof. Achim Menges, University of Stuttgart

The wide distribution, high performance and easy workability of timber make it an ideal building material for innovative structures. The goal of the research project is the development of a solid timber construction system in which simple wooden elements are processed through digital production methods to meet the constructive and structural-physical requirements of energy-efficient and sustainable building in design and form. The construction system is to be tested on the basis of a variable prototype building developed and built in partnership with the University of Stuttgart, Jade University of Applied Sciences and IBA Thüringen.

Development process

In addition to ecologically outstanding properties, solid wood is also economically one of the most cost-effective construction methods. In comparison to other construction materials for load-bearing structures, wood generally exhibits excellent insulation properties. The capillary structure of wood means that timber can be used as both a supporting and insulating material. The fundamental principle of an insulating solid wood construction was developed in a previous project under the direction of Hans Drexler at the Münster School of Architecture. In addition to significantly improving the insulating properties of the material, the incisions also relieve stress within the profiles. Thanks to their comb-shaped design, these relief incisions (which prevent tangential splitting of solid wood) are also effective as insulation here. Further development of the design system in conjunction with digital design and manufacturing methods occurs at two levels. On the one hand, the system should become more efficient in structural-physical terms and make construction easier and, on the other, the architectural scope for design should be significantly expanded through precise, digital prefabrication. Complete digital planning and production will enable the individual definition of the positions of specific beams relative to each other. The result is an extremely flexible material system in geometric terms that meets the design and structural-physical requirements of energy-efficient and sustainable construction in design and form. While highly sophisticated and expensive products are frequently used for building, a very cheap material is the starting point in this case. The project, therefore, sees itself as contributing to cost-effective construction. Similar to a modern log cabin, the only raw material which should be used is wood. In contrast to this classic construction and, also, the previous project, the grain direction in this innovative construction system runs along the supporting direction.

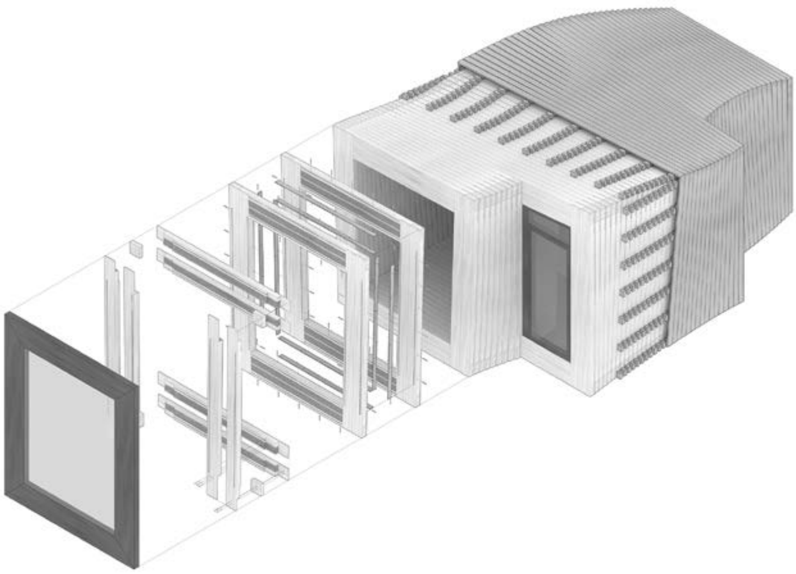

Figure 1: Exploded view of design system

Building perspectives in 2030

Prof. Achim Menges
Professor, Director ICD Institute for Computational Design and Construction,
Faculty of Architecture and Urban Planning

"Digitisation initially leads to a proportionate automation of actual pre-digital planning and building. The real potential of digital technologies will then be released when we rethink planning methods, construction processes and building systems on an integrative and computer-based level."

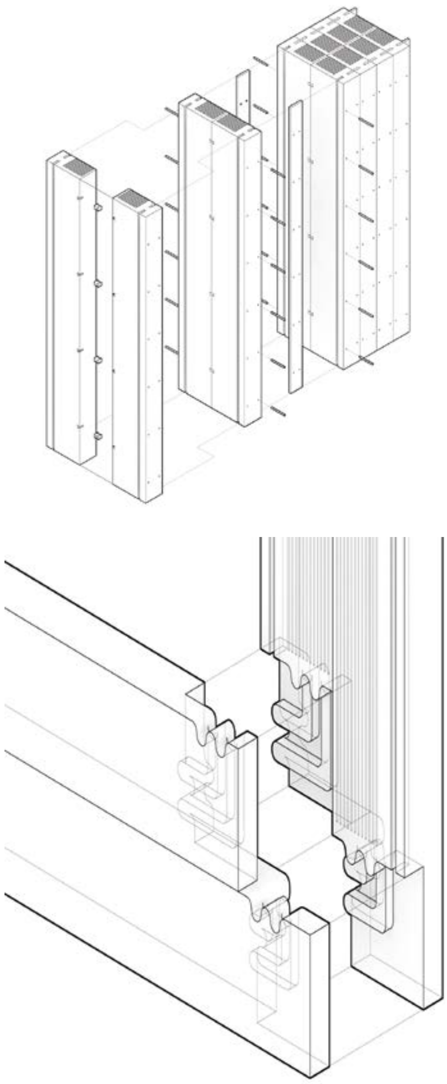

Figure 2 and 3: Design system with connection details in the wall level and corner

The number and arrangement of the incisions was initially examined during the course of the project in comparison to other materials using simulation software. The evaluation of prototypes at the Materials Research and Testing Institute of the Bauhaus-Universität Weimar (BUW) subsequently indicated a thermal transmittance of U = 0.20 W / (m²K) which, however, strongly depends on the airtightness of the construction. The development of design aspects is also closely linked to a digital design tool that allows the generation of complete designs with maximum information content. Not only the building geometry is created with the design tool, but the entire digital chain, including all design details, building information and machine data. Above all, connection diagonally over the corners and along the construction plays an important role in this case. The joining system employed is designed to increase airtightness and, at the same time, be structurally effective. Contact with industrial partners was essential for this development in order to evaluate the feasibility of the design on a continual level. Although several small prototypes have already been built in the ICD laboratory, the industrial robot used there has a different working space and machine data that differs from that of the latest conventional CNC machines. Production of the building demonstrator should therefore be realised in close cooperation with a timber construction or joinery company.

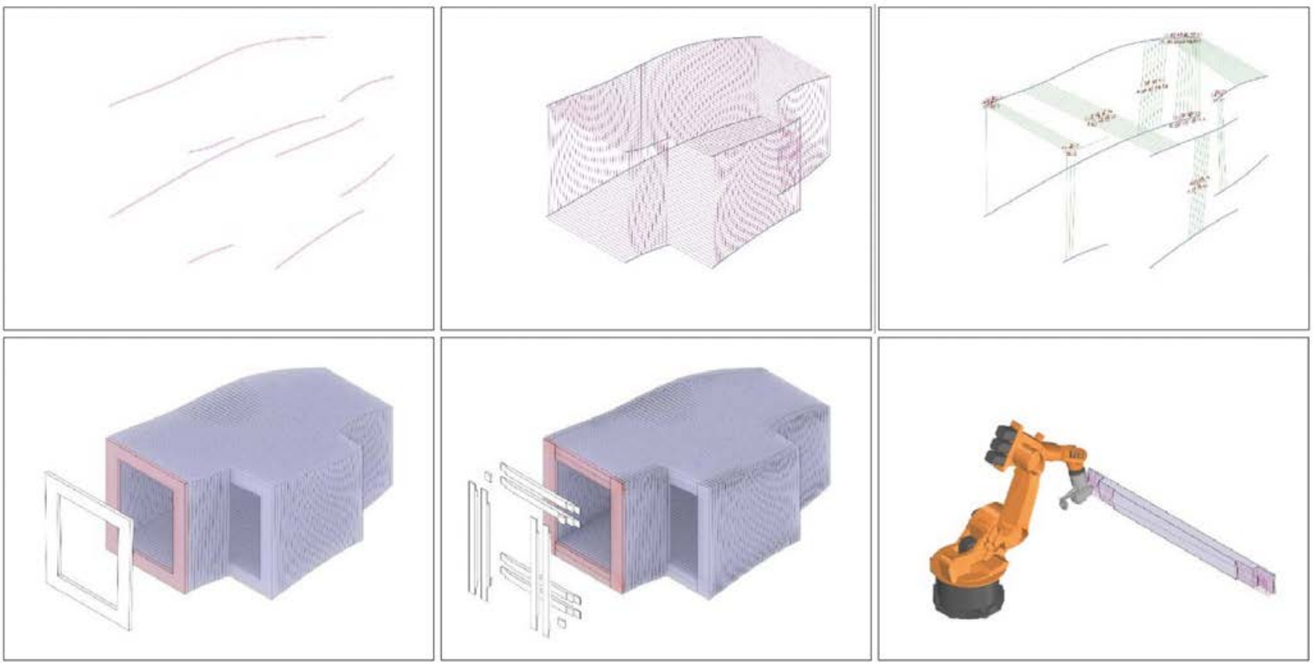

Figure 4: Visualisation of computer-based design tool steps from design input to production

Figure 5: All prefabricated building segments are ready on site for assembly. They are manufactured 'just in sequence'.

Planning and construction of the building demonstrator represent a significant step in specification of the planning and production technologies which were investigated under near-practice conditions within the framework of this research project. Final designs were made and detailed decisions taken in August 2017 to begin production of the demonstrator. From an architectural point of view, the design demonstrated that the building system also has a special effect on a structural scale, due to its geometric complexity. However, it was also established that simple solid construction timber is unsuitable for the high demands associated with precise manufacturing. The inaccurate raw material meant that the subtractive manufacturing process took much longer than originally anticipated. Within eight weeks, 464 individual beams were milled on a five-axis CNC machine and assembled into six modules. These modules were transported to the construction site on two low loaders in a single day and assembled into a complete building within two days.

Architectural concept

The International Building Exhibition IBA Thüringen, a project partner, has found a new office in Apolda in a historic building designed by the architect Egon Eiermann. There is an undeveloped green space at the back of the historic building with scenic qualities in the transition to gardens of the buildings and a small garden allotment. The prototype building

Figure 6:
Machined solid timber beams. Each beam has an individual number and was manufactured 'just in sequence'.

Figure 7:
Horizontal assembly of a total of six building segments, each of which was approximately 1 m long. Linen fabric is used for sealing between the layers.

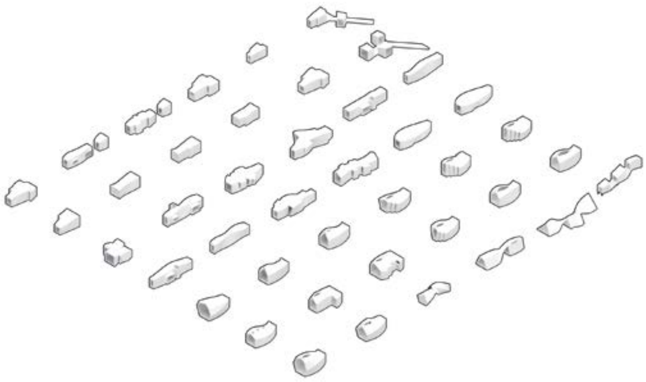

Figure 8:
Design variants which can be achieved with the design tool and were created during the research project.

on the gently rising open space will act as an architectural setting for the landscape context. This staging reflects IBA Thüringen's STADTLAND concept, namely an urban-rural interplay. In the largely rural and sparsely populated federal state of Thuringia, architecture should always be considered in terms of the tension with the landscape context.

As one of the first fully parametrically designed and digitally manufactured buildings with a solid wood construction, the project represents an important step in modern timber research. Above all, practical evaluation of the design and manufacturing methodology has produced a number of important findings. In principle, it can be assumed that mono-material constructions can be produced efficiently by intelligent design processes and digitised production, and that they allow for a much higher architectural scope of design. The high degree of accuracy required for the building demonstrator initially resulted in a much greater production outlay. This difference was greatly reduced in a further development stage through a general revision of the production process. The research project can be regarded as the first step in the development of a new construction system in this respect.

Key data

Highly insulated and recyclable solid timber construction

Project team:
University of Stuttgart,
Institute for Computational Design and Construction (ICD)
Prof. Achim Menges, Oliver Bucklin, Oliver David Krieg

Jade University of Applied Sciences, Oldenburg
Faculty of Architecture
Visiting Prof. Hans Drexler

In cooperation with:
IBA – Internationale Bauausstellung Thüringen
(International Building Exhibition, Thuringia)

Project support:
Thüringer Forst
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Serge Ferrari – Stamisol
Hoffmann GmbH
HolzWider GmbH

Development of an ideal type target process chain for application of the BIM method in the lifecycle of buildings

Agnes Kelm, Anica Meins-Becker, Matthias Kaufhold,
University of Wuppertal (Bergische Universität Wuppertal)

This project was proposed and realised to establish the BIM method and promote digital change. A particular deficiency existed in terms of standards and a common understanding regarding the BIM process and changes in the building and real estate sector emanating from this at the time the application was submitted.

The "BIM-based building in process" research project is intended to establish the framework for a longer-term major project. The aim is to promote standardisation efforts for building data models in all phases of the building lifecycle. In conjunction with legal and standard conformity, this will contribute to the transparency of the BIM method for stakeholders in the lifecycle of real estate.

Within the scope of this project, an ideal type of target process chain was developed using the BIM method over the lifecycle of a building. The standardised lifecycle process is designed to show the specific steps necessary for implementation of BIM projects from the clients' point of view. Information and communication interfaces can be identified on this basis. Analyses of changing performance requirements of stakeholders and open questions such as legal issues can be further elaborated on or dealt with. The research project is therefore oriented across the entire lifecycle of the building through various phases and examines processes from project development to the dismantling or demolishing of a property. Moreover, partial sections are also considered in depth in several BUW research projects conducted in parallel or in preparation.

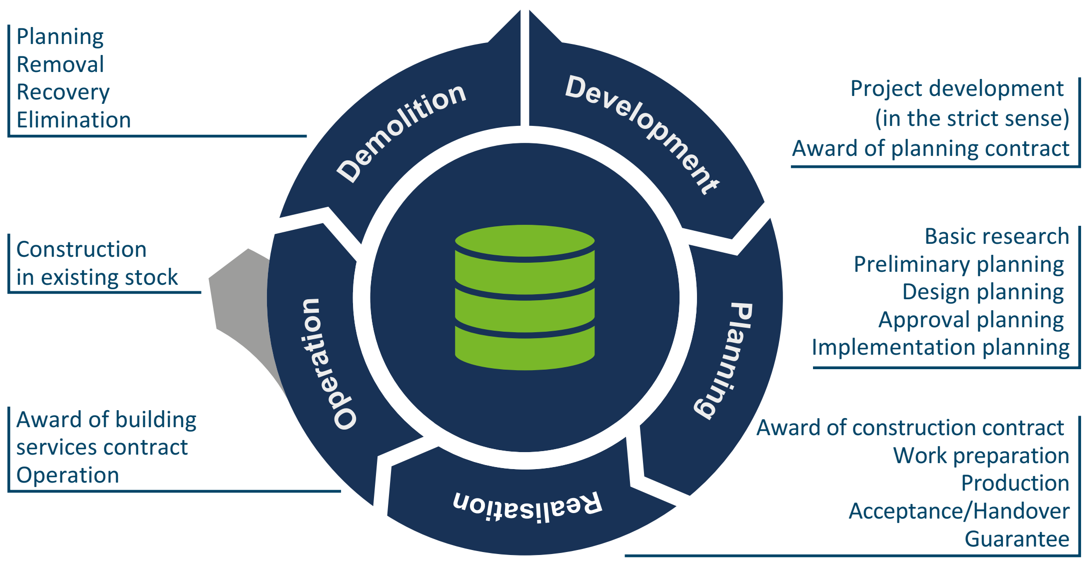

Figure 9: Building lifecycle

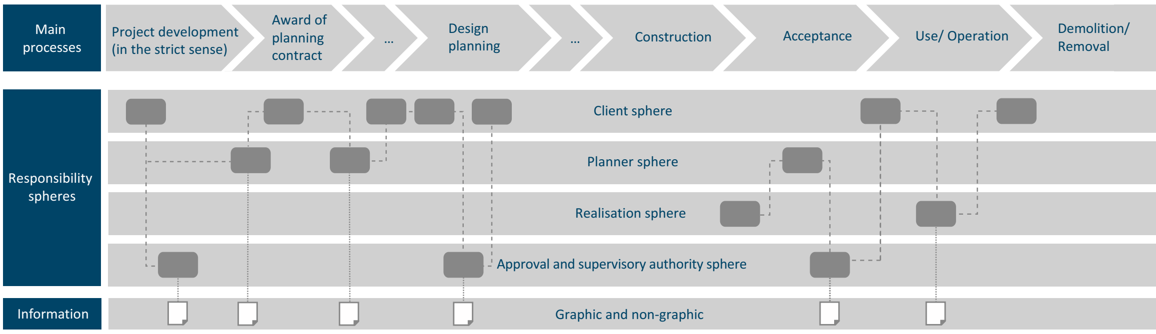

Figure 10: Process model with responsibility spheres and information sources

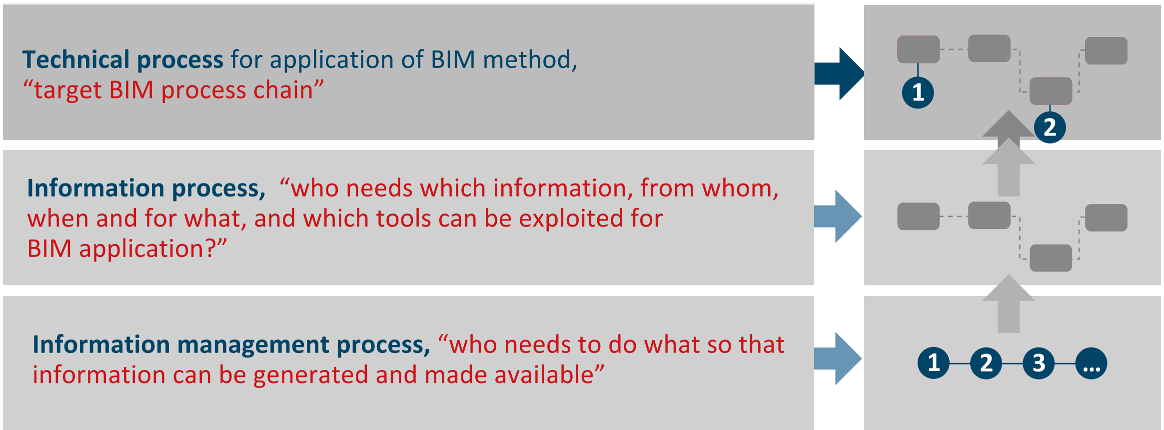

Figure 11: Relationship between technical process, content-related information process and information management process

The first step involved the derivation of a process scenario and development of a method-independent, standardised process flow. Communication and exchange interfaces with project stakeholders in all lifecycle phases of a building project which are essential from the point of view of the client, were examined in this respect. Based on literature research and expert interviews, the manner in which individual process steps are realised was analysed and determined, along with which participants would provide which services and information to whom and when, in order to fulfil the client's requirements regarding a successfully constructed and managed building. Companies involved in practical realisation, institutions and other stakeholders are thus given an overview of the existing situation with regard to the exchange of information, ensuring a common understanding of relevant technical correlations. A validation of processes was realised based on the holding of expert workshops. This created a so-called information process to answer the question: "Who needs which information, from whom, when and for what?"

In addition, a so-called information management process based on ISO 19650 was set up for application of the BIM method which, in turn, answers the question: "Who needs to do what in order for the information to be generated and made available free of losses?" This development occurred, on the one hand, through analysis of BIM guidelines, directives and standards and participation in various committees and, on the other, through support of practical projects and companies specialised in the realisation of BIM projects.

The information management process was subsequently assigned to the information process. The combination of both processes results in the BIM process. Implementation was achieved through application of business process modelling and a process model which was developed.

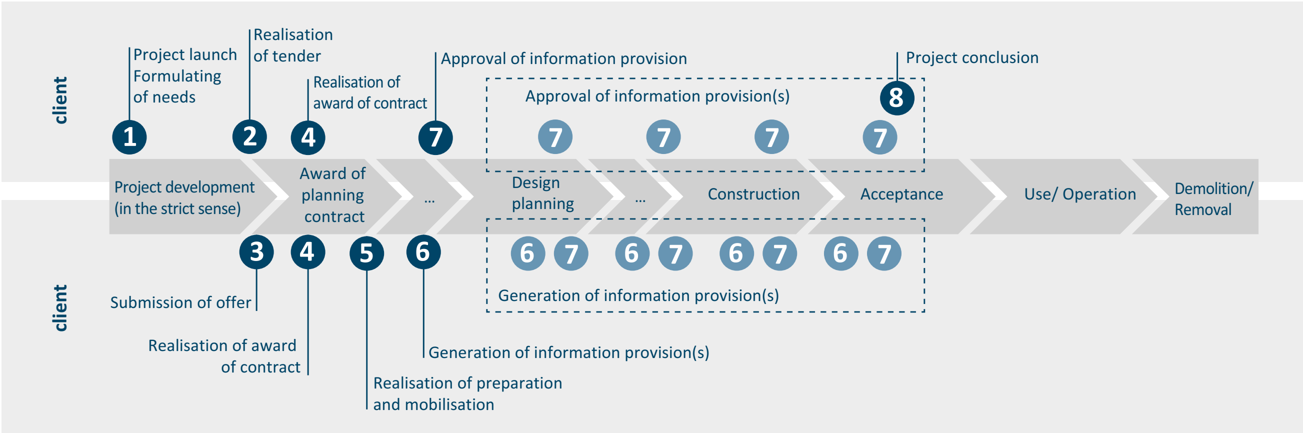

Figure 12: Overview of information management process

A client guideline for application of BIM and a method for generating BIM-targeted queries were developed for practical implementation based on the results of the BIM process analysed as a preparation for client information requirements (CIR).

In addition, an online survey of the "Status quo – digital planning, building and operation" was conducted in collaboration with the Karlsruhe Institute of Technology based on a survey conducted by the institute in 2011.

Key data

BIM in the process

Researchers:
University of Wuppertal (Bergische Universität Wuppertal – BUW)
Education and research body for building operations and construction

Prof. Manfred Helmus (Project Manager), Anica Meins-Becker, Agnes Kelm, Mathias Kaufhold

CDP // Energy

Simulation-based planning in the urban development context, taking energy and indoor climate aspects into consideration

Gerhard Schubert, Technical University of Munich

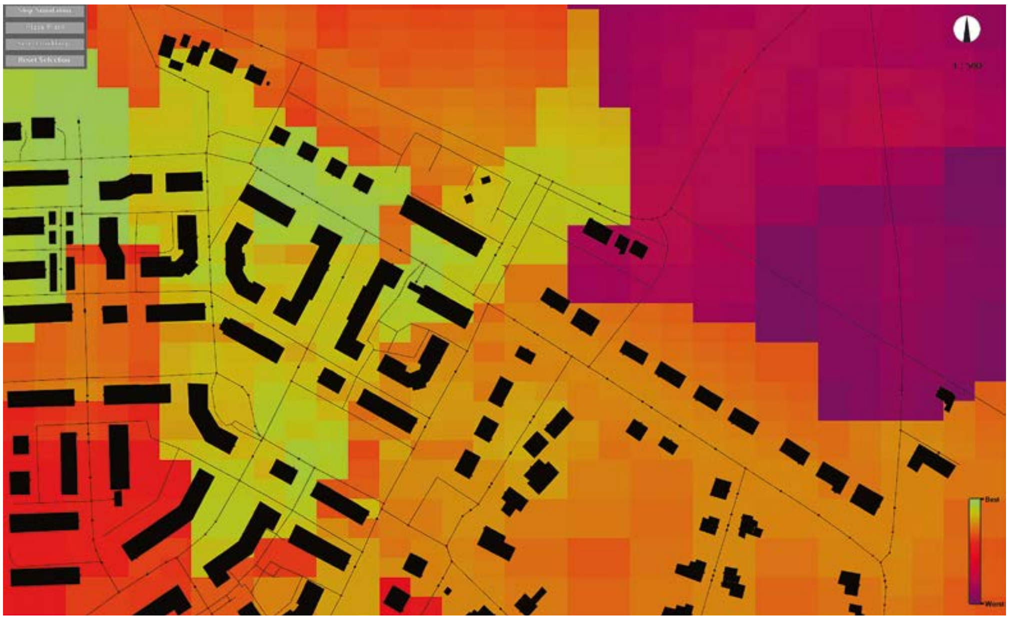

Figure 13: Analysis for identification of the most favourable positions to place the heating system

Nowadays, not enough consideration is given to energy and indoor climate aspects of decision making in urban planning phases. The reasons for this are to be found in inadequate control interfaces and software solutions. In order to resolve this discrepancy, requirements for analysis methods for energy consideration in creative planning phases were investigated and, based on this, solution approaches were developed conceptually and implemented prototypically.

Work in the project was realised in an interdisciplinary team consisting of the Chair of Building Technology and Climate Responsive Design (Prof. Thomas Auer) and the Chair of Architectural Informatics (Prof. Frank Petzold). Processing occurred in both parallel and linked working steps. Researchers for building technology and climate responsive design explored methods for the calculation and analysis of relevant energy and room climate aspects on a scale of 1 : 500 on the basis of which the definition of conceptual requirements for calculation models occurred. Prof. Petzold's team focused on computer-based implementation of the defined methods based on the existing CDP // Collaborative Design Platform infrastructure. As a design platform, CDP enables planners to design as usual using working models and freehand sketches. Analyses conducted in real time and simulations are illustrated directly in the model and broaden the margin of discretion of the user through additional decision levels. The focus of research in this respect was primarily on the development of efficient, but accurate algorithms and suitable application and visualisation concepts. The work steps are subdivided as follows in this respect:

1. Determination of relevant calculation and simulation methods

Appropriate calculation and analysis models were defined initially for the investigation of supply options with district heating networks and determination of renewable energy potentials (solar and near-surface geothermal energy) in early urban planning phases. These are based on determination of the heat requirement for an individual building and ascertainable amounts of solar and geothermal energy. In addition, appropriate simulation methods were identified for precision analysis of thermal behaviour and daylight conditions within a building. Here, the challenge lies largely in the available data which is vague and incomplete in these planning phases. Therefore, approaches had to be investigated and methods developed for real-time prediction of energy aspects and effects based on available incomplete planning data.

2. Expansion of the CDP // Collaborative Design Platform through additional plug-ins

Taking defined calculation models and methods into consideration, several new plug-ins were developed and implemented on the basis of the existing CDP // Collaborative Design Platform. Here, the focus was on implementation of the following analysis tools:

- **Plug-in for the analysis of supply options with heating networks**
  A plug-in was designed and implemented prototypically for the analysis of supply options through the district heating network. The basis of this plug-in is automatic, optimised routing on the basis of the road and path network. Drawing on this, the heat consumption per metre of network route for each route segment is calculated. Two different methods were implemented for analysis of the planning area. Method 1 calculates the supply potential in the network for a manually positioned heating system. Method 2 automatically evaluates the entire planning area for the location quality of the heating system.

- **Plug-in for calculation and analysis of solar potential**
  The plug-in for calculating solar potential encompasses the analytical investigation of all buildings in the planning area (both existing and planned developments). Based on the calculation of solar irradiation on the roof surfaces over the course of the year and taking shading into consideration, the amount of electricity that can be generated from photovoltaic is determined for each building and compared to the potential power consumption of the building.

- **Plug-in for analysis of near-surface geothermal potential**
  The system was expanded through the linking of WMS servers to estimate the near-surface geothermal energy potential. This enables the depiction of relevant information in the form of additional map levels. In addition, a method was developed for building-specific calculation of

Figure 14: Automatic generation and evaluation of the heating network relative to the position of the heating system (physical object on the table surface – marked in red)

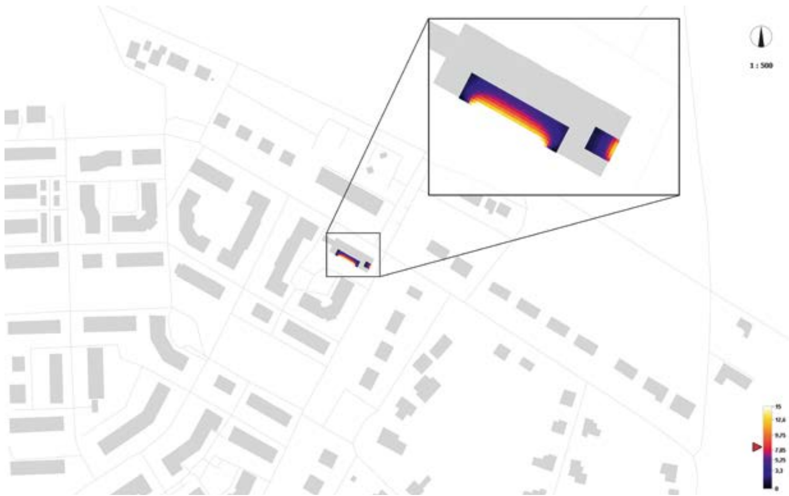

Figure 15: Daylight availability for a selected analysis room including magnification of the visualisation

Figure 16: Representation of the energy consumption covered by solar radiation as a percentage. Buildings marked in red are not part of the analysis.

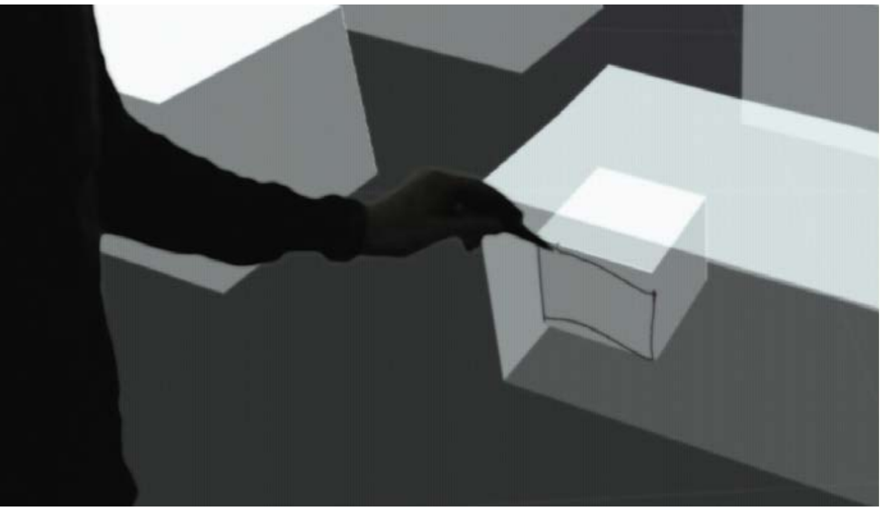

Figure 17:
Selection of the analysis room – the geometry with a room depth of 6 m is designed directly from the freehand sketch, assigned to the building and positioned and referenced in the 3D model

the heat potential from near-surface geothermal energy.

- **Plug-in for daylight simulation**
  At the threshold between exterior and interior areas, this plug-in enables a daylight simulation to determine daylight factor values for an analysis room inside a building. Selection/ marking of the simulation area is achieved using a freehand sketch, while simulation is realised with the radiance software. Input and output occurs directly on the CDP.

- **Plug-in for thermal simulation**
  Calculation of a thermal simulation is also realised through the definition of an analysis room using a freehand sketch. The method to determine the energy requirement and thermal comfort conditions was defined in the context of the project and an initial implementation tested through the involvement of the commercial-available TRNSYS software.

3. Strategies for information visualisation and consideration of corresponding degrees of abstraction

The embedding of analysis results in the planning process requires appropriate information visualisation methods and the representation of simulation results. In the context of the project, appropriate strategies for individual plug-ins were investigated, designed and implemented within the framework of the plug-ins. The main focus here was on the presentation of results in real time and possible forms of depiction of results reflecting trends. Solutions for this were found in, among other things, the successive detailing of analysis methods and transparent "faded" transitions.

Methods for energy analysis of urban planning in early planning phases were designed, investigated and prototypically implemented within the scope of the interdisciplinary CDP // ENERGY research project. Based on indoor climate and energy aspects, a requirements analysis was developed for district heating, renewable energy potential and both daylight and thermal simulations at building level. Taking these requirements into consideration, 5 calculation methods were developed within the scope of the project. Prototypical implementation of three of these methods was realised on the basis of the CDP // Collaborative Design Platform.

Among other contributors, the project was kindly supported by Stiftung Bayerisches Baugewerbe and Euroboden GmbH.

Key data

CDP // Energy

Researchers:
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Chair of Building Technology and Climate Responsive Design, TU Munich

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Prof. Thomas Auer,
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Cécile Bonnet, Ata Chokhachian,
Ivan Bratoev

Project support:
Stiftung Bayerisches Baugewerbe
Euroboden GmbH

Target-group and process-oriented examination of free BIM tools

Prof. Petra von Both, Steffen Wallner, Karlsruhe Institute of Technology (KIT)

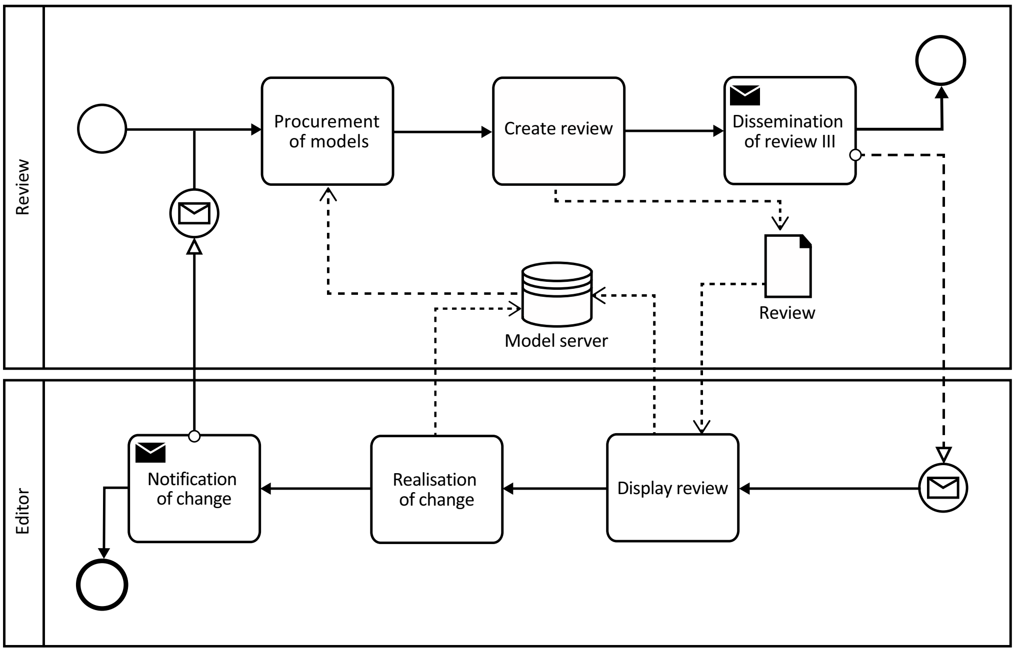


Figure 18: BPMN for "Merge" usage scenario

According to a structural survey of the Federal Statistical Office from 2016, approximately 90% of architectural and engineering companies in Germany employ less than 10 employees. Studies confirm that surpluses generated here are often insufficient to exploit cost-intensive BIM software solutions from commercial IT companies. On the other hand, various free tools exist which have been developed in research and community projects and by commercial providers. However, there is currently still a lack of systematic investigation and practice-oriented assessment of such tools to estimate their practical application.

The identification, process-related analysis and assessment of freely available BIM tools is the subject of the "BIM Tools Overview" research project. The research project was divided into the following steps:

- Identification of relevant BIM processes and development of usage scenarios
- The search for free tools and derivation of software classes
- Definition of evaluation criteria
- Testing and evaluation of the tools
- Assignment to usage scenarios
- Preparation of the results for the public on a website

It became apparent that far more sources needed to be examined than the number of free tools actually found. For this reason, a wiki system was set up during work preparation which could prevent redundant searches.

BIM processes and evaluation criteria were developed on the basis of our own knowledge and by referring to process descriptions in current literature (e.g. BIM guides and standards). An important document in this context was the Information Delivery Manual method. Although it was not possible to derive relevant processes directly from this, it underlined the importance of a data exchange for every BIM process. Other sources such as the BIM Guide for Germany, the BIM Reference Process, and publications from a variety of authors provide arguments for BIM by showing potentials and objectives. However, no practical usage scenarios were found here which could be applied directly to the target group aimed at. Based on the work of Hausknecht and Liebich, and also drawing on our own

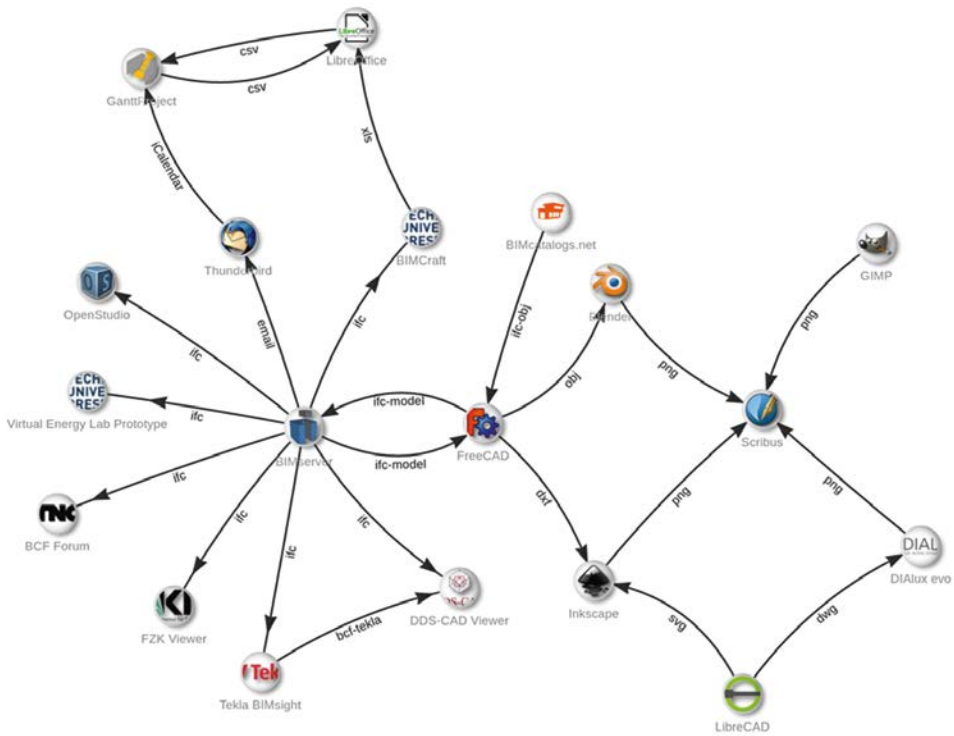


Figure 19: Overall process via tool interaction

expertise, six scenarios were developed and formalised in BPMN Notation. The search for tools was essentially conducted online and also included scientific publication databases available on the internet. Criteria were defined with regard to functionality, ergonomics and reliability for the selection, investigation and evaluation of the tools found. In addition, a relevant tool had to be:

1. available free of charge and commercially usable without licence fees
2. able to request registration for use
3. capable of running on a contemporary operating system

About 80 tools were identified according to these criteria. They were assigned to 13 software classes and recorded with a short description in the wiki system. From these,

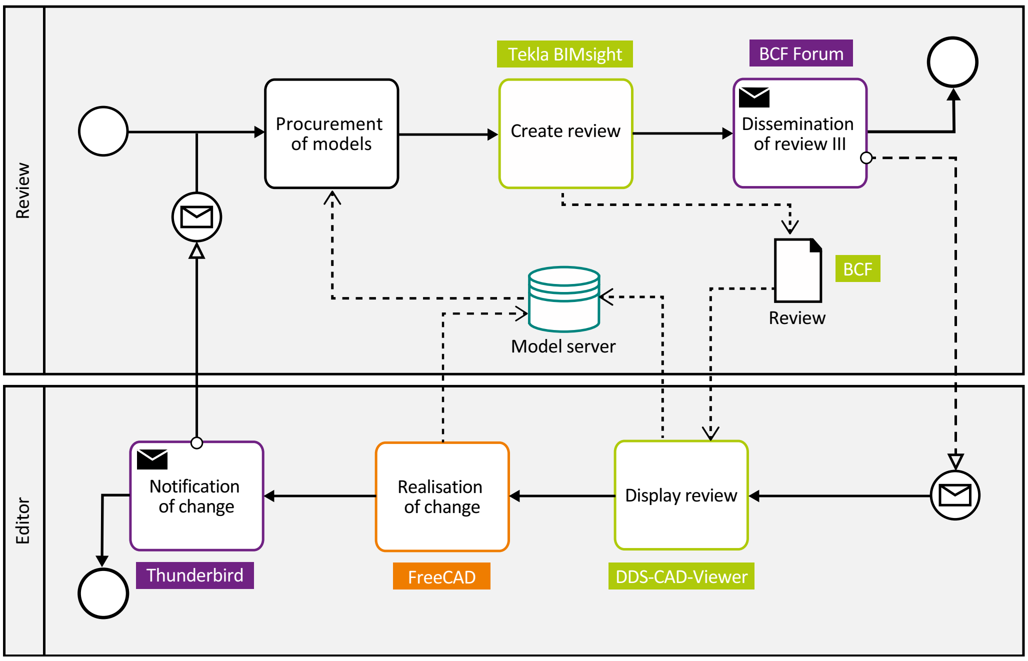
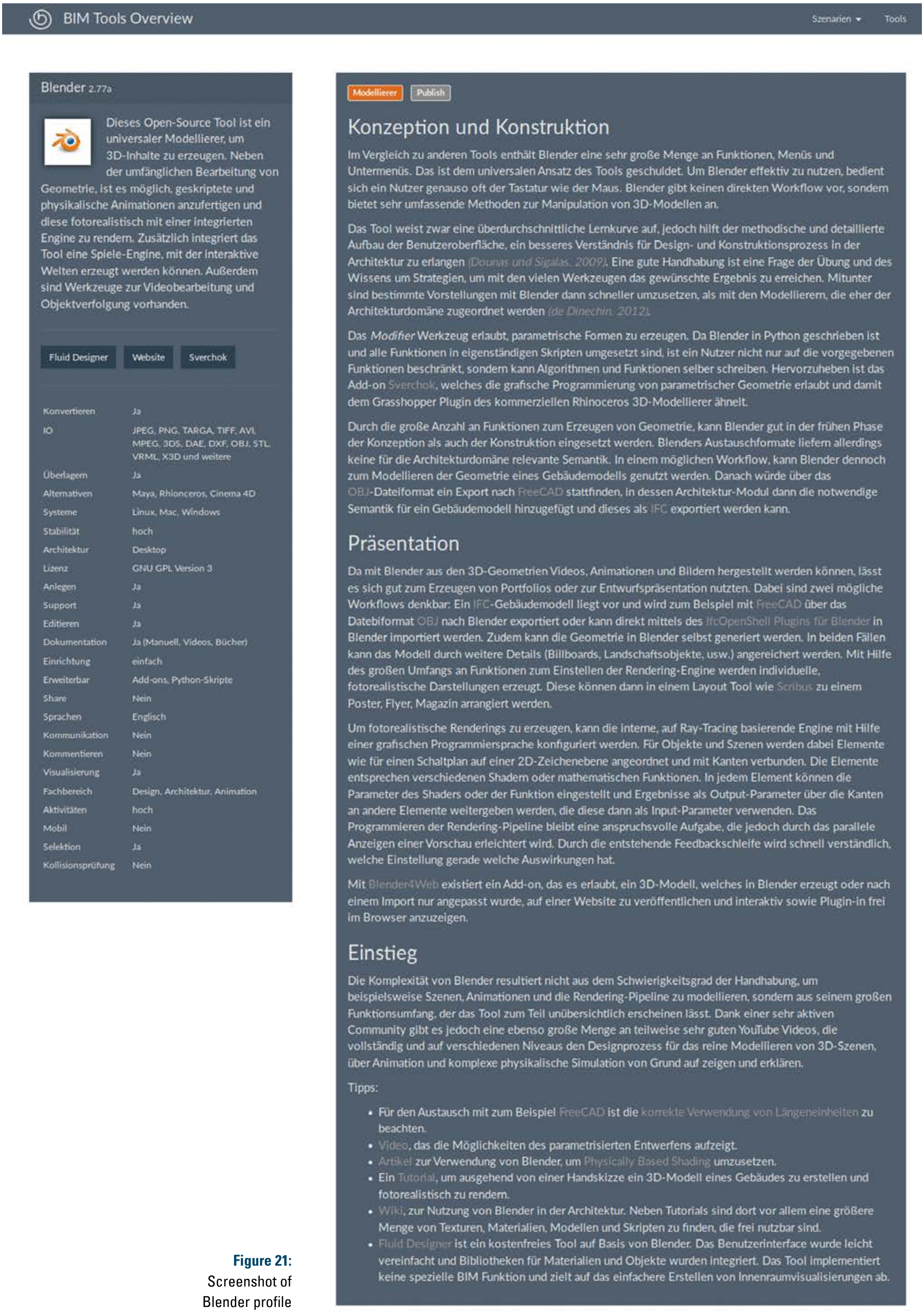


Figure 20: Usage scenario with associated tools



BIM Tools Overview

Szenarien ▾ Tools

Blender 2.77a

Dieses Open-Source Tool ist ein universaler Modellierer, um 3D-Inhalte zu erzeugen. Neben der umfänglichen Bearbeitung von Geometrie, ist es möglich, geskriptete und physikalische Animationen anzufertigen und diese fotorealistisch mit einer integrierten Engine zu rendern. Zusätzlich integriert das Tool eine Spiele-Engine, mit der interaktive Welten erzeugt werden können. Außerdem sind Werkzeuge zur Videobearbeitung und Objektverfolgung vorhanden.

Fluid Designer | Website | Sverchok

Konvertieren	Ja
IO	JPEG, PNG, TARGA, TIFF, AVI, MPEG, 3DS, DAE, DXF, OBJ, STL, VRML, X3D und weitere
Überlagern	Ja
Alternativen	Maya, Rhionceros, Cinema 4D
Systeme	Linux, Mac, Windows
Stabilität	hoch
Architektur	Desktop
Lizenz	GNU GPL Version 3
Anlegen	Ja
Support	Ja
Editieren	Ja
Dokumentation	Ja (Manuell, Videos, Bücher)
Einrichtung	einfach
Erweiterbar	Add-ons, Python-Skripte
Share	Nein
Sprachen	Englisch
Kommunikation	Nein
Kommentieren	Nein
Visualisierung	Ja
Fachbereich	Design, Architektur, Animation
Aktivitäten	hoch
Mobil	Nein
Selektion	Ja
Kollisionsprüfung	Nein

Modellierer | Publish

Konzeption und Konstruktion

Im Vergleich zu anderen Tools enthält Blender eine sehr große Menge an Funktionen, Menüs und Untermenüs. Das ist dem universalen Ansatz des Tools geschuldet. Um Blender effektiv zu nutzen, bedient sich ein Nutzer genauso oft der Tastatur wie der Maus. Blender gibt keinen direkten Workflow vor, sondern bietet sehr umfassende Methoden zur Manipulation von 3D-Modellen an.

Das Tool weist zwar eine überdurchschnittliche Lernkurve auf, jedoch hilft der methodische und detaillierte Aufbau der Benutzeroberfläche, ein besseres Verständnis für Design- und Konstruktionsprozess in der Architektur zu erlangen *(Dounas und Sigalas, 2009)*. Eine gute Handhabung ist eine Frage der Übung und des Wissens um Strategien, um mit den vielen Werkzeugen das gewünschte Ergebnis zu erreichen. Mitunter sind bestimmte Vorstellungen mit Blender dann schneller umzusetzen, als mit den Modellierern, die eher der Architekturdomäne zugeordnet werden *(de Dinechin, 2012)*.

Das *Modifier* Werkzeug erlaubt, parametrische Formen zu erzeugen. Da Blender in Python geschrieben ist und alle Funktionen in eigenständigen Skripten umgesetzt sind, ist ein Nutzer nicht nur auf die vorgegebenen Funktionen beschränkt, sondern kann Algorithmen und Funktionen selber schreiben. Hervorzuheben ist das Add-on Sverchok, welches die grafische Programmierung von parametrischer Geometrie erlaubt und damit dem Grasshopper Plugin des kommerziellen Rhinoceros 3D-Modellierer ähnelt.

Durch die große Anzahl an Funktionen zum Erzeugen von Geometrie, kann Blender gut in der frühen Phase der Konzeption als auch der Konstruktion eingesetzt werden. Blenders Austauschformate liefern allerdings keine für die Architekturdomäne relevante Semantik. In einem möglichen Workflow, kann Blender dennoch zum Modellieren der Geometrie eines Gebäudemodells genutzt werden. Danach würde über das OBJ-Dateiformat ein Export nach FreeCAD stattfinden, in dessen Architektur-Modul dann die notwendige Semantik für ein Gebäudemodell hinzugefügt und dieses als IFC exportiert werden kann.

Präsentation

Da mit Blender aus den 3D-Geometrien Videos, Animationen und Bildern hergestellt werden können, lässt es sich gut zum Erzeugen von Portfolios oder zur Entwurfspräsentation nutzten. Dabei sind zwei mögliche Workflows denkbar: Ein IFC-Gebäudemodell liegt vor und wird zum Beispiel mit FreeCAD über das Datebiformat OBJ nach Blender exportiert oder kann direkt mittels des IfcOpenShell Plugins für Blender in Blender importiert werden. Zudem kann die Geometrie in Blender selbst generiert werden. In beiden Fällen kann das Modell durch weitere Details (Billboards, Landschaftsobjekte, usw.) angereichert werden. Mit Hilfe des großen Umfangs an Funktionen zum Einstellen der Rendering-Engine werden individuelle, fotorealistische Darstellungen erzeugt. Diese können dann in einem Layout Tool wie Scribus zu einem Poster, Flyer, Magazin arrangiert werden.

Um fotorealistische Renderings zu erzeugen, kann die interne, auf Ray-Tracing basierende Engine mit Hilfe einer grafischen Programmiersprache konfiguriert werden. Für Objekte und Szenen werden dabei Elemente wie für einen Schaltplan auf einer 2D-Zeichenebene angeordnet und mit Kanten verbunden. Die Elemente entsprechen verschiedenen Shadern oder mathematischen Funktionen. In jedem Element können die Parameter des Shaders oder der Funktion eingestellt und Ergebnisse als Output-Parameter über die Kanten an andere Elemente weitergeben werden, die diese dann als Input-Parameter verwenden. Das Programmieren der Rendering-Pipeline bleibt eine anspruchsvolle Aufgabe, die jedoch durch das parallele Anzeigen einer Vorschau erleichtert wird. Durch die entstehende Feedbackschleife wird schnell verständlich, welche Einstellung gerade welche Auswirkungen hat.

Mit Blender4Web existiert ein Add-on, das es erlaubt, ein 3D-Modell, welches in Blender erzeugt oder nach einem Import nur angepasst wurde, auf einer Website zu veröffentlichen und interaktiv sowie Plugin-in frei im Browser anzuzeigen.

Einstieg

Die Komplexität von Blender resultiert nicht aus dem Schwierigkeitsgrad der Handhabung, um beispielsweise Szenen, Animationen und die Rendering-Pipeline zu modellieren, sondern aus seinem großen Funktionsumfang, der das Tool zum Teil unübersichtlich erscheinen lässt. Dank einer sehr aktiven Community gibt es jedoch eine ebenso große Menge an teilweise sehr guten YouTube Videos, die vollständig und auf verschiedenen Niveaus den Designprozess für das reine Modellieren von 3D-Szenen, über Animation und komplexe physikalische Simulation von Grund auf zeigen und erklären.

Tipps:

- Für den Austausch mit zum Beispiel FreeCAD ist die korrekte Verwendung von Längeneinheiten zu beachten.
- Video, das die Möglichkeiten des parametrisierten Entwerfens aufzeigt.
- Artikel zur Verwendung von Blender, um Physically Based Shading umzusetzen.
- Ein Tutorial, um ausgehend von einer Handskizze ein 3D-Modell eines Gebäudes zu erstellen und fotorealistisch zu rendern.
- Wiki, zur Nutzung von Blender in der Architektur. Neben Tutorials sind dort vor allem eine größere Menge von Texturen, Materialien, Modellen und Skripten zu finden, die frei nutzbar sind.
- Fluid Designer ist ein kostenfreies Tool auf Basis von Blender. Das Benutzerinterface wurde leicht vereinfacht und Bibliotheken für Materialien und Objekte wurden integriert. Das Tool implementiert keine spezielle BIM Funktion und zielt auf das einfachere Erstellen von Innenraumvisualisierungen ab.

Figure 21:
Screenshot of Blender profile

Building perspectives in 2030

Thorsten Klooster
Kennwert KW GmbH, Berlin

Digitisation in building results in a contradiction between high-tech (IoT, BIM) and low- tech (construction). Buildings are transformed into unique interactive physical (building) systems consisting of hardware and software in correlation to a material component. "It does offer one serious improvement ... better chances for mankind to mop up its own rubbish." (Bruce Sterling)

about 19 tools were then selected as practical in an initial rough analysis and evaluated in detail according to a criteria catalogue.

The possibility of data exchange played a significant role in the selection of these tools. A tool was then only evaluated in detail if it exhibited some form of meaningful data exchange with other free tools, since the greatest value added by the BIM method is the reduction of multiple inputs. The other criteria describe the usability and functionality of the tools. There are a total of 30 criteria which, however, differ depending on the software class and degree of complexity.

It was possible to make general statements on the quality of tools from commercial providers, research prototypes and community projects. Consequently, mainly viewers without functions for model enrichment were found on the commercial side. Contrary to expectations, research prototypes were underrepresented and rarely functional. Above all, the selection of tools from community projects was very broad outside the BIM context. Tools were identified here that permit modeling and exhibit a good level of usability.

A model was developed for the preparation of results on the website that permits formal assignment of the tools to usage scenarios. The design of the website was thereby separated from the content and divided into three views: a welcome page on which the underlying motivation and a brief description of the structure of the website is formulated. In addition, a description is displayed for each usage scenario together with the BPMN diagram with which the tools are hyperlinked. In addition, an idealised and a supported process are described on the basis of the process description. The list of evaluation criteria and an extensive review are displayed for each tool.

The information on free tools obtained here is intended to help small companies keep pace with the cost-intensive introduction of BIM in the planning process. Research prototypes were expected to be a rich source of such tools. Unfortunately, this could not be confirmed because these tools are either not available, not commercially available or often barely usable. Conversely, it was community projects that demonstrated through transparency and quality assurance measures that free tools can also be feasible and useful in the context of BIM processes. The results are published on the website https://bimtoolsoverview.building-lifecycle-management.de.

Key data

BIM Tools Overview

Researchers:
Karlsruhe Institute of Technology (KIT), Building Lifecycle Management (BLM)
Prof. Petra von Both
Steffen Wallner (Project Management)

Plotbot/Crawler

Development of an innovative web-based and sensor-guided motion automaton used to functionalise building surfaces through the application of complex layer systems

Prof. Heike Klussmann, BUILDING ART INVENTION, University of Kassel

The goal of the Plotbot/Crawler research project is to develop a web-based, sensor-guided automaton for façades. This mobile robot is designed to functionalise building surfaces through the application of complex layer systems. Consistent integration of tool and software logic enables guiding over the surfaces of structural elements in real time, regardless of the geometry, or directed to follow a preprogrammed processing pattern.

With the development of Plotbot/Crawler, the research team answers questions relating to the issue of physical computing in building. These are interactive, physical systems which impact the real world and address the relationship between human beings and the digital environment. The Plotbot/Crawler, database and building surface constitute a system of this nature in an exemplary sense. It is a combination of IT/software-based components with physical/mechanical and electronic parts that communicate via a data infrastructure.

Through processes of self-optimisation, self-configuration, self-diagnosis and cognition, a system of this nature can make essential automation technologies more intelligent and support people more effectively in increasingly complex life and work situations. Progress in the development of such systems for the building sector has been limited to date. However, it is of interest, because with regard to, for example, the requirements of sustainable and efficient restructuring of the building fabric (efficiency houses), it offers an equally conceptual and action-oriented approach through which this sector can tap the potential for technology-oriented and flexible production.

Figure 22:
Plotbot/Crawler, BAU 2017 trade fair, Future Building research initiative

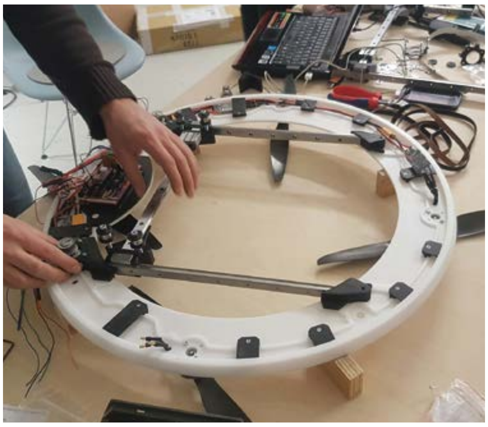


Figure 23: Plotbot/Crawler, mobile base, construction in Building Art Invention lab

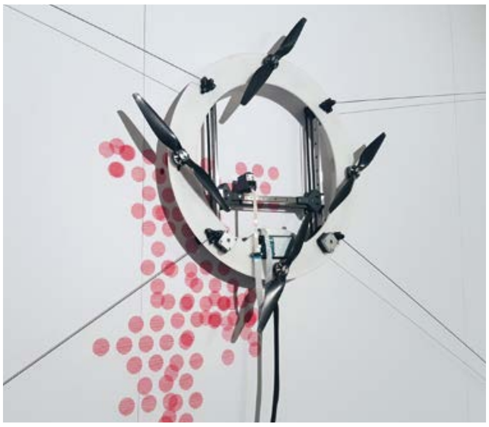


Figure 24: Plotbot/Crawler, mobile base on test surface

Building perspectives in 2030

Anica Meins-Becker
University of Wuppertal (BUW), Faculty for Architecture and Civil Engineering

These are dynamic times for the building and real estate sector, which makes any forecasts difficult. However, it's my opinion that important issues such as sustainable and resource-efficient building, digitisation of processes and implementation of the BIM method by 2030 will continue to gain importance.

With regard to positioning accuracy, repeatability and the desired flexibility of use of the Plotbot/Crawler on façades of a different structure, surface and size, the principle of wire-assisted robot guidance has proven to be the most suitable. For positioning, the mobile base is aligned vertically and fixed to four cables, each of which is anchored at the corner points of the façade (top left/top right, bottom left/bottom right) or surface to be worked. Precision control of routing and positions is achieved using the cable lengths and unimpaired by wind, slippage or other mechanical influences. A H-Bot was developed in the centre of the mobile base to hold functional tools. This dual-axis system holds the tool and achieves targeted control and positioning of the functional tool on the wall.

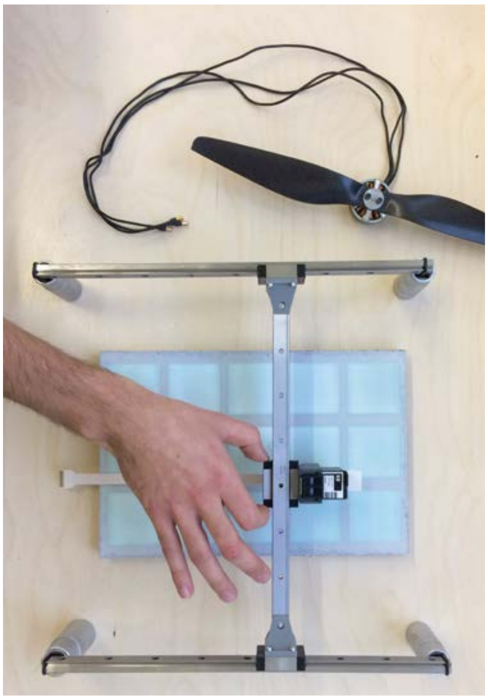


Figure 25: Plotbot/Crawler, H-Bot with spray/print component

The application and renewal of the DysCrete layering system means that the research project addresses a specific use case. DysCrete is a dye-sensitized, energy-generating concrete. Functional layers which can transform light into electrical energy employing the principles of technical photosynthesis are applied here to the concrete surface. Some are permanently joined to the concrete during this process, while others are renewed at regular intervals of time corresponding to the usual renovation cycles for façade coatings. The Plotbot/Crawler façade robot is suitable for application of these functional layers, but it can also be modified to accommodate other functional systems. Modification of the Plotbot/Crawler enables the integration of a variety of specific functional systems in the fabric of the structure through a printing process. Examples of such functional systems might include printed sensor systems, physical computing façades, effect pigment layers, photo concrete façades, multicoloured architectural graphics, guidance systems, reflective or luminescent surfaces, decorative layers or sealants. Plotbot/Crawler can also be modified to function as an on-site 3D printer. This modification is, for example, ideal for restoring geometrically complex structures in historical buildings (sandstone or printed bricks). The aim is to find solutions that exploit this potential while, simultaneously, accommodating the particular demands of the building industry. In this respect, the approach taken by the research project is both distinctive and exemplary. The additive integration and clear interface definition provided by this combination of high-tech (Plotbot/Crawler) and low-tech (façade element) is innovative and advantageous.

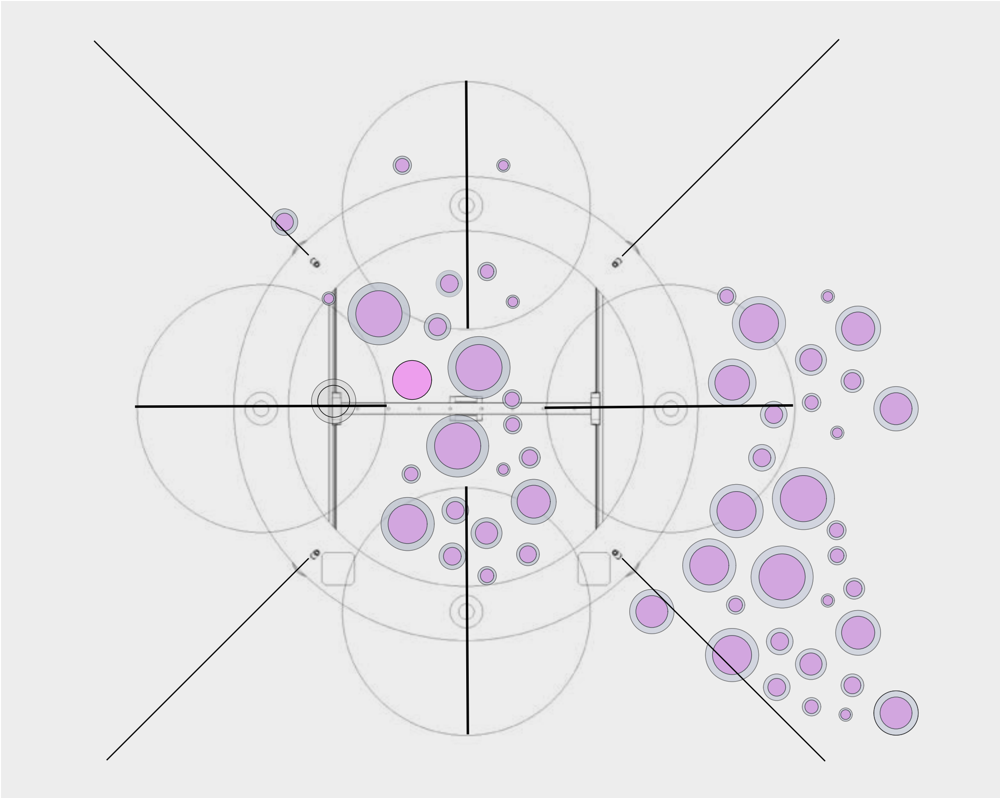


Figure 26:
Plotbot/Crawler, drawing

The Plotbot/Crawler system meets the requirements identified in an analysis of the Industry 4.0 strategy for robotic systems. The planned system is comparatively compact and mobile. It employs innovative spraying and printing technologies which, because of their efficiency and diverse application potential, are of growing significance for material research and building. Prototype P2 was presented for the first time in January 2017 and tested under realistic conditions on the Future Building research initiative stand at BAU 2017 – the world's leading trade fair for architecture, materials and systems. Prototype P3 will be displayed in February 2018 at the bautec trade event in Berlin.

Key data

Plotbot/Crawler

Researchers:
BUILDING ART INVENTION research platform, University of Kassel, www.baukunsterfinden.org
Prof. Heike Klussmann
Thorsten Klooster (Project Management)
Roman Polster, Jan Juraschek
Nils Kühn, Christian Wagner

Project support:
KENNWERT, www.kennwert.com

Digital Hut

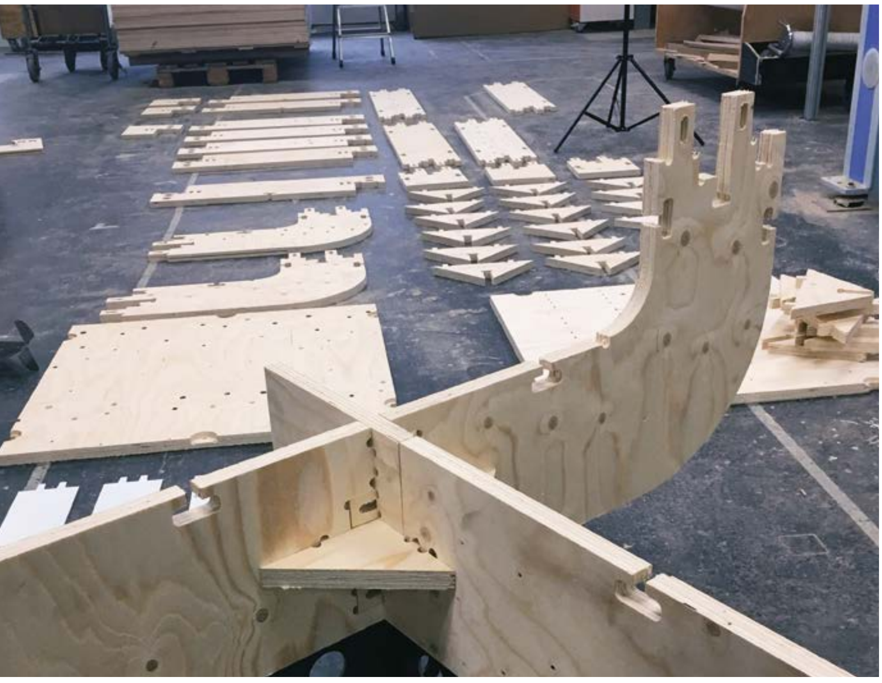
Design and production of a "minimal house prototype" using digital technologies in development and production

Prof. Julian Krüger, Hochschule Wismar, University of Applied Sciences, Technology, Business and Design, Prof. Hans Ostwestfalen-Lippe University of Applied Sciences

Against the backdrop of the rapid development and spread of digital technologies, we will be increasingly challenged by the need to reformulate social, economic and political strategies in future. At increasingly shorter intervals, a growing scope is opening up for innovative concepts in the interaction of people and buildings, intelligent automation and individualisation in production. The aim of the research project was to design and produce a "minimal house prototype" using digital technologies in development and production.

In the multi-phase project, digital production methods were employed to develop a variable and reduced light construction system which was configured (through an app) and built by the user without the need for complex tools. Through the use of innovative material processing and sustainable building materials in combination with an adaptive spatial concept, particular efforts were made to meet the requirements of a mobile and networked society. This primarily involves the connection of (software) interfaces, namely the collaboration of users (principles of "open innovation" and "mass customisation"), local, digitised production and individually adapted design/production of high-quality spaces.

Figure 27:
Timber node M 1 : 1



The Digital Hut is an experimental kit for digital building planning. The building system is in a permanent process of transformation, as users are an important part of the development process. A high level of adaptability results in a large number of possible applications, such as densification of unused urban areas or use of temporary buildings as a source of inspiration for sustainable and innovative architecture.

Customisable construction systems involving simply joining and plug fitting were tested and developed on the basis of different test series in the area of shape programming of certain semi-finished materials such as wooden and composite panels. These adaptive construction systems form the core of the Digital Hut building system. They are integral components of the process chain and provide a basis for parametric architectural design – both aesthetically and constructively.

A storyboard was developed in this respect during the project that describes and documents the digital process chain from the customer to the finished building. It illustrates the progress of a fictional building project in an urban context – from a 3D scan of the existing development to on-site D.I.Y. assembly of the prefabricated plug-in system generated.

The increasing importance given to digital tools in all processes (which determine the running and design of our everyday lives) mean that all building processes are also automated and parametrised, making them more flexible and, most importantly, more digital. The concept storyboard describes a possible scenario in which the Digital Hut building system can be used. The case study illustrates a building space or urban "gap" which is developed and compacted in this example.

The primary support system of the Digital Hut is a structure made of wood which can be created through CNC milling, cutting or lasering of panel material. As a renewable and environmentally compatible raw material, wood is particular suitable for a sustainable building system and, in addition to ecological advantages, offers further benefits such as good availability, relatively low costs, suitability for CNC machining and low weight.

Of central importance in the design process was the development of a statically determined timber node that can ensure the stability of the Digital Hut and, additionally, is easy to assemble. An important specification in this context was that connection of individual wooden components should be possible without additional tools and joining material to ensure simple and intuitive building.

The prototype of the Digital Hut was designed as a fragment of a building to the scale 1 : 1 and unveiled on the BBSR stand at the BAU 2017 trade fair in Munich. All fundamental components (roof/wall/floor/openings) of a dwelling were illustrated exemplarily through the prototype to communicate a spatial impression of the digital wooden building system.

The breaking up of boundaries between the disciplines of architecture, design, information technology, management, product development and materials sciences played a key role in the development of the Digital Hut research project.

1 : 1 prototype realised and the Digital Hut process chain described illustrates a radical approach to the development of a digital building system which, through the exploitation of comprehensive networking and automation of all development and production processes, questions current practices in the development, construction, usage and control of buildings from the bottom up and develops a new concept from the perspective of digital, intelligent control of processes.

Figure 28: Pleated shingles made of aluminium composite material

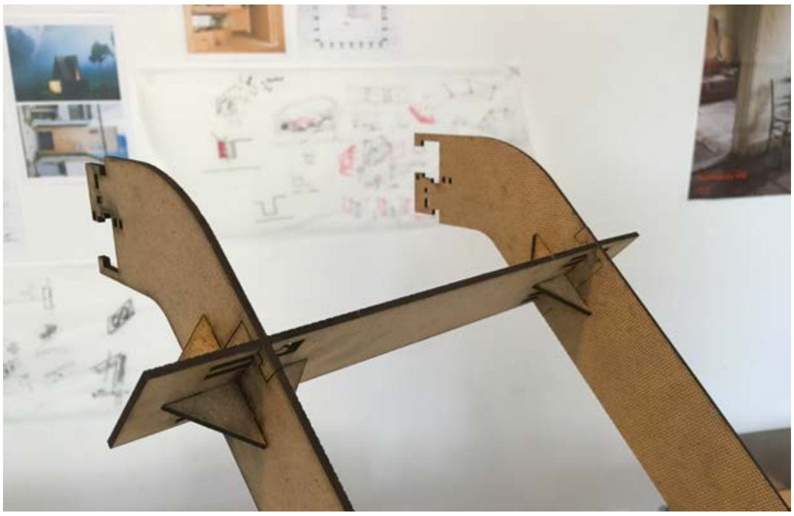


Figure 29: Lasered text model M 1 : 20

Key data

Digital Hut

Researchers:
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Prof. Julian Krüger

Hochschule Ostwestfalen-Lippe University of Applied Sciences
Prof. Hans Sachs

Building perspectives in 2030

Sebastian Otto
Department BI 1 – General Building Issues, Federal Ministry of the Interior, Building and Community

Digitisation is taking hold in all planning and building processes. Cooperation between all stakeholders is growing continually. Efficiency enhancements through, for example, greater planning quality and fewer media discontinuities will be achieved in planning and on the construction site.

Development and orientation of BBSR research towards digitisation and BIM

Sebastian Goitowski, Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

Digitisation has become an omnipresent focus in recent years for all disciplines associated with building. This effect is due, among other things, to the popularity of the BIM (Building Information Modeling) methodology which is frequently regarded as synonymous with the digitisation of building. A measurable increase in research activities is also apparent in the scientific field. Synergetic linking of these activities for targeted research of digital complexities is therefore all the more important.

The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), as the departmental research institute of the Federal Ministry of the Interior, Building and Community (BMI), conducts its own research and operates research and funding programmes in the areas of building and both spatial and urban development. Research of building issues in the context of the Future Building research initiative has indicated a steady growth in research needs in the field of digitisation in the last five years (especially in relation to BIM) and increased research activities conducted by scientific institutions. This can be primarily measured in the increase in the number of applications with a digital background regarding BIM of more than 10% of those submitted in each application round. The number of research projects commissioned by the BMI for public building has also increased in this area. For example, there is an increased focus on the establishment of digital processes, identification of potentials through the use of BIM, data consistency and exchange and appropriate support provided by software solutions and environments.

Embedding the BBSR in the Federal Office for Building and Regional Planning (BBR), which is responsible for implementation of federal building measures, ensures close feedback between this research and existing practical requirements in the building departments. For example, current BIM pilot projects of the BMI are being scientifically monitored by research projects of the BBSR and evaluated in terms of planning, execution and operation. In addition, specific application cases are investigated in further studies that can be gradually integrated as digital subprocesses on the basis of a component-oriented approach. Necessary framework conditions should be created successively for this purpose. These include the determination of quantities and automated generation of specifications based on building information models and use of the BIM method for sustainability analysis. The findings of this research flow directly into current and future BIM pilot projects of the BMI and can be exploited as orientation for other public and non-public building projects.

Through the interaction of contract research with the broad spectrum of research proposals relating to digitisation of building, the Future Building research initiative can avail of the potential to conduct comprehensive and

Figure 30: The need for research in the area of digitisation continues to grow

Figure 31: BIM dialogue aims to network research facilities and practice

targeted research of digitisation and, in particular, BIM with regard to public building and the German building sector. Development of a master plan was commissioned to encourage effective exploitation of this potential and targeted research co-ordination.

The aim of the research project is the development of the master plan to support the BBSR in research coordination and strategic monitoring of its orientation in questions relating to BIM and digitisation. In addition, the master plan is intended to provide a guideline for consistent research of digitisation by potential researchers from BMI and BBSR.

The study is based on the examination of previous research in Germany and its findings and current developments and tendencies regarding short and medium-term research requirements in Germany. A scientific BIM dialogue will be established for this purpose under the auspices of the BBSR. This will take the form of a regular event designed to strengthen the networking of universities and research institutes with practical players to address the issues of digitisation and BIM, thus promoting the exchange of current research requirements, projects, findings and experience and the formation of a common BIM understanding and to support the integration of research.

The scientific BIM dialogue will meet three to four times a year until 2019 and will consist of experts on various areas of focus who will, in part, change from time to time. Initial results are already expected as an orientation aid for applicants in upcoming application rounds of the Future Building research initiative.

Targeted, synergetic research of digital issues which leads to a reduction of redundancy and, consequently, effective exploitation of research resources and capacities requires the increased networking of stakeholders in the scientific and building sectors on the basis of a collaborative and cooperative approach to the BIM method and is an opportunity that should be embraced. The scientific BIM dialogue conducted in the BBSR as part of the "BIM Master Plan" research project potentially offers interested parties a platform to participate in the exchange on the research orientation of building digitisation.

Key data

BIM master plan

Researchers:
Leibniz University Hannover,
Bauhaus-Universität Weimar

Prof. Katharina Klemt-Albert
(Project Management)

eLCA – A new interface for EnEV calculation supplements the digital workflow in building planning

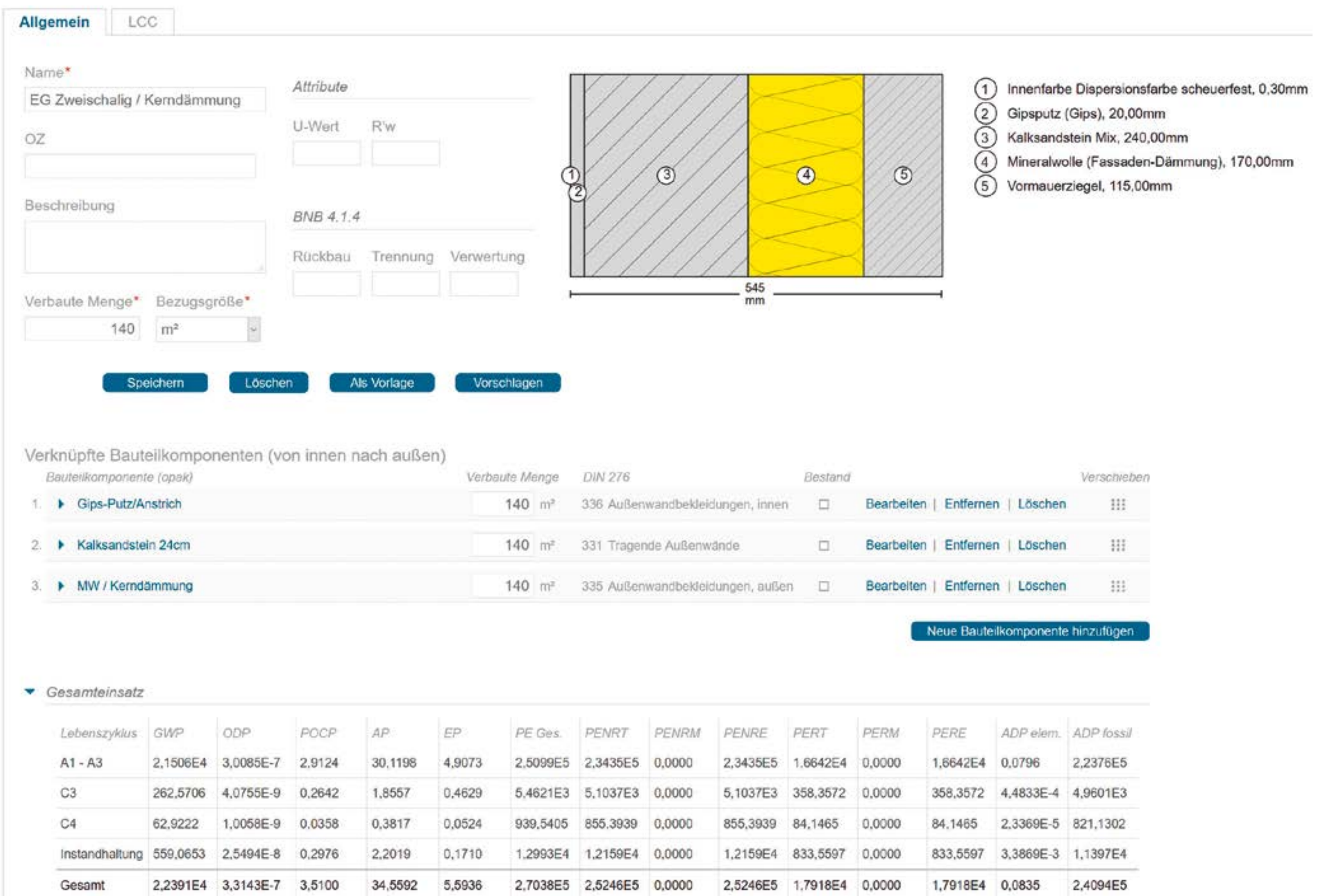
Stephan Rössig, Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

A new digital interface creates synergies and significantly reduces the effort required to determine the environmental impacts of a building.

Eco-balancing, also known as life-cycle assessment, is the instrument used to determine the global environmental impacts (e.g. grey energy) of buildings. In contrast to classic evidence, the environmental effects resulting from materiality are also included in the balance sheet.

Data input of detailed component assemblies has already been realised in eLCA in a very user-friendly manner. However, almost every specialist planner involved in the project has to measure the building anew for his planning, as there is only limited, if at all, consistency in data processing. The current version of eLCA focuses precisely on this point and integrates the building eco-balance into the digital workflow of construction planning via a new interface. It now enables further processing of data already collected for EnEV (Energieeinsparverordnung – the German Energy Saving Ordinance) verification as the basis for a building eco-balance. This synergy considerably reduces the workload involved in a building eco-balance. Following development and testing in a pilot project with the company BKI, this data transfer option is now freely available to all interested software manufacturers.

Figure 32:
eLCA component template



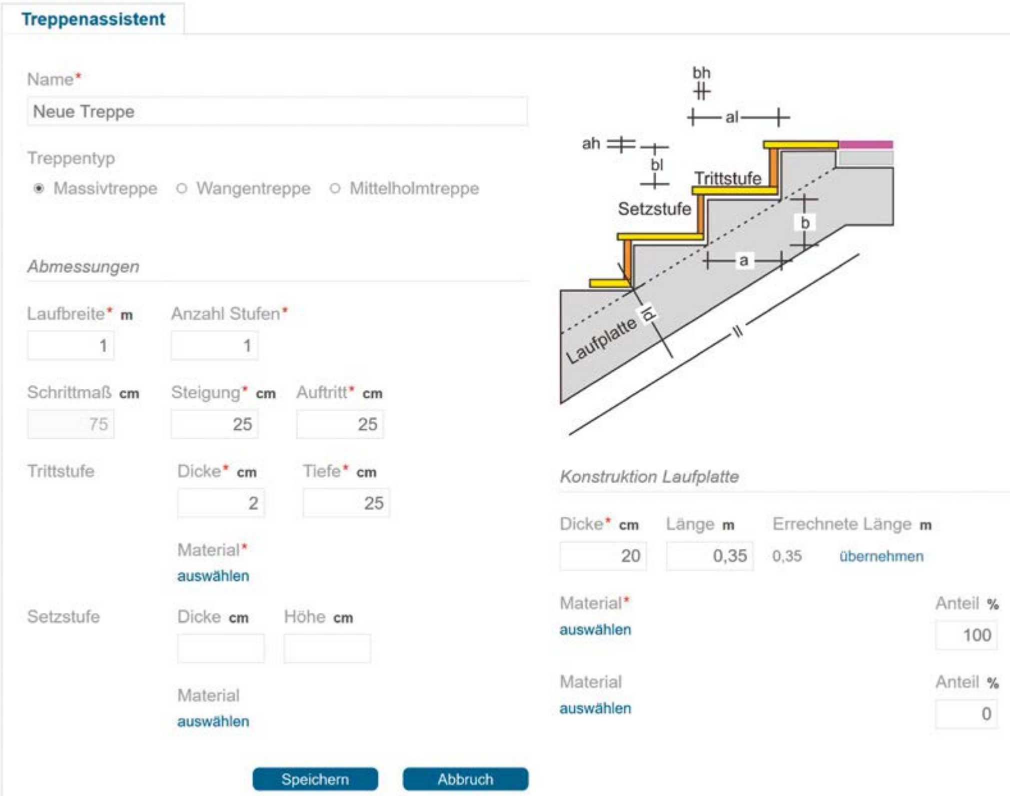


Figure 33: eLCA component assistant for modeling stairs

Eco-balancing for buildings, definition

Eco-balancing for buildings quantifies and qualifies the global environmental impacts caused by the erection and usage of a building over an assessment period of 50 years. The use of building materials employed for construction and the quantities of energy consumed during usage relative to the respective energy source must be taken into consideration. These processes are then depicted over the entire lifecycle (production, maintenance, use and disposal) relative to the useful life. Data collected is then analysed with regard to sustainability aspects with the aim of achieving good building quality with the least possible impact on the environment.

eLCA, component modeling

The core component in eLCA is the so-called component editor. The component editor allows the user to record all project components with extreme ease. For control inputs, a dynamic graph is available to the user. This graph displays the component being processed in its own control window. All material layers recorded in a component are depicted to scale with the corresponding material thicknesses, hatching and filling patterns, thus enabling immediate visual control of the input.

eLCA, component templates

In order to ensure that the user's introduction to the world of eco-balancing of buildings is as easy as possible, eLCA provides a selection of prefabricated components in the form of so-called open component templates. These component templates can be easily imported into a project. Project-specific adjustments in the component structure can be realised easily and transparently at any time. In addition, each user can supplement existing component templates with their own designs.

eLCA, variant comparison

A variant comparison is available to the user for the optimisation of a building model. Individual material layers can be quickly exchanged and the resulting impact on the building analysed.

eLCA, assistants

Practical application has shown that components exist that are not as easy to model as you would expect from standard components. In order to fully record these components, eLCA provides special assistants to aid the user in their creation. The material information required is queried on special forms and supplemented by example sketches. Currently, eLCA offers these assistants for modeling windows, stairs, supports and strip foundations.

Building perspectives in 2030

Prof. Thomas Auer

Chair of Building Technology and Climate Responsive Design in the Faculty of Architecture of the Technical University of Munich (TUM)

An increasing supercharging of geometric with semantic information and integration of logical links (scripting) has the potential to strengthen the industrialisation of construction even further with the aim of achieving real mass customisation. This will also provide a boost for digital production processes.

Benchmarks AUSWERTUNG

Bilanzierungszeitraum: 50 Jahre
Bezugsfläche (NGF): 240 m²
Hinweis: Diese Projektvariante enthält 1 Baustoffe mit einer abweichenden Nutzungsdauer.

Drucken PDF

Benchmarksystem

BNB - BN_2015

Gesamt INKL. A1 - A3, B6, C3, C4

Indikator	Einheit	Gesamt / $m^2_{NGF}a$	Zielwert	BNB Benchmark
GWP	kg CO2-Äqv.	10,4599970865		100,00
ODP	kg R11-Äqv.	1,9764785309E-8		100,00
POCP	kg Ethen-Äqv.	3,8432551215E-3		100,00
AP	kg SO2-Äqv.	0,0296325430		100,00
EP	kg PO4-Äqv.	2,7782943158E-3		100,00
PE Ges.	kWh	46.914709645218		40,00
PENRT	kWh	36.084821998899		60,00
PERT	kWh	10.829887646319		6,62
KSB 1.2.1				100,00

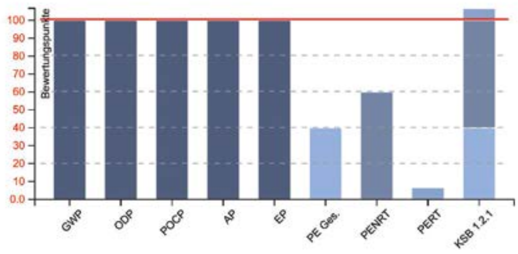


Figure 34: Display of reference values of relevant German certification systems for sustainable building as benchmark

Exploiting synergies, supplementing the digital workflow

Much of the data required for an ecological assessment of a building (wall structures in material layers with associated surfaces) also forms the basis of mandatory EnEV certification and has already been collected in this context. In order to avoid reinvesting this effort during eco-balancing, further use of this data already collected was realised via an interface. Data recorded for the EnEV calculation can therefore be transferred to the eLCA eco-balancing software and is immediately available for further processing or evaluation.

EnEV2eLCA

After an initial project import, eLCA automatically assigns the material data records transferred from the EnEV calculation to the corresponding ecological assessment data records. Data records which are not automatically assignable are highlighted in colour and can be easily supplemented for each specific project through the familiar eLCA selection dialog. The final project import is started after material assignment. On the basis of this data, eLCA creates a project with all transferred components of KG 300, the building services components of KG 400 and the energy data for building operation.

The components are assigned to the familiar eLCA structure (based on DIN 276) and are available layer-specific to the user for further processing or evaluation. eLCA component graphics are generated automatically and vividly document import results. All further processing steps can, as usual, be realised simply and without restrictions in the eLCA model. Components which have not been input through this workflow can be added in the usual manner (e.g. through the integrated component templates).

Classification of results, benchmark

The results calculated for a building are not easy for the inexperienced user to interpret. However, reference values of relevant German certification systems for sustainable building can be displayed in eLCA as a benchmark to facilitate speedy categorising of results by the user.

The laborious and complex creation of a building lifecycle analysis is considerably simplified through the workflow presented here. The time-consuming process of compiling and recording components with the associated areas was considerably reduced through further use of building data already available in EnEV verification.

The federal government is supporting the simplification and further dissemination of building eco-balance and sustainability assessment through integration of lifecycle analysis into the digital building planning workflow. With eLCA, the federal government is ensuring that a freely accessible life-cycle assessment tool for buildings is available to all interested users.

Efficiency House Plus initiative – 7 years of Plus!

Petra Alten
Project Leader of the Efficiency House Plus initiative of
Federal Ministry of the Interior, Building and Community

Building of the future

The responsible use of resources and climate protection are a central task for society as a whole, and an important starting point here is the issue of energy efficiency. Particular responsibility is attached in the current United Nations Environment Report to the area worldwide covered by buildings which, on average, will almost double by 2060. It is important to exploit the substantial savings potential in energy consumption (36%) and CO2 emissions (39%) today in this respect.

For Germany, this means rethinking future building. The creation of affordable and climate-friendly housing is an important basis for our social cohesion.

Practical solutions are needed to meet growing demand for energy and address noticeable climate change. Within the framework of its “Efficiency House Plus Initiative”, the Federal Ministry of the Interior, Building and Community is setting new standards in research and development issues in the field of energy-efficient construction. The ways in which energy efficiency and the use of renewable energies in the building sector can be further advanced are the subject of investigation. The principles of efficiency, receptiveness to technology, simplification and the question

Building perspectives in 2030

Petra Alten

Project Leader of the Efficiency House Plus initiative
Department BW I 3
Building and plant engineering, technical issues in the area of energy and building
Federal Ministry of the Interior, Building and Community

Times are changing in the building sector: From energy-consuming to energy-yielding building. The Efficiency House Plus initiative promotes new thinking in building and living without sacrificing quality: climate responsive, energy efficient, smart and affordable!

Figure 35a: Efficiency House Plus timeline

Figure 35b: “Efficiency House Plus” app

of voluntary action continue to apply in this respect. The CO2 savings aimed for are also being investigated at district level.

Efficiency House Plus initiative

Since 2011, the “Efficiency House Plus” initiative has pursued the goal of developing building standards that meet the energy requirements of sustainable building. An Efficiency House Plus generates more energy than it needs for its operation. It meets the energy requirements of sustainable building. Since it can be assumed that not all buildings in Germany will reach building-related climate protection targets in 2050, an Efficiency House Plus will also serve as a compensatory measure on the way to climate neutrality in the building sector from 2050 onwards. The Federal Ministry of Building specifically supports the dissemination of this climate-friendly building standard with a clear definition of the “Efficiency House Plus” building standard, funding programmes and the free provision of the Efficiency House Plus computer for standardised evaluation of an Efficiency House Plus.

Figure 36: Webinars from the Information and Competence Centre

Figure 37: Information and Competence Centre for Sustainable Building (IKzB)

Federal "Efficiency House Plus" model project in Berlin

This support is worthwhile. With a 15% market share of Efficiency House Plus in new and old buildings, the Fraunhofer Institute for Building Physics forecasts a CO2 savings potential of 6 million t/a from 2030 and up to 14 million t/a from 2050.

Guided by these hopeful figures, the "Efficiency House Plus" initiative, which Federal Chancellor Dr Angela Merkel launched in 2011, will also continue over the next few years. Seven years ago, she laid the foundation stone for research of this innovative building generation with the opening of the first state-owned "Efficiency House Plus" research and model project in Berlin.

The location of the first Efficiency House Plus prototype was well chosen in this context. It is the original location for the establishment of the TU Berlin (Technical University of Berlin) on today's Berlin City West scientific axis. In the meantime, two test families vetted the model project which had been certified with the gold standard of the federal "Sustainable Building" assessment system for its practicality. With the scientific support of the Fraunhofer Institute for Building Physics (IBP) and the Berlin Institute for Social Research (BIS), the building proved at this time that it meets all the requirement criteria set. While not ignoring aesthetics and quality of life, the house proved by way of example that it was much more than a dwelling: an innovative small power plant, an intelligent energy manager, a 24/7 filling station, a valuable resource depot and an attractive oasis of well-being. In addition to the test families, over thirty thousand interested visitors examined the flagship model of the future.

"Efficiency House Plus" network

The "Efficiency House Plus" network has grown out of the federal flagship project in Berlin since 2011. It bundles the Efficiency House Plus model project promoted by the federal government with housing construction and education building, both in the district and abroad (e.g. in Japan and the Czech Republic). It imparts comprehensive findings relating to this building standard via a website and newsletter and offers more than 150 partners from scientific, business, planning and trades communities a real-time exchange of knowledge. The network promotes a variety of in part awarded-winning building concepts and demonstrates that energy efficiency and a sophisticated building culture need not be a contradiction. It also offers findings from other accompanying research projects for building in the Efficiency House Plus standard of the Federal Ministry of Building.

Information and Competence Center for Sustainable Building

Persistently high demands for information on the Efficiency House Plus standard and regarding the possibility of visiting this new generation of buildings required the network to have a solid structural location. From 2017, the federal prototype in Berlin was transformed into an "Information and Competence Centre for Sustainable Building". This means that, over the next few years, the network will have a built-in dialogue and information platform in a "monument" to Efficiency House Plus homes. This should function as a think tank, further encouraging the discussion about sustainable, climate-friendly building. The scientifically grounded analog and digital information transfer will take place from here using real-time formats (e.g. Efficiency House Plus app, webinars).

The barrier-free, two-storey building has 130 square metres on two building levels, a covered entrance area with e-mobility charging facilities for cars and bicycles and a spacious garden area with a terrace where both federal and external events can be held. The fully furnished building is equipped with conference technology and offers a colourful programme of events with insights into the "Efficiency House Plus" and "Future Building" building research initiatives. In addition, interested parties can expect guided tours, conferences, exhibitions, events and webinars on sustainable building.

The ZEBAU GmbH team has been entrusted with programme design and support of the "Information and Competence Centre for Sustainable Building Experience" on behalf of the Federal Ministry of Building. The first "Efficiency House Plus" of the federal government invites everybody to actively participate in the transformation of the building sector and help shape the necessary adaptation to climate neutrality in the sector from 2050 onwards.

Information on the internet

www.forschungsinitiative.de/effizienzhaus-plus/

www.bauen-der-zukunft.de

Information and Competence Centre for Sustainable Building

Address:
Fasanenstrasse 87a
10623 Berlin
Opening hours:
Thursday and Saturday
from 1.00 p.m. to 6.00 p.m.

Please note the different
opening hours on public holidays.

Arrival by local public transport in Berlin:
"Zoologischer Garten" station
(Rail lines: U2, U9, S5, S7, S9, S75)

Further information is available at:
www.bauen-der-zukunft.de
www.zebau.de/projekte/bauen-der-zukunft.de
effizienzhaus@zebau.de, Tel. 040 380 384 0
www.forschungsinititaive.de/effizienzhaus-plus/dialog-zum-bauen-der-zukunft/

Educational buildings built to Efficiency House Plus standard

Arnd Rose, Federal Institute for Research on Building, Urban Affairs and Spatial Development

Educational premises meeting the requirements of the “Efficiency House Plus” standard are among the most energy efficient buildings of all. As part of the “Educational Buildings built to Efficiency House Plus Standard” funding programme, investigations will be conducted up to 2022 in eleven (sub)projects to determine how the goal of a positive energy balance can be implemented in practice and what lessons can be derived from these pilot projects for the planning of future educational buildings.

A total of seven clients face the challenge of realising an educational building that produces more energy in a year than is required for operation and use. A broad range of building tasks is involved, ranging from the extension of a primary school in Giebelstadt near Würzburg to the construction of a new faculty building for the Ulm University. In addition to further research and seminar building (Ansbach University of Applied Sciences, Campus Feuchtwangen), two vocational school centres (Hockenheim and Mühldorf am Inn) and two secondary schools (Kaufbeuren and Neutraubling) are participating in the funding programme. The two secondary schools are peculiar in that, in an initial step, an extension will first be erected and, following this, the existing buildings from the 1970s will be renovated to the “Efficiency House Plus” standard. Following completion of building, a 24-month technical monitoring period is planned for all projects to optimise operation of the buildings and check that energy goals have been achieved.

Building cubatures

The most important directions for the energy performance of a building are set during the design phase. The two classic parameters of orientation and compactness differ in importance for educational buildings. Since a low ratio of the building envelope to its volume reduces heating requirements, the new buildings in the funding programme were designed to be fundamentally more compact than the corresponding old buildings. Six out of seven buildings have flat roofs that are used almost fully for energy-generating systems. A southern orientation of glazed areas, as is useful in residential properties, cannot be regarded as a design principle to the same extent in educational buildings. For classrooms in particular, glare control and avoidance of summer overheating are important aspects that limit the potential use of solar heat input.

Figure 38:
Officially inaugurated in October 2017, the Louise Otto-Peters school in Hockenheim is the first educational structure completed in the funding programme.

High-quality building envelopes

All projects exploit the potential of high-temperature thermal insulation building envelopes. In addition to the use of components with low U-values, the avoidance of thermal bridges is ensured in as far as possible. For example, GRP spacers are to be used for the back-ventilated curtain façades in Kaufbeuren and Ulm. The two old buildings to be renovated will also receive new façades. Compromises only need to be made here with regard to floor slabs, as only internal insulation can be considered for the existing buildings.

Plant engineering

All projects use heat pumps for the heat supply to cover the base load, although very different concepts are pursued for their layout and operation. A basic distinction can be made between high-performance centralised systems and smaller decentralised, interconnected heat

Figure 39: Guided tour through the heat station of the Louise Otto-Peters school in Hockenheim during the inauguration on 13 October 2017.

pump systems. Local resources are exploited wherever possible. For example, groundwater is not only used as a heat source by the reversible heat pumps of the schools located close to the river in Neutraubling and Mühldorf am Inn, but also for cooling in summer. Peak loads are partially covered by local or district heating connections.

All projects have controlled ventilation systems. In three schools (Kaufbeuren, Neutraubling and Giebelstadt), the decentralised ventilation units are hydraulically interconnected with ceiling sails for heating/cooling. This creates a new type of system that manages with only one room-by-room control already integrated in the ventilation system.

User electricity consumption

In addition to electricity consumption calculated according to EnEV (Energieeinsparverordnung – the German Energy Saving Ordinance), "Efficiency House Plus" educational buildings are required by definition to pay a flat rate of 10 kWh/m²a final energy (or 15 kWh/m²a if highly energy-efficient appliances are not exclusively used) for user electricity consumption. Due to the very different uses and equipment involved in the projects in the funding programme, the user electricity consumption was forecast in detail beforehand for some buildings on the basis of the connection loads of all devices. For the new university building in Ulm which, due to housing the faculties for electrical engineering and information technology, accommodates very energy-intensive uses, the calculation resulted in an estimate of 16 kWh/m²a. The forecasts for the school buildings are in the range of 10 kWh/m²a. How individual consumption shares (especially the school kitchens) arise in practice will be part of the monitoring evaluation.

Power generation

All buildings in the funding programme use large-area photovoltaic systems (PV) to generate electricity. Whilst the one and two-storey buildings have sufficient roof space for PV systems to offset the annual energy balance relative to the base area, additional areas on the respective property must be used for particularly compact multi-storey buildings.

Goal: A high degree of own use

The projects are not designed to achieve the highest possible absolute energy surpluses and feed them into the power grid. On the contrary, the stipulation for an at least balanced energy balance went hand in hand with the desire to use as much as possible of the renewable energy generated on the property on site. The so-called own use level can be increased through intermediate storage of surplus energy produced during the day. The projects adopt different approaches in this respect. In Ulm, Neutraubling and Kaufbeuren, hot water storage tanks can be charged with surplus electricity and, consequently, store energy by the hour or day. In Hockenheim and Mühldorf, large underground ice storage facilities have been built which can be regenerated through solar thermal absorbers and are designed more for a seasonal effect.

Figure 40: The new Efficiency House Plus standard extension connects the existing buildings of the Jakob Brucker secondary school in Kaufbeuren.

Figure 41: The ice storage facility of the Berufsschulzentrum Mühldorf am Inn (vocational training centre) during concreting.

Networked buildings

Favourable conditions exist in different projects for the direct use of energy surpluses for neighbouring buildings without burdening the public electricity grid. In the case of new extensions such as in Giebelstadt or Neutraubling, the existing buildings can, in principle, be connected directly. In Feuchtwangen, networking of the new buildings of the university campus is being prepared. In Ulm, a special approach is taken involving intelligent networking with local energy networks. The building uses the return from a district cooling supply as an energy source for a reversible heat pump. The return in this case is cooled down again, whereby energy is saved which would otherwise have to be used in the cooling centre of the network.

The goal of constructing or refurbishing a building that consumes less energy on the annual balance sheet than that generated on site can be achieved in different ways in the area of educational buildings. But even if it is already possible today to construct such buildings with components that are available on the market, new technical approaches need to be explored in many areas for their planning. Hardly any transferable findings exist to date for the projected combinations of components and their technical interaction. Scientific investigation of the pilot projects in the "Educational Buildings built to Efficiency House Plus Standard" programme therefore provides an important basis for the widespread application of new energy-efficiency technologies in the area of non-residential buildings.

Key data

"Efficiency House Plus" educational buildings

Projects and monitoring teams:
Louise-Otto-Peters-Schule in Hockenheim (college),
Monitoring: INA Planungsgesellschaft

Research and Study Center Feuchtwangen
Monitoring: INA Planungsgesellschaft

Berufsschulzentrum Mühldorf am Inn (vocational training centre)
Monitoring: Rosenheim University of Applied Sciences

Jakob-Brucker-Gymnasium Kaufbeuren (secondary school),
Gymnasium Neutraubling (secondary school) and Grundschule Giebelstadt (primary school)
Monitoring: TU Dresden

Ulm University of Applied Sciences, new replacement building Oberer Eselsberg
Monitoring: Fraunhofer Institute for Building Physics (IBP)

Total costs: € 14,644,005
Federal subsidy share (total for all projects): € 5,327,707
Project duration: until end of 2022

5th SCHOOL OF THE FUTURE Congress 2017

Prof. Philip Leistner, Fraunhofer Institute for Building Physics IBP, Stuttgart

The public debate concerning spaces and buildings used for schooling and education remains unabated. Educational quality and the need for investment, missed opportunities and neglected trends are a cause of furore. An exchange between experts and of specialist knowledge is indispensable if the challenges of construction and school development are to be embraced in a tangible manner. The SCHOOL OF THE FUTURE Congress offers the right format and addresses current areas of action.

The addressing of concrete design priorities in school construction requires two things: an analysis of current needs and requirements and structured processing of appropriate findings and experiences. The programme for the 5th SCHOOL OF THE FUTURE Congress was developed with this in mind. The inclusion of current project findings which emerged within the framework of the Future Building research initiative is therefore obvious. The contemporary relevance is, for example, reflected in the opening of the first "Efficiency House Plus" school in the Rhein-Neckar district shortly before the congress began. It marks the beginning of the test phase for this innovative "Efficiency House Plus" building standard in the area of non-residential buildings. Energy efficiency is not the only reason why a thematic expansion of the fields of application of the congress towards higher education is of value. Specific questions were integrated in the programme for the first time this year. The core content of the congress programme can be summarised in the following guiding principles:

Figure 42: Prof. Klaus Sedlbauer greets guests at the launch of the congress

Figure 43: Lother Fehn Krestas from the Federal Ministry of the Interior, Building and Community establishes the contemporary congress connection to the first "Efficiency House Plus" school.

Energy and resource-efficient schools

The economic potential of energy-efficient school buildings alone is far from exhausted, even if their local and, at the same time, social significance is recognised. With its proven primary energy gain, the "Efficiency House Plus" standard is the leading implementation priority today. It feeds into a practical source of knowledge that can benefit other, even less ambitious projects.

Identity-building and participative school design

Today, responsibility for and awareness of architecture are not only expected with regard to aesthetic and functional school design. More than ever, architects are confronted by a need for participative development and design processes. Their coordination and moderation also places demands on the urban or municipal integration of school buildings.

Schools that enhance teaching and learning

The recognition of the school as a "third educator" has been confirmed and established, but its practical consideration remains a complex challenge. Light and air quality, indoor climate and room acoustics must be reconciled with pedagogical and structural goals, content and concepts. Changes in the school landscape as a result of demographic and pedagogical developments prove to be a dynamic companion in this respect. The focus is on the inclusion

Figure 44: Technical information and discussion in the thematic workshops – Congress Director Prof. Philip Leistner moderates the integral school construction.

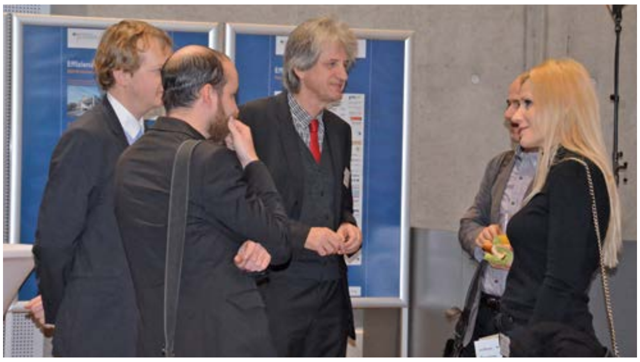


Figure 45: Encounters and technical discussions are the hallmark of the congress

of participation options and opportunities as a societal benchmark and design challenge.

Safe and healthy schools

Inseparable conditions for health and safety in schools range from the culture of prevention to structural and technical features. The priority of these categories is uncontested, and the tools available for practical implementation have also expanded considerably (e.g. in the area school catering).

Exercise and sport-friendly schools

Exercise, physical activity and sports need more attention and consideration in school design to promote health and social development, especially where considerably more time is spent in schools. The urgency of this requirement relates both to sports halls and swimming pools used for sports education and other areas for exercise, such as sustainable outdoor sports facilities.

These guiding principles were taken up by the 5th SCHOOL OF THE FUTURE Congress and actively and vigorously embraced by the almost 600 guests. Starting with plenary presentations from well-known personalities on different perspectives of construction and school development, specialist contributions in the three thematic workshops then addressed individual aspects and presented concrete knowledge-based solutions. These contributions will be available for future exchange on the www.zukunftsraum-schule.de website. The spatial and thematic opportunity integrated directly in the congress format to continue technical discussions at exhibition stands once again proved an important component of communication for the profile of participants. It is evident that school planners and boards, the authorities and companies represent the points of focus. Their consistently positive summary may be assessed as both a demand and a vote for the continuation of the SCHOOL OF THE FUTURE Congress.

In addition to political decision-making and financial resources, sustainable design of school buildings requires an interdisciplinary collaboration of users and designers, researchers and practitioners. Efficient buildings and their surroundings and spaces that promote performance and well-being interact with each other and must be designed according to economic standards. Neither the school nor construction will escape the digitisation which is currently the subject of discussion in this respect. Concepts are therefore needed and solutions for their meaningful and valuable implementation in practice, and well-known areas of action (e.g. energy and resource balance, inclusion) will also benefit from these.

Key data

5th SCHOOL OF THE FUTURE Congress 2017

Project Management:
Fraunhofer Institute for Building Physics IBP, Stuttgart
Prof. Philip Leistner

Figure 46: 3dTEX – Foamed woven spacer fabric

3dTEX: Textile lightweight wall elements

Prof. Claudia Lüling, Frankfurt University of Applied Sciences

When it comes to the improvement of quality and sustainability, prefabrication and lightweight design are as essential in architecture as they are already in the automotive and aviation industry. Contrary to classic textile lightweight structures, 3dTEX demonstrates how textile wall elements with an integrated support and insulating structure can be created through the transfer of three-dimensional textile manufacturing technologies and in combination with production techniques such as foaming.

The project focuses on spacer textiles and the examination of their suitability as a lost formwork for light wall elements. Spacer textiles are woven or warp-knitted textiles produced in a single working process. Their surfaces are linked by so-called pile threads at a specifically defined distance. The arrangement and spacing of the textile layers and use of the structural cavities created for other materials mean that spacer textiles can potentially perform an exterior wall element's main functions. In contrast to purely tensile stressed membrane constructions that offer no added value in terms of climatic insulation, spacer textiles can exploit their capacity to resist tensile forces in combination with other lightweight materials (e.g. porous and pressure-stable materials) to form a tensile and pressure-resistant material composite with insulating properties. They are suitable for industrial fabrication and in-situ production for self-supporting, thermal bridge-free, insulating single and multilayer building elements.

Research was first conducted into the production of spacer textiles, the manufacture of foams and the materialities of both technologies. Existing applications of textiles and spacer textiles in the area of wall elements, both in terms of products and research, were also the subject of investigation. In the area of products, foamed textiles are currently used for one variant of 'Big Bag' with a strong outer envelope utilised for the transportation of viscous material. Research had so far concentrated on the foaming of spacer textiles for the manufacturer of multi-material elements in moulds for the automotive industry.

Evaluation of research led to foaming of the first demonstrators in the 30 cm × 30 cm size range using the textiles as lost formwork. Using standard PE spacer fabrics employed as mattress covers and commercially available PU foams, the first goal was to determine how spacer textiles behave as lost formwork. It is apparent that the foam used behaves “lazily” in terms of expansion. This means the pile threads act as a simple barrier within the spacer textile if the foam can spread with greater ease in another direction. Accordingly, the foam only penetrates the surface if the internal pressure if the textile is too high. This leads to the creation of designs analogous to pneumatically generated architectural elements. Their elasticity means that warp-knitted spacer fabrics are potentially suitable in this respect for complex 3D structures. Woven spacer fabrics have a less drapable textile structure and are therefore better suited to planar elements. They can also be produced as multilayer structures, making them equally suitable for rear-ventilated wall elements.

Interim results showed that, on the one hand, the textile technologies (warp-knitting and weaving) and foam technologies (mechanical, physical and chemical processes) need to be appraised relative to the substances used as fibrous or foam material. On the other hand, potential process technologies for the manufacture of foamed spacer textiles represent a further reference parameter. The textiles can either be filled with pre-expanded or partially expanded foam, or particle foams can be blown in. Particle foams can either be used pre-expanded and adhered or partially expanded to finally expand when, for example, exposed to heat. Inelastic woven textiles are therefore more suitable for the latter, while the more elastic warp-knitted textiles are also appropriate for filling with pre-expanded particle foams. Parallel to the interim results, an attempt was made through a quantitative assessment of the researched fibrous and foam material parameters to define a potential mono-material combination of fibres and foams that enhances the recyclability and fire behaviour of the intended wall element made of foamed spacer textiles.

Following tests with different textile geometries, in-situ and particle foams with different expansion behaviour and different materialities, specially produced textile demonstrators measuring 80 cm × 80 cm were foamed. During testing, finally expanded EPS particle foam was used for the monolayer warp-knitted textiles, with PU in-situ foam being used for the double-layered woven spacer textile.

Figure 47: 3dTEX – Light wall element made of foamed single-layer, warp-knitted spacer fabric

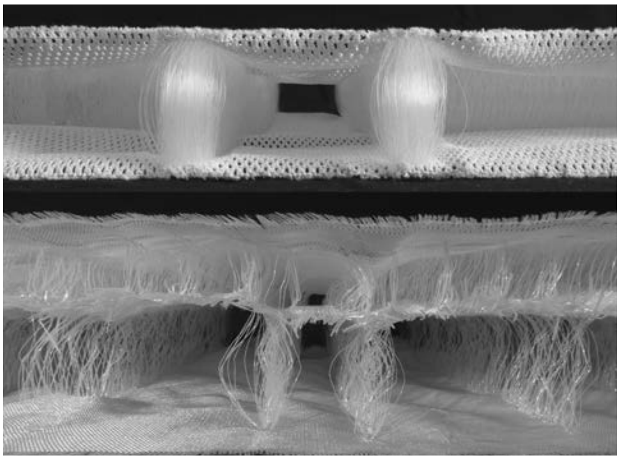


Figure 48: 3dTEX – Textile formwork: Single-layer, warp-knitted spacer fabric on top, two-layer woven spacer fabric at bottom

Figure 49: 3dTEX – Joining through hook and loop fasteners: rear-ventilated lightweight wall elements made of foamed two-layer woven spacer fabric

Figure 50: 3dTEX – Experimental student work FRA-UAS: Folded building skin made of partially foamed warp-knit spacer fabric

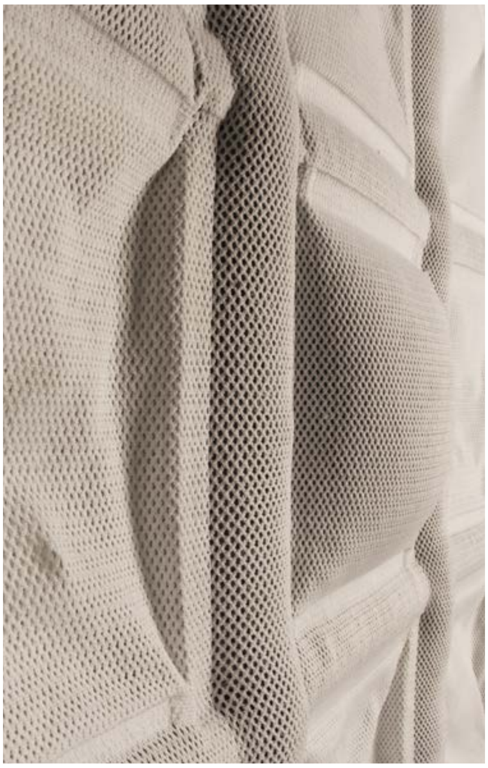


Figure 51: Folded building skin made of partially foamed warp-knit spacer fabric

It was demonstrated that, in combination with foam technologies, structurally differentiated mono-materials and semi-finished products with configurable mechanical, structural-physical and design properties are created. The realised demonstrators developed from two and three-layered spacer textiles made for the specific project illustrate different foamed design options, depending on whether woven or warp-knit spacers are involved. In addition, optimised material combinations of mineral foams and fibres were evaluated for recyclable components with good fire protection characteristics that can be further functionalised in the next step through programmed design and light-conducting, light-emitting, current-generating and temperature amplitude regulating fibres.

Key data

3dTEX

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Frankfurt University of Applied Sciences
Faculty 1: Architecture · Civil Engineering · Geomatics
Prof. Claudia Lüling

HYBAU – Structural hygiene in the hospital

Planning recommendations for structural infection prevention in the areas of surgery, emergency care and intensive care

Wolfgang Sunder, Technical University of Braunschweig

Hygiene in healthcare facilities plays a key role in protecting people from infections and, consequently, preventing serious disease progression. Immunocompromised persons come into contact with each other in hospitals, and further infectious diseases can develop during their stay.

A planning booklet published in February 2018 within the framework of the "Research for Practice" series illustrates how building structures in hospitals can be designed to have a sustainable infection prevention effect on patients and hospital staff.

Approximately 19.1 million people undergo inpatient care in Germany every year. Of these, up to 600,000 patients develop a nosocomial infection each year, leading to the death of around 10,000 people. This results in enormous damage in human resources and economic terms. In addition to other causes, infectious hospitalism can be traced back to poor hygiene and increased residual contamination on surfaces that are in direct and indirect contact with patients.

An interdisciplinary research team with experts from the fields of construction (Institute for Industrial Construction and Structural Design, Technical University of Braunschweig), materials science (Institute of Building Materials, Concrete Construction and Fire Safety, Technical University of Braunschweig) and hygiene (Institute for Hygiene and Environmental Medicine, Charité University Medicine Berlin) has addressed this issue since September 2014 and, in the HYBAU research project, investigated how hygiene could be optimised in structural and functional processes in hospitals and the use of materials in a sensible manner with a view to the efficient and sustainable design of new building structures.

The project was funded by the Federal Office for Building and Regional Planning (BBR) and the Future Building research initiative (registration SWD - 10.08.18.7 - 14.04). Hospital operators, medical device manufacturers, outfitters and planners were also involved. The research project benefited from the unique composition of the three research institutions involved and the involvement of the other partners in hospital construction.

Figure 52: Hygiene plays a crucial role in the hospital

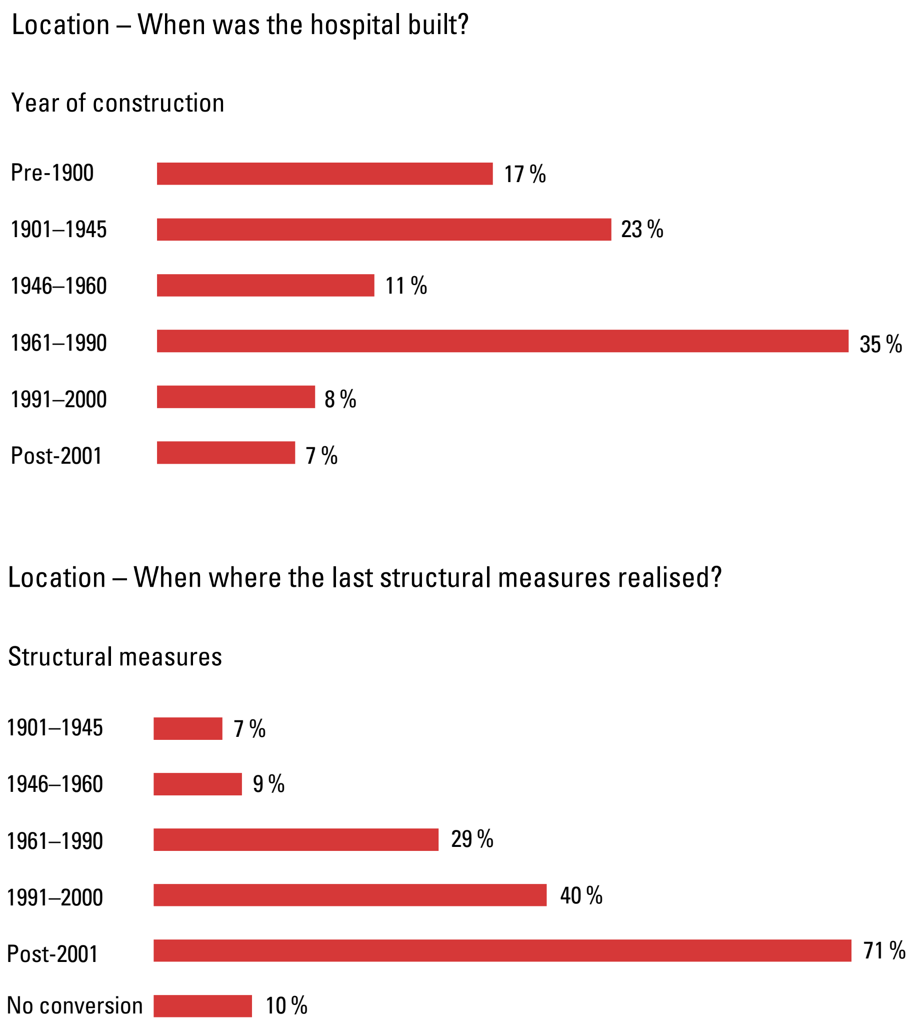

Figure 53: When was the hospital built? When where the last structural measures realised?

Figure 54: A view of the operating theatre

Location – Where is the hospital located?

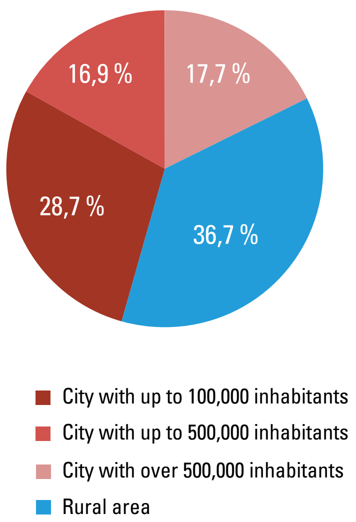

Figure 55: Hospital locations

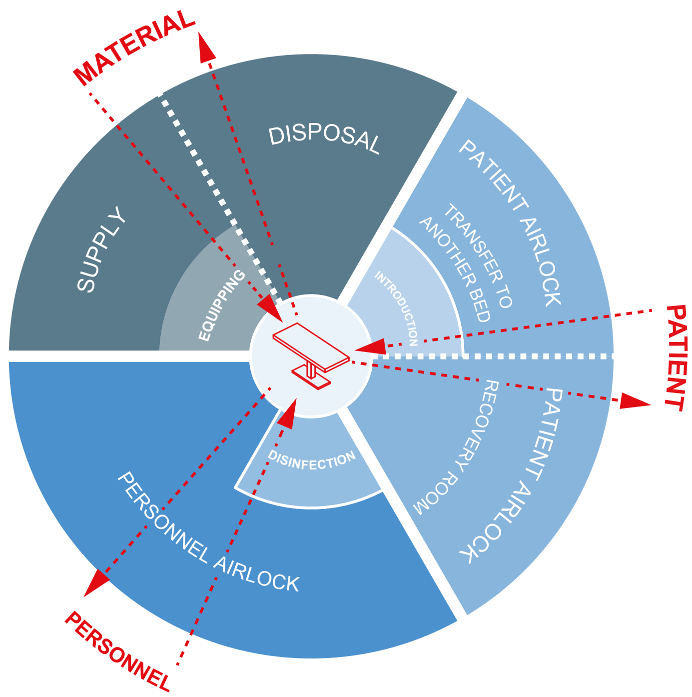

Figure 56: Gradation of hygiene relevance – patient, staff and material processes conducted separately where possible

Methods

The methods used in the research project managed to cover and assess requirements to be met in hygiene-critical areas and details and proposals for space and procedural improvements in the areas of surgery, emergency admission and intensive care units in an appropriate manner. For example, requirements for hygiene-critical areas and suggestions for the improvement of rooms and procedures were recorded and evaluated on the basis of a broad user survey.

In addition, a comprehensive empirical study of structural parameters was conducted within the framework of the Hospital Infection Surveillance System (KISS) of the National Reference Centre (NRZ) for surveillance of Charité Berlin. 621 German hospitals participated in the survey. The aim of the survey was to collect, summarise and critically evaluate existing knowledge of the actual structural situation in hospitals.

As a result of the survey, it can be stated that 65.4% of the participating hospitals are located in rural areas or in cities with up to 100,000 inhabitants, 16.9% in cities with between 100,000 and 500,000 inhabitants and the remaining 17.7% in cities with more than 500,000 inhabitants (see Fig. 55). After 2001, depending on the year of construction, between 41% and 91% of all hospitals underwent significant structural modification (see Fig. 53).

Possible effective hygienic planning recommendations for construction, processes and materials

Planning recommendations derived from the interdisciplinary cooperation build on investigations of the disciplines of construction, materials and hygiene conducted during the research project. When planning or redesigning surgery and emergency admission areas and intensive care units in hospitals, these recommendations mean that building structures can be designed to ensure that they have a sustainable infection prevention effect on patients and hospital staff. Taking the example of the operating theatre (OR), the following section explains how the structural and functional design and improved use of hygienic materials can support hygiene in this area.

Effective spatial planning is possible if the processes which take place in a surgical unit are already taken into account during the

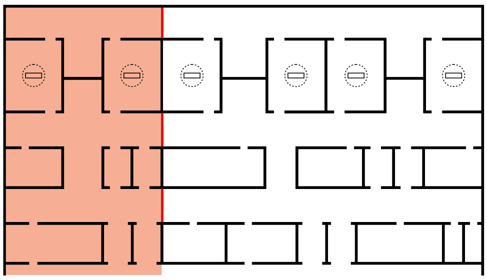

Figure 57:
Temporary separation for hospitals with a very heterogeneous surgical spectrum

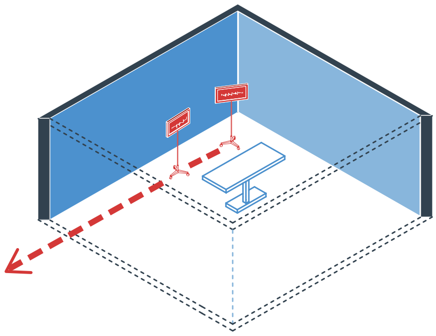

Figure 58:
Medical devices with as little floor contact as possible, fixed devices attached to the ceiling where possible

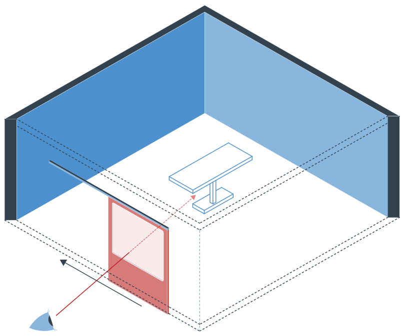

Figure 59:
Install doors with viewing windows for control and communication

Building perspectives in 2030

Helga Kühnhenrich
Director of Department – Research in Building and Construction,
Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

"Digitisation in the building sector not only benefits efficiency enhancement. It will also lead to more innovative architecture."

planning phase of a hospital. Up until now, the OR has only needed to meet a few specific functional requirements of a structural nature, so this deficit should be counteracted. Invasive surgery on the operating table is at the centre of every OR and represents a high risk of infection transmission. Separate spatial routing for clinic staff, the patient and the supply and disposal of the material should be ensured. It should be noted that the areas close to the surgical area have a higher hygiene relevance than those farther away (see Fig. 56). Medical devices in the operating theatre should have as little contact with the floor as possible, and fixed devices should be attached to the ceiling. In addition, there should be as few devices or instruments as necessary in this room. Collected external storage near the operating theatre is recommended (see Fig. 57). This ensures that, on the one hand, thorough cleaning is guaranteed and, on the other, hygienic procedures are supported. Operating theatres should be self-contained and have as few (but adequately dimensioned) doors as possible. Doors should have visibility windows. This simplifies operational procedures, ensures control and facilitates hygienic action (see Fig. 59). Attention should be given to temporary separation and the isolation of surgical areas this makes possible for hospitals with a very heterogeneous surgical spectrum (see Fig. 57). The aforementioned planning recommendations must be implemented in the respective local planning conditions and coordinated with hospital hygienists. Furthermore, the hygienic requirements are based on the structural and functional design of the respective surgical department.

With regard to the use of materials, one of the components examined was the near-patient floor in the operating theatre, and the following requirements were defined:

- The floor covering must not pose any danger to the user. Falls and similar hazards can be avoided by appropriate slip resistance of the floor covering.
- The harder a material is, the higher the resistance to permanent deformation such as scratches. Therefore, sufficient scratch resistance should be achieved.
- Scrub resistance assesses the resistance of a material to repeated cleaning, and, due to the high cleaning rate in operating theatres, high scrub resistance should be aimed for.
- Materials should withstand high stress without experiencing significant mechanical abrasion/wear. High wear resistance is required due to high stress levels in operating theatres.
- Materials should be liquid-tight.
- Floor coverings should be electrically conductive to allow for possible electrostatic discharge of electronic devices, thus avoiding their malfunction.
- The top layer of a coating should be resistant to the action of disinfectants, and the coating should retain its surface properties.
- Easy cleanability of surfaces is essential for the operating theatre. In addition to undamaged surfaces (no scratching, blistering) and a minimum number of joints, low roughness is to be recommended.

The occurrence and increasing prevalence of multi-resistant germs and nosocomial infections in German hospitals is a major problem. Much is being done in medicine and hospital administrations to avoid and contain these. However, the spatial conditions and structures of clinic buildings were not yet the focus of considerations of preventive measures.

That said, there are certainly interactions between the arrangement, distribution and size of hygiene-relevant rooms or areas of a hospital and the risk of occurrence and dissemination and the defence against hospital-specific infections.

Planning and realisation of future hospital buildings could make a noteworthy contribution to the defence against nosocomial infections if greater attention was paid to the design of hygiene-optimised building and room structures. In addition to spatial design, the architect must not forget the most important function of healthcare buildings during necessary planning of a highly complex and hygienic hospital, namely the recognition of diseases afflicting patients and their treatment and, ideally, cure. The challenges with regard to architecture therefore remain.

Key data

HYBAU – Structural hygiene in the hospital

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Ismaning

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Vorwerk & Co.
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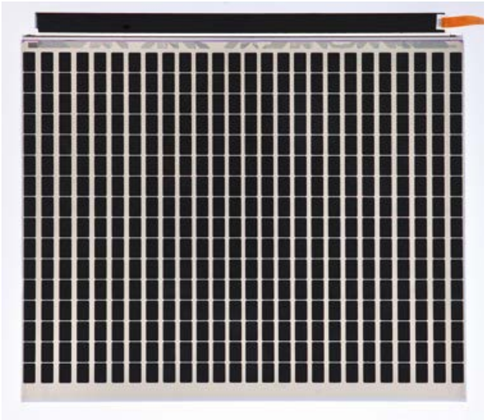
& Co. KG,
Hameln

TN technology for use in architectural glazings

Walter Haase, University of Stuttgart



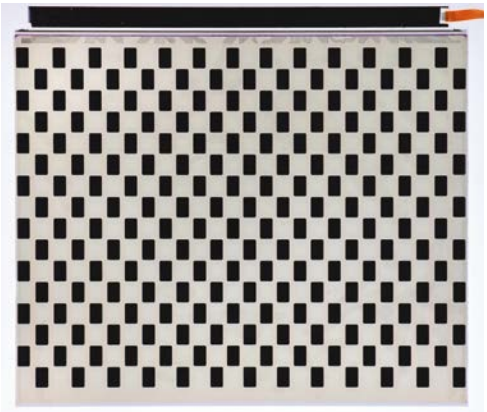


Figure 60 and 61: TN module in two different switching states: all pixels in "on" state (right), 50 % of pixels in "on" state and 50 % of pixels in "off" state (below)

Both mechanical sun protection systems and switchable glazings based on smart materials with changing properties are available for the control of light and energy input in buildings. However, most commercially available switchable glazing systems do not meet switching speed, colour neutrality or temperature insensitivity requirements to an optimum degree.

Display systems which use so-called TN technology (twisted nematic) to control the passage of light and, consequently, for displaying images and fonts are familiar from screen technology. Their switching behaviour from transparent to darkened is extremely rapid with negligible low colour distortion. A disadvantage of TN technology is significantly lower maximum transmission when compared to other switchable systems.

The aim of the research project was therefore to clarify the question of whether TN glazing is suitable as an alternative to previously known switchable systems.

An appropriate cell structure for the switchable unit (cell/module) was first defined in order to evaluate the possible applications of TN technology in façade glazings. This was followed by the manufacture of switchable TN modules and their involvement in insulating glazing.

Spectrophotometric measurements, the determination of switching speeds and long-term tests to determine the ageing resistance of small specimens of TN cells enabled empirical data for the evaluation of TN-based insulation glazing to be compiled. The type GV66 TN modules used for this purpose were manufactured by BMG MIS GmbH. Each pixel of these TN modules can be switched to "on" (minimum permeability) or "off" (maximum permeability) states via its own electrical supply line. 45 of these TN modules were integrated in floor-to-ceiling room glazing. This insulating glazing was used in the south façade of a room in the façade test building of the Institute for Lightweight Structures and Conceptual Design (ILEK). Control of the glazing was based on a simple temperature control system. This was followed by empirical investigations in the test room to determine the effectiveness of the glazing with respect to light and energy transmission control and the avoidance of glare.

The switchable glazing developed enables decoupling of the glare prevention and room brightness control functions from each other. Small-scale structuring into many individually controllable pixels also enables the display of graphic content and texts on the glazing. In fractions of a second, individual areas of the glazing can be controlled independently of one another in order to respond to rapid changes in irradiance. This achieves targeted sun and glare protection functionality with the best possible overall brightness in the room.

Figure 62: Floor-to-ceiling insulation glazing with 45 integrated TN modules. Graphic display on TN glazing ("Sky and Water I", woodcut from M. C. Escher). View from outside into room (far left).

Figure 63: Dimout pattern with graduation from maximum permeability (below) to minimum permeability (above). View from outside into room.

Figure 64: Text display on TN glazing, view from inside out

Despite the need to solve other tasks, TN glazing possesses enormous potential to achieve both an increase in user comfort and a reduction in energy consumption for building conditioning. Further investigations in this regard are currently being conducted with the aim of evaluating the system as fully as possible in terms of energy and comfort.

Key data

TN glazings

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The Future of Building

Interview with Robert Kaltenbrunner

Director of the Department for Building and Housing at the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

Current debates in the building industry revolve around increasing completion figures in residential construction and use of certain manufacturing methods such as serial construction or the prefabrication of large building units. Are these also the issues that will determine the future of building?

I consider the current absolute prioritisation of new building, with its one-sidedness, to be problematic. In this day and age, where the extent of building refurbishment drastically exceeds that of new construction, the question of the attitude to existing structures is just as relevant.

If one considers the intended goals of the energy turnaround, where an almost climate-neutral building stock in Germany should be achieved by 2050, it quickly becomes clear that refocusing on new construction will by no means suffice. But demographic change will also require an intensive examination of older buildings in future. However, we lack information about the stock of age-appropriate or barrier-free housing in Germany.

The Federal Institute for Research on Building, Urban Affairs and Spatial Development therefore attaches even greater importance to the examination of building stock in the future. We want to establish our own research cluster for this purpose.

The refurbishment rate has been pretty feeble at around 1% for years. How do you intend to achieve an increase here?

First of all, it's important to keep a close eye on renovation work to be able to intervene in a controlling manner. Information on building stock therefore has a high political relevance.

However, there's no single, binding definition for the refurbishment rate. And the renovation depth itself differs greatly. It's often a question of extremely small-scale measures, relating as it does to different energetic quality and differing comparative figures, such as the building shell or equipment. Quickly finding a suitable indicator for the improvement of energy efficiency in the building sector for different rehabilitation intensities seems to be imperative to us.

Several times already, the BBSR has recorded the structure of investment activity in residential and non-residential portfolios through extensive empirical surveys. According to these, the figures for construction work performed on existing buildings in 2016 in residential construction were around € 136 billion, of which € 38 billion was in energetic refurbishment. In non-residential construction, € 58 billion was invested in building stock, of which nearly € 19 billion was for energetic refurbishment. This study offers the only source of reliable data in all of Germany. However, it's impossible at the moment to draw a conclusion about the quality of the measures implemented. An important prerequisite for comprehensive monitoring of building stock and the associated successful control of energy transition in the building sector is the regular collection of data. One-off data collection may provide a valuable snapshot of the real estate situation, but this needs to be supplemented by continuous monitoring of development trends.

How will digitisation affect building?

There is a widespread accusation that goes something like this: In Germany, things are often planned and built as they were 50 years ago: with a plumb line and inch rule, by eyeing things up and delivering on demand. That may appear to be exaggerated. However, the question remains as to why, in the past ten years, productivity has only increased by 4% in construction, whereas the increase in manufacturing at 34 % has been about eight times as fast. A great deal of hope for the future may be attached to digitisation, but it's not an end in itself. And building information modeling (commonly known as BIM) also only represents one aspect among others. In general, it is expected that greater efficiency and transparency will lead to faster processes, more on-time delivery, cost certainty and savings. At the same time, it should be assumed that the availability of new tools in all areas of the construction value chain will directly influence design principles and the choice of materials in architecture. However, digital technologies and methods have so far hardly emerged in the construction sector itself, being usually transferred from other industries. The basic question is, under what conditions is it possible to achieve higher construction quality by digitising processes in the German construction sector. The focus should be on developing new efficiency potentials and strengthening the competitiveness and innovation of the German construction industry. It's also important to identify undesirable developments in good time and prevent rebound effects that can arise from the rash application of digital tools and methods. Research questions concerning digitisation in the construction industry should therefore always focus on controlling effects for future development.

What should we expect in future in building construction?

Up to now, one relevant aspect has, for the most part, been ignored when it comes to dealing with energy efficiency: the question of resources. But that's the real key to new building. Because building is an exceptionally resource-hungry affair. It devours not only raw materials, but also energy, and it also produces plenty of leftovers that end up in landfill. But its capacities are just as finite as global raw material stocks. Sand, a pretty trivial material at first glance, is already in short supply in certain regions, leading to illegal mining activities and organised smuggling. Conserving resources will become a central issue in future, if only because of the material price development, as can be easily seen in the cost of steel or copper. Recycling offers relief in this respect, but when it comes to building in particular, materials are usually inseparably connected with each other or already incorporated as composites. Appropriate and genuine recycling, which doesn't mean downcycling, is only conditionally possible given the current state of the art.

What approaches are there to solving the recycling problem?

This is where the cradle-to-cradle (C2C) concept comes into its own. Building design is gradually starting to focus on it and, in principle, it provides for the continuous circulation of materials – even in the technosphere. However, this not only requires a new way of thinking that challenges many of today's established standards, but new planning tools, new building concepts and, above all, new building products. These are also slowly beginning to appear in product catalogues.

The C2C principle requires for products be designed so that they don't become waste, but are traceable. Manufacturers should therefore be interested in getting their products back. In addition to the design of products, the take-back system is the challenge in this respect.

Large-format energy-efficient façades made of textile-reinforced concrete with a sandwich load-bearing effect – Development of production methods, dimensioning and joining concepts

Ann-Christine von der Heid, RWTH Aachen University

Sandwich elements with facings made of reinforced concrete usually have a thickness of at least 8 to 9 cm. The environmental and energy requirements, which the building envelope needs to meet, will grow stricter in the coming years. This means that exterior wall thickness will grow continuously due to thicker insulation. Reinforced concrete facings should be replaced with thin facings made of textile-reinforced concrete in order to counteract this.

This research project pursued the overarching goal of creating the technical basis for the production and dimensioning of large, light and energy-efficient sandwich elements for exterior walls with facings made of textile-reinforced concrete and an insulation core (Fig. 65). The achievement of a composite load-bearing effect of the concrete facing through the insulation core (sandwich load-bearing effect) was originally planned. However, this idea was abandoned because the sandwich load-bearing effect was significantly dependent on the insulation material inserted later and its bond. It was decided not to include this in the calculation in order to remain flexible in the selection of insulation material. The new approach therefore achieves the sandwich load-bearing effect exclusively through the bonding medium, meaning the insulation material can be freely selected. The thin textile-reinforced concrete facings meant that neither construction principles and bonding media nor design models of common reinforced concrete sandwich elements could be transferred to the construction and description of load-bearing behaviour.

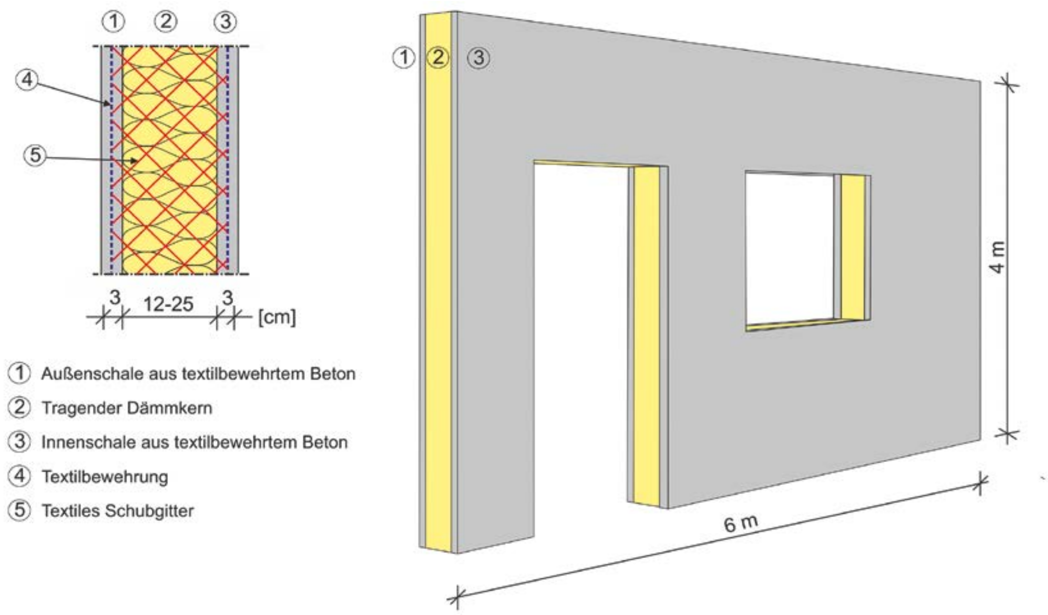

Figure 65: Research project goal – two thin textile-reinforced concrete facings with a non-metallic composite

Six working packages (AP) were defined to achieve the research goal. Requirement profiles were compiled in AP1 from a structural building physics and production point of view. Sandwich elements were then designed and pre-dimensioned based on this in order to define the minimum requirements for building materials subsequently. Suitable concrete recipes for thin

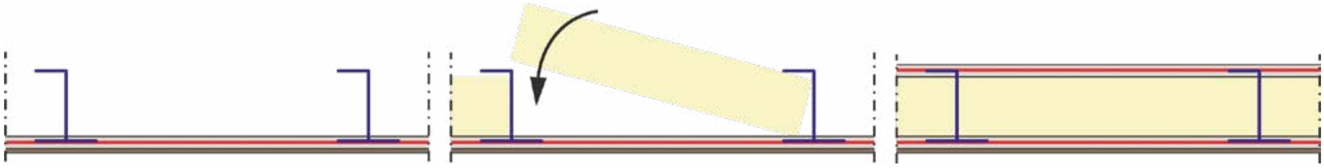

Figure 66: Production diagram

concrete facings were developed in AP2. The facings were designed to be bonded with composites with low thermal conductivity. Punctiform GFRP bonding media and linear shear grids were the point of departure for this. Decisive for the choice of the composite was the bonding depth in the thin facings and suitability in the manufacturing process. For further processing of the project, preference was given to a linear shear grid made of alkali-resistant (AR) glass impregnated with epoxy resin over a punctiform composite. The manufacturing technique for sandwich elements was developed in AP3 (Fig. 66–67). The primary technical challenge proved to be the secure positioning of the textiles and shear grids, since the textiles tend to float. At the same time, test specimens produced under factory conditions were subjected to load-bearing tests in AP4. In particular, tests were carried out on the load-bearing capacity of the textile reinforcement on slab strips, for anchoring the composite materials in concrete and for pressure capacity and shearability of the sandwich elements and the stability of the transport anchors. The overall load capacity of the system was tested subsequently on seven sandwich strips (Fig. 68). The specimens differed in the number of integrated shear grids, their width and their height. Production reasons meant that no large-sized test specimens could be produced without insulation material. Five specimens were therefore tested with a soft mineral wool and, for comparison, two specimens with a stable extruded polystyrene insulation (XPS). Test results were analysed in greater detail in the last two steps through simulations with the FE program ABAQUS. On the basis of experimental and numerical investigations, practical design models were developed that describe the load-bearing characteristics of the thin-walled sandwich elements. Two approaches were pursued in this respect: a simplified approach for square/rectangular slabs and the approach for geometrically sophisticated slabs. In the latter approach, the internal forces of the shear grids are determined by means of an FE program and then compared with the resistances determined experimentally. Since the elements cannot be connected to the building with conventional fasteners used with reinforced concrete, new fastening and connection details were developed. The project was concluded in the form of a demonstrator component to a scale of 1 : 1 (Fig. 69).

The object of the research project, namely to prove the functionality of sandwich wall elements with two thin facings, was achieved.

Figure 67: Integration of non-supporting insulation material

Figure 68: Deformation of large-scale specimen with mineral wool insulation

Figure 69: Sandwich slab with door opening

The load-bearing capacity has been determined on the basis of experimental and numeric investigations and can be considered very satisfactory. Variable spacing of the shear grids in the system facilitates individual and efficient adaptation to the anticipated effects. In addition to the load-bearing capacity of elements, production of large-sized sandwich elements with experience and skill in handling the material also poses no problem.

Key data

Large-format energy-efficient façades made of textile-reinforced concrete with a sandwich load-bearing effect

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H_2O_WoodController

Development of a safety-relevant monitoring system to detect moisture-induced problems in timber structures

Daniel Heite, Fraunhofer Institute for Building Physics, Stuttgart

Most structural damage affecting wooden structures can be attributed to the penetration of moisture. Due to the many possible causes of damage (e.g. ageing of sealing materials, errors in planning and assembly, etc.), it is almost impossible to predict where damage will occur. As monitoring systems have rarely previously been employed in the building sector, there is a need for the fullest possible monitoring of structural conditions.

Recent years have seen the increased initiation of research projects in the area of building monitoring – and researchers are also focusing on the monitoring of timber moisture. However, these all tend to fall back on severely limited measuring process available in the application area. Only a few sensors can be connected in many cases, but the measuring range of the sensors is severely restricted to a localised area and, very often, batteries need to be changed on sensors and measuring instruments.

The H_2O WoodController compensates for these application restrictions and enables the conducting of practically fully comprehensive and cost-efficient analyses of a building's structural condition. The functional principle of the sensor is described below using the example of a recently developed sensor segment made of laminated timber.

This sensor segment consists of three layers of spruce wood. Inserting wire meshes electrically conductively renders the glued joints. The wire meshes are contacted via cables and connected to a newly developed resistance meter. The central layer of the GLT sensor segment acts as an electrical conductor, enabling determination of the wood moisture content on the basis of "cable resistance".

- Decreasing "cable resistance" = increasing wood moisture content
- Increasing "cable resistance" = decreasing wood moisture content

With regard to the sensor segment, the central layer of the sensor field (solid spruce wood) is regarded as an electrical conductor whose electrical conductivity varies depending on the respective moisture content.

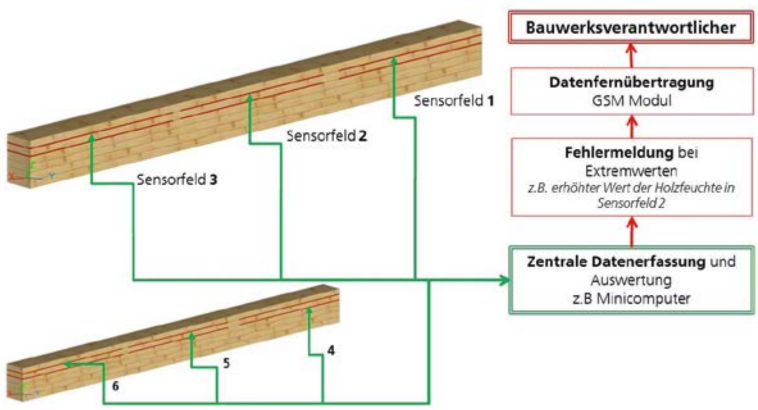

Figure 70: Graphic illustration of the bridge supports with sensor segments (plan view)

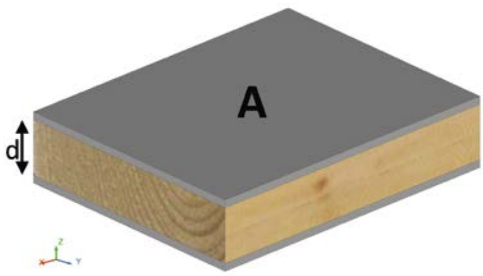

Figure 71: Possible measuring point contacting variants

Figure 72: Retrofitted sensor segment solution with thin prefixed segments

The cable resistance R in Ω of any given material can be calculated for any given dimensions using the equation $R = \frac{\rho \times d}{A}$. In this context, ρ = specific resistance in Ω mm²/m, d = thickness in m and A = area in mm².

The specific resistance for the respective temperature and moisture conditions can be calculated by transposing the equation (1) for ρ via the measured resistance R. The traceability of the measured resistance values to the specific resistance is advantageous in that the dimension A of the sensor fields can be varied as required, particularly with regard to practical applications as a large-scale wood moisture monitoring system.

16 sensor segments (dimensions: 260 × 100 mm, total thickness: 15 mm) were prepared to determine the specific resistance of spruce wood. These sensors were exposed to different climatic conditions and electrical resistance was continuously measured. Several gravimetric measurements were conducted to determine the wood moisture content. A final kiln-dry test enabled determination of the exact wood moisture content of the sensor segments at the time of gravimetric measurement, and it was possible to assign the specific resistance of the wood moisture content.

The approximation equation $R_{spec.} = 2E\text{-}0.5\ u^{-10}$ describes the correlation between the wood moisture content u and specific resistance R_{spec} of spruce wood at 20 °C.

The following monitoring concept is possible for a composite wood-concrete bridge.

Figure 73: View of the Neckartenzlingen bridge with fitted sensor segments in the intermediate layer area

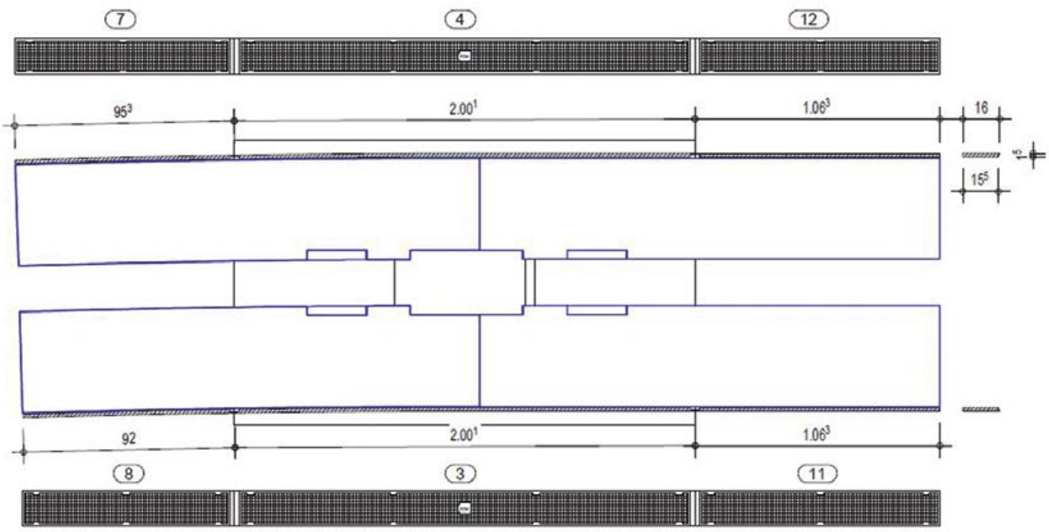

Figure 74:
Graphic illustration of the bridge supports with sensor segments

Composite monitoring of transition area

- Wood – concrete – maximum damage potential (damage in the sealing layer and moisture penetration caused by this can cause damage to the support structure which could go undetected for many years.)

Monitoring of support areas

- Blocking of drainage systems frequently leads to moisture development and damage in the support area.

Underside monitoring

- Detection of long-term poor structural-physical conditions (e.g. permanently damp ambient conditions due to severe proliferation of vegetation in the support area)

The broad range of sensor dimensions available means that an adaptation to numerous structural conditions, design details and application cases is conceivable. In addition, the measuring instrument offers the possibility to expand the monitoring concept through the addition of further sensors (e.g. humidity and temperature sensors).

The primary goal of the research project was to realise a comprehensive system for the monitoring of wooden structures which takes the variety of connection and installation situations which can arise into consideration. The focus was, therefore, on the development of a process for area-based wood moisture content measurement. A further goal was the development of a measuring instrument adapted to these applications with an option for reliable remote data transmission and flexible use of the most varied sensors. Comprehensive laboratory measurements indicate that the functional principle of area-based wood moisture content measurement delivers good and reproducible results. Only the measurement of very high wood moisture content levels > 20 % is likely to produce errors. Following the project, prototypes of the measuring instrument were installed on a newly erected wooden bridge in Neckartenzlingen and investigated in continuous operation.

Key data

H2O_WoodController

Researchers:
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Daniel Heite (Project Management)

Testing new forms of living: The vario apartments model project

Anne Bauer, Federal Institute for Research on Building, Urban Affairs and Spatial Development

Social change demands a rethinking of housing planning and construction. The shift towards ever more diverse lifestyles, a more mobile society and progressive urbanisation are increasing the demand for low-cost, small and variable housing in cities and conurbations. The funding program for model projects relating to sustainable and affordable construction of vario apartments involves testing and research of innovative living concepts for students and trainees in 19 projects.

The demand for housing in German cities and conurbations has been growing for years. Rents have increased significantly, especially in prosperous metropolitan regions, cities and university locations. It is becoming increasingly difficult to find affordable housing in these areas. In particular, a mobile society in which two homes are no longer the exception, new and ever-changing forms of individual and shared lifestyles and an ageing society are increasing the demand for small and variable housing. In addition to older people, refugees, young professionals and commuters, it is students and trainees who are affected by this tense situation.

Against this background, the Federal Ministry of Building established the funding programme for model projects relating to sustainable and affordable construction of vario apartments at the end of 2015 as part of the Future Building research initiative. This programme provides funding for sustainable housing projects for students and trainees. They keep fixed maximum rents low (no more than € 320 per domicile and per month) and create innovative housing solutions that can be rapidly built and are sustainable. Consequently, subsequent reuse is already taken into consideration during the planning of vario apartments. Flexible and easily changeable floor plans ensure that the apartments are adaptable for future usage and, potentially, families or senior citizens.

The testing of innovative living concepts should provide answers to the question of how densification could be adapted to the

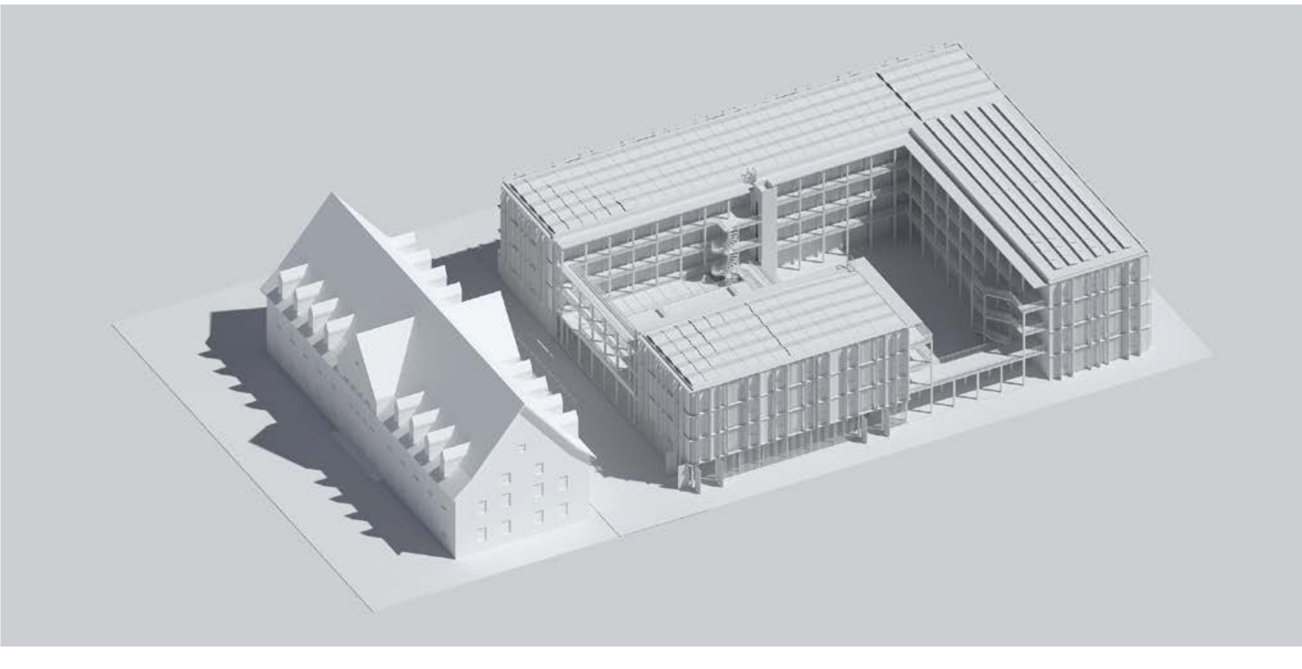

Figure 75: A self-governing student hall of residence for communal living and learning with 158 residential spaces is to be created on the site of the former US military hospital in Heidelberg-Rohrbach in a combination consisting of innovative timber construction and the conversion of two old buildings. The new building, which has been funded under the programme, has generous communal areas and is to be built as a timber construction. This involves a high level of prefabrication and dispenses with metallic joints.

Figure 76: A newly designed urban district is being built on the former site of a prefabricated residential complex. The final stage of the five buildings planned is a development with 126 vario residential units. Planning provides for differentiated and generous shared indoor and outdoor spaces. The outdoor areas in particular, such as the barbecue site and sports facilities, can encourage a sense of identity among residents and in the neighbourhood.

Figure 77: Accommodation for apprentices with 190 residential spaces is being built in Hamburg-Harburg. This development is intended exclusively for apprentices with a valid apprenticeship contract. Since the area was originally intended for the volunteer fire brigade station, the integration of this facility makes the creation of this living space possible here.

Figure 78: **Vario living: Locations of model projects**

Figure 79: The former dental clinic in Erfurt is being converted by the Thuringian Student Union (Studierendenwerk Thüringen) into a residential building with 251 residential units. Located in the immediate vicinity of the university, the twelve-storey building is constructed as a reinforced concrete column and beam system. This makes modernisation as a modular system with a high degree of modularity and prefabrication of elements possible.

requirements of an ageing and changing society and aspirations relating to individual housing needs in the community. Special attention is paid in this respect to innovations in the field of modular and prefabricated construction and the question of how far architectural quality can be reconciled with low rent.

The level of funding depends on the innovation potential of the respective project, and this in turn hinges upon the degree of fulfilment of various eligibility criteria. The aim is to shorten construction times and save costs through optimised planning processes, element and module-based prefabrication and serial production (funding module 1 (FB1)). Special expenditures for the reduction of operating costs (FB 5) are to be implemented in the projects to reduce ancillary costs and ensure that rents are affordable. In addition to the required flexibility (FB 4), sustainable aspects of housing encompass innovative concepts for living in a community (FB 6), consideration of (retrofittable) accessibility (FB 3) and ecological open-space design (FB 7). Building on residual areas, a high degree of urban design quality (FB 2) and the structural provision of an option for using the ground floor for non-residential purposes (FB 8) ensure resource-efficient densification and networking into existing districts.

Integrated scientific support during each project examines innovative planning, construction and re-use processes. Requirements relating to vario apartments and their implementation in practice are documented and analysed to create a basis for the development and sustainable use of innovative living concepts. The required sustainability certification provides a summarised and comparable depiction of the sustainability aspects of the projects and serves as an integral planning tool.

The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), which is responsible for technical and scientific supervision and administrative implementation of the programme, translates the findings gained into the superordinate technical and current context in a cross-project evaluation. This is supported by a team commissioned by the BBSR from the sol•id•ar planning workshop, Ostwestfalen-Lippe University of Applied Sciences and HTW Berlin University of Applied Sciences.

19 projects at various university locations were selected for funding by a panel of experts. These range from a small inner-city infill development with 20 dwellings to a new development project with around 400 apartments. This will create around 2,600 residential units, primarily for students, but also for trainees. These will be available to tenants by 2020 at the latest, as all projects must be implemented by the end of 2019. Initial measures have already commenced with the construction. Funding totalling € 35 million will be provided to public-sector institutions such as student unions, housing associations and numerous projects from small private investors.

Accompanying research in the model projects for sustainable and affordable construction of vario apartments

BFvario: sol•id•ar, HTW-Berlin, HS-OWL

Small, flexible and affordable apartments are in short supply, especially in metropolitan areas and student hotspots. Demographic change also demands new housing and care concepts. Vario apartments can relieve bottlenecks in this respect. Vario and micro-dwelling concepts already exist in a variety of different forms. Market penetration and broad, rapid implementation of concepts, especially with regard to existing building stock, must be intensified.

Planning and realisation of several model projects nationwide is being supported by higher-level accompanying research in a process extending over several years. The model projects set their own individual priorities and also evaluate these scientifically with their own research team. The accompanying research team collects, structures and compares this data across projects. In addition to hard figures, soft factors that can significantly determine the success and performance of the projects are also examined. In the context of project-related interviews, planners and builders are to be interviewed about process flows, decision making and user involvement.

Another focus will be the analysis of planning, construction and operating costs which will be examined in the context of lifecycle cost analysis in different phases of the project. Construction technologies and prefabrication concepts will be analysed in terms of their cost-saving potential. All model projects will be certified according to the systems operated by NaWoh, the association for the promotion of sustainability in housing construction, or the German Sustainable Building Council (DGNB) as proof of a comprehensive understanding of quality.

It is also planned to establish a network for a professional exchange relating to all aspects of vario apartments. The central contact point is the website on the portal of the Future Building research initiative. Options for the exchange of experience in the form of internet forums and various events will be offered to the various

Figure 80: Data acquisition concept through higher-level accompanying research

Figure 81: New construction of a student hall of residence on residual site (Wuppertal model construction project, ACMS Architekten)

interest groups. In addition to the internal exchange of knowledge and experience at regular network meetings, important results will also be presented to the public with a professional interest in the context of symposia.

Comparisons will be made with "standard" housing construction as part of the cross-evaluation. In particular, appropriate parameters and features are of interest for the characterisation of vario apartments. These should go beyond merely superficial characteristics and cover the following topics:

- Elaboration and documentation of particularly suitable building and plant engineering standards for vario apartments
- Development and documentation of a typology for vario apartments at the building and spatial structure levels
- Determination of absolute efficiency indicators (energy, areas) and specific figures per resident/residential unit
- Analysis of effects when using different methods in planning and construction processes: integral planning, digital planning, Building Information Modeling (BIM)
- Investigation of innovations in the field of modular and prefabricated construction (with regard to the prefabrication process, detailed training, building materials/material)
- Description of the framework conditions for rapid and economical construction of flexibly usable and sustainable micro-apartments, especially for urban/metropolitan areas
- Basic research in the area of architectural-sociological analysis of flexible housing and the close coexistence of different population groups within common housing structures.
- Recommendations for mixed usage and combinations of use in vario apartment buildings (usage proportions, usage synergies, etc.)
- Comparison of reuse and conversion concepts in planning and practice and across projects
- Best practice examples for the implementation of spatial, social and design qualities in a low-cost context
- Cross-comparisons in the context of sustainability certification/lifecycle assessment (differences/similarities, DGNB, NaWoh)

Through comprehensive accompanying research, cross-sectional analysis of more than 19 model projects offers the opportunity to examine innovative planning, construction and usage processes intensively from the very outset from the perspective of building practice and the expansion of theoretical principles for field-tested vario apartments.

The most important goal of the accompanying research is the compression and transmission of collected experience and project data in the form of recommendations for action. These recommendations are prepared in a stakeholder-specific manner as a planning guide and assigned to individual planning and implementation phases from determination of requirements, planning and approval to operation and the utilisation phase.

Key data

BFvario

Researchers/Project Management:
Accompanying research team consisting of:
- sol•id•ar planungswerkstatt berlin (Project Management)
- Ostwestfalen-Lippe University of Applied Sciences, Detmold School of Architecture and Interior Architecture
- HTW Berlin/Faculty of Regenerative Energies and Climate Responsive Design

Total costs: € 925,544.44
Federal subsidy share: 100 %
Project duration: until end of 2019

Figure 82: Residential development in central location and revitalisation of inner-city districts (Chemnitz model construction project, Brühl 65, raumfeld architekten)

Buildings as intelligent components in the energy system – Load management potential of buildings in the context of the future energy supply structure in Germany

Manuel de-Borja-Torrejón, Technical University of Munich

The expansion of renewable energy is promoted in Germany. In order to exploit the resulting power generation fluctuations (Fig. 80) in the electricity sector, one approach adopted is to adapt consumption to generation. Space heating offers potential in this respect. In view of the existing renovation backlog in the building sector, sector coupling of this nature should also be considered as an accompanying measure to achieve climate goals.

This project examined the impact of increased interaction between the building and electricity sectors. A coupled simulation approach was chosen in order to analyse the influence of buildings and their load management potential on the electricity system until 2050. Detailed building models and their heat generation (including control) are coupled with a power system model in this respect (Fig. 81).

Building models are classified according to building types and energy efficiency classes,

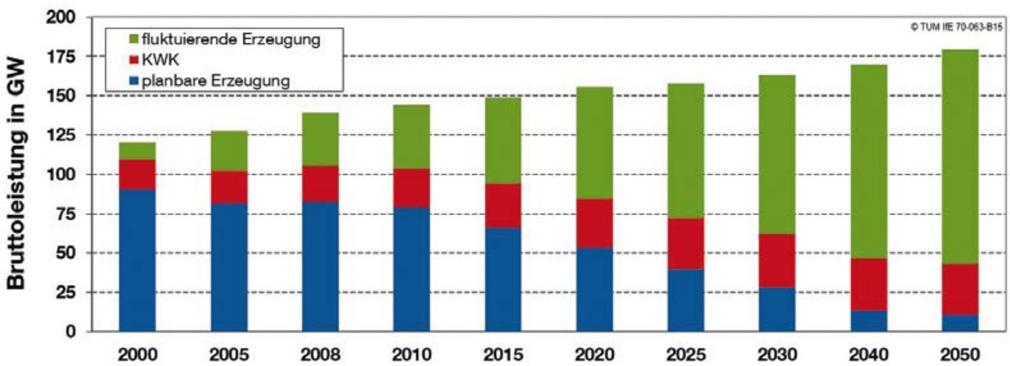

Figure 83: Development of the gross output of power plants in Germany, with a sharply rising variable renewable share and a decreasing share of predictable conventional and controllable generation from CHP

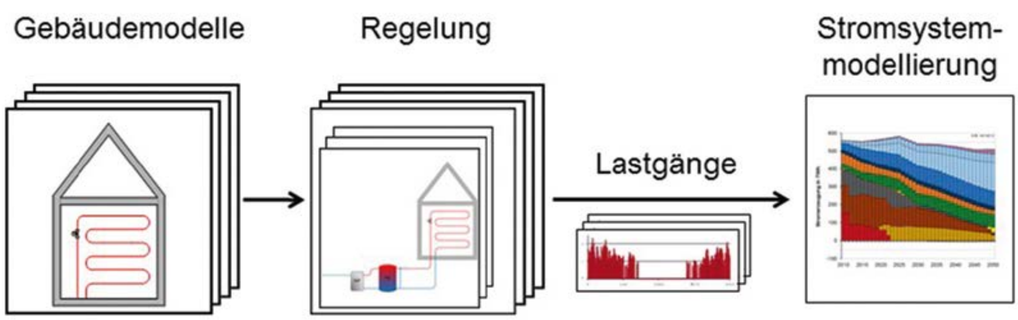

Figure 84: Model coupling method involving building models, plant engineering and control and electricity system modelling

Building perspectives in 2030

Gerhard Schubert
Senior Researcher, Head of the CDP Research Group

Technical University of Munich
Department of Architecture
Department of Informatics (affiliate membership)
Chair for Architectural Informatics

" Seamless use of analyses and simulations in early planning phases broadens the margin of discretion of planning decisions. Processes with specialist planners, stakeholders and citizens are incorporated into early planning phases and change the shape of cooperation on a sustained level. "

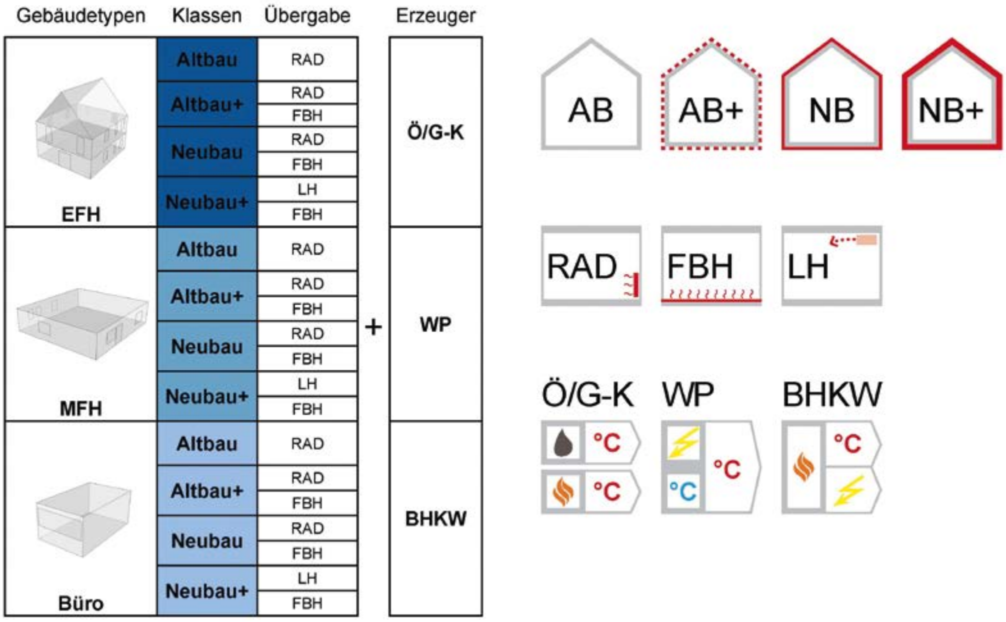

Figure 85: Overview of building model and considered heat generators

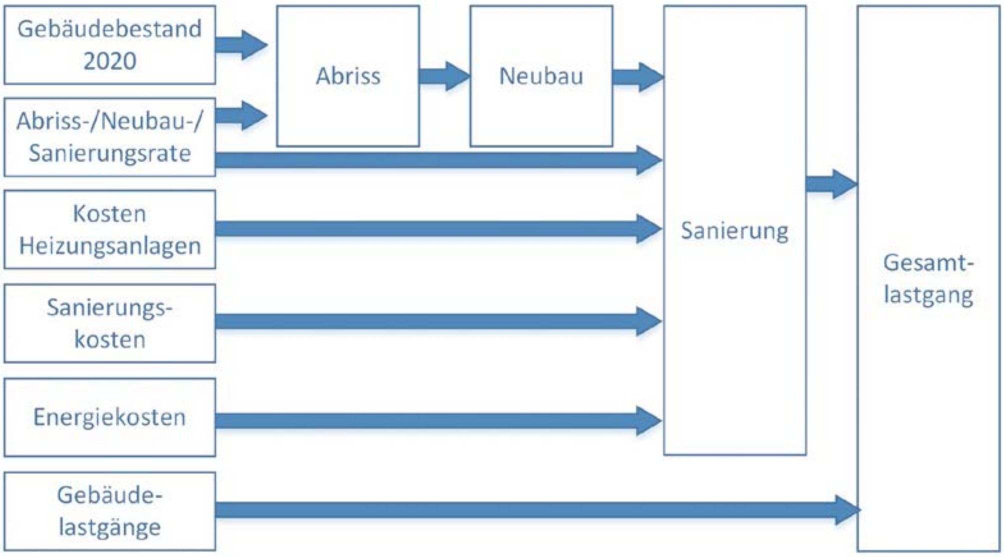

Figure 86: Basic structure of tool for calculation of building development and the total load profile

with the typing used (see above) serving as the starting point. Single-family house (EFH), multi-family house (MFH) and office (office) building types are modelled, whereby a total of approx. 75% of the final energy consumption is taken into account for room heating. Each type of building is divided into the four energy classes: old building (Altbau (AB)), old building+ (Altbau+ (AB+)), new building (Neubau (NB)) and new building+ (Neubau+ (NB+)). In addition, different heat transfer systems are considered according to the type of building and energy efficiency category. The various building models are further combined with heat generators (Fig. 82). In addition to conventional generators such as gas and oil boilers, heat pumps are also available here.

Development of the building and plant structure and its transformation up to 2050 through demolition, new construction and renovation were considered in the project. A software tool was implemented for this purpose for the selection of renovation decisions and plant technologies, taking various scenarios into account (Fig. 83). The selection tool initially considers the demolition and new construction of buildings based on current building and plant stock (see above). A fixed proportion of the buildings are subsequently rehabilitated,

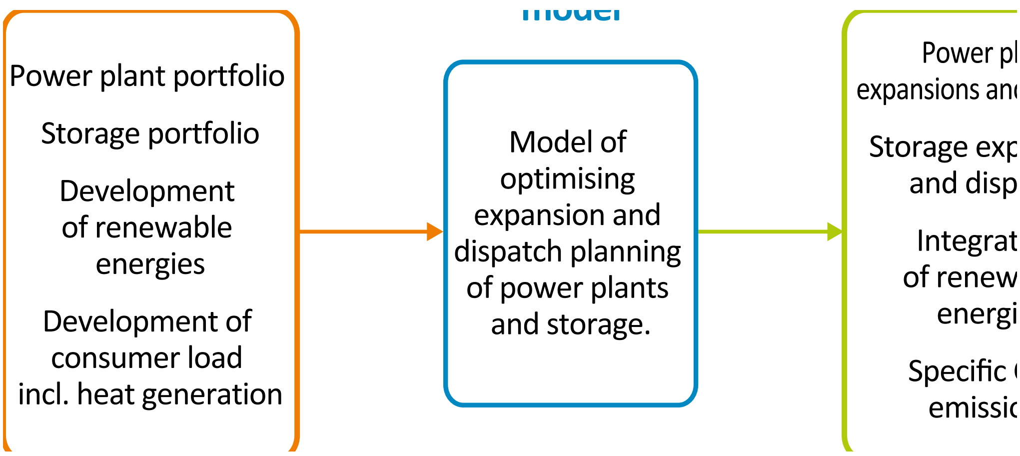

Figure 87: Schematic depiction of electricity system model

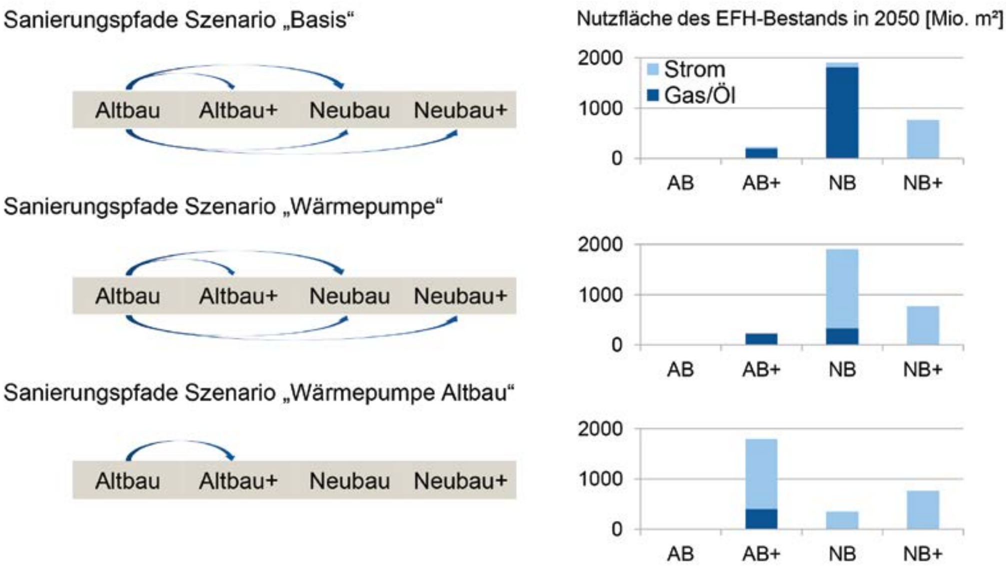

Figure 88: Existing premises of single-family house type (EFH) in 2050 calculated according to energy sources for room heating, for “Base”, “Heat pump” and “Old building heat pump” investigation scenarios

a process which includes both structural measures and replacement or new construction of the heating systems. A total electricity load is determined with the aid of the new building distribution identified and load profiles obtained from the simulation and transferred to the electricity system model.

The impact of electricity-based heating on the building stock is analysed using the IMAKUS electricity system model (see above), the aim of which is to cover the demand for electricity at all the times examined at a minimal cost (Fig. 84). The starting point is the existing power plant portfolio in Germany and currently existing pumped storage power plants. The IMAKUS model can set different targets for the share of renewable energies in the electricity demand. 80% were assumed until the year 2050 for investigations within the framework of the project. The findings of the model include an optimum power plant and storage expansion. System reliability is taken into account by calculating secured power plant output.

Various scenarios for the refurbishment of buildings and plant engineering are examined on the basis of the described procedure. In the “Base” scenario, renovation is realised as economically as possible, while heat pumps are enforced in plant engineering in the “Heat pump” and “Old building heat pump” scenarios, whereby in the latter case, renovation is only realised to the occurs in old building+ standard (Fig. 85). Analysis occurs over several reference years. The resulting total load profiles of building stock

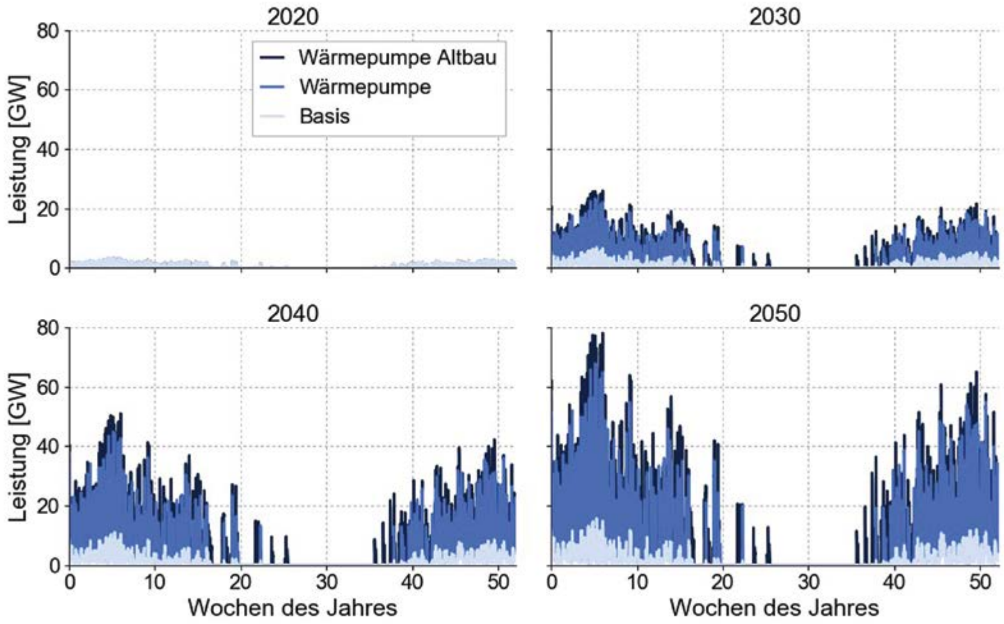

Figure 89: Total load profile for reference years for "Base", "Heat pump" and "Old building heat pump" scenarios

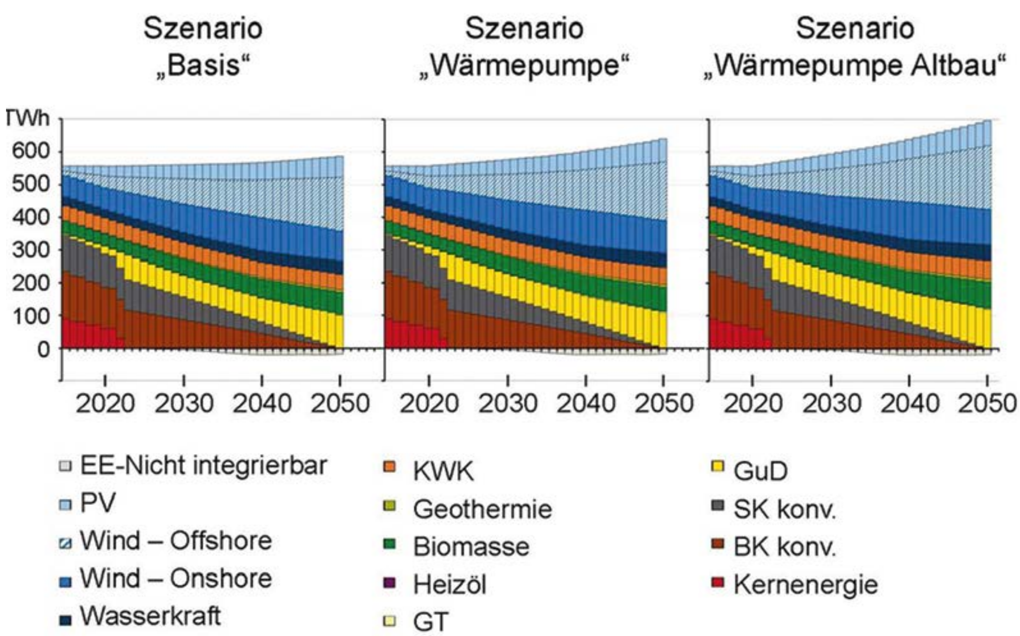

Figure 90: Power generation structure for "Base", "Heat pump" and "Old building heat pump" scenarios

are illustrated in Fig. 86. These were added up for the rest of Germany's electricity demand in order to analyse the future development of the power generation structure in the aforementioned scenarios (Fig. 87).

The influence of load management potential on the electricity system is analysed in the "Heat pump" and "Old building heat pump" scenarios. In addition, the "Optimised" and "Not optimised" variants are also compared with each other in the "Heat pump" scenario, whereby the electricity load profile of the buildings in "Optimised" is adapted on the basis of the electricity price. The results were examined with regard to the composition of power generation, expansion and behaviour of large-scale storage facilities and development of CO_2 emissions.

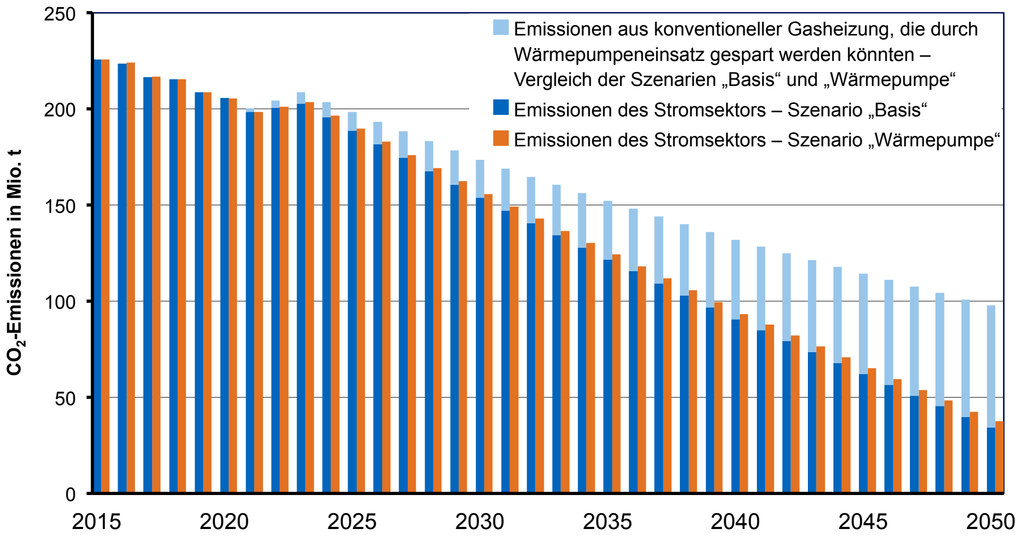

Figure 91: Comparison of CO_2 emissions. Comparison of “Base” and “Heat pump” scenarios

The coupling of space heating with the electricity system will result in an increase in electricity demand by 2050 in all scenarios. This additional demand can be met to a large extent from renewable energies. Emissions for electrical heat generation are far lower than those of conventional gas heating (Fig. 88). This trend is reinforced by load management. In addition, storage investment can be decreased and storage losses reduced through more direct use of renewable energy. According to this investigation, sector coupling will primarily result in positive aspects. However, a significant expansion in network capacity may be necessary.

Key data

Buildings as intelligent components in the energy system

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Feasibility study of continuous and formwork-free construction process with 3D printing of fresh concrete

Mathias Näther, TU Dresden

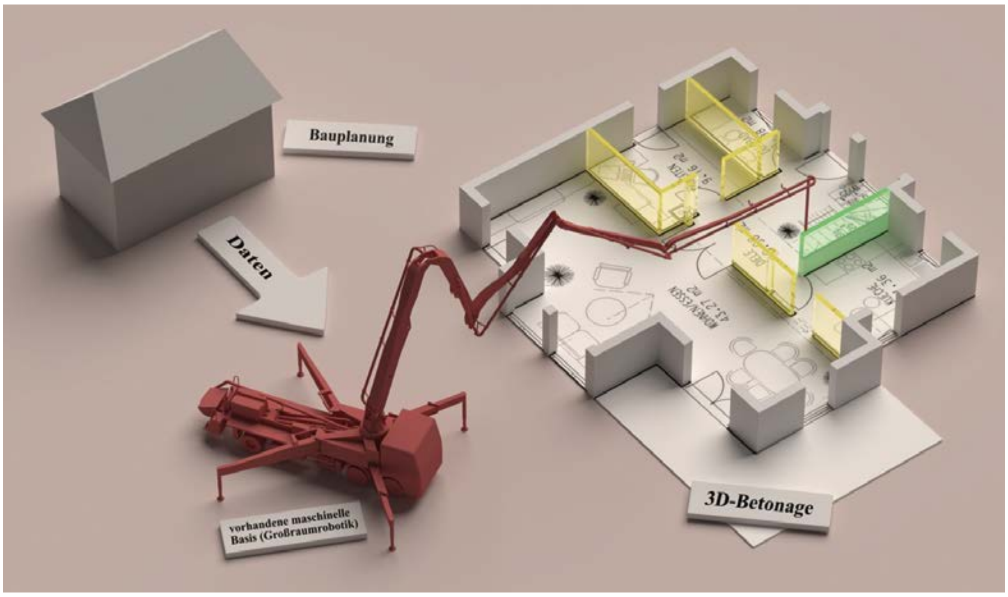

Figure 92: The essential elements of concrete 3D printing technology

Common in-situ casting of concrete is highly labour intensive and time consuming. Researchers around the world are currently investigating methods to transfer established 3D printing technologies to building processes. This could limit deficits in conventional concrete construction, reduce costs and increase working productivity. The purpose of the research project was to investigate the feasibility of an innovative, formwork-free construction process at an interdisciplinary level (mechanical engineering, building materials technology and construction management).

Figure 93: Concrete 3D printing directly on the construction site (animation)

Taking previous international research findings into consideration, measures and conditions which would enable use of efficient formwork-free systems for casting concrete were first analysed. In contrast to hitherto familiar approaches, this research project focused in particular on practical implementation. The innovative construction process should be realised directly on site (in-situ concrete casting), with equipment based on established building machinery and concretes commonly used in solid construction providing the materials.

Known additive manufacturing processes were analysed within the research project and their potential suitability for building processes examined. Requirement criteria were subsequently defined for the site process and investigated at an interdisciplinary level. The Chair of Construction Machines investigated technical solutions for concrete pumping and the printhead and mechanisms employed for large-scale robotics. The Institute of Construction Materials investigated the rheological properties of fresh concretes and mechanical properties of hardened concretes and developed concretes suitable for 3D-printing. The Institute of Construction Management focused on critical areas of the building process. Analyses focused on building process optimisation, investigations of required data structures and data formats and feasibility studies of cost and time reduction potentials.

As a technological concept, it is intended that a printhead will discharge layers of concrete while it is moved precisely along predetermined paths by a large-scale manipulator. Following comparative studies of different robotic concepts, the truck-mounted concrete pump became the focus of machinery investigations. The truck-mounted concrete pump is equipped with the necessary concrete delivery technology as a standard feature, and the mechanical structure of its boom is suitable as a large-scale manipulator. Control algorithms were developed for computer-controlled movement of the boom and tested in collaboration with the industry partner on a commercially available machine. Statements regarding the positioning accuracy of truck-mounted concrete pumps proved possible following a comparison of the measured coordinates of the automatically controlled masthead with the predetermined path of motion.

The main functions of the printhead include the controlled discharge of fresh concrete and the casting of individual layers of concrete. Different solutions for individual subtasks were developed and evaluated for technical implementation. These will serve as a basis for the further development of the overall system.

Building material analyses focused initially on the selection of source materials and the determination of suitable compositions of printable concretes. These should be selected so that the concrete exhibits a high green strength and rapid hardening properties at an early age (0–3 hours) without any impairment of processability and pumpability in the fresh state. Following this, a scenario catalogue was compiled with a variety of source materials. Suitable methods were then developed to examine the mechanical properties, extrudability and buildability of different concretes. A holistic approach to experimental material testing of printable concretes was developed in this context which combines several investigation processes. 3D-printed specimens were created to investigation compressive and flexural strength and systematically tested with the aid of this new experimental approach ("lab testing device" for 3D printing). Further printable concretes were designed with different source materials in the final phase and characterised for a variety of application cases. Experimental studies confirm the feasibility of formwork-free extrusion of fresh concrete through 3D printing. The printable fine-grained concretes developed are distinguished by their good extrudability, adequate buildability and high compressive strength.

User requirements and possible application scenarios were first analysed in construction investigations. Replacement of masonry was defined as the main application for the first development step. The majority of application areas are to be found in residential building, especially up to 5 floors. Following this, an analysis of required data structures and data formats was conducted. The basis for this was the process chain of existing small format 3D printing procedures. The analysis of cost efficiency was conducted on the basis of an example building the size of a single-family house. Construction costs and the impact on deadlines for production of wall elements in the envisaged process were examined during this in comparison with conventional masonry construction. The results proved that a significant reduction of construction costs and execution times was achievable with the envisaged process.

Figure 94:
Laboratory testing device for 3D concrete printing (CAD representation)

Research findings verified the feasibility of the suggested concrete technology. Key results were as follows:

- List of specific requirements for machine technology (printhead, robotics, concrete pumping)
- Suitable fine-grained concrete compositions and methods for testing the technological properties of concrete

Figure 95: Section of a printed concrete wall (above)

Figure 96: Specimen

- Profitability analyses of construction costs and times
- Demonstration through laboratory trials to the scale of 1 : 5 with the aid of a testing device.

The basis for further development of this construction process has thus been established, both in technical and economic terms. The award of the "bauma Innovation Prize 2016" for this research and the growing interest demonstrated by industry and the public underline the major importance of this project. Therefore, the project participants urgently recommended that research be continued until practical implementation of the technology.

Key data

Concrete 3D printing

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Trends and structures in the building industry

Christian Schmidt, Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

The general public's interest in the development of building activity in Germany focuses almost exclusively on the building of new homes. This applies all the more in times where there is a strong influx into metropolitan areas, as these are particularly attractive to the young and well-educated. However, this very one-sided view greatly distorts the image of the building industry, because it is measures in existing buildings which actually determine the construction process.

The background to this unbalanced depiction and perception of the economic situation in the building industry can be essentially explained through the data situation. Official statistics provide reliable and timely information for the construction industry and new building activities often associated with it. On the other hand, building installation and other sectors of the finishing trade which are particularly involved in renovation and modernisation measures are statistically underrecorded. Over 90% of companies in the finishing trade are below the recording limit of less than 10 employees. However, the finishing trade is now achieving higher turnovers and employing more people than in the main industry. In addition, other sectors also generate a considerable volume of building services, including sections of the manufacturing and service sectors, but this building work is insufficiently acknowledged in official statistics. Furthermore, building activity in existing buildings is not indicated separately in building investment, although renovation and modernisation measures comprise the majority of building activity. This is especially significant for increasingly energetic renovation measures. Equally, no regional subdivision into east and west occurs. These gaps are closed by the German Institute for Economic Research (DIW), Berlin with the calculation of construction volume conducted by the DIW on behalf of the BMI and BBSR in the context of departmental research in the Future Building initiative. Based on a complex estimation model developed by DIW Berlin, calculations and forecasts are made annually in order to close the information gaps in official statistics. Building industry activities and structures can be illustrated comprehensively on this basis. Results of the most recent calculations are presented here.

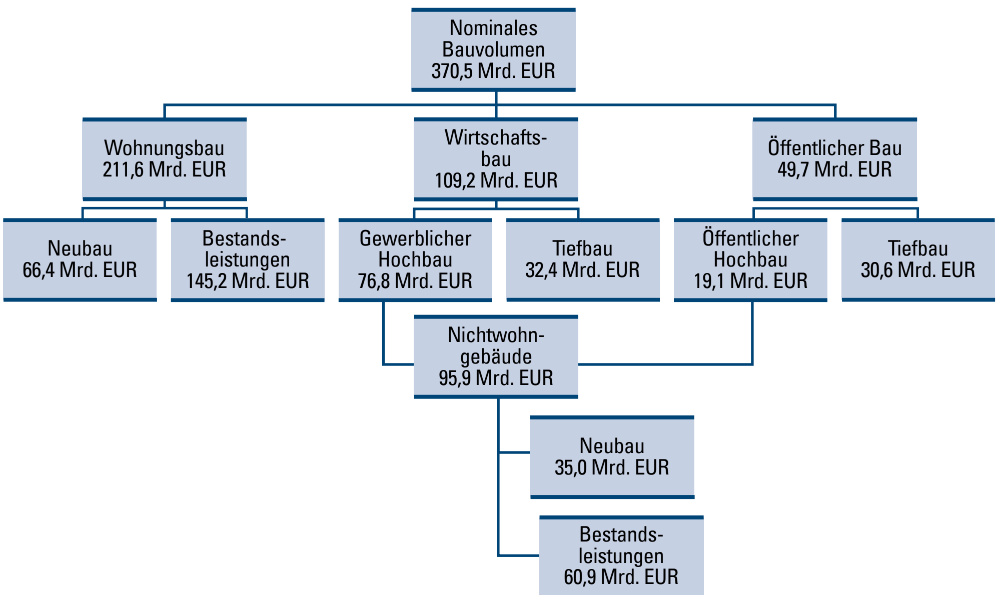

Figure 97: Construction volume in 2017 by construction sector (at current prices)

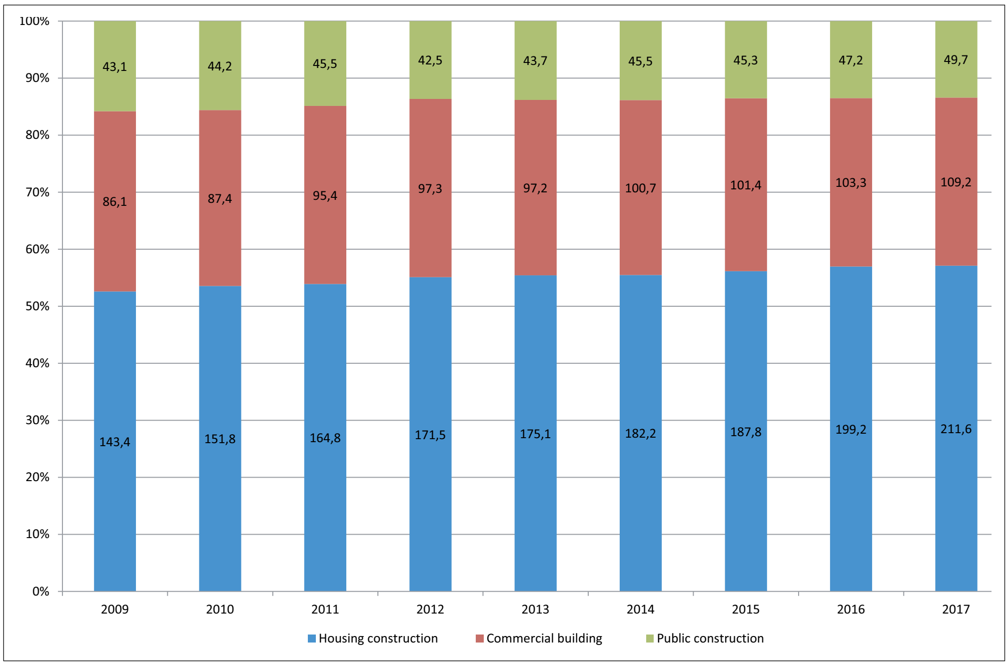

Figure 98: Nominal construction volume by construction sector from 2009 to 2017 (at current prices in € million)

Figure 99: Nominal construction volume by producer from 2009 to 2017 (at current prices in € million)

Around € 370 billion (in current prices) flowed into the construction and maintenance of buildings[1] in Germany in 2017. This is equivalent to around 11% of gross domestic product (GDP). The German construction volume is dominated by housing at 57%, with this share having increased in particular in recent years. Above all, construction of new multi-family homes has been recording double-digit growth rates for many years. Growth in this segment was even higher from 2013 to 2016 in the new German federal states than in the west, mainly due to the high demand for apartments in Berlin. However, a countermovement is currently emerging, as there was also considerable investment in cities in the west of Germany. Just under 30% of the construction volume is attributable to commercial building, with public building accounting for around 13%.

Most construction work takes place in existing buildings. Although the relative importance of renovation and modernisation measures is decreasing due to the boom in new housing construction, they still account for 69% of all housing construction. In the new German federal states (Länder), construction work on existing buildings accounts for almost 76% of the total, a higher percentage than the 67% recorded in the

1 The final report, “Structural data on production and employment in building – Calculations for 2017”, is available as a BBSR online publication; cf. www.bbsr.bund.de.

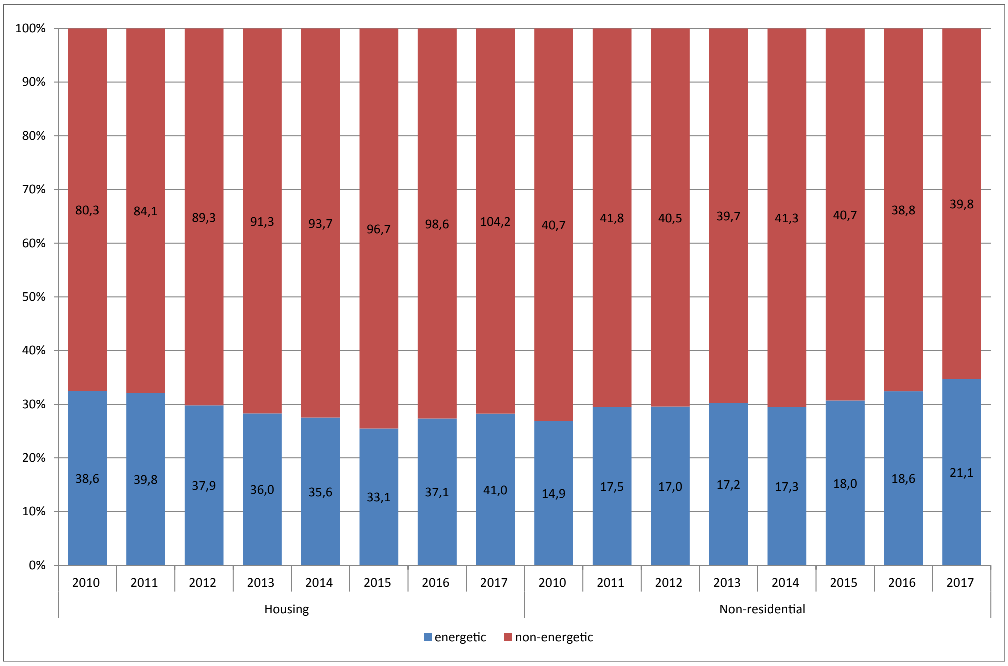

Figure 100:
Structure of R&M services from 2011 to 2017 according to energetic and non-energetic refurbishment measures (at current prices in € million)

west. In non-residential construction, renovation and modernisation services were of less importance (most recently 63% of the total) than in residential construction. Again, there are significant differences between west and east. In the western federal states, renovation and modernisation measures account for around 60% of work in non-residential buildings, while this proportion is significantly higher in the eastern federal states at 76%.

As renovation and modernisation services are predominantly provided by companies in the finishing trade, the finishing trade continues to be the most important producer group, providing building services valued at € 136 billion, well ahead of the construction industry at around € 114 billion. Consequently, the finishing trade accounts for around 37% of the total construction volume. The fact that the construction industry accounts for a similarly high proportion of the construction volume as other producer groups that are not part of the building industry continues to be remarkable. In addition to the use of cost-intensive building services and higher state taxes and fees, this may also be due to a change in the use of materials, higher prefabrication percentages and increasing subcontractor services.

The structure of renovation and modernisation services can be differentiated in more detail according to partial modernisation, full modernisation, maintenance and energetic refurbishment measures. This is based on calculations made by Heinze GmbH for the years 2010 and 2014 in the context of departmental research. The results are included in the calculation of the construction volume and continually updated. These results show that partial modernisations account for more than 70% of all refurbishment measures in building construction, whereby in the housing sector, partial modernisations even account for around 78%. In non-residential construction, the share is significantly lower at 55%. Although modernisation in the housing sector has recently increased significantly, it is still at the same level of expenditure for repair measures.

A considerable proportion of full and partial modernisation is attributable to energetic refurbishment measures. However, there was a negative trend until 2015 in this area. The main reasons for this development are the reduction in subsidies for the construction of photovoltaic systems and falling prices for heating energy. There has been a significant increase recently in energetic refurbishment in residential construction, with around € 41 billion being spent on this in 2017. Energy measures in non-residential construction also indicate a positive trend. Around € 21 billion was spent here in 2017. In building construction, the total volume is € 62 billion, with energetic refurbishment measures accounting for about 30% of renovation and modernisation services. This extremely comprehensive empirical survey of completed renovations will be repeated in 2018, due to the particular importance of renovation and modernisation services. Structural results obtained from this are included in the construction volume calculation and improve calculation results to a significant degree.

Building perspectives in 2030

Guido Hagel

Future Building research initiative, Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)

The robots are coming! Construction with digital production methods on ^ sites will enhance their efficiency.

Development of resource efficiency potential in construction-related recycling

Claus Asam, Federal Institute for Research on Building, Urban Affairs and Spatial Development

Figure 101: Demolition site with presorted rubble

With regard to raw material and waste management, the building sector is at the forefront in terms of the consumption of mineral raw materials and waste generation. It therefore plays a key role in improving resource efficiency, which is at the heart of the Resource Efficiency Programme adopted by the federal cabinet in March 2012 and currently being updated. The aim of this report is to highlight the state of play and existing shortcomings in the recycling of construction waste and to develop recovery alternatives.

This report focuses on the production, efficiency and current uses of recycled building materials and future recovery alternatives. In addition to material recycling, which is based on the physical properties of recycled building materials and, as a rule, is practised, raw material recovery is introduced as a new option. This is understood to mean recycling in a material transformation process in which targeted changes of the chemical or mineralogical composition occur to generate new product properties.

Processing

Construction waste consists of soil and stones, asphalt and concrete road surfacing, concrete and masonry rubble and mixed construction, demolition and gypsum-based waste. Within these groups, sorting of asphalt and plasterboard waste is comparatively pure, whereas rubble from building construction usually consists of a mixture of different construction material types.

The future task faced by processing is to produce high-quality recycled construction materials with defined properties, particularly from mineral construction waste.

Supportive steps in this context are already decided before actual processing commences. Separation into, on the one hand, concrete and masonry rubble and, on the other, material contaminated with unwanted components is achieved through selective upstream removal, pre-sorting on the demolition site and/or the control of material flows through acceptance fees.

Processing currently usually occurs in three steps. **Im 1. Step 1** involves the crushing of rubble in crushing plants. **Der 2. Step 2** of construction waste processing is classification. It serves, among other things, the generation of specific particle size distributions. **Der 3. Step 3** is sorting. Light unwanted materials such as film, paper, insulating materials, etc. are usually sorted through the aid of wind sifting in a **dry sorting process**. However, only fractions > 4 mm can be handled. Special **wet sorting processes** can also be used to separate light mineral construction materials such as aerated concrete, lightweight gypsum construction materials and lightweight concrete. Fractions < 4 mm can also be sorted in appropriately designed machinery if a high volume of sludge is accepted. Separation of different wall building materials cannot be achieved through the wet sorting process. However, this can be achieved through **sensor-assisted single particle sorting** which has long been used for processing plastic waste, waste glass, etc. This has rarely been employed to date in construction material processing, although it has been frequently proven that it is possible to achieve a significant increase in quality through its use.

Recovery

Options for **material recovery** exist for concrete-based materials for the creation of base courses and renewed production of concrete. Technical regulations and requirements relating to water management quality are in place for these application areas. State-of-the-art processing technologies can be used to produce high-quality recycled construction materials for these sectors based on concrete fractions.

Material recovery is only possible to a limited extent for recycling construction materials obtained from masonry rubble. Brick and calcareous sandstone particles may be present up to specified proportions as minor constituents in base course material or recycled aggregates. In addition, an option exists for use of separated brick particles in vegetation technology.

Two concepts exist for **raw material recovery** from masonry rubble and its components:

1. Firstly, masonry rubble is used as a raw material substitute for the production of new construction materials following separation into construction material types in so-called substrate subcycles. Based on the limited information available, it is currently estimated that scarcely more than 20% of natural raw materials can be replaced by recyclates.
2. On the other hand, mixed masonry rubble can serve as a raw material in, for example, the production of ceramic products or pozzolans. Laboratory tests have proven that it is suitable for the production of light aggregates. Thermal treatment is required for its use as pozzolan.

Figure 102: Recycled construction materials from masonry rubble

Figure 103: Recycled aggregates (16/32 mm)

Scenarios for processing and use strategies

Three scenarios were developed in the project on the basis of a recovery matrix for components of rubble.
Processing and use occur in scenario 1 according to the state of the art. The recycled concrete construction material is used in road construction and concrete production. A small proportion of brick particles from masonry rubble is sorted by hand and used for applications such as roof greening or tree substrates. The vast majority of masonry rubble is used for backfilling.

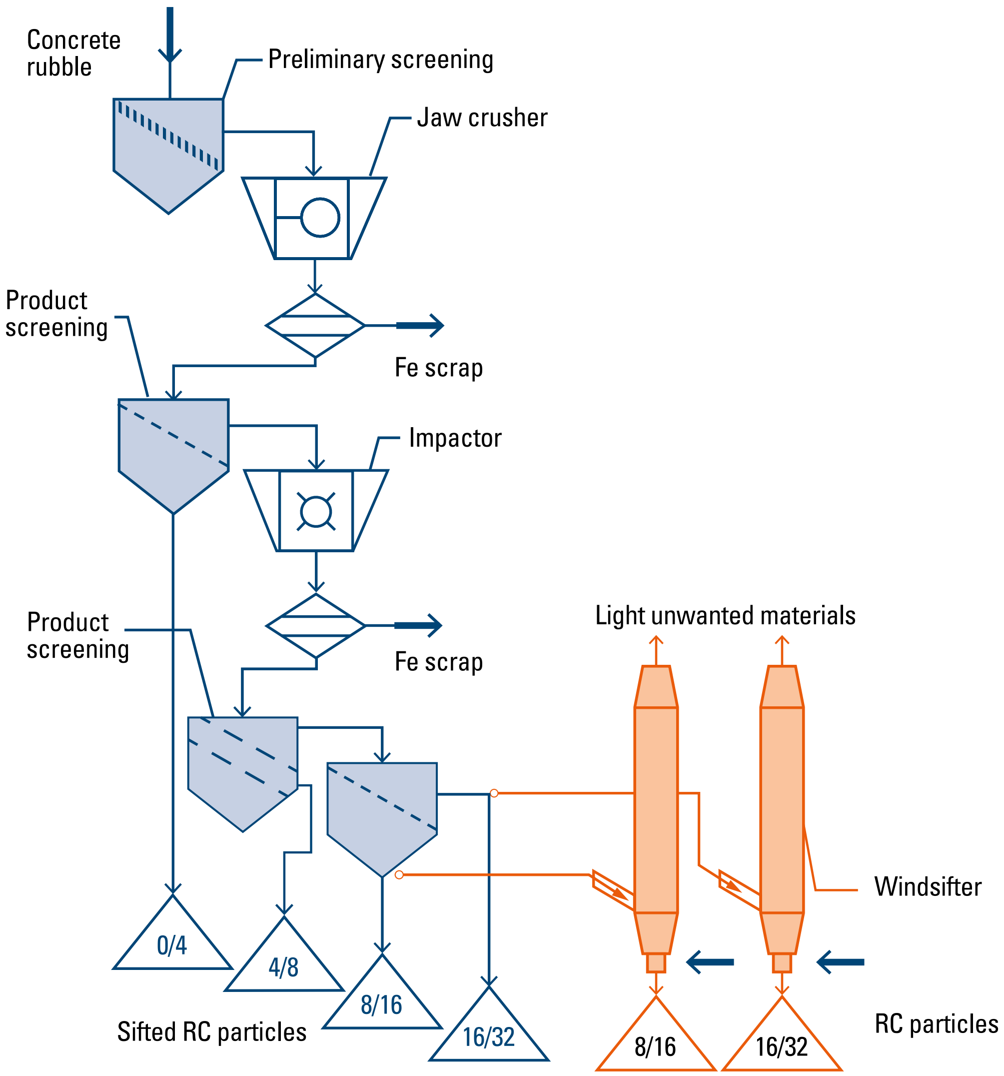

Figure 104: Simplified process flow chart of a stationary processing plant

In scenario 2, concrete rubble is processed and used as in scenario 1. In the case of masonry rubble, it is assumed that brick particles > 8 mm are separated through optical sorting. This means that this component can be used for applications such as plant substrates and as an ingredient of base course material. Furthermore, brick particles can be processed by grinding to a particle sizes < 150 µm and used as a raw material in brick production. Particles < 8 mm with a masonry composition would, in turn, be suitable as a raw material for the production of light aggregates. Other uses would have to be found for particle sizes > 8 mm.

In scenario 3, recycled concrete construction materials from concrete rubble continue to be handled as described above. Low fine particle fraction crushing is realised in the case of masonry rubble. The resulting fraction < 8 mm which is created despite this is used as raw material for the production of light aggregates and/or pozzolanic additives. Coarse fractions are separated into brick, calcareous sandstone, aerated concrete, lightweight concrete, mortar and plaster in multi-level sensor sorting. All material fractions are recycled according to the concept of material subcycles.

The report was able to demonstrate that the consistent application and further development of processing and recovery technologies can significantly improve resource efficiency potential in the construction industry recycling economy. Further development of the following areas is strongly recommended:

Figure 105: Recycled construction materials from concrete rubble

- Quality control with particular consideration of the heterogeneity of recycled raw materials.
- Regulations for concrete production with consideration of raw material recovery
- Solutions for sorting and determination of material requirements as a prerequisite for the realisation of substance subcycles
- Techniques for the separation of gypsum plasters and screeds from rubble
- Technologies for raw material recovery from mixtures, right up to the construction of pilot plants
- Methods for assessing the recyclability of newly developed construction materials and composite structures

Key data

Development of resource efficiency potential in construction-related recycling

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Discussion on the interface between the architectural debate and research discourse

Martina Zwack, DETAIL transfer, Munich

2018 will see the "The Future of Building" event series, which is being held in cooperation with DETAIL research and the Future Building research initiative, entering its sixth round. Experts will grapple with future-oriented architectural and construction issues in five German cities. Architects and scientists will present innovative building and research projects, formulate answers and demonstrate the potential which can be exploited for new markets. The event will be both a review and a look forward.

Figure 106: Moderator Eva Herrmann at the "Wandelbarer Wohnungsbau" event ("The Changing Face of Housing")

Figure 107: Expert panel at the "Wandelbarer Wohnungsbau" event ("The Changing Face of Housing")

Architectural research is often understood as a theoretical confrontation – not infrequently with history. Building research, on the other hand, is often interpreted as something very technical or purely an engineering activity. That the truth lies in the middle and future-oriented research has a direct impact on all involved in building has been proven 20 times already by the "The Future of Building" event series. Every year since 2013, architects and engineers, researchers and planners, industry and politics meet in five German cities to exchange views on hot topics at the interface between architectural debate and the research discourse. Following an in-depth discussion in a small panel of experts, the topics are passed on to interested experts in the form of a public symposium. Topics in this context are either highly exciting funded research projects or relevant issues that emerge from the architectural debate and social discourse. A tangible relationship to a project is always important at every event, which is why planners are always invited as experts who present their concrete buildings with an appropriate connection to the issue of the day.

Over the course of the years, this has led, for example, to the discussion of living environments undergoing demographic change with as much fervour as new approaches to resources with regard to materials and products. Model projects were presented and sustainability criteria analysed, the influence of new mobility concepts on the city emphasised and innovations in construction involving existing building stock demonstrated. In 2017, experts and participants jointly answered the questions: How do city planners and architects react to current living requirements? Which individual, cost-effective and worth living solutions exist? What opportunities does building in existing structures offer? How do new technologies change the use of materials, and how much technology do we really need to design a high-quality and comfortable building? Digital planning methods such as BIM and serial production processes open up new perspectives and potential for the building sector. Integrated process chains (from design to prefabrication, site logistics and building operation to recycling) result in more transparency, lower error rates and greater efficiency in planning, construction and use. At the same time, individualisation in prefabrication, innovative new processing options for different materials and growing cost pressure are changing the way planners and builders view modular construction. Modern system construction promises individuality in series and high quality at attractive prices. Criticism is not infrequently ignited in this respect: Can densely packed structures still be considered urban habitats? Does the high economic pressure to which urban construction is subjected today still permit the creation of liveable yet affordable housing with vibrant diversity? Politicians, planners and industry are looking for attractive concepts that intelligently combine cost-effective, new construction solutions in series with existing structures and, simultaneously, contribute to the building culture. In addition, mixed concepts that provide adaptable space for different user groups can also create a better connection between living and working, private and public spaces. As a result, qualities and open spaces are created for everyone, despite high urban density.

From the many individual voices, statements and results of previous discussions, the following topics emerged for the event series in 2018:

- Modular construction: Broad spectrum, diverse potential
- Digital planning and building: Greater individuality in series
- Reduce – Recycle – Reuse: Old buildings, unique hallmarks
- Multitalent façade: Intelligent and identity-building
- Changing housing concepts: Qualities and open spaces for all

Digitisation, Industry 4.0 and technical innovations open up completely new possibilities for the building sector. The interactions between the manufacturing process, material, construction and forms are more diverse than ever. The intersection between research and application is growing all the time. Simultaneously, the role of building culture as a regulator is increasing. The next few years hold the promise of exciting developments for building. In addition to dissemination of this know-how, it is important for the event organisers to promote the exchange between architects and representatives across many disciplines. Further information is available at: www.detail.de/veranstaltungen/die-zukunft-des-bauens/

Figure 108:
BBSR info material at the "Wandelbarer Wohnungsbau" event ("The Changing Face of Housing")

Key data

The Future of Building

DETAIL Business Development GmbH
Prof. Meike Weber,
Martina Zwack (Project Management),
Heike Kappelt

The event series is realised by the DETAIL research platform of the DETAIL architecture journal in cooperation with the Future Building research initiative of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) and the Federal Ministry of Building.

Building perspectives in 2030

Martina Zwack
Project Manager, DETAIL transfer, Munich

"Future building will be determined by the cooperation of all partners, without technical barriers and limitations. Planning is digital, limits fluid: Virtual reality and the built environment become one – benefiting greater creativity and architectural experiments."

Building with Vision – System construction kits for industrialised social housing construction

Markus Lechner, Technical University of Munich

Figure 109: Visualisations in panel construction system

A major and, indeed, worsening shortage of affordable housing continues to be experienced in many places, and politics and the housing sector urgently need to create socially compatible housing. Simultaneously, planning and building continues to follow archaic patterns. An industrialisation of housing construction that also preserves architectural diversity is required. Possible approaches to industrialisation and their implementation are investigated in the project.

Figure 110: Configuration of buildings with 3-D Tetris building assemblies

The aim is to create a "system construction kit for multi-storey building" to enable industrialised social housing construction with high sustainable building quality.

A requirements catalogue was first developed. All performance requirements were defined on the basis of the funding criteria and building regulations of the German federal states (Länder). The involvement of partners in the housing sector was particularly significant in the initiation of the requirements catalogue which provides all information needed for future developments. The function and product structures necessary for a system construction kit were developed from the requirements.

A system construction kit is a modular construction system of a specific system consisting of a number of building blocks (building assemblies) which are chosen for a specific application

Figure 111:
Buildings with multiple variety building assemblies (NSo BG-G)

and then combined, taking their intercompatibility into consideration. The building assemblies possess standardised geometrical and material properties, are harmonised and may, in turn, consist of a combination of (less complex) building blocks. The shape of the building assemblies is not altered during configuration.

The original approach to the development of a unique "system construction kit for social housing construction" therefore cannot be realised. A system construction kit can only be developed for a specific building system (e.g. using prefabricated reinforced concrete), as structural planning, structural-physical and fire safety characteristics differ markedly and complete parameterisation currently cannot be mastered.

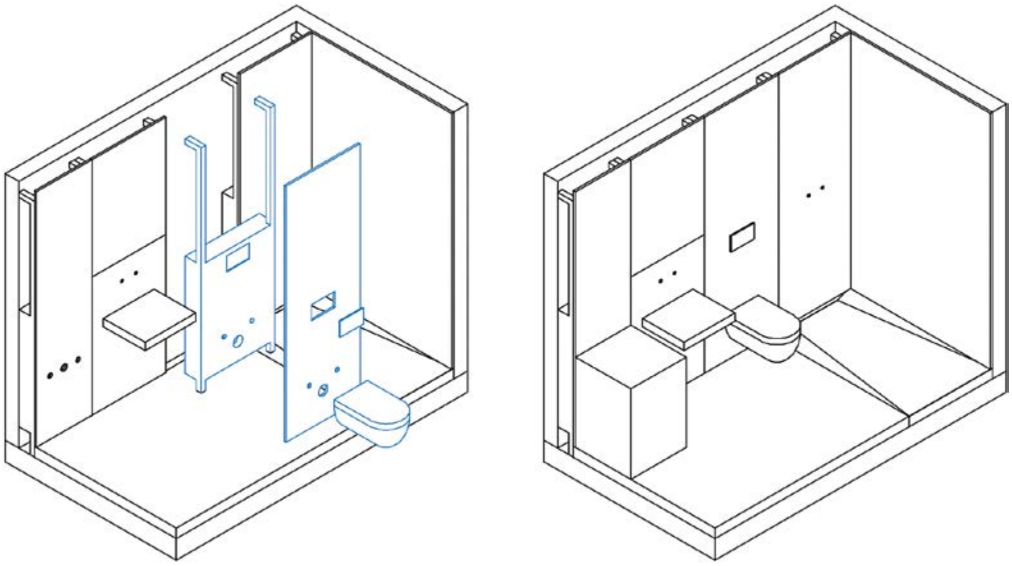
Building blocks were developed in the project with the aid of a building assembly system which, in the form of building assemblies (BG-G), contain apartment groups or complete floor types.

Digital definition of building assemblies encompasses all building construction elements (shafts, partition walls, ceilings, roofs) and technical building services. It also includes all relevant data needed to produce building assemblies, providing complete production planning for the company realising the work. A building assembly is a complete planning unit and, consequently, an ideal application of Building Information Modelling (BIM), as data is created once for repeat applications (in contrast to the "one design" approach adopted today). Parameterisation in sub-divisions (e.g. window formats, façade design or floor spans) is possible.

The system construction kits tested in the project employ a concrete module construction technique, a hybrid panel construction method for all walls and the roof and prestressed concrete hollow-core slabs for ceilings.

It was thus demonstrated that generation of a required housing mix of middle corridor, arcade, centre and multi-apartment buildings is possible. Architectural freedom is preserved through partial parametrisation and the addition of building assemblies such as balconies, arcades (BG-A) and access units (BG-E).

Process analyses were conducted in several optimisation cycles which, in particular, indicated the savings potential achieved in the area of internal planning and production optimisation through repetition effects. Additional savings potential is achieved through high quantities of the same building products. A limitation of these effects can be traced back to the current market situation (shortages of building products, production capacities and labour).



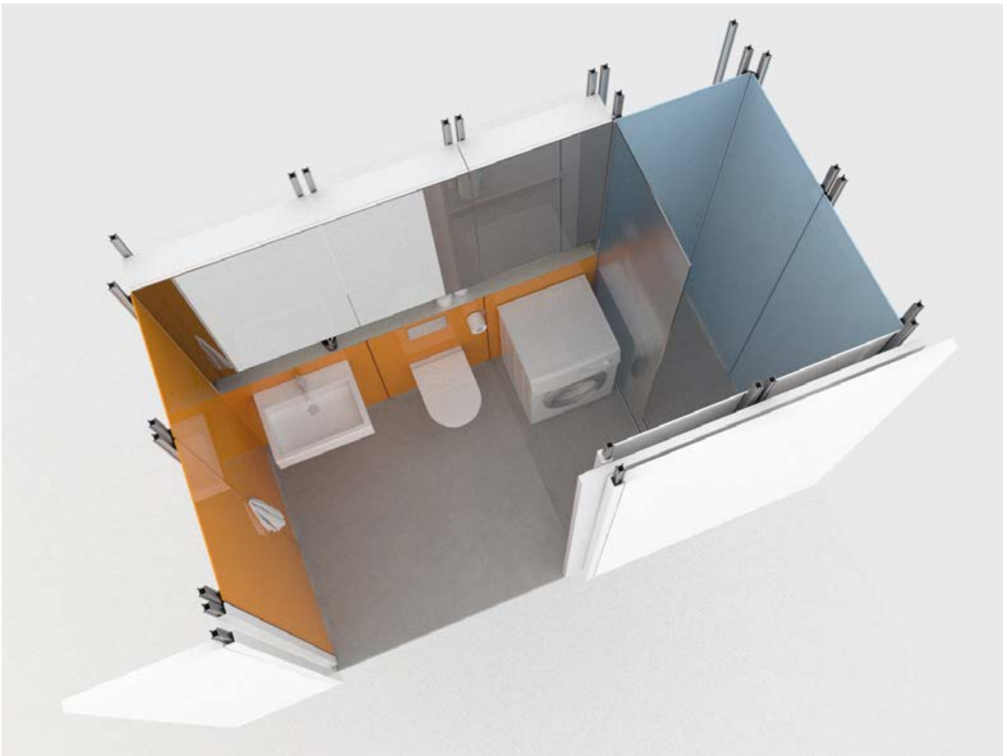


Figure 112 and 113: Combination of sanitary installation, wall surface and flush-mounted system to create function units

Building perspectives in 2030

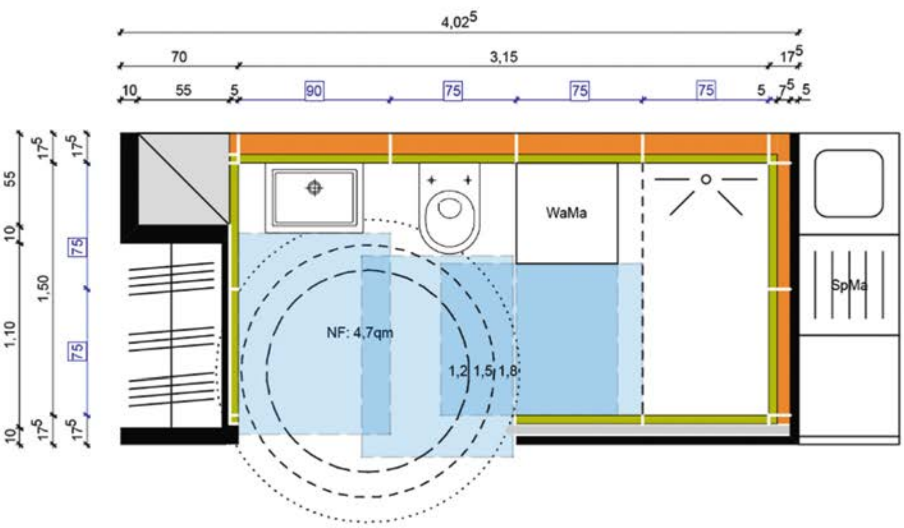
Prof. Frank Will
Technical University of Dresden, Institute of Fluid Power, Endowded Chair of Construction Machines

"Digitisation and automation will still not replace man completely as the machine operator in 2030 – but his work will shift from control tasks to monitoring of machine functions, thanks to intelligent assistance systems, ergonomic information provision and autonomous work processes."

The initial target cost limitation of € 1,200 €/m² usable area for the 300, 400 and 700 cost groups pursuant to DIN 276 could not be verified. However, the achievement of an at least stable price level considerably lower than € 2,000 €/m² through the industrialisation steps described does appear to be realistic.

A series of further aspects was also investigated. These included the development of a system construction kit for handicapped-friendly and accessible bathrooms with replaceable installation building blocks or the actual air exchange rates required. It was verified that, with regard to maintenance of the required humidity, an air exchange rate of 0.2/h is adequate.

Taking regulatory constraints into consideration and with due regard for progressive changes in



Standard DIN 18040-2 "barrierefrei"

Anforderung	Soll	Ist	Begründung Abweichung
Bewegungsflachen			
vor WC	120 x 120	✓	
WC seitlich (a|b)	20 | 20	✓	
vor Waschtisch	120 x 120	✓	
vor Badewanne	120 x 120	✓	
im Duschbereich	120 x 120	90 x 150	Fl. ohne WaMa: 150 x150
Durchgänge / Türen	b >= 90	✓	

Standard "ready"

Anforderung	Soll	Ist	Begründung Abweichung
Bewegungsflachen			
vor WT, WC, DU, BA	90 x 120	✓	
vor WaMa	60 x 90	✓	
WC seitlich	90 x 90	(✓)	ohne WaMa
Dreh- / Wendefläche	d >= 120	✓	
Durchgänge / Türen	b >= 80	✓	
Raumgröße			
Nutzfläche	min. 3,6qm	✓	
min. Wandlänge	min. 1,7m	1,5m	Flurbereich mitnutzbar
Ausstattung			
Waschtisch	Tiefe >= 40	✓	
WC	Tiefe >= 65	60	WC austauschbar
Dusche	>= 90 x 90	✓	bodengl. Fläche: 90 x 150

Standard "ready plus"

Anforderung	Soll	Ist	Begründung Abweichung
Bewegungsflachen			
vor WT, WC, DU, BA	90 x 120	✓	
vor WaMa	60 x 90	✓	
WC seitlich	90 x 90	(✓)	ohne WaMa
Dreh- / Wendefläche	d >= 150	✓	
Durchgänge / Türen	b >= 80	✓	
Raumgröße			
Nutzfläche	min. 4,0qm	✓	
min. Wandlänge	min. 1,8m	1,5m	Flurbereich mitnutzbar
Ausstattung			
Waschtisch	Tiefe >= 40	✓	
WC	Tiefe >= 65	60	WC austauschbar
Dusche	>= 90 x 90	✓	bodengl. Fläche: 90 x 150

Figure 114: Proof of concept for barrier-free use pursuant to DIN 18040-2 and ready study

the energy mix, it was also proved that direct electrical heating can now be realised in Germany in highly insulated buildings.

[1] N. Kohlhase, Strukturieren und Beurteilen von Baukastensystemen, dissertation, Düsseldorf; VDI publications, 1997.

The development of a system construction kit based on building assemblies was enabled for specific building methods. As a consequence, the enterprises involved have developed company-specific system construction kits (concrete modules and a hybrid wood and concrete panel construction). Building on these findings, provider-independent system building kits can now also be developed for specific building methods. These can be employed by independent planers through configuration tools and offered through open tender. Complete workshop drawings relating to these will be made available. An open-source system which permits complementary development and the addition of further building assemblies would be ideal, as this would represent the achievement of real industrialisation.

Key data

Building with Vision

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Technical University of Munich, Chair of Industrial Design,
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Joachim Brech,
Kommunale Wohnungsgesellschaft mbH Erfurt,
Max Bögl Modul AG,
Regnauer Fertigbau GmbH & Co. KG

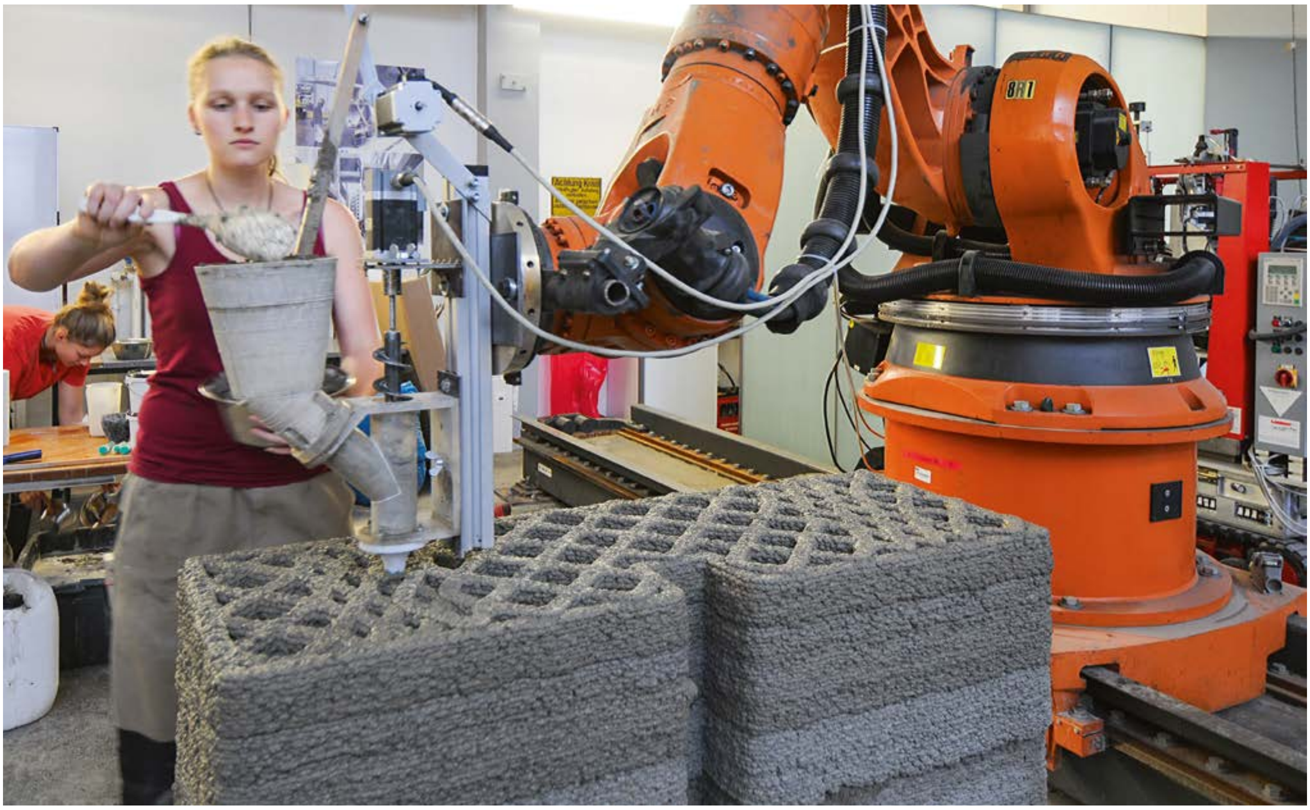

Figure 115: Manufacture of a multifunctional wall element through extrusion of lightweight wood chip concrete. Zones of differing density and an integrated installation shaft are visible on the image.

Additive manufacturing by extrusion of lightweight wood chip concrete

Klaudius Henke, Technical University of Munich

Shape-optimised support structures, supplementary components fitted into the existing structure – the application options additive manufacturing offers in building are extensive. But while additive manufacturing is already a new standard in many sectors, it is still at a very early stage of development in the building industry. The research project presented here involved investigation of how large-format components can be manufactured additively through the extrusion of lightweight wood chip concrete.

The additive manufacturing (3-D printing) of components or entire structures can be realised with different methods and materials. The majority of previous research and development projects focus on mineral materials, especially on concrete. Two methods are employed for 3-D concrete printing: selective bonding and extrusion. In selective bonding, flowable material is deliberately introduced into thin layers of a dry bed, solidifying it locally in the areas where the later component is to be created. During extrusion, the concrete components are formed without the use of formwork by depositing fine strands of fresh concrete. While selective bonding is primarily characterised by its broad geometric freedom, extrusion is at an advantage when it comes to the rapid production of large components.

3-D concrete printing was investigated in the extrusion process variant during the research project presented here. The usual heavy aggregates in concrete were replaced by a lightweight aggregate consisting of a renewable raw material: wood. This not only contributes to protection of the environment and finite resources, but also produces a comparatively light material with good heat insulating properties which is easy to process. The goal was to demonstrate that, when compared to similar solutions with regular concrete, the limits of production technology can be extended and new areas of application developed.

The extruder used was a screw conveyor powered by a stepper motor that presses the fresh concrete from top to bottom through a nozzle with a circular opening. The mixed concrete was fed in manually in small batches through a hopper. This solution proved easy to implement in technical terms and shortened the time between mixing and spreading the concrete. The modular design of the experimental extruder developed in the project enables testing of different screws, nozzles and hopper.

A concrete which is to be used in additive manufacturing by extrusion needs to meet very different and, in part, conflicting requirements. While the fresh concrete in the material processing and transporting system should exhibit good flow characteristics, it should develop strength as quickly as possible after emerging from the nozzle. Only if this is guaranteed can a practical construction speed and appreciable geometric freedom be achieved. In addition, the hardened concrete properties need to meet the usual requirements in terms of strength, thermal conductivity, fire behaviour, etc. It was therefore necessary to create a lightweight wood chip concrete that meets these requirements for the trials conducted in the project. Material development was realised experimentally through variation of the concrete recipe with regard to its components and their proportions. The lightweight concrete developed in this way consists of Portland limestone cement and untreated softwood chips in a volume ratio of 1 : 1. The additives used were air-entraining agents, stabilisers and accelerators.

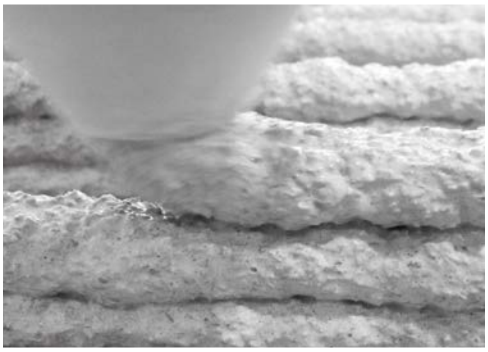

Figure 116: Extrusion of lightweight wood chip concrete

Figure 117: Test object manufactured through extrusion of lightweight wood chip concrete with an overhang of 26%

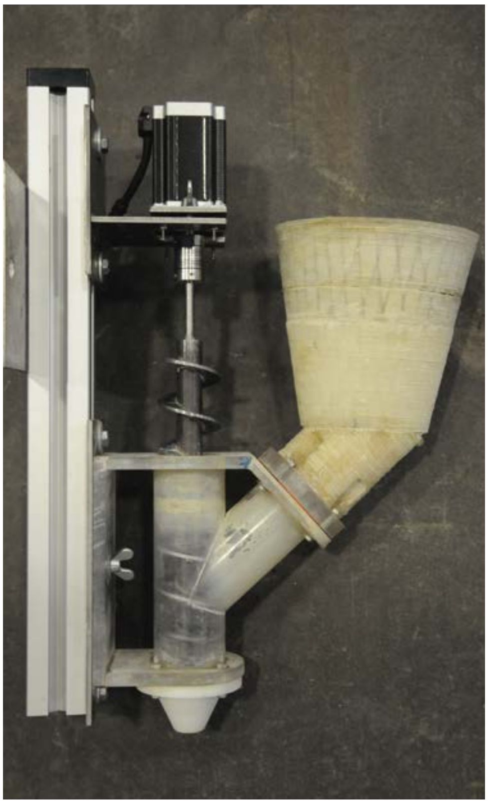

Figure 118: Test extruder

Various test objects and demonstrators were additively manufactured from this concrete through extrusion. For this purpose, the extruder was moved by an industrial robot in accordance with the desired component geometry and the components formed without formwork through the depositing of narrow strands of fresh concrete.

Testing of the test objects showed that the 3-D printed components made of the lightweight wood chip concrete developed in the project have a compressive strength of approx. 10 N/mm² and a flexural strength of approx. 4 N/mm² with a dry bulk density of approx. 1,000 kg/m³ and are therefore within the range of lightweight concrete of a purely mineral basis. The thermal conductivity determined is approx. 0.25 W/(m*K).

Overhangs of up to 26% were realised. This indicates that the use of lightweight materials can make a significant contribution to increasing the geometric freedom of additive manufacturing through extrusion.

The hardened lightweight wood chip concrete can also be processed easily with conventional

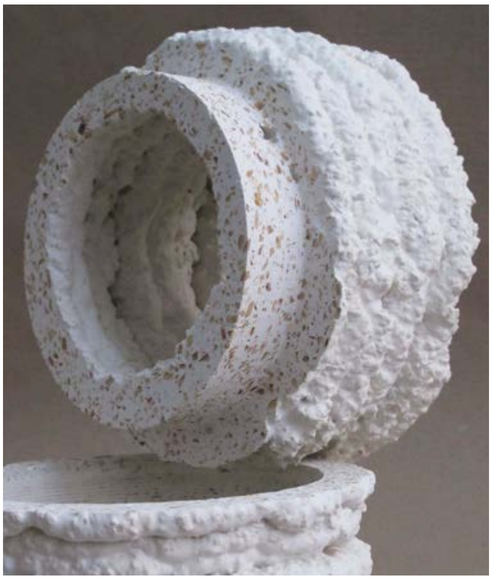

Figure 119:
Lightweight wood chip concrete test object additively manufactured through extrusion and subjected to partial subtractive post-processing through milling

tools used for metalworking. This allows for subtractive post-processing in areas where a special degree of precision (e.g. component connections) or surface quality is required.

Finally, several large-scale demonstrators with dimensions of up to (L × W × H) 1,500 mm × 500 mm × 930 mm were realised.

3-D concrete printing was investigated in the extrusion process variant during the research project presented here. The usual heavy aggregates in concrete were replaced by a lightweight aggregate consisting of the renewable raw material wood. It proved possible to demonstrate that advantages are achieved for both the manufacturing process (smaller mass, improved workability, etc.) and the properties of the hardened building material (low weight, low thermal conductivity, etc.). The main application of this material-process combination is to be seen in multifunctional, monolithic shell elements without additional heat insulation.

Key data

Additive manufacturing by extrusion of lightweight wood chip concrete

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Daniel Telke

Incentives and disincentives in new residential construction

Alexander Schürt, Federal Institute for Research on Building, Urban Affairs and Spatial Development

Housing and real estate markets are developing in very different directions in the subregions of Germany – from market tensions with housing bottlenecks and drastic rent and price increases on the one hand, to population declines due to migration with increasing levels of vacancies and public service problems on the other.

Finding a home and buying a property have become a time-consuming and financial challenge for households in many booming cities and regions. The consequences are compromises with regard to housing needs and evasive migration to other neighbourhoods or communities. Construction completions have, indeed, increased markedly in recent years. They are supported by multi-family housing in growing cities and counties, whereas owner-occupied construction has stagnated since 2013. However, current planning permission numbers are, overall, on the decline in 2017, with only multi-storey housing construction remaining stable.

A total of just under 278,000 homes were realised and 375,000 approved in 2016. The realisation of the increased building overhang in recent years would in itself bring some relief to real estate markets. However, actual housing completions are not enough to meet the expected annual new construction demand of over 350,000 homes by 2020. It is, therefore, important to know which incentives and disincentives exist when it comes to the realisation of new construction projects and how and where homes can be realised to meet demand.

Favourable conditions exist for more new residential construction in the numerous growth regions in Germany. Demand has outstripped supply for many years. This ensures stable market situations that reduce the real estate investment risk. The favourable market situation provides security when renting or marketing properties and enables the achievement of higher prices.

Figure 120: New multi-family developments in a prime location in Dresden – Striesen

Figure 121: New semi-detached houses on small plots, Aachen

Figure 122: New development in favourable locations south of the historic city centre, Nuremberg – St. Leonhard

Simultaneously, other forms of investment with falling returns have been losing their attractiveness for years. There has been a noticeable increase in the number of interested real estate investors. Low interest rates on residential mortgages allow more households to realise the dream of owning their own four walls – at least where sufficient equity is available. In addition, rising property prices can be compensated in this manner up to a certain level. Loan sums and the fixed interest rate term have increased noticeably in recent years. With regard to retirement provision and a "rent-free" life in old age in particular, home ownership continues to be a high priority in Germany. However, these driving factors are also creating further demand pressure on the growing real estate markets, pushing prices up further.

The interest in building new homes or apartments is great among potential clients – businesses, investors and private households. However, numerous obstacles are encountered here which limit a further increase in new construction figures. The biggest shortcoming is to be found in available and affordable building land, a situation that leads to long and sometimes unsuccessful acquisitions. The competition for land is great. Companies that focus on the common good can barely keep pace with rapidly rising building land prices. Long planning and approval procedures and increasingly complex requirements and specifications for housing construction make real estate projects longer and more expensive. The capacity utilisation of construction and planning companies is high, resulting in delays in the realisation of projects which have already been approved. The construction overhang has increased in recent years. Market tensions are also reflected in declining numbers of transactions involving both undeveloped and developed sites in the growing urban areas as calculated by expert committees for land values. At the same time, transaction volumes are rising due to significant price increases.

Current housing bottlenecks cannot be eliminated through new construction alone. Additional living space can also be created in the building stock through initiatives such as the addition of storeys, attic extensions or conversions of non-residential buildings into residential properties. There is still extensive potential for this in towns and cities. These inner development measures have the advantage of utilising existing resources and infrastructures with correspondingly integrated layers and of reducing the take up of new land, but they also often encounter major neighbourhood resistance or have to compete with other urban uses. Therefore, in some cities with limited inner development potential, outer development measures, including on a larger scale, are inevitable, as for example is planned in Freiburg im Breisgau (Dietenbach), Aachen (Richtericher Dell) or Frankfurt am Main (Am Eschbachtal - Harheimer Weg, new district bordering Niederursel). Flexible floor plans and technical features offer new construction the opportunity to respond better to changes in demand in the future. Furthermore, regional cooperation between municipalities is required for the coordinated development of living options and, also, business, traffic and other infrastructure.

However, despite all efforts to create more housing in the wake of acute bottlenecks, the medium-term demand for housing and commercial real estate in cities and the regions must always be borne in mind. The expansion

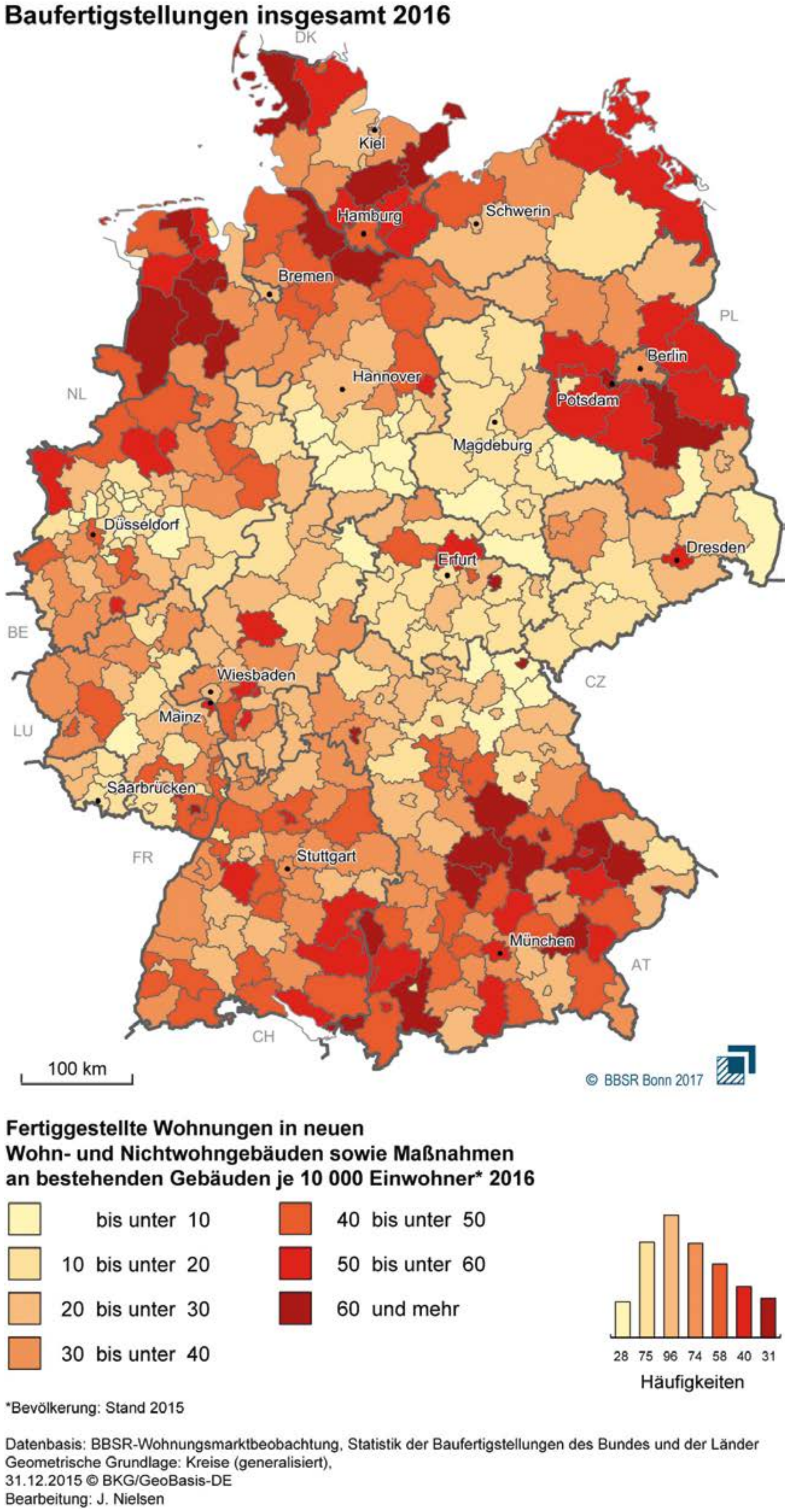

Figure 123:
Construction activity in Germany in 2016

of new construction should not overshoot the target and, as a consequence, create future vacancies. Vacancies already exist, especially in stagnant and shrinking areas where they are evident to a considerable degree. For this reason, permanent and, also, small-scale housing and real estate market monitoring is immensely relevant if timely identification and communication of market trends is to be assured.

Establishment of a virtual "Museum of 1000 Places" for presentation of the federal Percent for Art collection

Ute Chibidziura, Federal Office for Building and Regional Planning

Percent for Art works have been realised on federal buildings since 1950. As a result, thousands of works of art have accrued over the years, but these are scattered across hundreds of properties worldwide and, for the most part, are not displayed for public viewing. Nevertheless, in order to present this rich collection of art to the public, a "Museum of 1000 Places" which can be accessed via the internet is being established in which state Percent for Art works can be presented in their structural and institutional context.

For 70 years now, the commissioning of Percent for Art works has been an integral part of the task performed by the federal government in Germany as a building client. They are regularly commissioned in the case of building measures for nationally relevant institutions such as government and constitutional bodies, federal authorities and institutions, embassies and diplomatic missions, the police, customs and defence forces and medical, cultural and scientific institutions. Around ten thousand Percent for Art works have accrued over the years in Germany and abroad, and almost all the major artists of their time have been commissioned by the German government. Taken together, Percent for Art works represent a magnificent collection of post-war art that encompasses all artistic trends and expressions and is also internationally unique in terms of its scope and diversity.

This art collection has been built up since 1950 and, for some years now, has been scientifically and photographically documented and recorded in a Percent for Art database. An invitation to tender was put out for the development and design of an appropriate web application to enable the presentation of widely dispersed Percent for Art works in a virtual "Museum of 1000 Places". The online museum was opened by Minister Barbara Hendricks in June 2017.

The "Museum of 1000 Places" offers its visitors several ways to discover art. Following quick visual access via the homepage, a mouse click on one of the illustrations links the visitor directly to the corresponding artwork or building, while the names of the artists lead to information on the artists' lives. As an alternative to intuitive use, systematic accessing of the art is possible using the Museum, Places, Artists and Artworks tabs. In addition to providing interesting information on the content and structure of the "Museum of 1000 Places", the area captioned **Museum** also informs the visitor about the history of Percent for Art, building-related art in the German Democratic Republic and federal regulations governing Percent for Art. Subsequent to this, information is also provided on research relating to Percent for Art, and the question of how Percent for Art works are created and why they are commissioned at all is addressed.

The **Places** tab lists properties in the **museum** with their current names in alphabetical order. If a property comprises several structures, this is evident in the images recorded of these. It is possible to sort by location here or filter by entering a postal code to select works of art in the immediate vicinity.

Artists are listed in alphabetical order under the **Artists** tab, and up to three works of art available in the online museum are displayed for each person. A click on the name or photo of the work of art links to the vita of the artist and the works in the museum.

Works can be displayed in chronological or alphabetical order under the **Artworks** tab. They can be filtered by different categories according to accessibility, year of installation, artistic techniques or user groups to obtain a specific work group. The use of multiple search criteria is just as possible as the combination of preconfigured categories with a free text search.

Individual works of art are initially presented in a series of images in the "Museum of 1000 Places" and then described in detail in their structural and institutional context, including references to literature. Core information on material, technique, costs, placement type

Figure 124: Homepage www.Museum-der-1000-Orte.de

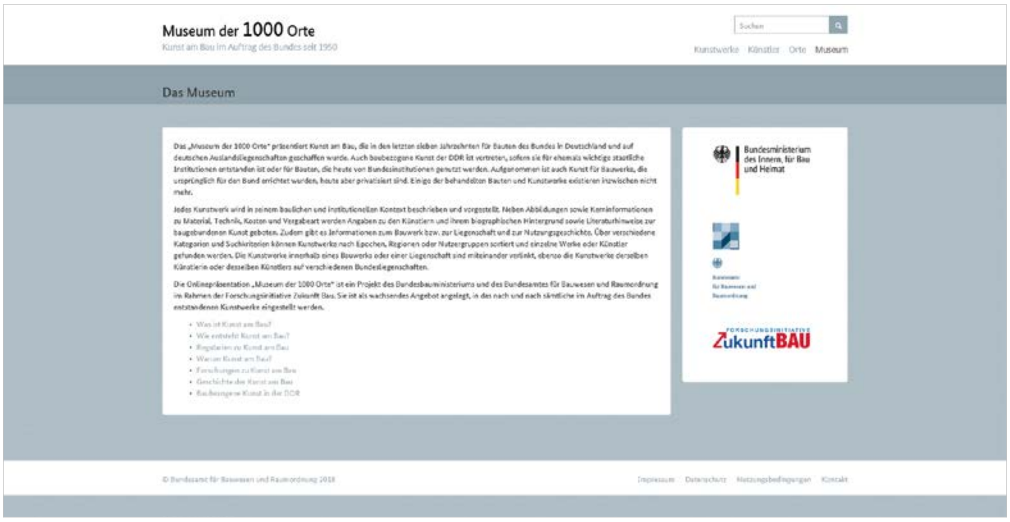

Figure 125: Museum tab

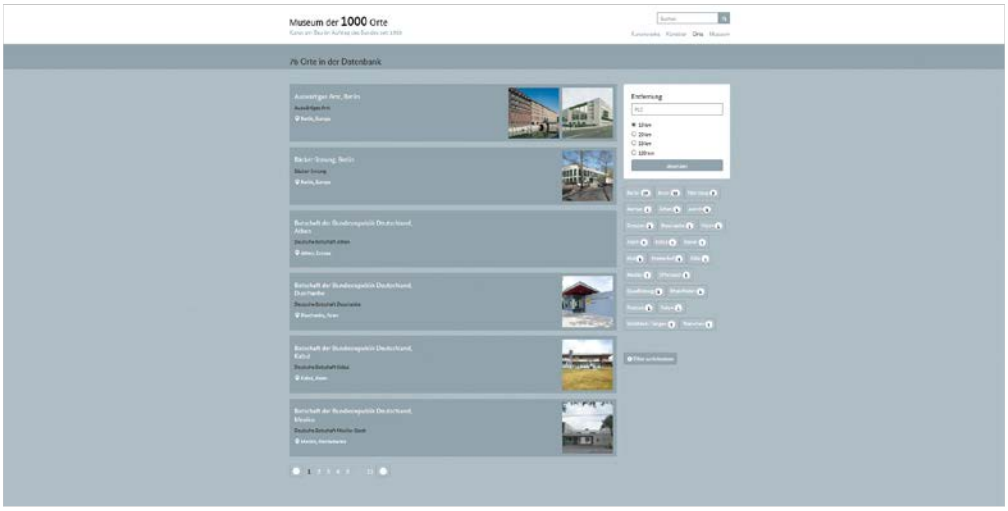

Figure 126: Reiter Orte

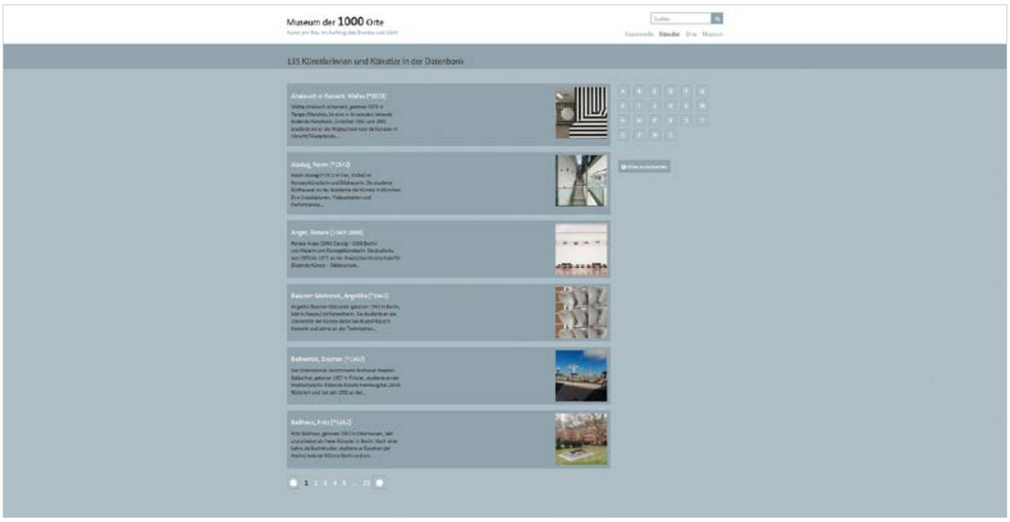

Figure 127: Artists tab

and location and whether works are public accessibility is provided, along with information about the artists.

A section of the city map and an image of the building with information relating to it and the history of its use complete the presentation.

All information about a work of art can be printed or saved in PDF format in the form of a project

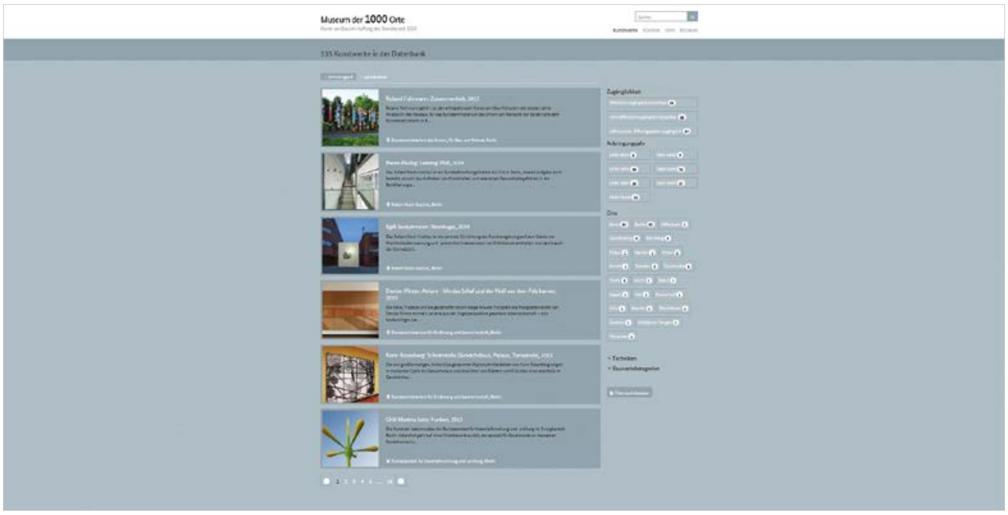

Figure 128:
Artworks tab

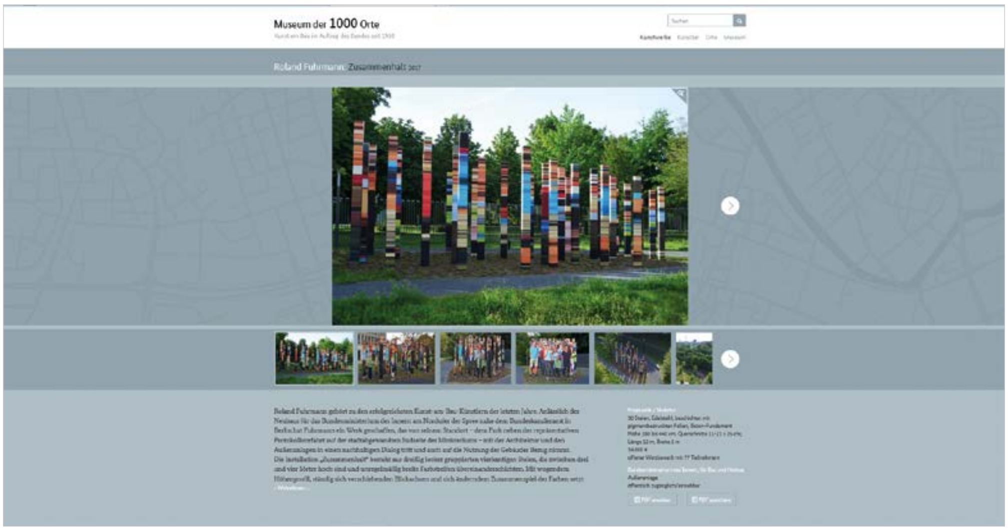

Figure 129:
Percent for Art for the Federal Ministry of the Interior in Berlin

sheet. There is also a QR code on the project sheet. This will be transferred to local artwork signposts in future to facilitate direct linking to the presentation in the "Museum of 1000 Places".

The "Museum of 1000 Places" has been designed as a growing work in progress which will gradually be expanded over time.

In contrast to a "classical" museums, the online collection at www.Museum-der-1000-Orte.de presents works of art that have been created since 1950 for permanent display in and on federal buildings at home and abroad. It includes building-related art of the German Democratic Republic and Percent for Art works from federal buildings that are privatised today. It also highlights works of art that are missing or no longer exist. In this respect, the online museum is also an archive of Percent for Art works which is continually being expanded. Some of the artworks are being presented for the first time in the online museum, making the "Museum of 1000 Places" an important source of information not only for the general public, but also for research.

Key data

www.Museum-der-1000-Orte.de

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HauptwegNebenwege GmbH Köln

Project Manager BBR: Dr Ute Chibidziura, A2

Director:
Beate Hückelheim-Kaune, A2

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Federal subsidy share: 39.436,60 €
Project duration: January 2016 to June 2017

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