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Promoting sustainable building design that is climate-sensitive and resource efficient

When the new federal government was formed in December 2013, responsibility for building was transferred to the environment ministry, which then became the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. I see that as a great opportunity to forge even stronger links between the aims of modern building design and our work to protect the environment, the climate and nature. After all, we have set ourselves the target of reducing greenhouse gas emissions by 40 % by 2020. The building sector is very important here and must be encouraged to play an even more active role. Important issues such as resource efficiency, improving recycling of materials and accessible building design have also been incorporated into my ministry's sustainability criteria. And sustainability is not just an environmental issue; economic and sociocultural aspects are also key dimensions. We are equally concerned with achieving affordable modern housing and low life cycle costs as with high-quality architecture and comfort.

Dr Barbara Hendricks

The construction and real estate sector in Germany is made up of predominantly medium-sized businesses and, although it is one of the country's major industries, it needs support to help it put innovations into practice more quickly. This is the only way to achieve our objectives which are important for society.

The Zukunft Bau research initiative plays a key role in this. It is a programme that commissions studies to support policy-making, but it also supports research jointly funded with the construction and real estate sector. Since it was launched eight years ago, the research initiative has supported a total of 750 research projects with € 83 million in federal funding. Last year alone, it channelled € 6 million into 40 new grant-funded research projects.

We will continue to operate this research initiative in the new Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The list of projects in the current year's funding programme is looking good with over 50 research topics and is set to be implemented without delay by the executing agency, the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), as soon as the budget is approved.

The research findings and projects that are published in the research initiative's current magazine show that we are on the right track. Particularly questions of energy-efficient, climate-sensitive building design are increasingly dictating developments in building technology. We are very pleased in this connection that the Efficiency House Plus network is expanding according to plan and that we are able to study these pilot buildings intensively. This will enable us to make a decisive contribution to the success of one of society's major projects, which is the Energiewende, Germany's transition to a new energy era. I hope that everyone reading this brochure gains some interesting insights and wish all practitioners courage and strength in translating the latest research findings into reality.

Dr Barbara Hendricks
Federal Minister for the Environment, Nature Conservation, Building and Nuclear Safety

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Innovations for sustainable building design

Hans-Dieter Hegner, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

The construction, housing and real estate industry is intricately connected with the objectives and measures of the federal government's sustainability strategy. The main priorities to be stressed here are climate change mitigation, improving energy efficiency, improving energy and resource productivity, reducing land use and addressing demographic change. The building sector therefore occupies a key position in the federal government's sustainability strategy.

Assessment System for Sustainable Building (BNB)

Sustainable building design aims to achieve an overall improvement in quality throughout the entire life cycle of a building – from the initial design stages and construction through to its actual use. The assessment of buildings' contribution to sustainable development includes comprehensive environmental, economic and sociocultural aspects. It is very clear that sustainability cannot simply remain a buzzword; it has to be something we can measure in reality. That is why the State Secretaries Committee on Sustainable Development at the Federal Chancellery presented an action plan for the federal government in December 2010. Top of the list of priorities is sustainable building procurement and, in connection with that, the introduction of an assessment and certification system for federal buildings, which is based primarily on quantitative assessments and descriptions. This Assessment System for Sustainable Building (BNB) was developed as a voluntary market instrument. With its "Guideline for Sustainable Building" the government made it mandatory for the federal building authorities. Of course, the system can also be used by the private sector. Regulations on this have also been published. The government has concentrated on types of building that are of significant public interest. The system was developed on a sound scientific basis by working groups involving a range of public agencies and has also been discussed and trialled on a broad basis.

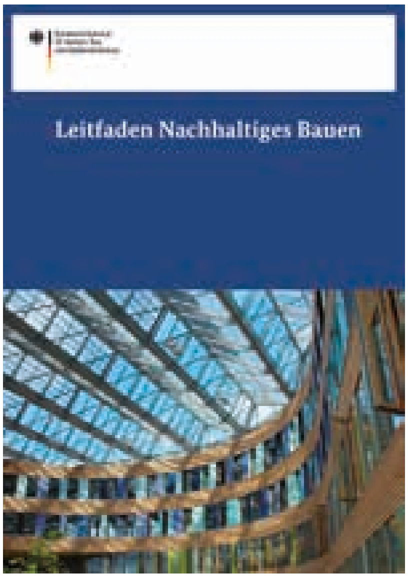


Figure 1: Cover of the Guideline for Sustainable Building

The government's assessment scheme uses a modular approach, which mirrors the objectives set out in the Guideline. In addition to the principles of sustainable building (set out in Part A of the Guideline), three assessment modules were also developed, which can be specified for different categories of building:

- New Construction module (Part B)
- Use and Operation module (Part C)
- Refurbishment module (Part D), (Figure 2)

The modules were developed first for office buildings. Other system variants were then developed on the basis of these modules.

The government's Guideline for Sustainable Building became a statutory requirement for all major new construction projects (investment sums over € 2 million) in 2012. Parts C and D were added in 2013. The latest version of the Guideline thus also covers existing properties. The system variants relating to office, administrative and educational buildings and outdoor facilities are already in use. System variants for laboratories and vocational training centres are currently being developed. The Assessment System is organised around a precise number of criteria, for which measuring methods and benchmarks are clearly described in criteria profiles. The aim was to incorporate building regulations of all kinds and other public law provisions.

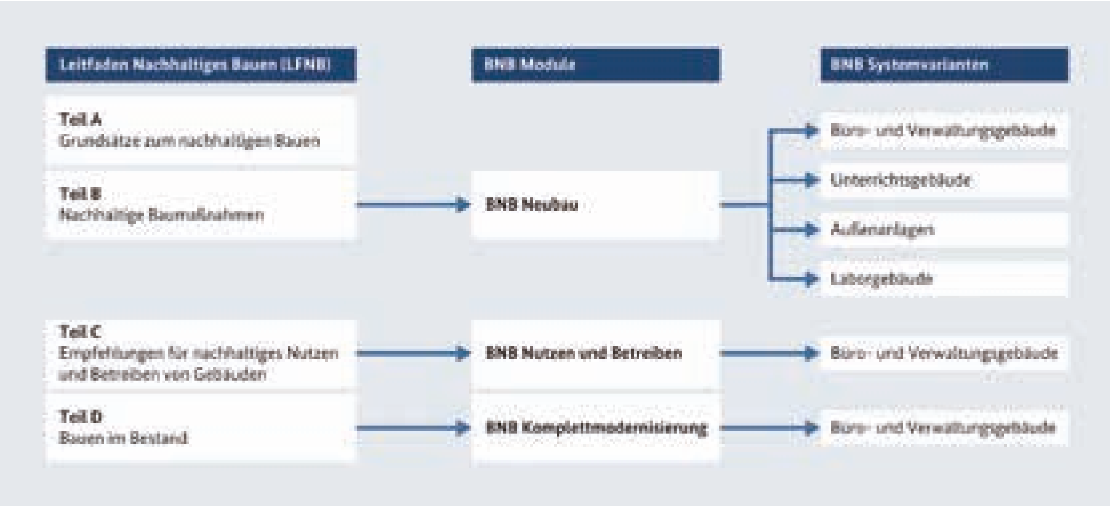


Figure 2: Overview of the different modules and system variants in the Assessment System for Sustainable Building (BNB)

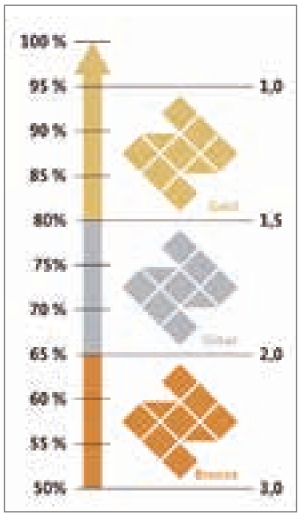


Figure 3: BNB assessment scale

With regard to environmental regulations, not only the evidence that is required during the planning stage has to be submitted but also a life cycle assessment. The economic aspects to be ascertained are not only the capital costs but also the life cycle costs. The additional documentation required is not as extensive, provided evidence of sustainability has already been submitted in the course of the normal planning process.

The main feature of sustainability certification is that it testifies to the fact that a building has been designed to surpass the minimum requirements and has undergone quality control checks throughout the process. In the summary of the assessment results, the building is given a grade and the characteristics of the site are described. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) requires a building to comply with the "silver standard" (65 % of criteria met) with regard to sustainability. In terms of energy saving a building must meet standards that are up to 30 % better than the minimum required by the Energy Saving Ordinance. Buildings in Germany usually achieve up to 50 % compliance. As the leading public sector building owner, the federal government is seeking to lead by example and is hoping that the Guideline for Sustainable Building will also be widely used by other major market participants such as real estate companies, other public sector building owners such as Länder or local authorities and private building owners.

Figure 4: Federal Minister Dr Barbara Hendricks at an event on sustainable educational buildings organised by BMUB in Berlin during bautec 2014 – the international trade show for the building industry

The profiles, methods, databases and tools developed as part of the Zukunft Bau research initiative help to provide a balanced set of practical criteria for sustainable building design, in particular for the public sector.

Sustainable educational buildings

At an event organised by the BMUB in Berlin in connection with bautec 2014 – the international trade show for the building industry – examples of sustainable educational buildings in practice were presented and their quality features discussed with experts from the field and representatives of Germany's Federal Environmental Foundation (DBU). The assessment system for sustainable educational buildings, which had been developed as part of the Zukunft Bau research initiative and is based predominantly on the findings of joint work carried out by the federal government and Länder, was also presented.

In the information brochure of the same name, which is designed to be a working tool, the sustainability assessment system is not only outlined in theory but also explained using examples of practical trials at different educational

Figure 5: Primary school in Hohen-Neuendorf – received a BNB Gold Award

Figure 6: Foyer of the school in Hohen-Neuendorf: high visual quality

buildings. A particularly sustainable educational building, which is worthy of special mention, is a primary school in the town of Hohen-Neuendorf near Berlin, which was constructed to the Efficiency House Plus standard. That means that, taken over an entire year, the school produces more energy than is needed to run it. The design and planning and subsequent study of the school was based on the federal government's Assessment System for Sustainable Building. The school's overall score meant that it was awarded a Gold Certificate, not least because it scored the top grades for 24 of 40 criteria. The building design is outstanding, allowing good public participation and flexible use that includes modern teaching methods. The school hall, gymnasium and library can also be used by the public. This has been facilitated by the fact that all the areas that are open to the public are situated near the entrances. The building can easily be used for different purposes, it provides high-quality spaces, and it complies with accessibility standards. The design is based on "home areas," i. e. self-contained units consisting of a classroom, area for group work, cloakroom, sanitary facilities and corridor bays. This means they can be used for different kinds of lessons. With regard to sustainability, this has a positive effect on

- the options for use by the wider community,
- preventing vandalism,
- quality of interior space,
- user ownership.

Thermal comfort is particularly important when assessing sustainability. The building's envelope meets the Passivhaus standard. The windows are all triple-glazed. External loads are minimised by sun shading. The struc-

Figure 7: Perspective view of the extension to the Federal Environment Agency in Dessau

Figure 8: Model of the extension to the Federal Environment Agency in Dessau

ture's thermal mass is used as a buffer for peak loads in the summer, with the heat being extracted using automatic night-time ventilation. Heating is provided by a boiler and a micro CHP unit fired by pellets. Electricity is produced by a photovoltaic system and by the CHP unit. Some of it is used by the school itself and the rest is fed into the grid. This significantly reduces the primary energy demand, which has a favourable effect on the life cycle assessment and on the building's operating costs.

Overall, when all indicators are taken into consideration, the school has managed to halve the (negative) impact on the environment. The CO_2 emissions involved in manufacturing components and operating the school have been lowered by 77 %. The approximately 10 % higher construction costs compared with a standard building are offset by 21 % lower life cycle costs and 6 % lower running costs. The owner of this building was interested in the long term and therefore in sustainable development.

Sustainable building in competition procedures

A recent priority has been to establish sustainability criteria in the early design stages. Design competitions present a particular challenge. Individual aspects of sustainable building have always been part of the competition process. They include, for example, functional requirements such as circulation and accessibility, or economic aspects such as construction costs and space efficiency. However, the integrated approach to sustainable building under the Assessment System for Sustainable Building over an entire life cycle have not to date been included. It is therefore important to examine how the sustainability approach could be integrated into the established competition system. This would include answering questions such as:

- Which sustainability criteria are appropriate to which phase of the process and which are relevant for competitions?
- How are these criteria examined and in what depth of detail?
- How are the findings of the preliminary examiners summarised and presented to the jury?
- How do competition processes need to be structured and carried out in order to integrate sustainability requirements?

As part of a research project, specific recommendations for systematically integrating sustainability requirements into design competitions were developed and published in a brochure entitled "Systematik für Nachhaltigkeitsanforderungen in Planungswettbewerben" (SNAP brochure). A core set of 15 sustainability criteria was selected in order to integrate the sustainability methodology into the established competition system. They were chosen on the grounds of decisive influence on design aspects and relevance to the preliminary design stage and also on the basis that it is possible for designers to demonstrate them with a reasonable amount of effort and for the preliminary examiners to assess them. As is common practice in building research, a practical test was carried out before the research findings, in this case the brochure, were published. Test projects were the new building for the Federal Ministry of Education and Research at Kapellenufer in Berlin and the planned extension for the Federal Environment Agency in Dessau. The building in Dessau had to struggle with particularly high specifications. Here a zero energy building was called for that was required to achieve the gold standard in the Assessment System for Sustainable Building. The winning competition scheme combined various individual aspects of sustainable building in a high-quality integrated concept.

Digital tools

Current research on sustainable building focuses mainly on quality assurance, provision of electronic tools and updating databases in the context of European standardisation. This is intended to ensure that both the federal building authorities and all other public and private sector stakeholders are able to implement the sustainable design and building systems promptly and without disproportionate expense. Tools such as eLCA and eBNB link existing database systems to the sustainability assessment system and give rapid answers to questions arising during the design process. The BMUB is working on upgrading its internet portal (www.nachhaltigesbauen.de) to make the necessary tools available quickly and provide information about new developments.

Figure 9: Federal Minister Dr Barbara Hendricks at the stand displaying BMUB's Zukunft Bau research initiative

Supporting sustainable building design in the private sector

Private sustainability assessment systems, such as that developed by the Deutsche Gesellschaft für Nachhaltiges Bauen e.V. (DGNB), which also include further building categories, benefit from the results of the Zukunft Bau research initiative. Firstly, private systems can apply to the BMUB to acquire official recognition through a formal procedure. Secondly, private systems make use of methodological developments and databases. For example, the system variant for laboratories was jointly developed by the BMUB and DGNB. Furthermore, building research has an ongoing interest in updating the data needed to carry out life cycle assessments for construction products (national database Ökobau.dat), as well as data on the useful life of building components and systems providing information on building products and hazardous substances (e.g. WECOBIS which is made available by the BMUB and the Bavarian Chamber of Architects).

Sustainability assessment systems in housing have also become established with the help of developments within the Zukunft Bau research initiative. The associations of the housing and real estate industry established an association to promote sustainability in housing construction (see also www.nawoh.de) and advance nationwide implementation. The system is set up for new apartment buildings and is scheduled to be extended in 2014 to include a system for small houses.

The Zukunft Bau research initiative helps to make buildings fit for the future – both in their design and their construction. In this way it is shaping the future market. ■

eLCA – the life cycle assessment tool for buildings that every designer should have

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

For most designers, carrying out a life cycle assessment for buildings is something new. eLCA is a tool with which the environmental quality of a structure can be demonstrated in a simple way. It has been available online free of charge since summer 2014.

The aim of sustainable building is to protect public goods, such as the environment, resources, health, cultural assets and capital. The three classic dimensions of sustainability – environmental, economic and sociocultural aspects – are based on this and they are the benchmarks that must be used to measure the quality of a building. In addition to that, technical aspects such as process quality have to be taken into account since they are cross-cutting qualities that influence all aspects of sustainability.

As certification systems for sustainable building design gain increasing acceptance, assessment of buildings from an environmental and health point of view is becoming increasingly important and with it the appropriate choice of building materials. Since buildings are in use for a long time, insight into the actual quality of a building is only possible if a long-term view is taken, which encompasses its entire life cycle.

The phases in a building's life, such as construction, maintenance, operation and disposal, must be analysed with regard to the different aspects of sustainability and their interaction optimised. The aim is to achieve a high-quality building that has as low an impact on the environment as possible.

The Assessment System for Sustainable Building (BNB) includes a tool which can be used to quantify the environmental impact and on that basis make an evaluation: the life cycle assessment at building level.

Topic of the research project

eLCA was developed as an easy-to-use tool to facilitate and standardise life cycle assessments for buildings. It helps the user to meet the complex requirements involved in these assessments throughout the entire design process.

eLCA, life cycle assessment tool for buildings

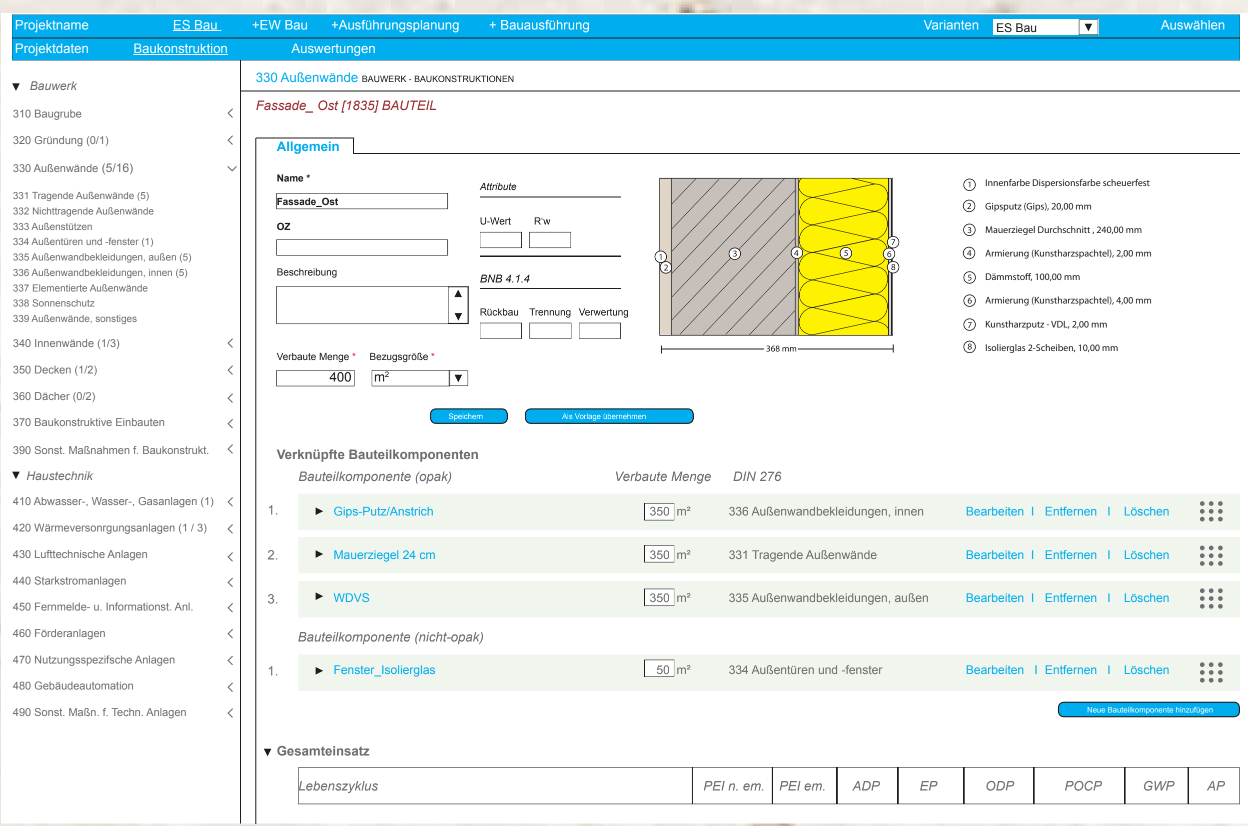
Life cycle assessment

Life cycle assessments for buildings quantify and also make a qualitative statement about the environmental impact of constructing and using a building over a period of 50 years. It takes into account the construction materials used, including the mass and also the amount of energy used during the building's use, broken down by energy source. Processes (manufacture, maintenance, use and disposal) across the entire life cycle are depicted as a function of the building's lifetime.

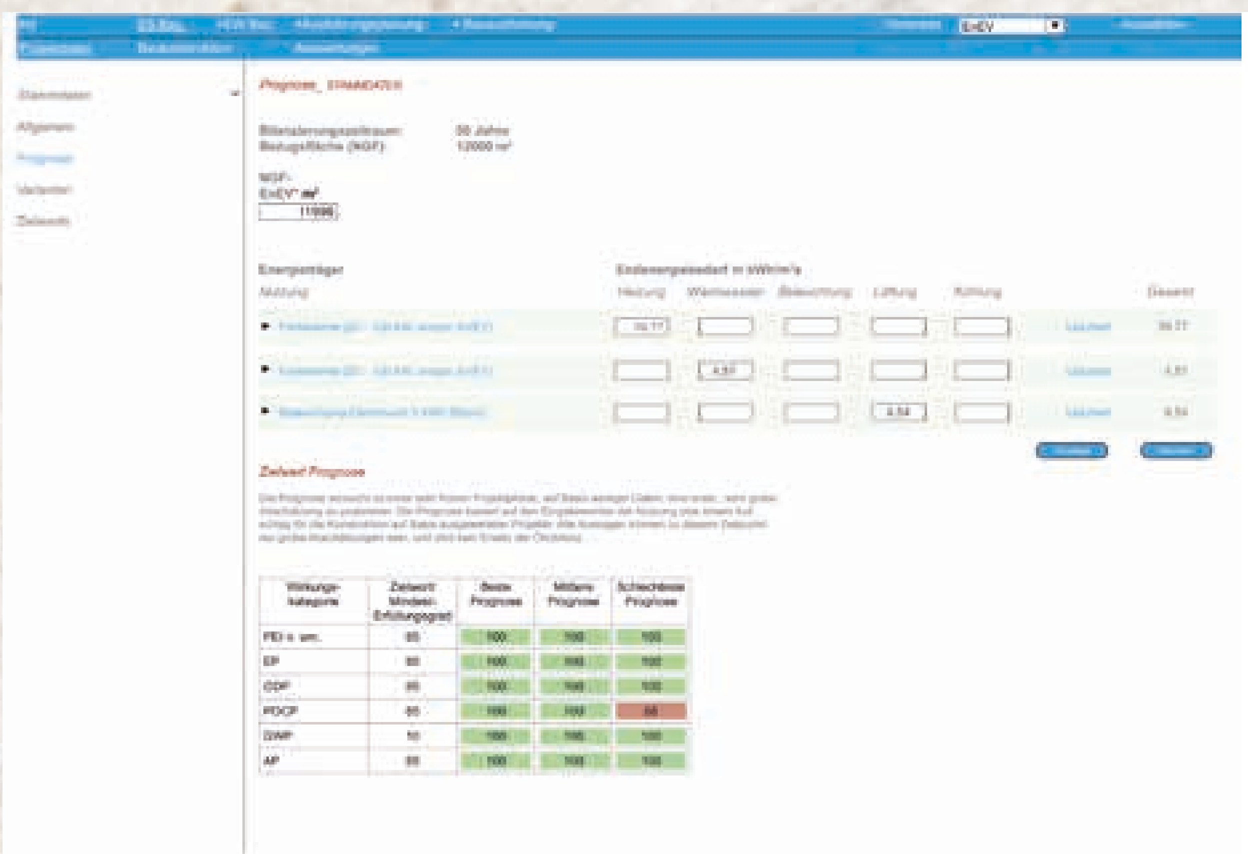
Data on building materials

ÖKO-BAU.DAT data provides the basis for carrying out life cycle assessments for buildings. This German building material database provides a standardised dataset for all stakeholders carrying out environmental assessments of structures. It contains over 1000 data sheets describing the environmental impact of not only building materials but also construction and transport processes. ÖKOBAU.DAT contains both generic datasets and also datasets specific to particular companies or associations, which are based on Environmental Product Declarations.

When carrying out a life cycle assessment at individual building level, the data sheets for the building materials throughout the life cycle, i.e. the data sheets on the manufacture, use and disposal of the different building materials, usually have to be linked up and different lifetimes taken into account. The eLCA already contains all the completely preconfigured datasets on building materials. This establishes a rational and uniform approach and saves the user from having to go through the complex process of linking the datasets.



The building component editor, eLCA's core modelling feature



The prognosis module produces rough estimates at an early stage in a project.

When using the eLCA tool, it is possible to select all the ÖKOBAU.DAT versions (2009, 2011, 2013) as a basis for the calculations because the data is directly linked to the tool. ÖKOBAU.DAT 2013 already includes life cycle assessment data in compliance with DIN EN 15804.

The project component

Within the eLCA tool, each user can create and edit as many projects as they wish. All the basic data needed to carry out a life cycle assessment for a building can be retrieved and compiled in an easy-to-understand form. As well as the relevant areas and quantities, each project is divided into the construction of the building and the amounts of energy needed to operate it. To make it easier and quicker for the user to learn, the tool follows the established structures of the planning process and the basic requirements of the Assessment System for Sustainable Building (BNB). For example, the part of the software used to record building components follows the categorisation used in DIN 276 and the part for recording energy quantities follows the system used in Energy Performance Certificates. This makes it possible to generate the first rough estimates of the project's global environmental impact on the basis of just a few input values and at a very early stage in the design process. As the project progresses and more data becomes available, additional project phases can be generated to reflect that. Data already entered can be incorporated with ease and further processed. An unlimited number of alternatives within these project stages can be created, edited and compared. This makes it possible to fully document projects from start to finish with great ease.

Modelling building components

The building component editor is eLCA's core feature. The user can input materials and data on their thickness, for example, to create layers and then bring them together to generate a complete building component. All the parameters needed for the calculation (parameters from the material datasets linked throughout the entire life cycle, useful life) are automatically assigned to the building component, as already stored in the building material configuration. The user can generate a dynamic view to check their input. This graphic view shows in a separate window the building component currently being edited with all the materials and thickness of layers. This enables the user to carry out an instant visual check of their input so that errors can be recognised early on and corrected.

Building component templates

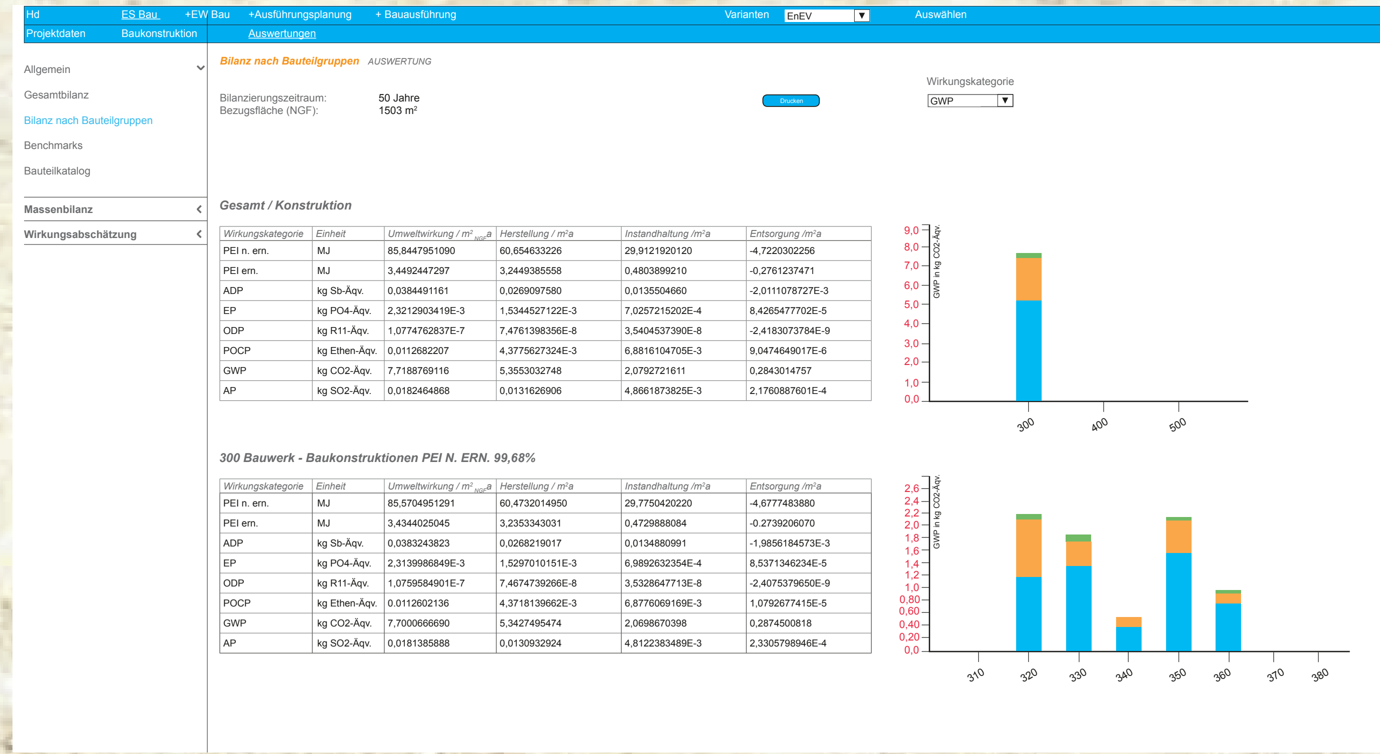
In addition to the possibility of creating user-generated building components, the user can also select building component templates. eLCA provides all users with a basic stock of typical building components as templates. The templates can easily be incorporated into projects and adapted to the specific needs of the project. The templates are user-friendly and make it possible to quickly carry out a complete life cycle assessment.

Catalogues

The building component templates are organised in catalogues to enable users to access them with ease. Catalogues divide the building component templates into categories by type of building and type of construction. Thus, it is possible for example, to view only those templates that are most commonly used for office buildings. In addition to the type of building, the user can also restrict the search to a particular type of construction, such as a timber or steel structure. These filters help the user to search the appropriate templates quickly and specifically.

Assessment

In addition to the project evaluation that complies with the Assessment System for Sustainable Building (BNB), numerous other assessments that are of value in construction practice are available. The results for the different building components are depicted separately for each different stage in the life cycle, making it easier for users to carry out their analysis. The vast number of figures is structured and presented in easy-to-understand tables. Furthermore, all the figures are depicted in easy-to-read diagrams, permitting a rapid interpretation of the results.



Wirkungskategorie	Einheit	Umweltwirkung / m² NGF a	Herstellung / m²a	Instandhaltung /m²a	Entsorgung /m²a
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PEI ern.	MJ	3,4492447297	3,2449385558	0,4803899210	-0,2761237471
ADP	kg Sb-Äqv.	0,0384491161	0,0269097580	0,0135504660	-2,0111078727E-3
EP	kg PO4-Äqv.	2,3212903419E-3	1,5344527122E-3	7,0257215202E-4	8,4265477702E-5
ODP	kg R11-Äqv.	1,0774762837E-7	7,4761398356E-8	3,5404537390E-8	-2,4183073784E-9
POCP	kg Ethen-Äqv.	0,0112682207	4,3775627324E-3	6,8816104705E-3	9,0474649017E-6
GWP	kg CO2-Äqv.	7,7188769116	5,3553032748	2,0792721611	0,2843014757
AP	kg SO2-Äqv.	0,0182464868	0,0131626906	4,8661873825E-3	2,1760887601E-4

Wirkungskategorie	Einheit	Umweltwirkung / m² NGF a	Herstellung / m²a	Instandhaltung /m²a	Entsorgung /m²a
PEI n. ern.	MJ	85,5704951291	60,4732014950	29,7750420220	-4,6777483880
PEI ern.	MJ	3,4344025045	3,2353343031	0,4729888084	-0.2739206070
ADP	kg Sb-Äqv.	0,0383243823	0,0268219017	0,0134880991	-1,9856184573E-3
EP	kg PO4-Äqv.	2,3139986849E-3	1,5297010151E-3	6,9892632354E-4	8,5371346234E-5
ODP	kg R11-Äqv.	1,0759584901E-7	7,4674739266E-8	3,5328647713E-8	-2,4075379650E-9
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AP	kg SO2-Äqv.	0,0181385888	0,0130932924	4,8122383489E-3	2,3305798946E-4

An analysis of a building's CO_2 performance

Project results

Evidence of compliance with 11 criteria is needed for a building to achieve environmental quality under the Assessment System for Sustainable Building (BNB). Environmental quality accounts for 22.5 % of the overall assessment. Using the eLCA tool, seven of these 11 criteria from the environmental quality category can be generated to be fully compliant with BNB based on a single calculation. The individual building-specific values are shown in a transparent way and compared to the standard required by BNB. The aim is to achieve a positive assessment by selecting materials in a way that will minimise any negative environmental impact.

The eLCA tool is currently in an intensive test phase. The first positive feedback reaffirms that the tool is of very high quality and extremely user-friendly. Its ease of use and the transparency of the calculations were rated as being particularly positive. The tool is scheduled to go live sometime in 2014. Once it is successfully registered, this BNB approved life cycle assessment tool for buildings will be available online free of charge. The software's well-structured user interface allows users to generate a life cycle assessment for a building quickly and easily. ■

Developing an online life cycle assessment tool for office buildings

Researchers/project leader	BEIBOB Medienfreunde Tobias Lode und Fabian Möller GbR
Project leader	Stephan Rössig, BBSR, Division II 6
Term	up to November 2013

Figure 1: BHV Homme, Paris, a vertical garden planted without soil; it provides cooling, purifies the air and adds visual appeal to a dense urban area.

Buildings, planting and energy: potential and interactions

Nicole Pfoser, TU Darmstadt

As we gear our behaviour towards increased environmental awareness and focus on efficient implementation strategies, the paradigm of responsible use of resources increasingly becomes the driving force of progress in architecture, landscape architecture and urban design. Applied to architectural design this means that the building envelope in future will have to be treated differently and in a more interdisciplinary way – both in terms of form and function. The aim of the research project is to illustrate the range of benefits green walls and roofs can offer and show how they interact with energy-efficient building technologies.

The realistic possibility of using the surfaces of buildings as green spaces without having to use any land, the increase in the value of the building fabric, the added prestige, and the newly recognised synergy between environmental responsibility and quality of the living or working environment has begun to reach building developers and investors who have to optimise cost.

The research report begins by describing the benefits greening buildings can potentially offer for the urban realm, open space and individual buildings (see Figure 3). It also describes the principles of energy efficiency and energy production and their effect on the building. It is in the interest of all parties that the building be fit for the future. It is first and foremost concerned with greening systems for private and urban purposes and with their contribution to future strategies regarding climate targets, air quality control, protecting water as a valuable resource and conserving nature and species diversity. The different systems currently available for creating green roofs and facades are explained in detail, especially the methods for implementing them and their effects. At the same time, a current overview of efficient ways the building envelope can produce and conserve ambient energy are presented and the full spectrum of passive, partially active and active systems is explained.

This part of the research report explores in detail basic knowledge concerning green roofs and facades in combination with energy-related measures and their performance criteria: the synergies and competing aspects of meeting the demand for heating energy and cooling are described (see Figures 4 and 5). Possible improvements in efficiency in meeting the demand for electricity (PV cooling), fresh air, cooling, heat and water are outlined (see Figure 2), as are the combined benefits achievable as a result of planting and energy with regard to treatment of surface water, rainwater evaporation, noise insulation and biodiversity (see Figure 6). The impact of greening buildings on climate and energy is documented on the basis of literature reviews and a number of on-site measurements.

Below the individual benefits of greening buildings on the immediate environment and urban climate are explored and quantified. Rainwater retention and evaporation as a result of planted buildings – in conjunction with (summertime) shading of the structure's heat stores – are described as efficient natural ways of counteracting the building and ground heating up and as a means of providing protection against premature aging of roofs and facades due to temperature extremes. In addition to their aesthetic appeal, cooling, air purification, noise reduction and introducing an element of nature amidst increasing urban density are the reasons for high acceptance of planted buildings.

Figure 2: Measures to meet a building's demand for electricity, fresh air, and water in its day-to-day operation and life cycle aspects associated with manufacturing components; a depiction of synergies and competing aspects in a planted building

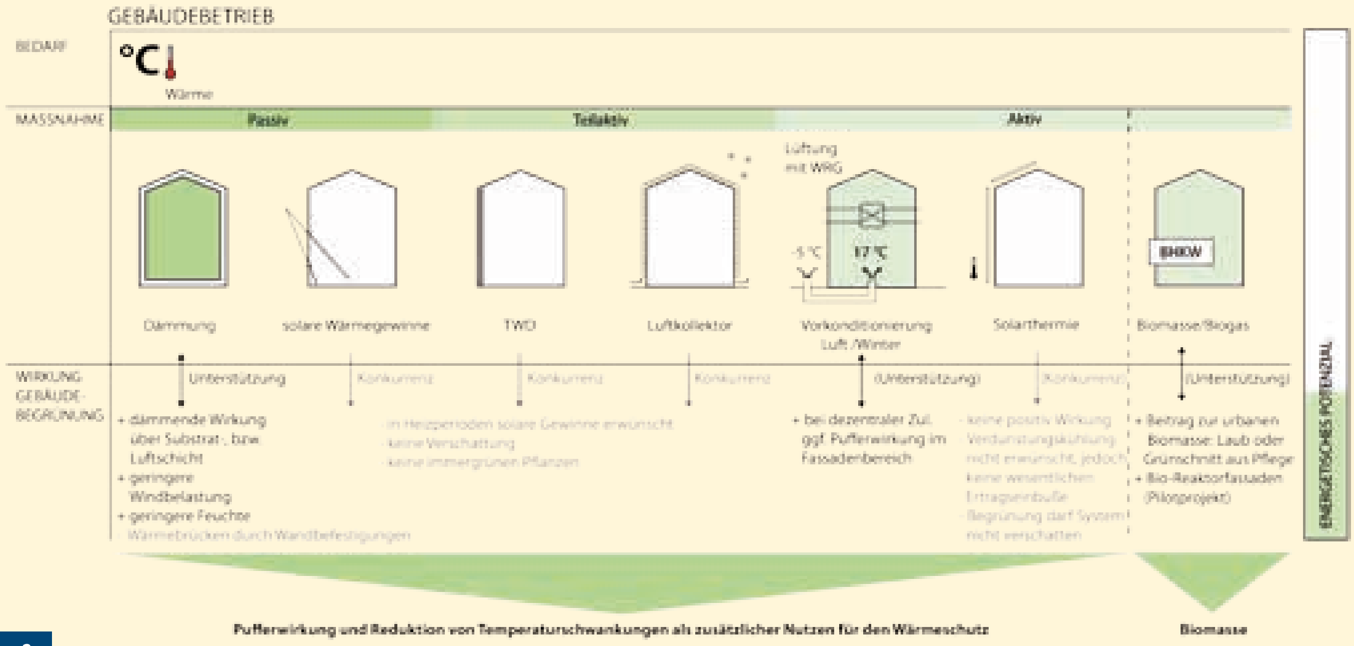


Figure 3

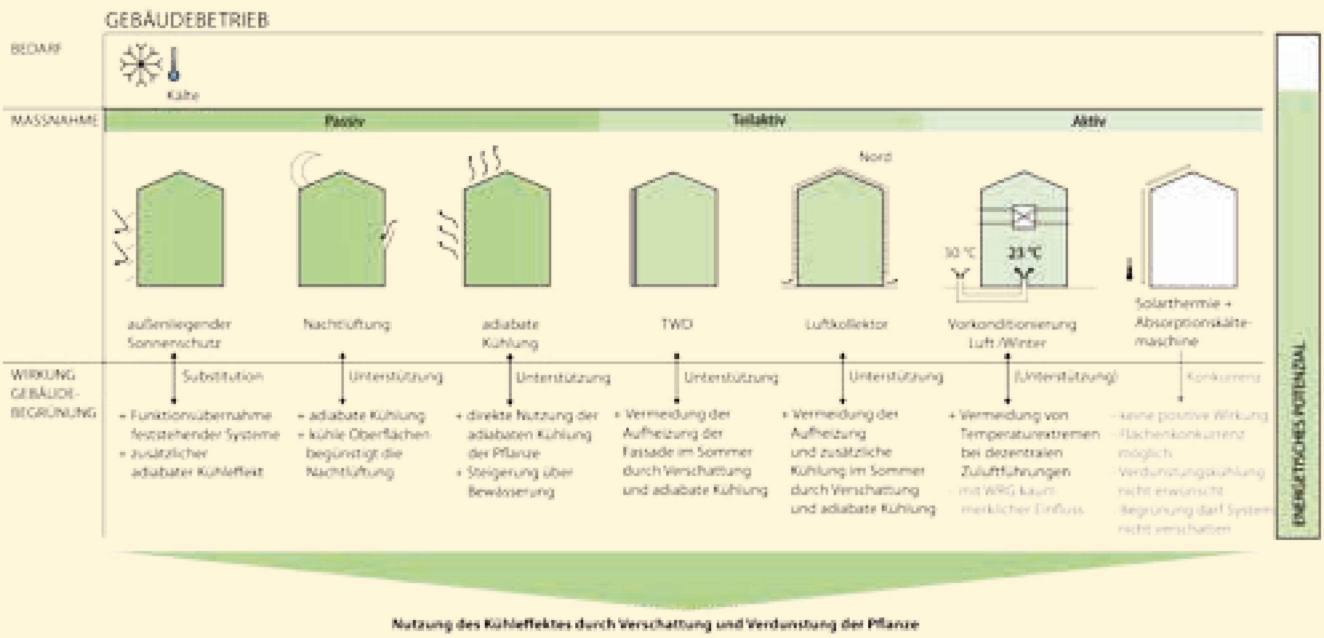


Figure 4

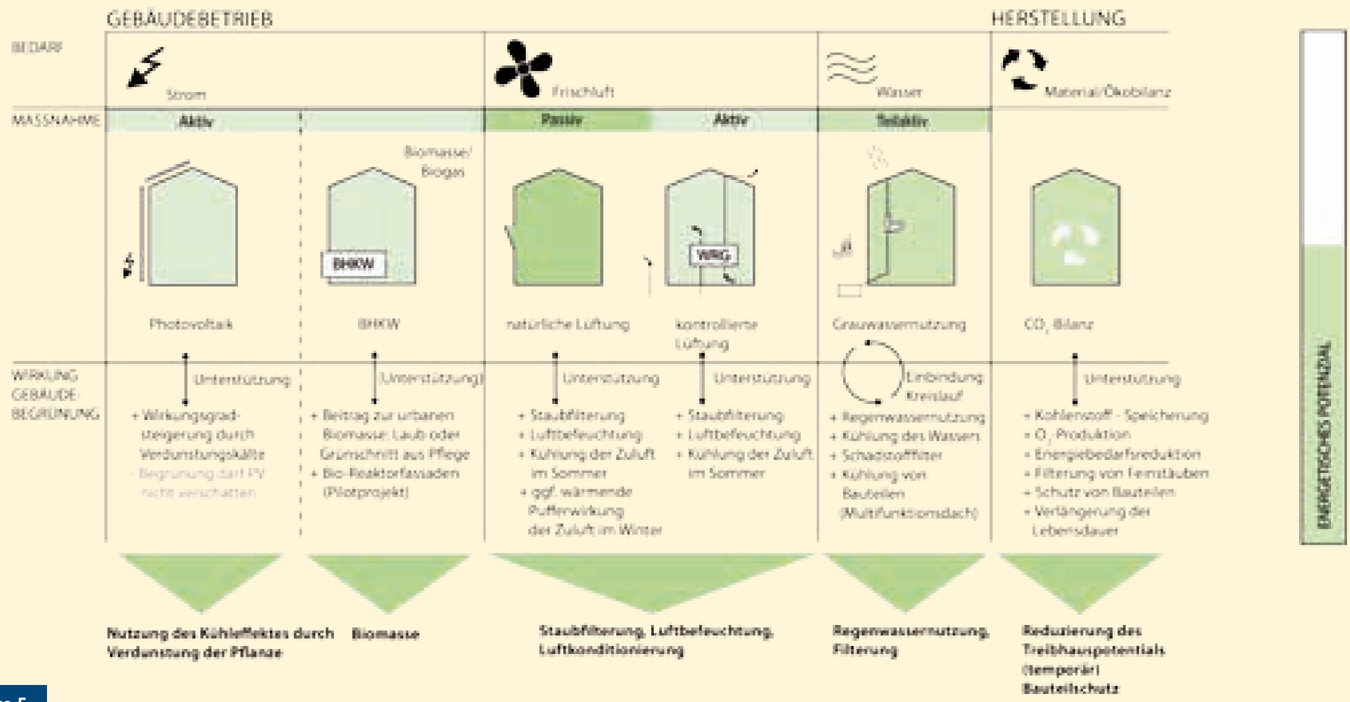


Figure 5

Figure 3
The potential impact greening buildings can have on the urban realm, open space and the individual building

Figure 4
Measures to meet the demand for heating energy; depiction of the synergies and competing aspects in a planted building

Figure 5
Measures to meet the demand for cooling; depiction of the synergies and competing aspects in a planted building

Figure 6
Depiction of the synergies in the area surrounding the building with regard to treatment of surface water, rainwater evaporation, noise insulation and biodiversity in a planted building

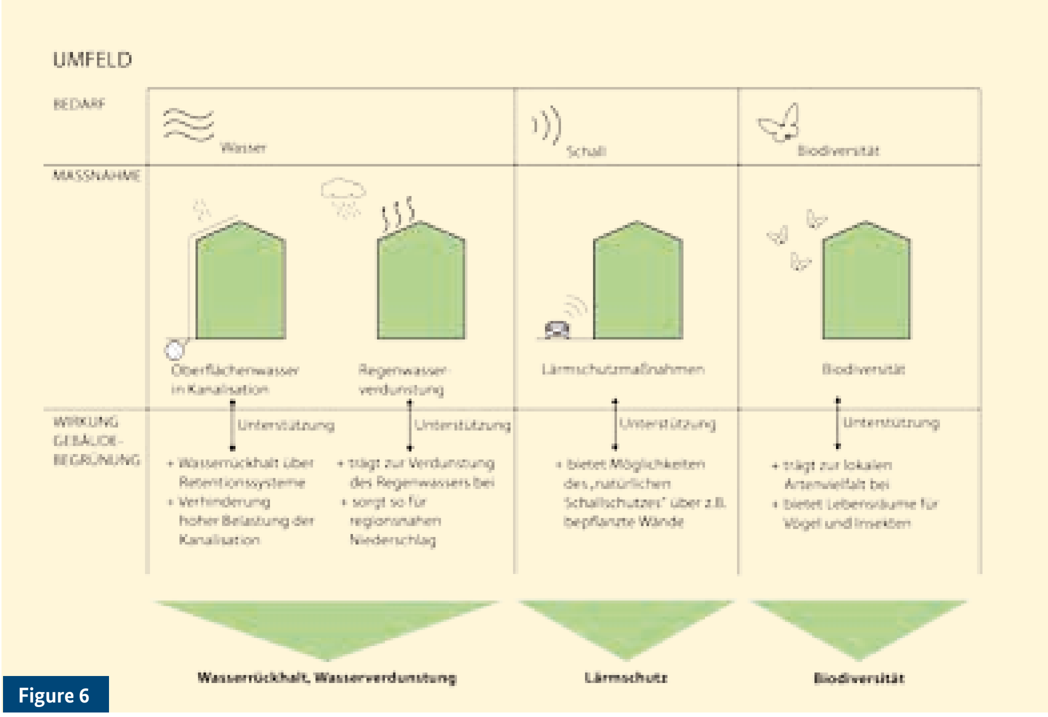


Figure 6

This practice-oriented handbook also gives a comprehensive overview of the parameters to be observed when designing and carrying out planting on buildings with regard to geographical exposure, the influence of the site and existing buildings, building regulations or neighbour law, and recommendations for steps to be taken when planning a project on an interdisciplinary basis.

To illustrate the topic of planted buildings and energy production, the handbook describes a selection of outstanding international building projects. They are all examples of projects that have been successfully executed and as such provide empirical values on the climatic, acoustic, environmental and economic benefits that can be achieved and on the aesthetic synergy between energy-efficient design and planted buildings.

The annex provides an overview of the costs of the different systems for greening buildings and the first comprehensive list giving information on which plants are suitable for use with each different system.

The handbook provides guidance to enable planting projects to be carried out without errors while ensuring energy-efficient building design. It summarises the current state of knowledge on the different greening techniques and on the principles of energy-efficient building design and then goes on to describe the parameters for decision-making when trying to achieve specific goals in installing green roofs and facades on individual buildings, along with the parameters for organisational and design decisions at urban development level.

Linking up energy-efficient building design, greening techniques and overall design is key to successful buildings for the future. Motivating and advising people who make decisions on policy and in practice is only possible with cross-disciplinary information. People who are interested and willing to put this approach into practice can be supported by exemplary prototypes, information on the range of benefits that planted buildings can provide, thermo-active building systems and ways of linking the potential of both to produce synergies. The interdisciplinary handbook provides motivation, design support, research findings and practical experience with the aim of establishing planted buildings – in conjunction with use of ambient energy – as a realistic option in the broad spectrum of construction activity. ■

Buildings, planting and energy: potential and interactions

An interdisciplinary handbook as a planning tool to help harness energy, climate and design potential and to identify the interactions between a building, the planting on it and its immediate surroundings.

Researchers	N. Pfoser, N. Jenner, J. Henrich, J. Heusinger, Prof. S. Weber
Collaborators	J. Schreiner, C. Unten Kanashiro Technische Universität Darmstadt, Architecture Department, Design and Landscape Architecture, Prof. J. Dettmar, Design and Energy-Efficient Construction, Prof. M. Hegger In cooperation with: Technische Universität Braunschweig, Institute of Geoecology, Climatology and Environmental Meteorology Department, Prof. S. Weber
Project leader	N. Pfoser
Overall costs	€ 105 98
Federal government grant	€ 73 500
Term	August 2012 to August 2013

"The reason for funding research is to strengthen the German construction industry's competitiveness and support innovation. The development of the Efficiency House Plus standard is an illustration of the success of this strategy."

Harald Herrmann,
director and professor at BBSR

Harald Herrmann has been director and professor at the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) since 2012. After studying law in Mainz, he went on to become private secretary to Federal Building Minister Klaus Töpfer and head of the construction industry division at the Federal Building Ministry. From 1998 to 2011, Harald Herrmann was head of the Central Department Z at the Federal Office for Building and Regional Planning.

"Research depends on funding"

BBSR is the executing agency for the Zukunft Bau research initiative and is responsible for grant-funded research. What does the work of BBSR's programme management team involve?

Our top priority is operational: we prepare and implement the application procedure and monitor the projects right through to approval of the research findings. Our research administration department checks handling of the funding. That is part of the "administrative behaviour" of a research funding body. But our work is not finished when the research report is submitted. We then have to make sure that the research is published and explore what elements of it can be put into practice.

Generally speaking, the researchers have to publish their findings themselves, but we also try to link up individual results. We bring together researchers who are working in the same field and offer opportunities for them to present their findings in a coordinated way: at scientific conferences, series of seminars and our own BBSR publications. In conjunction with the Fraunhofer Information Center for Planning and Building, we also operate the research initiative[1] internet portal and the building research databases connected with it. Interested parties can research all the reports of work funded and request a copy free of charge.

As you can see, we are seeking to publicise the research findings to a wide audience. This is the only way we will be able to fulfil the actual purpose of the programme, which is to support innovation in the building industry.

Can you give us some figures to describe the programme management activities?

Within our grant-funded research programme, we deal with some 180 applications each year. External reviewers deem an average of 40 of these project proposals to be eligible for funding. At any given time, around 120 projects are being worked on and are monitored by us. And to quote another figure: as part of the research funding programme, our team monitoring the individual projects are in contact with about 1,200 people each year. That means that my team needs not only excellent subject knowledge but also outstanding communications skills.

[1] (www.forschungsinitiative.de/ew)

Who defines the content? Who sets the priorities?

The description of the Zukunft Bau research initiative lists a number of priorities, such as energy-efficient building design, work on existing buildings and sustainability. But ultimately it is up to each researcher to apply for funding for the subject they believe is important. The content framework is created by the competing ideas. However, the outcome of each individual research project has to be of practical use in the construction industry. In that sense, the researchers set the priorities themselves.

Looking at the subject clusters, which would you say are the most predominant?

About half of the applications and funded projects are concerned with energy in one form or another – either in terms of material research, looking at the energy balance of a building, controlling the building services or storage technologies. The applications on this subject indicate that researchers see this as the most urgent issue to be addressed – quite irrespective of any input from policymakers. But materials research and the development of innovative building components are also popular. The most interesting projects, in my opinion, are those looking at innovation in facade design.

What influence does research funding have on building in Germany? What sort of effects does research funding trigger?

The reason for funding research is to strengthen the German construction industry's competitiveness and support innovation. The development of the Efficiency House Plus standard is an illustration of the success of this strategy. This began with support for TU Darmstadt's entry for the Solar Decathlon competition organised by the US Department of Energy in 2006. TU Darmstadt constructed and exhibited its scheme at the National Mall in Washington

D.C. in front of the Capitol and won the competition. From then on the "plus energy" idea was present in the world of construction and numerous individual projects were funded that took it further. Since then it has evolved into a new building standard in Germany – the Efficiency House Plus standard – which is also highly regarded abroad. German expertise in this field is in great demand internationally. But this is just one example from a range of interesting developments which our research funding programme has triggered.

What are the most important topics for the future? What will we be talking about in five to ten years' time?

I believe that there should be more research done on refurbishing and remodelling existing buildings. There is simply not enough happening in this field. It is crucial that we find a way of using fewer resources. Here the use of new kinds of material in innovative building components can be very valuable. I am thinking for example of the ultraslim lightweight windows that we were able to exhibit at the Bau 2013 trade show in Munich. This is an energy-efficient window system, which was developed for use when replacing existing windows and is only 25 % the weight of other windows in common use. This is for me an example of a ground-breaking project.

What is your own home like? Have you been able to fulfil your personal wishes for building design?

I can refer back to what I was just talking about. We live in a house that is now 35 years old. In other words, it is an "existing building," which we have gradually adapted to the evolving standards over the years, from refurbishing the roof and upgrading the heating through to the windows. We live in an urban environment that has evolved over time. Everything is easily accessible. That was exactly what we were looking for when we were young and we are still happy with it today. ■

The Zukunft Bau research initiative – turning vision into reality

Helga Kühnhenrich, Federal Institute for Research on Building, Urban Affairs and Spatial Development

The building sector has a greater influence on what tomorrow's world will be like than almost any other sector. To meet the challenges and developments in this sector, the federal building authorities work not only on drafting the appropriate regulatory framework and implementing its own buildings, they also engage in a range of activities to promote research and make sure that Germany's building sector remains fit for the future. What are the major driving forces and megatrends in tomorrow's building research? What effect are scarcity of resources, demographic change and Germany's "energy revolution" having on the building sector? What direction does it need to take to meet the needs of future generations? What contribution can the federal government make? How can the vision and new ways of thinking be turned into living reality?

These are the kinds of questions that are being explored in numerous research projects that have been instigated or are being supported by the government's own Zukunft Bau research initiative.

The Zukunft Bau research programme, which was set up by the Federal Building Ministry in 2006, is comparable to the research department of a large company. It stimulates ideas both for the federal government's own building activities and for Germany's entire building sector. The aim of the research initiative is to prepare the sector for the challenges of the future, strengthen the German building sector's ability to compete in the single European market and promote new technical, architectural and organisational innovation and knowledge. The research initiative sees itself as a research programme that is explicitly dedicated to applied building research – turning vision into built reality.

The research findings are presented and discussions on building for the future are initiated through numerous events, pilot projects and publications. Since the beginning of the year, the Zukunft Bau research initiative has had a new website at www.forschungsinitiative.de. The website has interactive functions designed to promote sharing of ideas among building researchers and with the construction and housing industry. It is becoming a knowledge broker in the industry.

Implementation

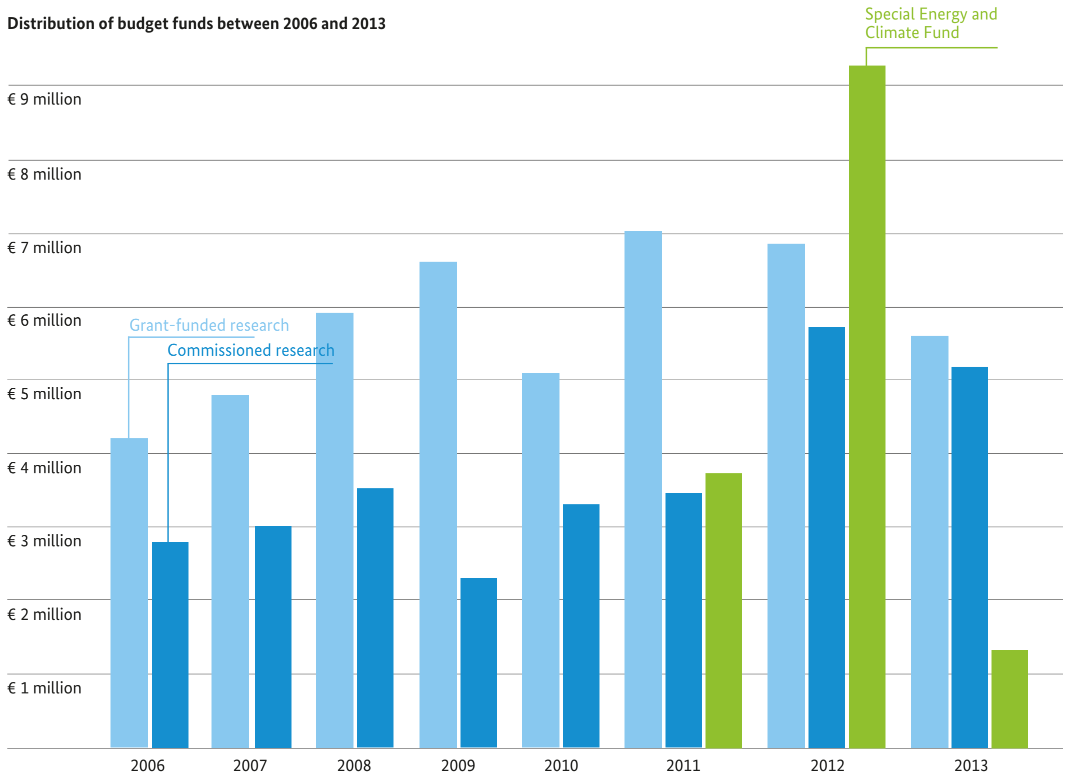
When the new federal government was formed, responsibility for building, and therefore for the Zukunft Bau research initiative, went to the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The Federal Building Ministry under this new name will still have policymaking and organisational responsibility for the research initiative, whereas the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR) is the contract partner for researchers and advises the ministry on technical matters.

During the eight years since the research initiative was set up, a total of 750 research projects have been funded with approximately € 83 million in federal funding. The research programme has three components: commissioned research, grant-funded research and the Efficiency House Plus network.

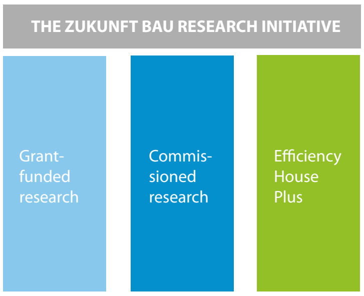
Commissioned research

The federal agencies prepare the government's policies by issuing carefully targeted calls for research proposals and by commissioning expert reports and investigations on proposed legislation and current policies areas. Sectoral research is funded exclusively from federal coffers. In recent years the following areas have played a particularly prominent role:

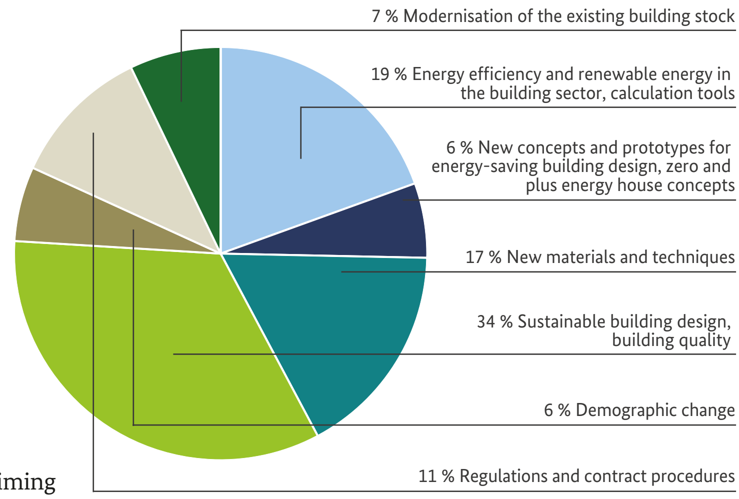
- updating the Energy Saving Ordinance and developing the energy performance certificate
- further developing sustainable building (launching the BNB system variant sustainable research and laboratory buildings)
- developing building material databases such as WECOBIS and Ökobau.dat
- compiling a digital manual on accessible building design



Trend in budget funds since the Zukunft Bau research initiative was launched



The three components of the Zukunft Bau research initiative



Grant-funded research 2013: breakdown of applications received by topic

Grant-funded research

With grant-funded research, the research initiative is aiming to incorporate research ideas that come from the market. Working in conjunction with academia and sometimes with support from partners in industry, the building sector submits research proposals on predetermined priority issues. The idea of this is to strengthen in particular the innovative capacity and market position of small and medium-sized enterprises as a priority. The research projects receive grants from the federal government to cover some of their costs.

Pilot projects within the Efficiency House Plus network

In addition to developing new building materials or using innovative technologies, the research initiative is also concerned with building designs that are fit for the future. In 2010, the research initiative introduced the Efficiency House Plus standard, which buildings comply with if they generate more energy over a year than is necessary to run them. This “plus,” i.e. surplus, energy is to be used particularly for electromobility or neighbourhood heating. In addition to the federal government’s pilot project in Berlin entitled “Mein Haus, meine Tankstelle!” (my house, my filling station), a nationwide network of roughly 35 different pilot projects for both houses and apartment buildings was set up in 2011 as part of the funding programme for Efficiency Houses Plus in the domestic sector. The first results from the buildings that have already been completed reaffirm the long-term goal of establishing this building standard on a nationwide scale in the future. ■

Metastudy on thermal insulation materials: products – applications – innovations

Technologies and techniques to improve the energy efficiency of buildings using thermal insulation materials

Christoph Sprengard, FIW Munich

Carrying out energy-efficient refurbishment work and improving the energy efficiency of existing buildings is crucial to reducing energy consumption in Germany and is thus the key to the success of the country's Energiewende or "energy revolution". However, to date no study of the energy-saving potential of specific building components in unrefurbished buildings has been carried out, taking into account the differing starting situations in terms of energy efficiency. Similarly, there is no comprehensive, neutral description of the technical, environmental and economic aspects of the insulating materials used. The building sector repeatedly has to listen to the reproach that it is not innovative. Added to that is the predominantly negative reporting on insulating materials, refurbishment measures that are not cost-effective, and isolated cases of facades catching fire. These – sometimes factually incorrect – reports have unsettled potential investors, with the result that the rate of energy efficiency improvements is not progressing.

The project began by analysing the structure of final energy consumption by consumer sector and end use. A breakdown of energy consumption in the building sector was carried out and the huge role in final energy consumption in Germany played by space heating in private households was demonstrated. (Figure 1)

The data on materials typically found in insulation used in the building sector was compiled in a standard and structured form. It includes details of raw materials used, form of delivery and processing, properties, health and environmental aspects, and areas of application. Normative regulations were set in the context of the legislative and regulatory environment in Germany and Europe. Figure 2 shows an overview of market developments and the distribution of the most important insulating materials on the market. The study also gives comprehensive details on the use of insulating materials by place of use and building component.

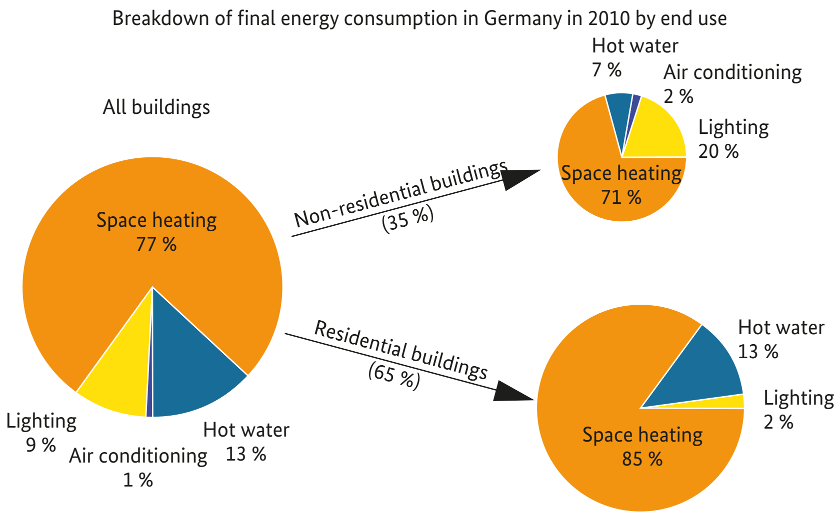


Figure 1: Final energy consumption of buildings in Germany and breakdown into residential and non-residential buildings

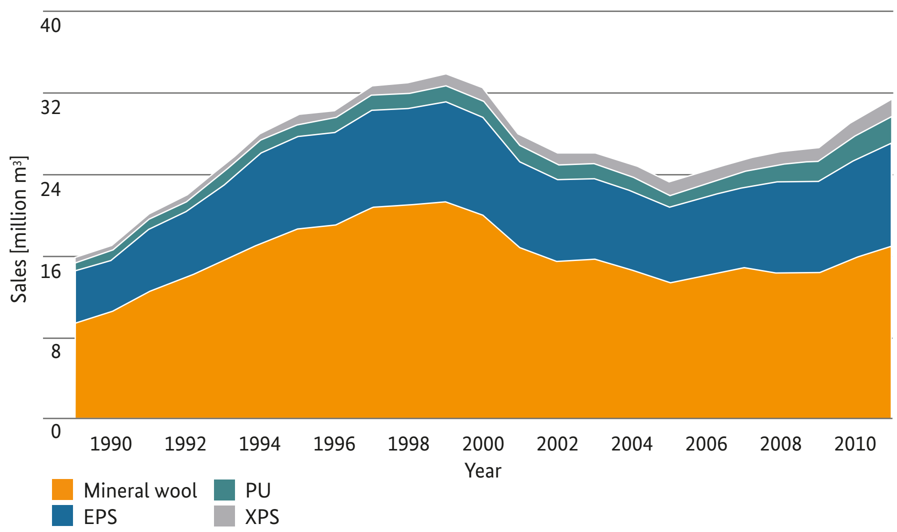


Figure 2: Sales of the most important insulating materials in Germany in million m³ per annum (1989–2011)

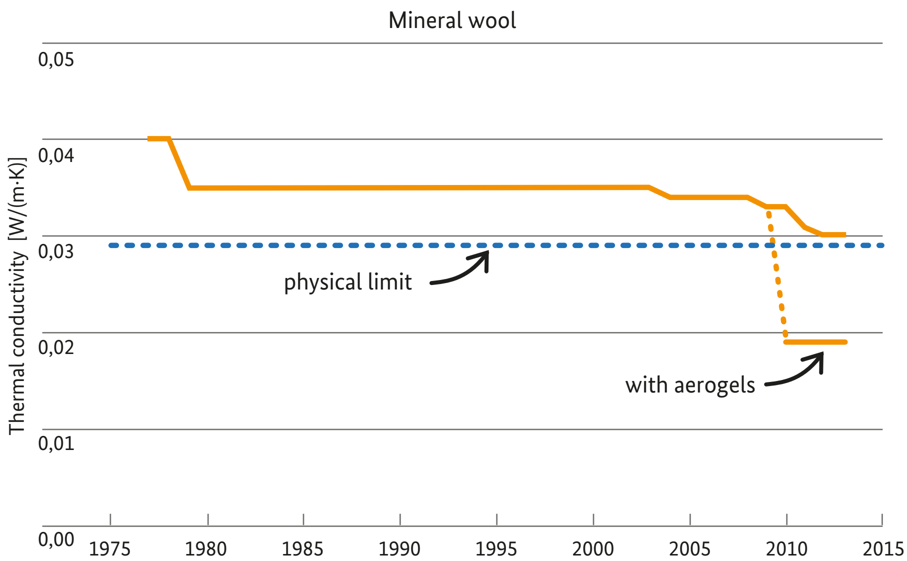


Figure 3: The example of mineral wool showing how thermal conductivity has improved since 1975

Following a description of the physics of heat transfer, the most important innovations in recent years in the field of insulating materials and building materials were compiled and evaluated. Figure 3 uses the example of mineral wool to illustrate reduction in thermal conductivity. Potential areas of development in terms of manufacturing processes (production technology, cell gases etc.), ease of assembly and replacement of functional additives (fire protection) for the different groups of materials are listed.

The sustainability of insulating materials is described using selected examples for each of its three dimensions (environmental, economic, sociocultural aspects). Insulation materials' payoff in terms of energy savings and its dependency on the characteristics of the material are discussed. Examples of rating insulating materials on the basis of life cycle assessment datasets, their cost structures (manufacture, maintenance, disposal/removal), useful life and the potential health and ecotoxicological hazards resulting from additives

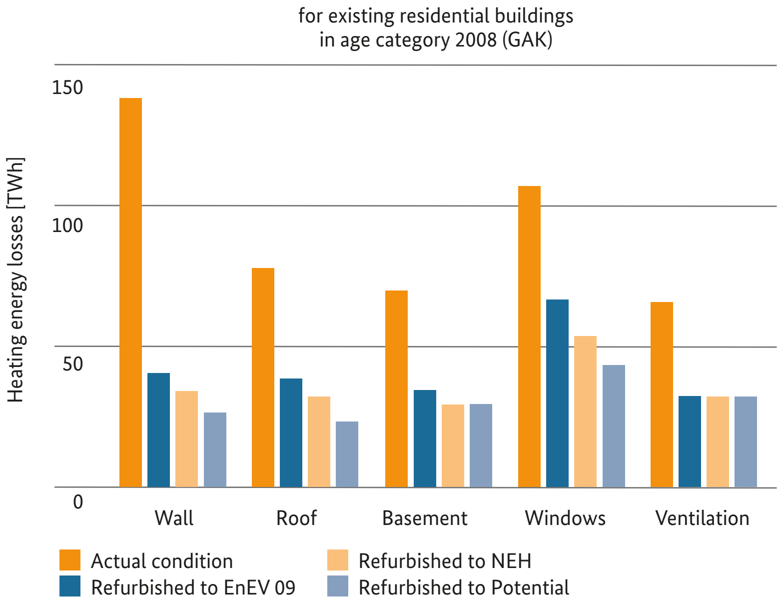


Figure 4: Total heating energy losses per building component in various states: unrefurbished (actual condition) or refurbished to standards of the Energy Saving Ordinance (EnEV 09), to the level of a typical low-energy house, or to Passivhaus standard (potential) for existing residential buildings in age category 2008 (GAK)

and fibrogenic dust help to understand the relevant product properties despite the complexity of their possible interactions.

Based on existing data on the building stock, a component-specific estimate of the savings potential offered by energy-efficient refurbishment is made. Based on the datasets, assumptions about the required thickness of insulating materials and estimates of the volumes of insulating material needed for different refurbishment goals can be deduced. The total heating energy losses per building component in unrefurbished and refurbished residential buildings up to age category 2008 (GAK) are shown in Figure 4.

Finally, typical barriers to refurbishment are identified. The terminology that is often imprecisely used in the media concerning architecture, energy saving, costs and cost-effectiveness, biological infestation, fire hazard and disposal is defined more precisely and described in fact sheets.

Broken down by components, refurbishment that complies with the Energy Saving Ordinance (EnEV) 09 saves between

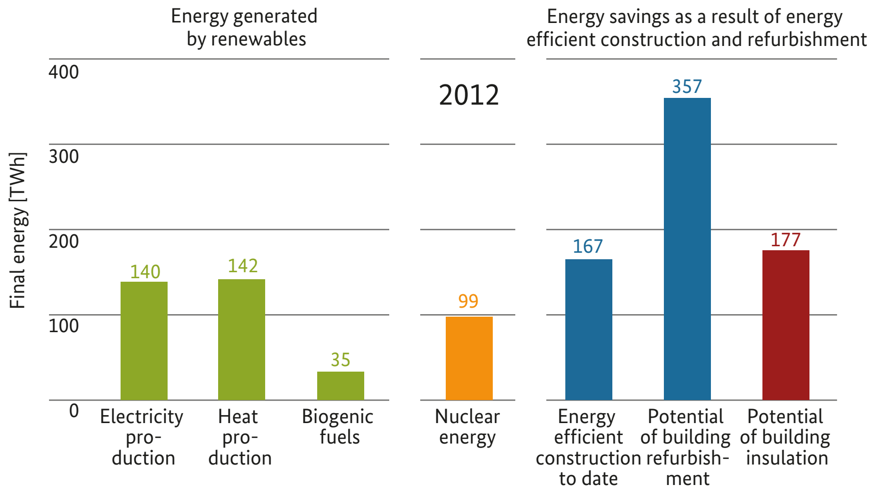


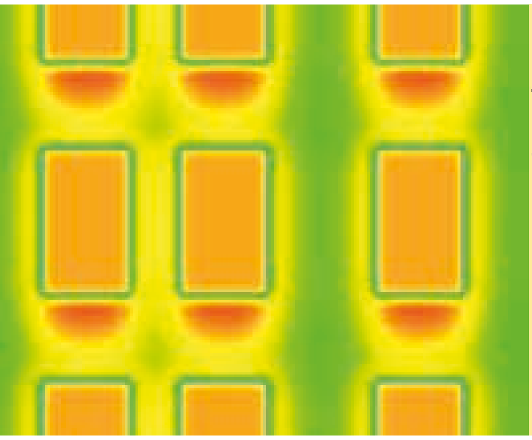
Figure 5: Significance of insulating buildings (refurbishing all residential buildings to the standards set out in EnEV 09) by comparison with final energy supplied from renewables or nuclear power stations

55 % (roof, basement) and 78 % (facade) of transmission heat losses. These measures alone undertaken on existing buildings up to age category 1993 (GAK) produce potential savings of around 54 % based on the actual final energy demand for space heating. Figure 5 shows the major significance of better energy efficiency as a result of energy-efficient building design and refurbishment.

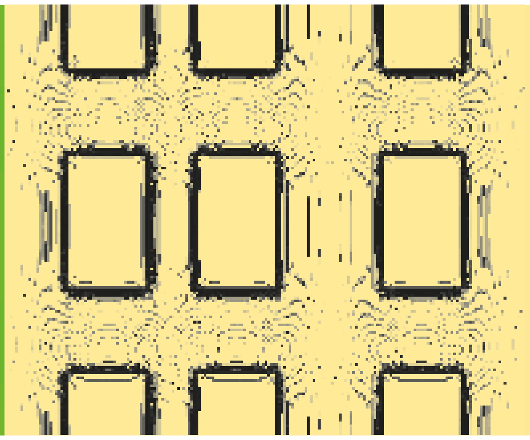
The additional costs of refurbishment resulting from energy efficiency measures pay off within a reasonable period of time. Damage to thermal insulation measured against the amounts used in a building is low. If installed correctly, the systems commercially available meet all fire protection specifications. The complete study can be downloaded from the Fraunhofer IRB website or at: www.fiw-muenchen.de/media/pdf/metastudie_waermedaemmstoffe.pdf . ■

Metastudy on thermal insulation materials – products – applications – innovations

Researchers/project leader	Christoph Sprengard (project leader) Dr Sebastian Treml (research scientist) Prof. Andreas Holm (head of the institute)
Applicant	FIW Munich, www.fiw-muenchen.de
Overall costs	€ 108 000
Federal government grant	€ 75 600
Term	September 2012 to November 2013



Facade detail as thermographic image



Facade detail showing isotherms

Facade detail as 3D model

Possibilities of modulating the skin of buildings using thermographic imaging processes

Faraneh Farnoudi, Hild und K Architekten, Munich

Facade insulation is an indisputable necessity and, particularly in the existing building stock, thermal insulation composite systems are among the most crucial building materials of our time. Yet modern thermal insulation systems offer only limited scope for individual design and even the scope that does currently exist is not being fully used during the design and construction phase.

This advancing process harbours the risk that in many places our towns and cities will lose their character.

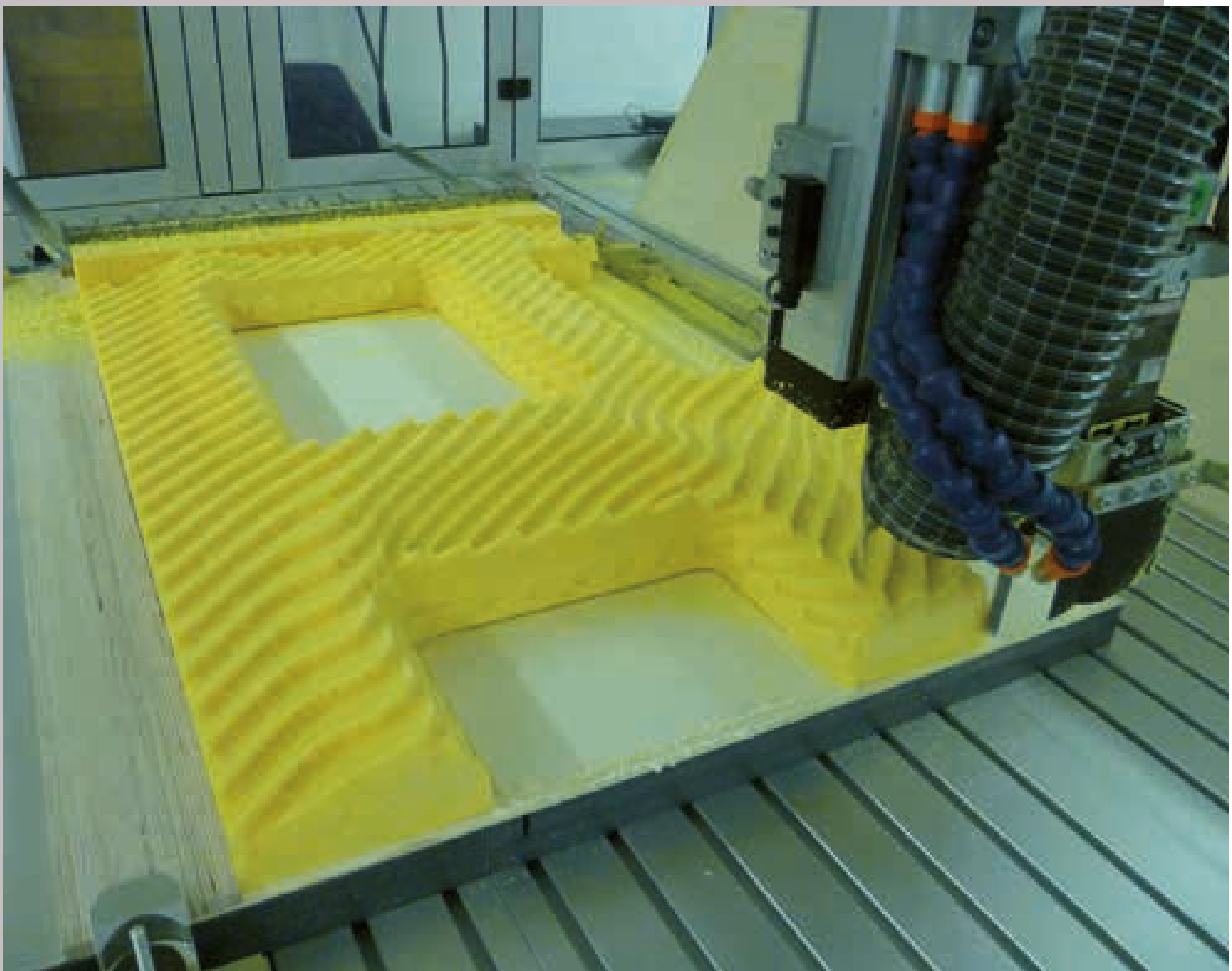
This research project sees making a building's envelope energy-efficient as not merely an issue for engineers but as a design task and opportunity. Specifically, the project is exploring the possibility of three-dimensional modulation of the insulation layer with the twofold aim of individualising the facade design and improving the system's performance.

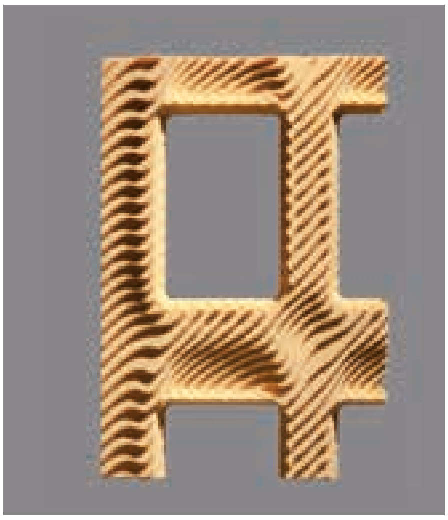
Using a specific test building, ways of combining expressive design with the use of thermal insulation composite systems are being developed. It is not a question of simply "prettifying" the existing systems, but of developing their aesthetic potential and consequences.

Most of the attempts at architectural design of thermal insulation composite systems failed as soon as they tried to imitate rendered solid walls. The material itself and its features prevent that kind of analogy.

The approach taken by this research project therefore does not work on the plaster but on the thermal insulation behind it. Its properties make it suitable to work on: it is perfectly possible to shape it, provided horizontal surfaces – which would cause damp problems – are avoided. If the insulation was either modelled in 3-D or cut to size, the surface of the building would be a plane that could be designed, which would permit far more subtle graduations than we are used to with solid buildings. Thus, instead of attempting to mimic rendered buildings, the research project is seeking an aesthetic solution that evolves naturally from the qualities of the thermal insulation composite system itself. It attempts nothing less than making its function visible within the facade. The starting point for the considerations that follow is the difference in thermal transfer of different building

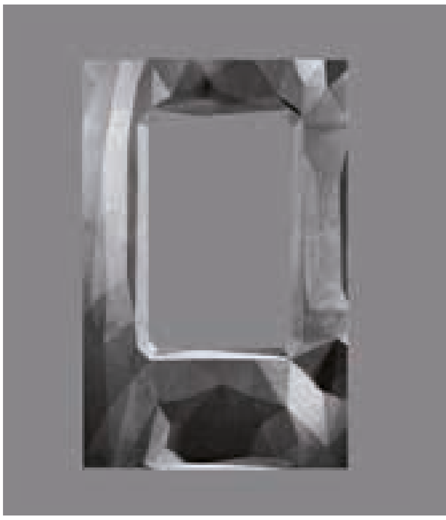

Manufactured as a multilayer model


Preliminary manufacturing trial using a CNC milling cutter



Model variant: 30°

Model variant: vertical



Model variant: triangulation

components on the facade of an existing building. If the dimensioning of the insulating material is adapted to the differing heat transfer coefficients, a surface modulation is created that reflects the different thermal conditions of the building's skin. To achieve this, a computer program based on thermographic images calculates heat transfers and defects in the thermal skin, the temperature distribution and water vapour diffusion in the building and simulates them in a three-dimensional model. In fact, this modulation based on heat transfer through the facade could be depicted in relief on the insulating material. However, the surfaces that would be created would be double-curved and therefore only possible to manufacture using a very complex process. Added to that is the problem that to date there is no render mesh that can be modelled in three dimensions. The research project is therefore looking at modulations which, on the one hand, reflect the heat transfer based on the model described and, on the other hand, are likely to be simpler to manufacture.

Thus simulating heat transfer becomes the basis for a diverse range of design possibilities. Not only are facades with a completely new look created, at the same time resources are conserved, since only as much insulation is ever used as is necessary at any given point. Thus the function of the thermal insulation composite system is reflected in form.
After the blocks of insulating material have been manufactured, they have to be fixed to the building, reinforced and rendered in the same way as for conventional thermal insulation composite systems. In the trials that were carried out, different models were rendered using different methods, in order to verify both the technical and the design aspects. Using appropriate tools and materials it proved possible here to achieve the desired result. Higher specifications have to be met, and especially a higher standard of workmanship, than is the case with conventional systems, but we believe that this can be achieved.

Successful plastering trials on a polystyrene model

Successful plastering trials on a polystyrene model

In conclusion it should be noted that the scope for design with thermal insulation composite systems is vast. The research project developed a method for designing a modulated outer skin for a building using a thermal insulation composite system. It proved possible to manufacture all the design options from EPS insulating material and it would be possible to execute two of them using reinforcement and a top coat that are already available today.

This shows that thermal insulation composite systems can function as materials in their own right and that the further intelligent exploration of the subject that is needed to fully sound out the potential is possible.

Thus the first incentive to further develop thermal insulation composite systems under completely new aesthetic aspects was created, moving one step closer to the aim of achieving an aesthetic that is appropriate to the material. ■

Modulating thermal insulation composite systems

Researchers/project leader	Hild und K Architekten, Munich
Project leader	Faraneh Farnoudi
Overall costs	€ 158 958
Federal government grant	€ 99 659
Term	until September 2013

Professor Andreas Hild is joint partner with Dionys Ottl and Matthias Haber in the firm of architects Hild and K. He has also held the Chair of Architectural Design, Rebuilding and Conservation at TU Munich since 2013. As part of the Zukunft Bau research initiative, Professor Hild has been researching new design possibilities for thermal insulation composite systems.

“Increasing the rate of energy efficiency refurbishment is the key issue”

You have taken up a professorship that includes conservation. At the same time, you are carrying out research on polystyrene as a thermal insulation material. How do those two things fit together?

The title of the chair is Architectural Design, Rebuilding and Conservation. If you stress the rebuilding element, then refurbishment, which is a part of that work, is simply an issue you have to engage with. But energy efficiency of historic buildings is also something we have to tackle in conservation work. It is simply not right to behave as if there were no need for discussion in this field.

The rate of energy efficiency refurbishment in Germany is just 1.5 %, which is regarded as far too low, given the current demographic changes and the fact that we are trying to transition to a new energy era. What has to happen to boost refurbishment activity?

I believe we will have to start making radical changes in the fairly near future. The refurbishment rate is too low for a number of very different reasons. I will limit myself to talking about just three issues. The first is that, in most cases, refurbishment is more expensive than new build. There are several reasons for this but the key one is that the “grey energy” embodied in existing buildings never appears in investors’ calculations. If costings for pulling down a building to make room for a new building included the carbon that society has already paid for, then that new building would be significantly more expensive than refurbishing the old one and the refurbishment rate would automatically rise.

So how can we factor embodied energy into the building costs?

There are many ways of doing that. One would be to introduce tax relief on refurbishment or another option would be to set up a fund into which people had to pay whenever they demolished a building. Some kind of emissions trading could also be considered. We are currently working with business engineers and construction economists to set up a research project to explore options. There are, for example, a number of interesting effects on the labour market.

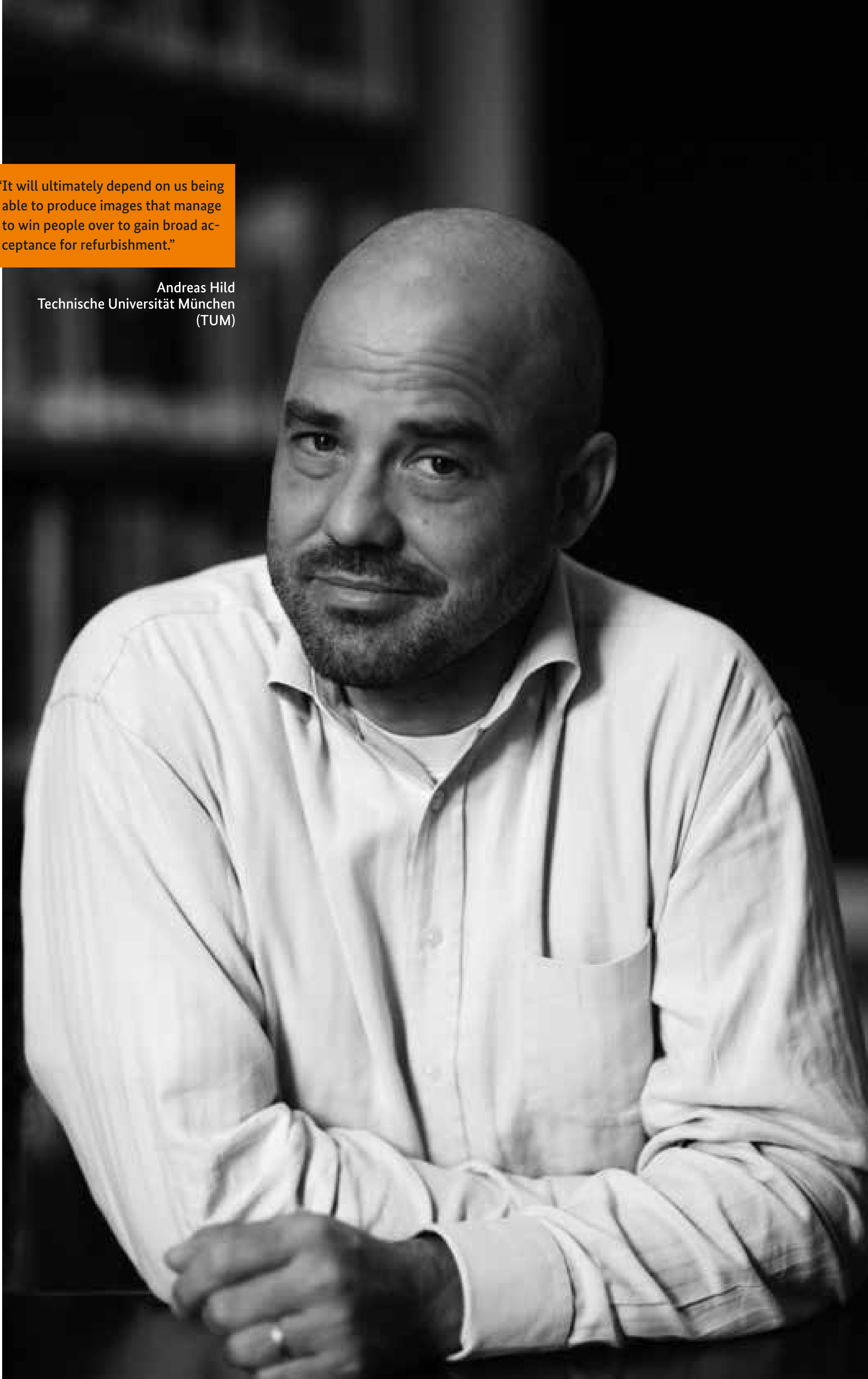
But you mentioned three issues.

One of the reasons the rate of energy efficiency improvements is so low and building costs are so high is the fact that we have to comply with regulations that are quite clearly designed with new builds in mind.

When it comes to refurbishing existing buildings, these regulations produce situations that cannot practically be resolved. That, in conjunction with current case law, is systematically lowering the refurbishment rate – quite simply

“It will ultimately depend on us being able to produce images that manage to win people over to gain broad acceptance for refurbishment.”

Andreas Hild
Technische Universität München
(TUM)



because it has become too complicated and too expensive to deal with. You only have to think, for example, about certain questions of fire protection or noise insulation in existing buildings. We will have to find other assessment possibilities if we want to sustainably increase the rate of energy efficiency improvements.

The third issue, in my opinion, is the fact that we need to have a broad-based discussion in society about comfort. If we want to increase our refurbishment activities, we will not in the long run be able to achieve a new build standard plus X in every respect. We have to analyse the standards used and discuss what we can afford and what the consequences of that will be.

What are the most important issues for the future? What do you think building research should prioritise?

As I said, I think increasing the refurbishment rate is the key issue and I believe that the main thing we need to achieve is the political will to make changes. Political will is, of course, not an isolated factor, but we have to move the carbon discussion away from being just about how to save extra cost and make it into a discussion about our attitude to embodied energy. That is an ambitious task because the interrelationships are complicated. But we really must tackle it.

But acceptance for any activities in this field will ultimately depend on whether we architects can win the support of society for the impression buildings make after we have refurbished them. That includes aesthetics but, of course, it also covers things such as accessibility and inclusion, and also cost transparency.

It will come down to our ability to produce images that rally support and achieve broad acceptance for refurbishment.

How will architectural teaching change?

One of the places the search for refurbishment strategies has to begin is in universities. That is where the people who will carry out those strategies in the future are being trained. It is obvious that quite different design strategies are needed for refurbishment than for new build. Our teaching institutions will have to come up with a response to that. We have already begun to do so but we are not teaching refurbishment as much as you might expect in view of the work ahead of us. There are only a handful of chairs in architecture faculties in Germany which systematically focus on it.

What is your home like? Have your wishes been fulfilled?

I am completely happy with the way I live. I live right in the centre of town, on the edge of Munich's historic core, where urban density is highest. I see being able to live there as a privilege, although I am sure it would not suit everyone's needs. ■

Climate-sensitive redevelopment in historic neighbourhoods

Julia Drittenpreis, Thomas Schmid, Technische Universität München (TUM)

Preserving the architectural culture of our past while at the same time ensuring that historic neighbourhoods are liveable and offer residents modern standards of comfort and convenience requires climate-sensitive urban redevelopment strategies. Climate-sensitive urban redevelopment will be a key factor in implementing Germany's energy revolution. 75 % of the country's building stock was constructed before 1975 [1] and is due for refurbishment. Conserving the existing building stock also plays an important role in view of the current demographic changes and decline in population figures. To achieve these goals, new and integrated ways of thinking about designing, building and refurbishing buildings are needed.

The strength of historic buildings and neighbourhoods lies in their ability to create an ensemble. As well as creating a sense of place and identity, this also has a decisive impact on the potential for saving energy and using renewable energy sources. It is vital that we make use of this potential. With this in mind, we need in future to not just consider the individual building but broaden our view to include the entire neighbourhood and community. In this way, the energy issue is not reduced to a consideration of individual buildings but takes a broader focus that involves designing energy strategies for entire neighbourhoods (Figure 1). This makes it possible to take advantage of synergy effects and local energy resources. This in turn is only possible on the basis of intensive engagement with historic buildings, local energy potential, energy consumption density and infrastructure.

This requires appropriate planning tools so that individual measures for saving energy, increasing efficiency and using renewable energy sources can be specifically developed and coordinated at local authority level. An energy use plan is an informal planning tool that makes it possible to link complex energy questions. It is an important instrument that plays a valuable role in coordinating energy issues within urban planning and redevelopment schemes (Figure 2).

To identify ways of dealing with historic urban neighbourhoods in the future, a research project on energy use plans tailored to conservation, using the town of Iphofen as an example, was funded by the Federal Ministry of Transport, Building and Urban Development's Zukunft Bau research initiative. The project illustrates options for small towns that have a high percentage of historic buildings to use energy efficiently and reach a high share of renewable energy sources. The research findings are illustrated using the practical example of the town of Iphofen and are transferable to other towns and cities. Iphofen is characterised by a high percentage of historic half-timbered and solid buildings dating back to the 17th and 18th century.

Figure 1: Different levels for consideration when developing energy use plans for historic neighbourhoods: municipality – neighbourhood – typical buildings

Figure 2: Different levels of an energy use plan (map excerpts)

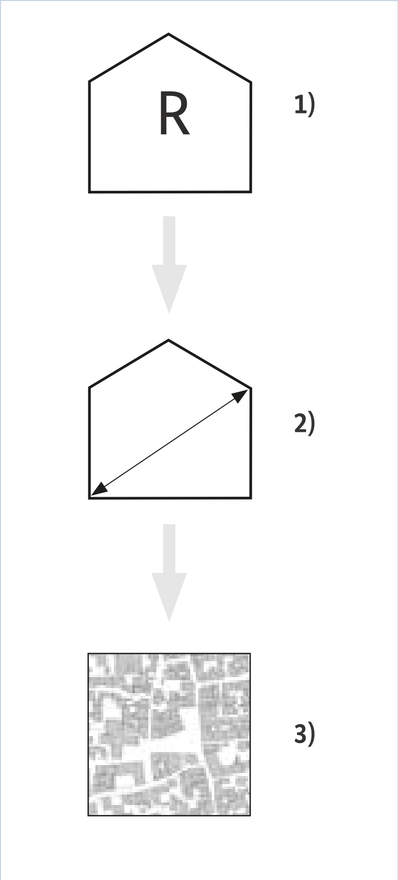
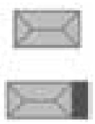
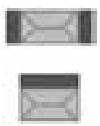
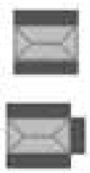


Figure 3:
Reference building technique used in the energy balance software GemEB (Gemeinde-Energieberater Bilanzierungssoftware)

1) Reference buildings
The specific values for heating energy demand found in the HEGT classification system are based on calculations that serve as examples for typical historic buildings. These buildings are also archived in GemEB 2.0 as reference buildings.

2) Geometrical adaptation
Since the size of a building has a decisive influence on heating energy demand, the HEGT reference buildings are geometrically adapted to the actual building under consideration. This adaptation is carried out using the energy balance software GemEB 2.0.

3) Location-specific values for heating energy demand
This makes it possible to establish specific heat demand density values, which factor in the individual local development structure and size of buildings.

HEGT			Storeys	Construction class **A** Q'h [kWh/(m² $_{living\ space}$ *a)]	Construction class **B** Q'h [kWh/(m² $_{living\ space}$ *a)]
1 **Detached/low extent to which other buildings adjoin the building**			1	227	278
			2–4	176	230
2 **Medium extent to which other buildings adjoin the building**			1	202	239
			2–4	149	188
3 **High extent to which other buildings adjoin the building**			1	167	182
			2–4	110	127

W/(m²K) ... 1.4 1.9 2.4 ....

A: Reference Building
B: Reference Building

Figure 4: Energy performance classification tool for historic buildings (HEGT)

The energy performance classification tool for historic buildings (HEGT) provides a simple way of assessing heat demand based on the extent to which a building has other buildings adjoining it and the type of construction. The HEGT table gives a first indication of a building's heating energy demand. The heating energy demand depends on the compactness of a building, the extent to which other buildings adjoin it (scored 1, 2 or 3) and the number of storeys. Buildings that are adjoined by other buildings to a great extent have a lower heating energy demand. The type of construction is of secondary relevance to energy performance. There were two typical types of construction in Iphofen, but they are transferable to many buildings, including other regions. The type of construction can, if necessary, be interpolated and adapted.

Construction type A
For example, timber frame walls with daub infill, and solid masonry walls, such as brick walls, with a low relative density; the thermal conductivity of these walls tends to be U = 1.40 W/(m²K)

Construction type B
For example, timber frame walls with stone infill and solid natural stone walls made of sandstone, shell limestone, quarrystone, timber frame structures with rubble infill of natural stone or fieldstone, timber frame with clay brick infill; depending on their thickness, the thermal conductivity of these walls tends to be U = 2.40 W/(m²K)

Energy use plans tailored to conservation, using the town of Iphofen as an example	
Researchers/project leader	Julia Drittenpreis Thomas Schmid Oliver Zadow
Overall costs	€ 240 000
Federal government grant	€ 120 000
Term	Januar 2011 to Oktober 2012

As part of the research project, a handbook was published that gives general recommendations, information on ways of working, benchmarks and important background knowledge for implementing energy use plans in local authorities with a high percentage of historic buildings. The following issues are explored:

- Historic neighbourhoods have very high potential for a central energy supply from renewable sources. This is particularly due to their high density, which means that they have a high heat consumption density. The research project identified key aspects to be considered and possible strategies.
- Energy-efficient refurbishment of historic buildings and neighbourhoods is possible to only a limited extent. The project identifies refurbishment and technical retrofit options for buildings, which are designed to ensure efficient energy supply. Tools that can be used in conjunction with energy use plans make it possible to model refurbishment and supply scenarios at local authority and neighbourhood level.
- In order to ensure that the key criteria – urban density and the use of typical local building materials – are taken into account when ascertaining the heat demand density in historic neighbourhoods, an energy performance classification tool for historic buildings (German abbreviation: HEGT) was developed (Figure 3). This can be used to ascertain heat demand density irrespective of building age category and historic classification.
- The HEGT matrix illustrates with examples the impact on energy performance of various refurbishment measures. This makes it possible to consider a range of aspects such as aesthetic appeal, cost-effectiveness and the effect on energy efficiency, when taking decisions on appropriate building refurbishment schemes.

The heating energy demand needed to map heat demand density can be identified with the aid of software. To do this, the HEGT classification system with its reference buildings was incorporated into the specially developed energy balance software GemEB. This program can be used to identify domestic heat and hot water demand for different refurbishment scenarios on the basis of geometrically adapted reference buildings (Figure 4).

It is possible to carry out energy-efficient refurbishment of historic neighbourhoods in an integrated way. The aim in Iphofen is to gradually implement the energy use plan over the coming years. Currently, further expansion of the existing local heating network is planned. There are also plans to hold public information meetings on appropriate and historically sensitive refurbishment measures. In summer 2013, the town of Iphofen, the Chair of Building Climatology and Building Services, Prof. Gerhard Hausladen, and SBS-Planungsgemeinschaft received an award for "Historische Stadtkerne – integriert denken und handeln" (Historic cores of towns and cities – integrated thinking and action) in a nationwide competition on urban heritage conservation. ■

Sources and literature:
[1] Erhorn, H., Erhorn-Kluttig, H., Hauser, G., Sager, C., Weber, H., co2online gemeinnützige GmbH; Friedrich, M., Becker, D., Grondey, G., Laskowski, F.: CO_2 Gebäudereport 2007, (eds), Federal Ministry of Transport, Building and Urban Development, Fraunhofer Institute for Building Physics (IBP), Berlin, 2007

Aktiv-Stadthaus
The first plus-energy apartment building in a city centre

Manfred Hegger, HHS Kassel

The idea behind the Aktiv-Stadthaus is to transfer developments to date in plus-energy houses to large-scale apartment buildings in inner-city areas and verify their feasibility in a demonstration project. The Aktiv-Stadthaus is an apartment building currently being constructed by ABG Frankfurt Holding in Frankfurt am Main and scheduled for completion in 2015. It will be eight storeys high and have 74 apartments.

The aim of the research project

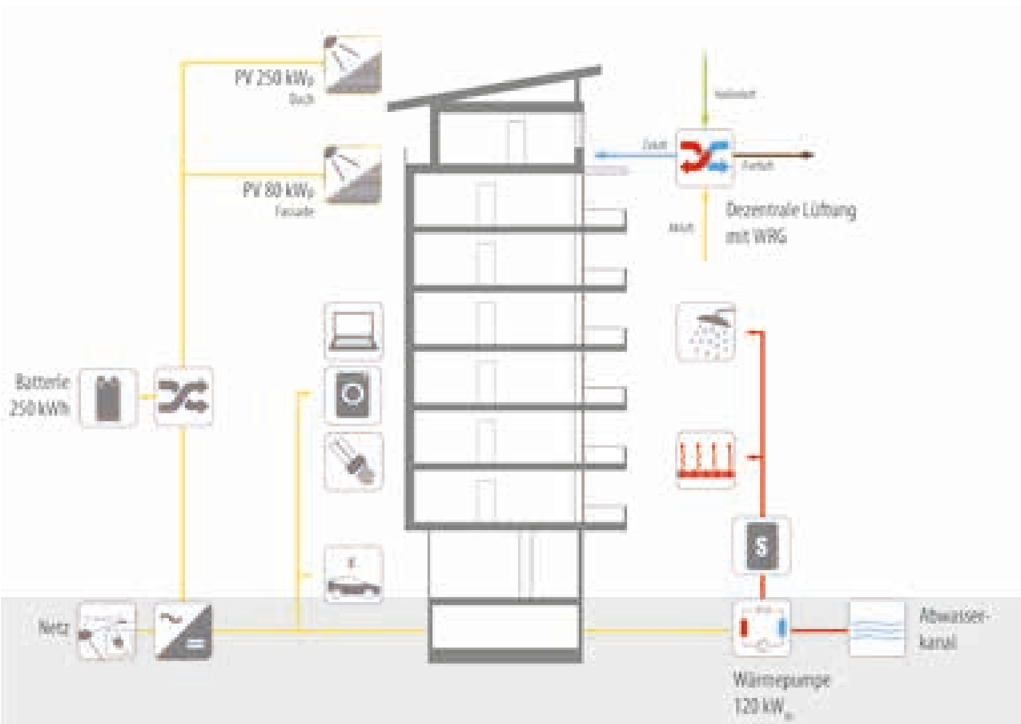
The goal is to carry out a feasibility study in preparation for developing and designing apartment buildings to a net plus-energy standard. The study concentrated on four core topics:

- energy strategy
- electric car sharing pools based in the building
- energy management for users
- life cycle approach

Energy strategy

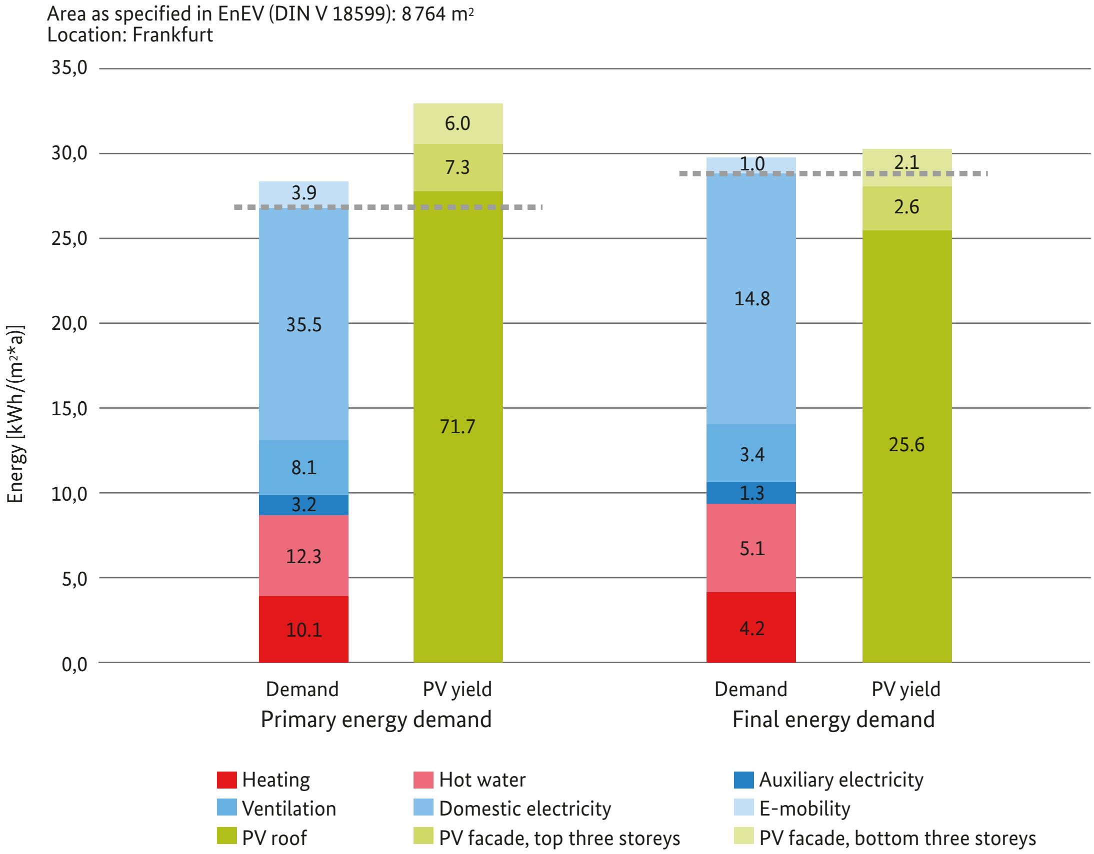
The energy performance was assessed in compliance with the BMUB's Efficiency House Plus definition and compared with the specifications in the Passivhaus Planning Package. Key differences were identified and recommendations made.

The idea is to minimise energy demand and meet the remaining demand as efficiently as possible from renewable sources. An analysis of the potential for optimising household electricity demand revealed that optimising a building's envelope and shape has the greatest impact. The cubic content and number of storeys are also important factors for achieving an energy surplus in apartment buildings. The Aktiv-Stadthaus will be constructed as an "electricity only" building. The building services scheme includes a waste water heat recovery system and heat pump to provide heating. The electricity demand will be met from photovoltaic panels integrated into the roof and facades. In inner-city areas the focus is on optimising the yield of the PV system on the roof. According to the BMUB's energy balance calculation, a plus of 11 % is achieved. Smart load management and storage should also increase the build-



Energy flow diagram for an Aktiv-Stadthaus

Architectural rendering of the Aktiv-Stadthaus, perspective view from the southwest



Final and primary energy balance, location Frankfurt, as at 22.10.12

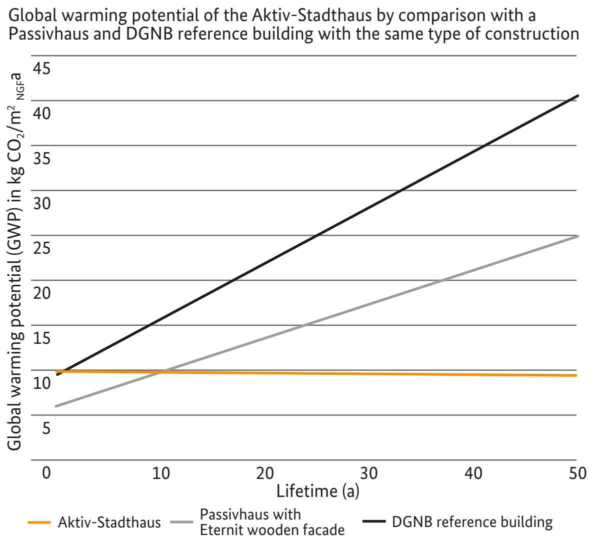
ing's use of the solar electricity it generates. Taking cost effectiveness into account, an electricity storage system makes it possible to use about 50 % of the energy generated on site. A further increase can be achieved by integrating the heat pump into the load management system. To implement the energy strategy, a new kind of energy charging system is needed in rental housing and the research project also analysed this. A monthly flat rate for electricity and heating guarantees the operator of the system economic feasibility and guarantees the users stable prices for a renewable energy supply.

E-mobility

Integrated energy schemes for buildings of the future consider the energy flows beyond the boundaries of the building itself. Here a key source of energy consumption connected with the building is the residents' mobility. The Aktiv-Stadthaus seeks to develop a sustainable mobility scheme by integrating an electric vehicle sharing system into the building. The plans include a fleet of up to eight shared electric cars and five e-bikes, for use by the residents of the building and the public. The aim is to achieve a sustainable mobility scheme that has a number of benefits: lower parking space requirements, making increased use of each car by multiple users and lower environmental pollution by cars charged with solar electricity. The charging infrastructure will include both conductive charging points and inductive charging pads.

Energy management for users

Another aspect of the project alongside innovative electricity generation technology is a user interface designed to encourage residents to save energy and increase the percentage of self-generated solar electricity used by the



Development of an Aktiv-Stadthaus's global warming potential (GWP) resulting from its construction and operation over 50 years in comparison to a Passivhaus and DGNB reference building with the same type of construction

Examples of pages from the user interface: home page, energy balance, e-mobility, electricity consumption (month, current and a comparison of individual consumption levels)

building itself. Touch panels in the apartments will display both energy consumption and the renewable energy the building is generating. A system whereby heating is included in the rent and residents have “energy accounts” tailored to their usage is also intended to act as a further incentive to save energy. A draft user interface that integrates the account idea has been developed by the research project.

Life cycle analysis

The reduced energy consumption needed to run the building means that energy costs throughout the building’s entire life cycle assume greater importance. Particularly for the plus-energy standard, the materials used have to be examined in detail and optimised so that the plus-energy balance is not achieved at a high price due to invisible energy costs. Photovoltaics are an example of systems that use a great deal of energy in the manufacturing stage.

The plus it achieves in terms of running costs means that the Aktiv-Stadthaus has a slightly negative greenhouse gas potential in operation. Compared with a Passivhaus, it offsets the additional emissions caused during construction in about ten years.

The study demonstrates the feasibility of a plus-energy apartment building in an urban setting. The more difficult conditions, such as a more cramped site and the eight stories, nevertheless produce on balance a surplus of final and primary energy. The main reason for this is that the building’s envelope has been optimised in energy performance terms, it has a highly efficient system for generating heat using a heat pump and energy-efficient household appliances, in combination with a photovoltaic system on the roof and facades. The plus-energy standard requires an interdisciplinary dialogue between architects and service engineers starting in the early design and planning stages. The additional effort produces results for the building, the environment and the profession that pay off in the long term. ■

Aktiv-Stadthaus

Researchers/project leader	• TU Darmstadt, architecture department, Design and Energy-Efficient Construction, Prof. Manfred Hegger, project leader • Steinbeis-Transferzentrum Energie-, Gebäude und Solartechnik (STZ), Prof. Norbert Fisch • HHS Planer + architects AG
External funding	• ABG FRANKFURT HOLDING, Wohnungsbau- und Beteiligungsgesellschaft mbH • Hager Vertriebsgesellschaft mbH & Co. KG
Overall costs	€ 277 597
Federal government grant	€ 164 697
Term	December 2011 to the end of February 2013

Efficiency House Plus Berlin

An overview of the home battery market

Tobias Mayer, LION Smart

The number of renewable energy generators is rising, a fact which holds a range of benefits such as climate protection, energy self-sufficiency and cost savings. But, unlike conventional power stations, they also produce electricity at times when it is not needed and only when the climatic conditions permit.

The federal government's plan to meet a large part of the country's energy demand from renewable sources is focusing increasing attention on the question of electricity storage options. Home batteries are one of these options.

This research project on the home battery market began by taking a closer look at the types of building that would be particularly suitable for home batteries in order to define the standard situation for using large home batteries. The European Parliament's Industry, Research and Energy Committee has called for all buildings constructed from 2019 onwards to be able to cover their own energy needs. This can only be achieved by using renewable energy sources and interim storage. In the next stage, the project looked at consumption, generation capacities and volumes generated in more detail. Factors that play a particular role here are the number of people in a household, the way heat and electricity are generated and the use of heavy consumption items such as electric vehicles. Electricity generation from solar panels is especially important for stationary batteries in buildings. The project also compared procurement costs and tariff costs in a study of cost-effectiveness parameters. An overview of the possible types of energy storage highlighted the particular benefits of stationary lithium-ion batteries. A separate chapter explores the "second-life" option, i.e. used

Stationary second-life battery bank for an Efficiency House Plus

battery cells. This idea is being trialled by the Efficiency House Plus pilot project in Berlin, a research project funded by the BMUB. The experience gained by LION Smart GmbH indicates that a number of conditions still have to be fulfilled to make comprehensive commercial second-life use of battery cells feasible. The study concludes by describing questions concerning building law, various operating modes and funding guidelines. An overview of the stationary systems available on the market, based on selected parameters, paints a picture of the state of the art. Forecasts of how the market might develop further and a discussion of disposal conclude the analysis.

Generally speaking, lithium-ion batteries are well suited for stationary storage applications, but there is not yet enough experience with using them and they are too expensive to be economically viable. However, at cell level they have already achieved cost parity with comparable lead systems. A number of conditions still need to be met for second-life applications to get off the ground. If battery cell prices continue to fall, that kind of reuse scenario in private households would seem unlikely. Growing numbers of batteries, particularly for electric vehicles, are likely to drive battery prices down still further and make cost-effective stationary storage systems a real possibility. Funding for stationary storage systems is providing an initial incentive here. Basically, when purchasing a stationary storage system, it is important to pay attention to its guarantee and useful life and to ensure that it has safety certification from an independent testing agency, such as LION Smart's joint venture with TÜV SÜD Battery Testing GmbH. A stationary storage system is a good choice for all users who are interested in maximising the amount of self-generated solar electricity they use themselves or who wish to have an emergency electricity supply to cover the possibility of a grid failure. ■

An overview of the home battery market – LION Smart GmbH

Researchers/project leader	Bojan Sandurkov, Waldemar Parschkoff
Project leader	Tobias Mayer
Term	to the end of 2015

Battery capacity tool

Oliver Mayer, General Electric Global Research

Storing energy is currently an important factor in the use of renewable energy. Storage is actually a natural part of anything to do with energy. We store food on shelves and in refrigerators, we store fuel in the tank of our cars, a coal-fired power station cannot work properly unless it has a stockpile of coal and a nuclear power station has large numbers of fuel rods in its reactor, which are also a kind of storage system. The question of storage for renewable energy is thus important but completely normal. It is not out of the ordinary.

This project focuses on renewable energy management for residential buildings. The cost of electricity is constantly rising, which is producing a positive trend towards people using energy they have generated themselves. Renewable energy generated by photovoltaic systems or wind turbines is intermittent. A storage solution is needed to boost the amount of self-generated energy that can be used on site. Batteries are small and powerful and therefore meet the requirements for residential use.

The project is seeking to ascertain the battery capacity needed for a house and how much self-generated electricity can be used as a result.

Simulation software was developed to study the design of the system. The specifications were entered into a simple, easy-to-use program. A special feature is that the calculation can be carried out with user-definable load and generation profiles. It is possible to increase the amount of self-generated electricity used to an acceptable level provided the energy yield is continuous and adequate.

Overview of how a PV and battery system works:

1. PV generator
2. Inverter
3. feed-in meter
4. two-way meter
5. battery
   - storing surplus energy, if demand has already been met
   - power demand, if generation is at a sufficient level
6. grid
   full battery:
   - feed into the grid
   empty battery:
   - power demand from the grid
7. consumer

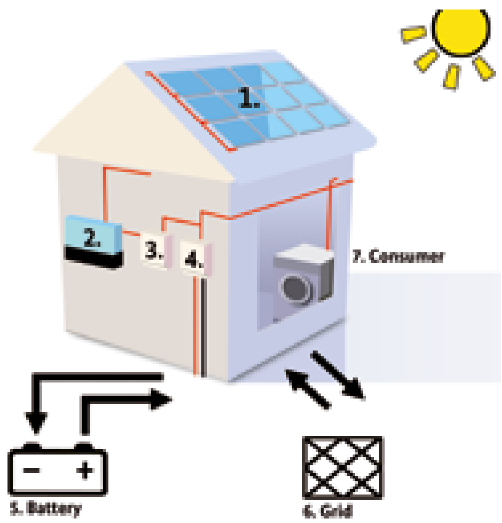


Diagram for a domestic system

The diagram shows a typical energy system for a detached house with PV system. The PV system produces electricity during the daytime, which an inverter converts from direct to alternating current. The amount of electricity generated is measured. A battery is connected through a controller to the AC grid. Depending on the energy generated by the PV system, the battery's state of charge and the consumer load, the battery is either charged from the PV system, discharges to an internal consumer or is charged from the grid. A software tool was developed for these scenarios with which the ideal battery capacity can be determined, taking energy and economic considerations into account.

Methodology

The PV battery program was designed using the KISS approach (keep it short and simple). For that reason, Excel and the integrated Visual Basic for Applications language (VBA) were chosen for the program platform. This is an Office product that is in widespread use.

A photovoltaic generator supplies the energy consumers in a house with electricity in addition to that obtained from the grid. The consumption of a household is described using a standardised load profile called H0. H0 is the only profile for households. There are other profiles for non-household users, such as G0 for business, N0 for night-time heating, L0 for farmers and A0 for street lighting.

New battery storage system, capacity: 13.2 kWh

The H0 profile is based on an average of 150 households. The time step accuracy is 15 minutes. The interval size of 15 minutes is the default used by utility companies for billing purposes. The PV data was acquired from the SQL database maintained by GE Global Research Europe in Garching near Munich. The one-second accuracy values were combined to 15-minute means.

The load and generation profiles can be subtracted to calculate the energy that needs to be charged or discharged.

The battery calculation algorithm was then developed. Surplus energy is stored in the battery within set boundaries. The battery supplies energy until the minimum state of charge is reached. The rate of consumption of self-generated energy in the program is applied to the total load data, not to the overall generation.

Simulation tool

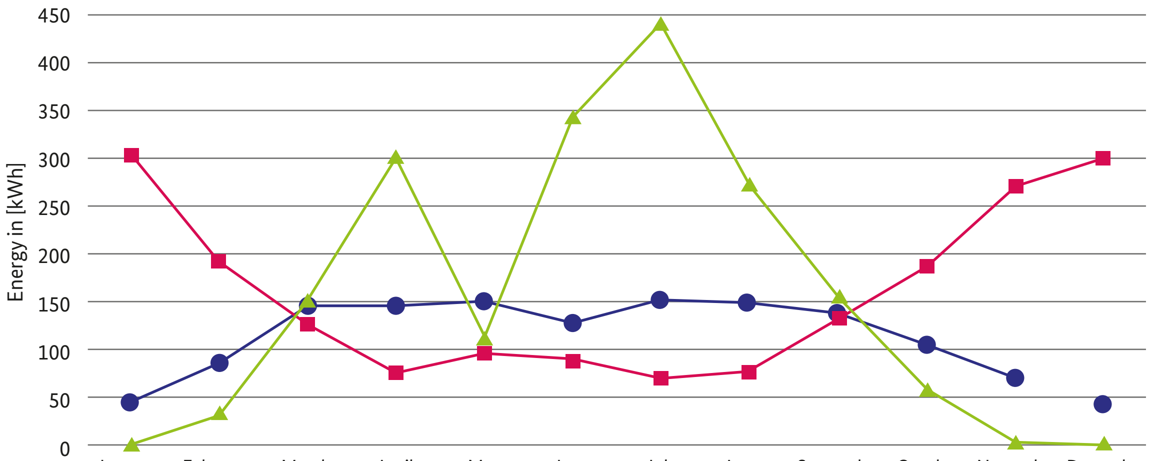
The simulation tool is divided into a number of tabs:

1. main menu
2. profile overview
3. parameter settings
4. one-year data calculation
5. Monte Carlo simulation
6. robustness analysis

Main menu

The main menu contains all the key input parameters for generators, loads and battery and key output values, such as energy feed into the grid, energy supplied from the electricity supply and battery characteristics. Generation, load and battery can be edited. After data has been entered in the INPUT section, the [Calculate] key is pressed to instantly update the OUTPUT data, monthly view and two-day sample view.

Results graph



	January	February	March	April	May	June	July	August	September	October	November	December
Energy from ESC	304	194	128	77	97	89	71	77	133	188	271	301
Feed into Grid	2	31	153	303	113	344	441	271	157	59	4	0
Battery Input	45	86	148	148	152	128	154	150	139	106	71	44

Results graph

The chart shows the annual result of a simulation. The feed into the grid rises until July (green line), whereas the opposite is true for consumption from the grid, which rises in the winter months; the throughput of the battery depends on its capacity. From March to September, battery input is virtually identical. The capacity can be increased for higher rates of consumption of self-generated energy, since feed into the grid is adequate and energy has to be delivered by the electricity supply company in any event. The battery input reached its maximum level in March and September due to the moderate solar irradiation and moderate energy demand. In summer the energy input is lower. There is plenty of surplus energy and demand is at a minimum. The battery is probably not even discharged at night. For that reason the consumption of energy from the grid is also at a minimum. The battery is not used efficiently in the months from October to February inclusive. During this period the charging algorithm should be optimised for a higher average charge level to improve the battery life.

Summary

Storage systems are crucial for people wishing to use the electricity they have generated using their own PV system. The question to be addressed is what is the right size for a battery to try and strike a balance between capital costs, on the one hand, and saving on electricity costs on the other hand. To answer this question a simple but effective simulation tool using Excel was developed. ■

Using buildings to store electricity

Jakob Schneegans, Klaus Klimke, Hana Riemer, Technische Universität München (TUM)

The need to integrate renewable energy sources is becoming increasingly important as a result of Germany's energy revolution. To achieve this integration, electricity generators and consumers will in future be controlled within a smart grid. The system will be able to actively manage load profiles in order to match consumption to increasingly fluctuating generation.

An ongoing research project being carried out by the Chair of Building Climatology and Building Services at Technische Universität München (TU Munich) is seeking to establish which types of building and fixed building services are suitable to play a role in a load management system in which peak electricity is thermally stored in the building mass.

The potential for load management in buildings depends both on the building services and on the construction physics of the building. The potential for storage and load management is being studied using linked building and services simulations. Delaying the operation of the building's services occurs on the condition that all the thermal comfort criteria inside the building are met. The first step towards ascertaining potential involves looking at operative room temperature as the sole criterion. During the heating period, the comfort range is set at 20–24 °C and in the cooling period at 22–26 °C. To actually implement load management measures, other comfort criteria would also have to be considered (e.g. radiation asymmetry, air humidity).

In order to narrow down the numerous different types of use, age groups and construction characteristics, residential, office and retail buildings were first of all classified into eight representative types. The variation in heat and cold transfer systems is summarised in Figure 1.

Sensitivity analysis

A sensitivity analysis using thermal building simulation of a model room was carried out to quantify the influence on thermal storage potential. The parameters considered in isolation include type of construction, storage mass, fixed building services and internal heat loads. Based on a predefined starting temperature (comfort temperature), the heating or cooling behaviour of the room in response to each of the different parameters is studied. A distinction is made between constant boundary conditions for the heating and cooling scenario.

Figure 2 illustrates the heating scenario, showing the cooling behaviour for the model room as a function of type of construction. It can be seen that in a heavy type of structure the length of time the heating can be switched off before the comfort threshold is reached is more than four times greater than in lightweight types of construction.

Figure 3 describes the case of a medium-heavy type of construction, showing the model room and what happens when the heating system is switched on as a function of the heat exchange system (thermo-active building system, radiator heating and underfloor heating). The maximum possible switch-on time before the upper temperature limit of 24 °C is reached is about seven times as long with an inert thermo-active building system as with radiator heating, which responds more quickly and first of all heats the air.

Building-specific simulation

In a dynamic simulation approach based on changing boundary conditions, the selected types of building and use profiles are studied to determine their potential for dynamic load management. Using selected ambient temperature and radiation data for a test reference year, the behaviour over time when the heat and cooling exchange systems are switched on and off is analysed. This approach addresses the question of *how much* power can be switched off or on, when and for *how long* in order to relieve pressure on the electricity grid.

As an example, the changes in the operative room temperature in a new office building after the heating is switched off on a very cold winter day are depicted in Figure 4. The influence of the hours the building is in use and the internal heat

Photovoltaic panels on the roof of a house

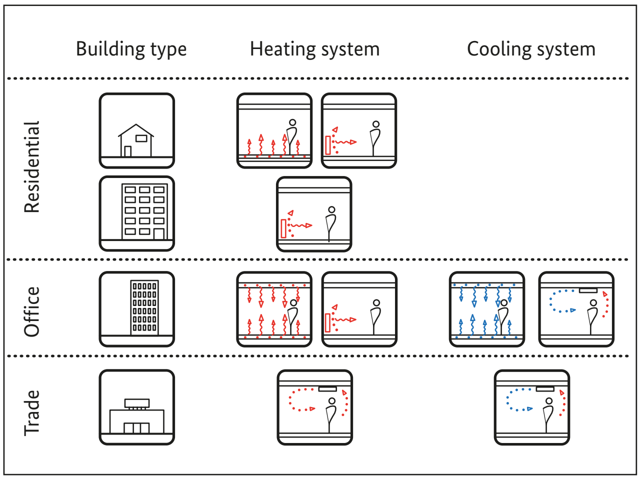


Figure 1: Selected types of buildings and their building services

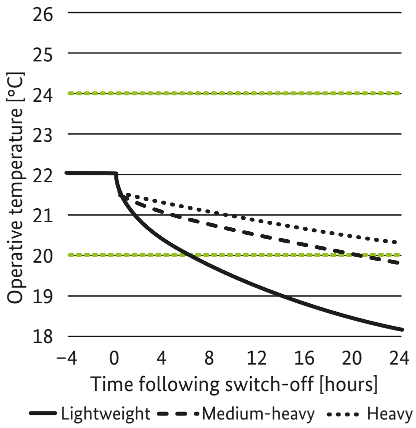


Figure 2: Simulations of maximum possible switch-off duration as a function of the type of construction

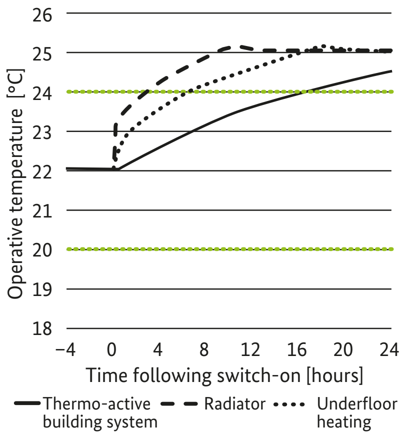


Figure 3: Simulations of maximum possible switch-on duration as a function of the heat transfer systems

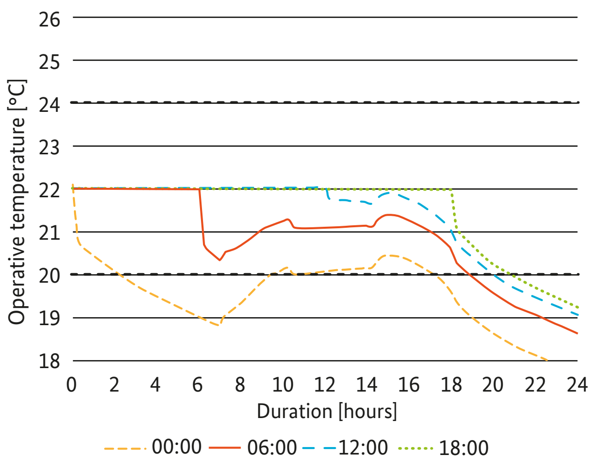


Figure 4: Change in the operative room temperature after the heating is switched off at different times of day in a new office building on a very cold winter day

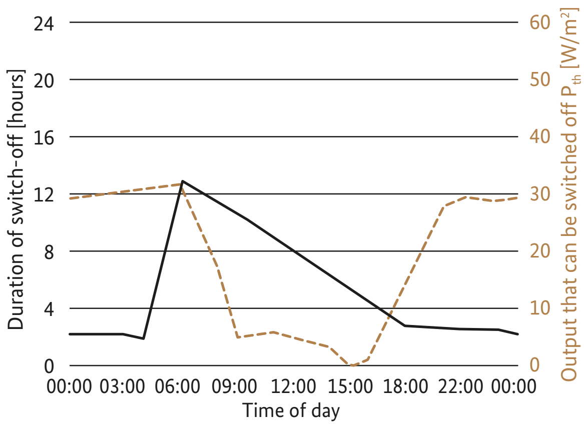


Figure 5: Duration of switch-off and output that can be switched off in a new office building on a very cold winter day

loads of people and electrical appliances is plainly evident. If the heating is switched off at midnight, the temperature falls below the comfort threshold of 20 °C after only two hours. From 7:00 am onwards, internal heat loads and heat gains from solar irradiation halt the cooling process and the operative temperature even rises temporarily. If the heating is switched off at 6:00 am, the temperature therefore does not move out of the thermal comfort range for about 13 hours. The maximum switch-off periods for the winter day under consideration as a function of the time of day are shown in summary in Figure 5 by an unbroken black line. The same diagram depicts in red the specific heat output needed to maintain the comfort temperature of 22 °C at all times. The maximum load management potential at any given time is calculated by integrating the output over the longest possible switch-off duration. In the case under consideration, when the heating was switched off at 6:00 am, integrating the heat output that can be switched off over the following 13 hours gives a maximum usable thermal potential of about 125 Wh/m². For the integration of volatile renewable energy generation even a brief balancing service is relevant to taking pressure off the electricity grid. The study therefore also looked at the potential for brief load management interventions, limited to two hours. As Figure 6 shows, the brief night-time switch-off potential for the office example is on average 60 Wh/m², falling to just 10 Wh/m² during the daytime due to the lower heating demand resulting from internal loads.

The analysis of load management potential has been summarised in a building catalogue in which the suitability for taking pressure off the electricity grid of the types of buildings studied is compared under differing weather conditions and for different times of day.

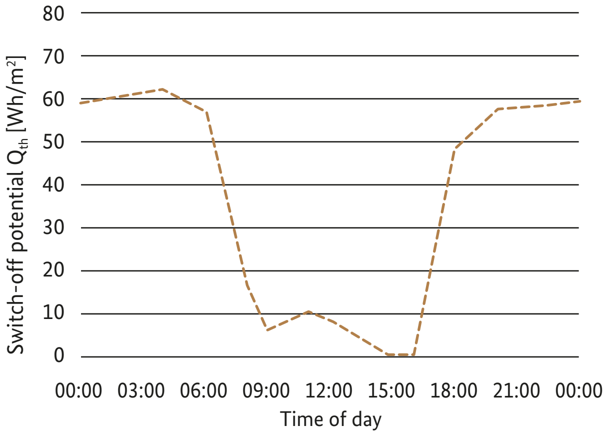


Figure 6: Potential for brief load management for the example of a new office building under the selected boundary conditions on a very cold winter day

Each type of building is simulated for seven typical days, which are representative of the weather over the course of a year. This makes it possible to estimate the load management potential during the different seasons of the year. For example, the new office building type has particularly high potential for switching off the heating at night during the winter months. This decreases between the seasons and in summer is negligibly low. The seasonal differences are primarily due to the variation in power demand. The peaks in heating during very cold nights have a high potential for brief switch-offs. The reduced heat demand in spring and autumn offers the highest potential for switch-on periods. Because cooling systems are usually switched off at night in offices, there is no available output to be switched off at night in the summer.

To estimate absolute load management potential the next step will involve studying the same types of buildings with a floor space weighting. The study is scheduled for publication in July 2014. ■

Managing storage and load potential in buildings

Researchers/project leader	Jakob Schneegans, Klaus Klimke
Overall costs	€ 150 000
Federal government grant	€ 100 000
Term	up to May 2014


The plus-energy house at Köln- Frechen

The plus-energy house in a virtual power station

Tobias Langshausen, TSB Bingen

To date batteries have been used in Efficiency Houses primarily in order to increase the amount of self-generated electricity used. However, other grid system services are conceivable. In a research project by the Federal Institute for Research on Building, Urban Affairs and Spatial Development a battery was integrated into a virtual power station in order to test the system services options. At the same time, an online optimiser was installed upstream to improve cost-effectiveness.

One of the elements of Germany's energy revolution is to steadily increase the number of renewable electricity generators. This kind of generation is usually intermittent, which will cause a further increase in the demand for balancing energy to stabilise the grid frequency. This balancing energy will in future have to be increasingly supplied by distributed units.

A drop in grid frequency causes a supply shortage and either additional electricity generation units have to feed into the grid or consumers have to reduce their power draw. If the grid frequency rises, there is a surplus of electricity. Electricity generation has to be reduced or additional loads have to be activated. The activation or reduction of capacity is paid for in the balancing energy markets.

One of the aims of this project is to explore what building management can contribute in this context by providing batteries. In theory, they could be charged at night from balancing energy and discharged in the daytime. This could be at odds with the actual purpose of a battery. The chart on page 58 shows how a battery's state of charge typically changes. Charging the battery at night from negative balancing energy would reduce the possibilities for charging from self-generated electricity during the daytime. Here it is necessary to find the optimum option in economic terms. To this end, an online energy management optimiser was developed, which incorporates not only learnt use patterns of the building but also monitors the weather forecast and the electricity markets in order to achieve maximum flexibility in terms of balancing energy and optimum state of charge in terms of using self-generated electricity.

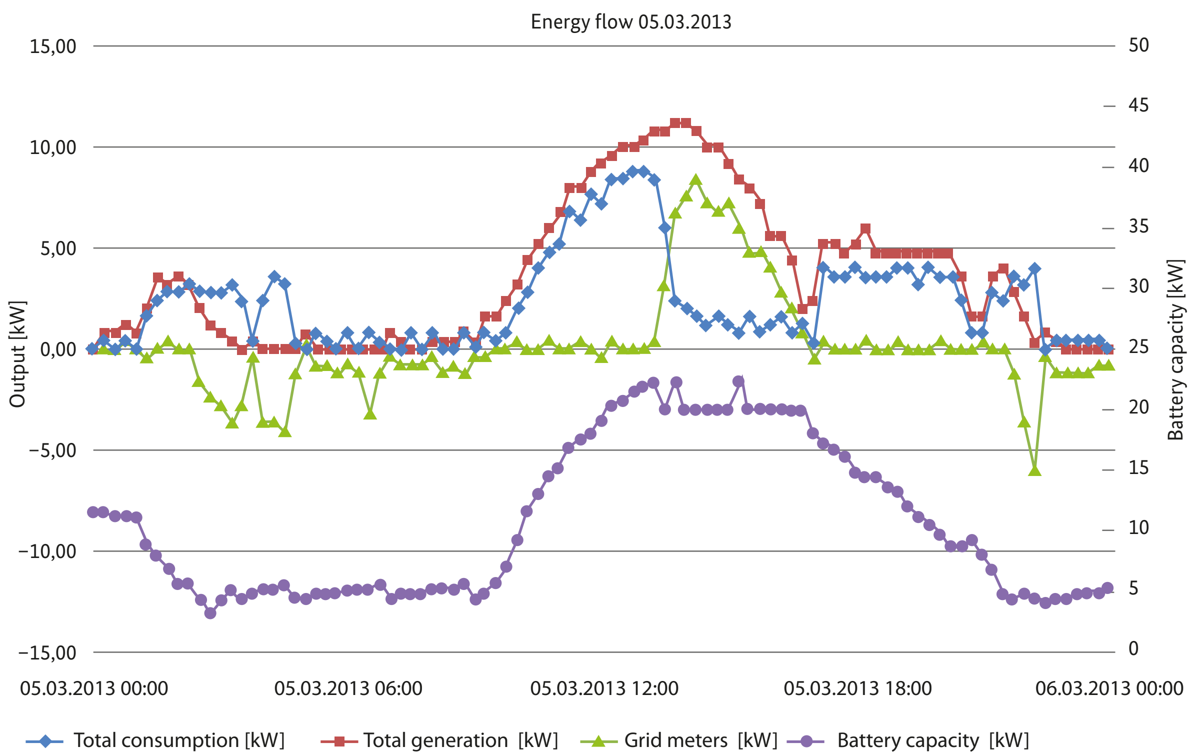
Communication link to a virtual power station

The virtual power station technology (EC24 software), which has been developed over the past ten years by the Transferstelle für rationelle und regenerative Energie Bingen (TSB) and is currently running with a pooled output of over 200 MW, was used to set up the system. The connection to EC24 was achieved by linking it directly to the building automation system/energy management system.

The necessary data points were defined and their transfer to an energy data management system was set up so that the data can be archived, visualised and analysed. The activation of the battery bank with the necessary parameters to ensure the 15-minute reserve was defined in full on the interface. Data transfer in both directions was established as fully functioning.

Development of an energy management optimisation tool

In the energy management optimisation tool, purchase of electricity and use of self-generated PV electricity with the battery providing buffer storage were assumed as the standard electricity supply and battery use scenario. The energy management optimiser can be used to achieve additional yields, which depend primarily on the degrees of freedom of the battery and how good the forecasts for consumption and generation on the following day are. The balancing services market of the 15-minute reserve (traded the next day) and the intraday market (traded the next hour) were used as a basis for the optimisation.



Energy flow in the Efficiency House Plus

The energy management optimiser processes current measured values from the Efficiency House Plus and also the available forecast values for consumption and generation. Based on these values, the services to be traded are calculated for the individual time slices of the 15-minute reserve. To do this, the time slices were ranked according to their income potential. Trading then occurs first of all in those time slices where there is statistically the highest demand for 15-minute reserve.

Trading on the intraday market can occur if the service has not yet been traded in the same direction in the 15-minute reserve. Trading on the intraday market becomes interesting if offers in the 15-minute reserve are not taken up because the service prices are too high or new intraday degrees of freedom are created.

Estimating financial potential

The degrees of freedom calculated by the energy management optimiser can be traded in the 15-minute reserve and thus generate income. Depending on the offer strategy in the 15-minute reserve, a range of revenue can be achieved but the revenue will always depend on the kilowatt-hour price bid.

Trading example

With the given battery and its degrees of freedom, it was possible to generate about € 150 per year in additional revenue based on a kilowatt-hour price of € 1.000 per megawatt-hour in both a positive and negative service direction. This would be connected to a call-off time of about 3 hours per year.

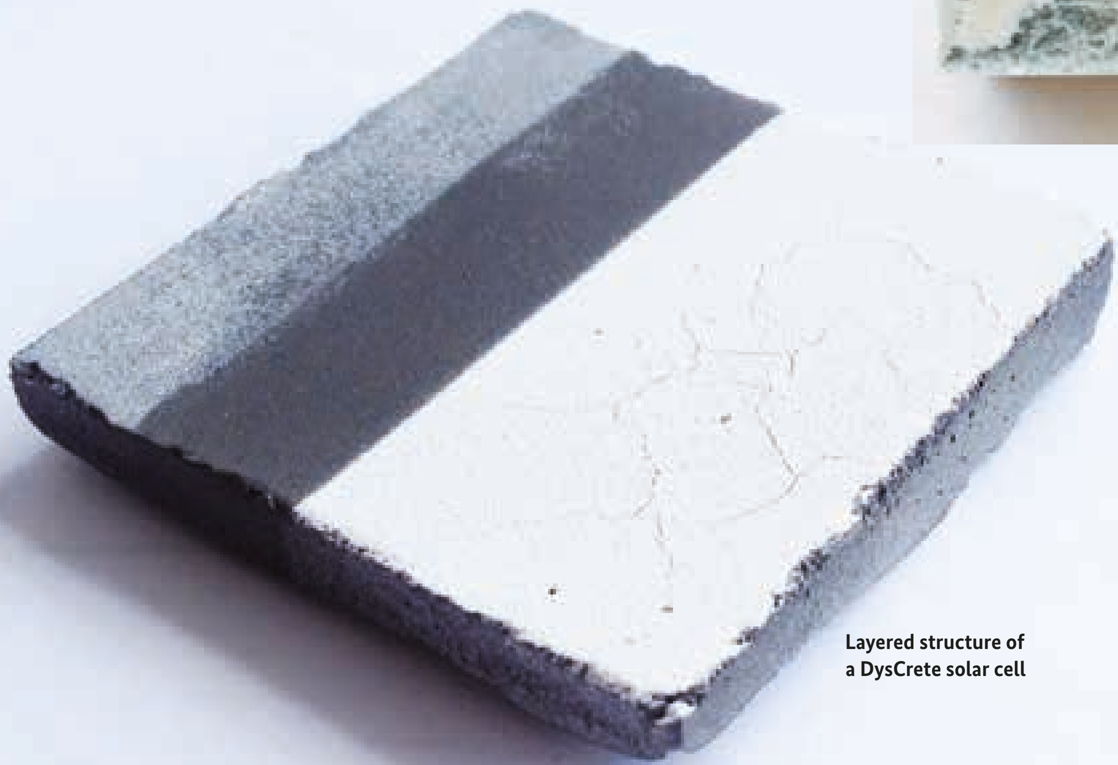
This value gives an indication of the potential income, which is nevertheless dependent on many influencing factors and also on market price changes and changes to the market design.

The degrees of freedom in the Efficiency House Plus could already be traded. But, due to the low capacity and the complexity and inaccuracy of forecasts, it would not currently make economic sense to implement this trading model. The forecast inaccuracies with regard to the individual house could also mean that the optimum in terms of energy management is not achievable. For that reason, this trading model would only be possible with a large number of buildings because that would even out fluctuations and mean that some of the output could always be traded. ■

Efficiency Houses Plus in a virtual power station

Researchers/project leader	Transferstelle für Rationelle und Regenerative Energienutzung Bingen – TSB
Project leader	Prof. Ralf Simon T. Langshausen Markus Sinß
Overall costs	€ 43 750
Term	to the end of 2013

Prototype of a DysCrete solar cell, series of experiments with green dyes



Layered structure of a DysCrete solar cell

DysCrete – solar electricity from concrete

Photovoltaic functionalisation and activation of concrete/development of a new kind of photoreactive cement-bonded material for innovative facade, wall and floor systems in the construction industry

Heike Klussmann, Uni Kassel

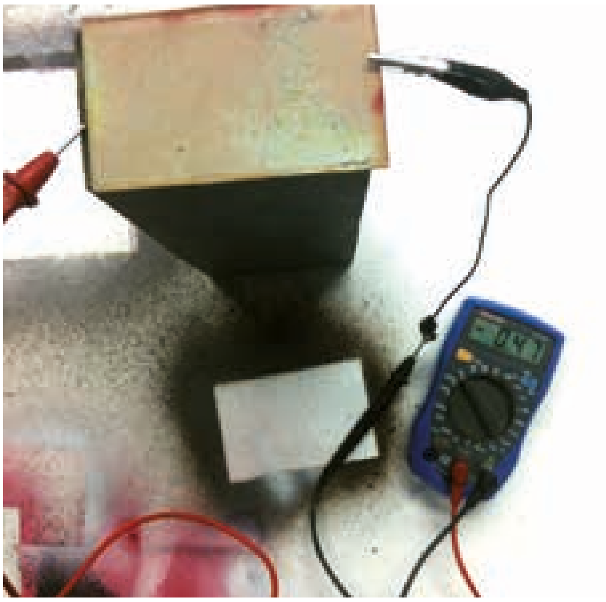
DysCrete is a new process that adds a photoreactive functionality to concrete surfaces (enabling them to generate electricity). It is based on the technical principles of dye-sensitised solar cells (DYSC).

Over 20 years ago, chemist Michael Grätzel developed a solar cell that followed nature's lead: the dye-sensitised solar cell (DYSC) absorbs light not with semiconducting materials but with suspensions of organic dyes. This principle is now also known as technical photosynthesis. From an architectural point of view, the obvious question is whether this – still relatively new – dye-sensitised solar cell technology can be used on building materials such as concrete. DysCrete, which produces energy by an electrochemical reaction, uses organic dyes to absorb light in the same way that plants use chlorophyll. The material is largely recyclable and environmentally friendly. The letters DYSC in the name stand for dye-sensitised solar cell, with "-crete" being short for concrete. The new material can also use the energy of diffuse light. DysCrete is particularly suitable for manufacturing prefabricated concrete components, for innovative facades and wall and floor systems. The use of this technology on materials such as concrete has largely been ignored to date because attention focused initially on glass-based translucent modules. Its great potential lies in its simplicity. Its main components, such as titanium oxide, are used in toothpaste and emulsion paint. The system has technological potential as a low-cost energy source.

Prototype of a DysCrete solar cell, series of experiments with red dyes

Prototype of a DysCrete solar cell, series of experiments with red dyes

Conductive concrete creates the rear contact of the DysCrete solar cell module.



Conductive concrete creates the rear contact of the DysCrete solar cell module.

DysCrete produces energy by an electrochemical reaction and uses organic dyes to absorb light. The energy-generating functionality is created without causing any toxic emissions using readily available components. Used in the way currently planned, the material system is largely recyclable and environmentally friendly. The innovative process and materials are able to use the energy of diffuse light, which means that concrete as a building material and its construction logic open up new application possibilities for photovoltaic systems that are integrated into buildings. DysCrete is particularly suitable for manufacturing prefabricated concrete components, for innovative facades and wall and floor systems. ■

DysCrete – Dye-sensitised, energy-generating concrete

Researchers	Prof. Heike Klussmann, Thorsten Klooster, Roman Polster, Jan Iwanovicz, Tanja Simonovic, University of Kassel/FB 06 architecture, Stadtplanung, Landschaftsplanung/Forschungsplattform BAU KUNST ERFINDEN – www.baukunsterfinden.org
In cooperation with	Prof. Bernhard Middendorf, Dr Alexander Wetzel, Johannes Arend University of Kassel/FB 14/Department Werkstoffe des Bauwesens und Bauchemie www.uni-kassel.de/fb14bau/institute/iki/werkstoffe-des-bauwesens-und-bauchemie/startseite.html
Industry partners	Fabrino Produktiongesellschaft mbh & Co. KG, Memmingen Lothar Beeck Fertigteilbau GmbH, Mönchengladbach
Project leaders	Thorsten Klooster, Dr Alexander Wetzel
Overall costs	€ 219 500
Federal government grant	€ 153 600
Term	up to September 2015

Opaque facade panels with integrated photovoltaics

Bernhard Weller, Marc-Steffen Fahrion, Sebastian Horn, Jasmin Fischer, TU Dresden

Figure 1:
The potential of large expanses of opaque spandrel panels for integrated PV systems

Opaque facade panels with integrated photovoltaics (PV) for use in mullion/transom facades have the same aesthetic qualities as their conventional counterparts: their large format creates the same scale facade articulation and they have the same materiality and colour quality. This is aesthetically more attractive than roof-mounted PV systems. Developing and testing innovative panels of this kind was therefore the main goal of this research project.

Opaque panels for mullion/transom facades generally consist of an insulating core, a backing sheet and an outer face. They can be factory produced in large numbers and installed on site with relative speed and ease. The mullion/transom facade also makes it possible to conceal the PV cabling in the profiles. Opaque panels can cover a large proportion of the facade and thus have huge potential for producing electricity, as Figures 1 and 2 show.

This research project therefore integrated a photovoltaic module into the outer face of an opaque spandrel panel, which was a step towards creating an electricity-generating building component (see Figures 3 and 4).

The idea behind this was to first of all create the basic conditions needed for the product development and market launch of a structure that is both sustainable and suitable in terms of structural qualities and building physics, and which would also meet the specific requirements associated with photovoltaics.

The problem of the module temperature played a crucial role, since the efficiency of solar cells decreases steadily with increasing temperatures. The back insulation of the PV element in the panel meant that higher temperatures were anticipated than would be the case for a back-ventilated facade. In the case of crystalline modules, the

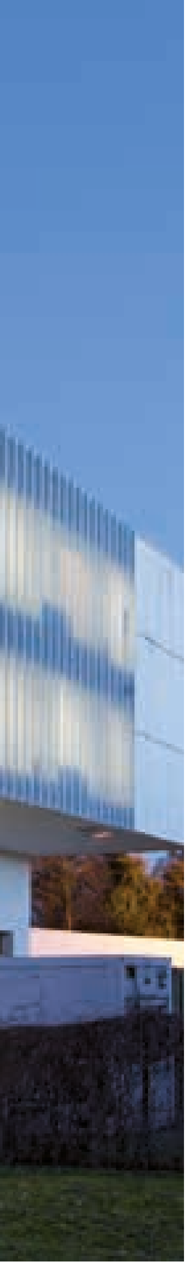
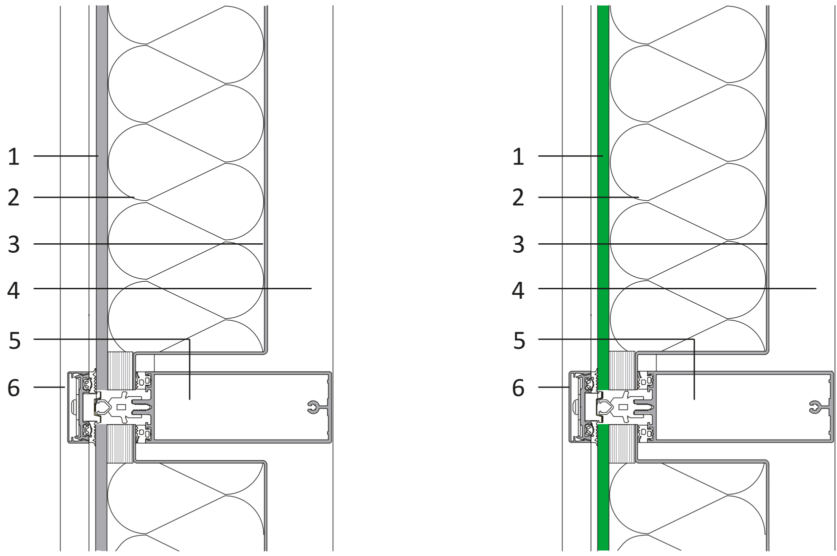


Figure 2: A facade with opaque spandrel panels

Figure 3: Prototype series 1 to be fixed using clamping bars



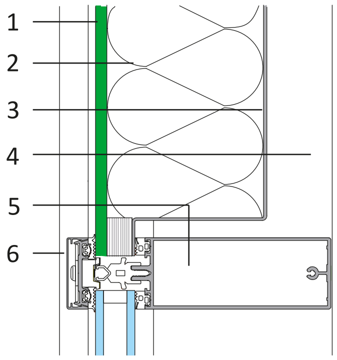
Opaque panel without PV
1 outer face
2 insulating core
3 backing sheet
4 mullion
5 transom
6 clamping bar

Opaque panel with PV
1 PV element
2 insulating core
3 backing sheet
4 mullion
5 transom
6 clamping bar

Figure 4: Detail of a spandrel panel with and without integrated PV

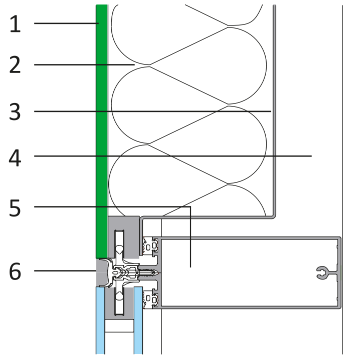
efficiency losses can be as high as half a percent per Kelvin of temperature increase. For this reason, the panels tested here used thin-film modules. Their temperature coefficient is generally lower than that of crystalline modules. The use of thin-film modules made of CIGS solar cells provides homogenous surfaces that do not have a crystalline structure. They also provide more design options since they can be produced in different colours.

Two prototype series were manufactured during the research project, using 60 x 120 cm standard modules. The difference between the two prototypes lies in how they are attached to the mullions and transoms. Whereas the prototype series 1 is attached by clamping bars on all four sides, the prototype series 2 is attached to the transoms and mullions using load-transferring structural silicone bonding. Figures 5 and 6 show the structural differences between the two series.



1 PV element
2 insulating core
3 backing sheet
4 mullion
5 transom
6 clamping bar

Figure 5: Fixed by clamping bars on all four sides



1 PV element
2 insulating core
3 backing sheet
4 mullion
5 transom
6 bonding

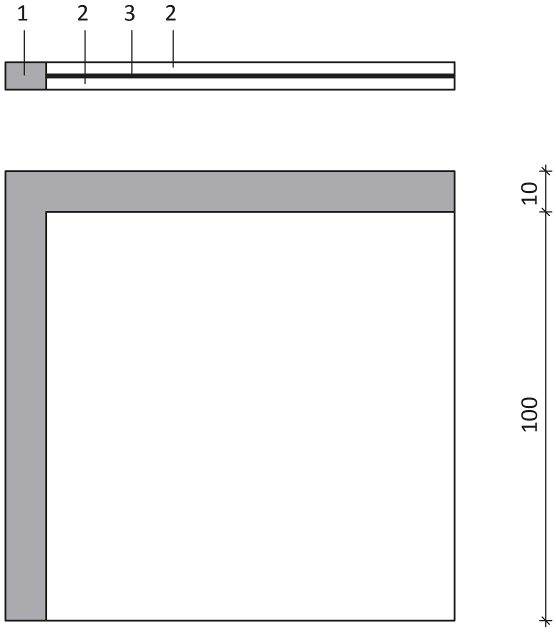
Figure 6: Fixed using load-transferring structural silicone bonding

For the adhesive option, the compatibility between the adhesive used and the laminating film was tested following ift guideline DI-02/1 (on the suitability of sealants, Part 2 testing materials in contact with the edge of laminated glass and laminated safety glass). The adhesives were applied to two of the four edges of the test units to a thickness of 10 mm (see Figure 7) and then subjected to different tests depending on the intended use in a glazing rebate or weather joint.

The test units with adhesives for use in a glazing rebate were stored at 60 °C in a convection oven for 21 weeks. Test units with adhesives for use in weather joints were stored at an atmospheric temperature of 58 °C and air humidity of > 95 % and then exposed to UV irradiation for 14 weeks. No changes that would indicate an effect on safety in use occurred during any of the tests.

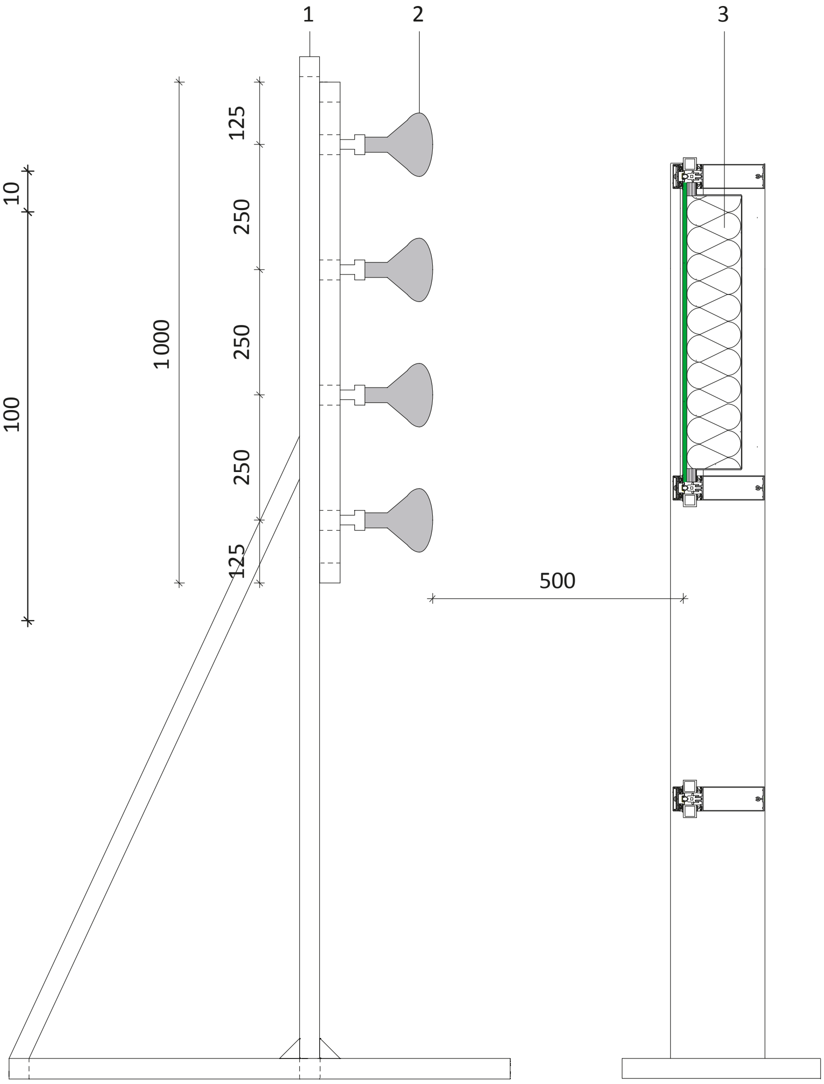
In a further test, the prototypes were exposed to irradiation in a realistic environment to study temperature development and the temperature behaviour of the PV panels under constant boundary conditions (see Figure 8). The measured data acquired can be used to validate a simulation model that can calculate the temperature and module performance under different boundary conditions. Taking Munich as a reference climate, it was seen that temperatures in the PV module with back insulation in the panel tested can be up to 20 K higher than in a simple back-ventilated PV module. The maximum temperatures reached were below 75 °C.

The prototypes for an opaque panel for mullion/transom facades with integrated photovoltaics manufactured for this research project and the tests conducted on them provided important information needed to evaluate the performance level that must be achieved. It was seen that back insulation of the PV module in the panel leads to a temperature up to 20 K higher than in a back-ventilated PV module. For the temperature coefficients of approx. 0.4 %/K that were ascertained this means output losses of up to 8 %. More research is needed here to make use of this kind of panel an economically viable option. ■



1 adhesive
2 pane of white glass, d = 3 mm
3 laminated film, d = 0.7 mm

Figure 7: Test specimens for material compatibility tests



1 UV lamp holder
2 UV lamps
3 prototype installed in a realistic setting

Figure 8: Set-up of irradiation test

Study of insulated panels with integrated photovoltaics for use in mullion/transom facades (insulated PV panels)	
Research institute	Technische Universität Dresden Institut für Baukonstruktion Prof. Bernhard Weller, Jasmin Fischer
Project partners	Manz CIGS Technology GmbH, MBM Metallbau Dresden GmbH
Overall costs	€ 172 855
Federal government grant	€ 115 104
Term	July 2012 to August 2013

Kurt Speelmanns has a degree in building services engineering. After graduating, he worked for a firm of building services consultants, moving in 1976 to the Federal Office for Building and Regional Planning and the Institute for Federal Real Estate (BImA). From 1998 he was involved in setting up and operating an organisational unit for facilities management for the supreme federal authorities in Berlin and Bonn. Since 2009, he has been head of the Construction Research and Facility Management division. One of his areas of specialisation is building automation, in particular building management systems.

Building automation – potential and limits

What can building automation do today?

Building automation is an indispensable feature of any building today, because no-one wants to still have to switch the heating or ventilation on and off manually. Apart from these comfort features, building automation also offers unlimited possibilities for operating the technology to match actual demand and thus minimising energy consumption and wear and tear on plant and equipment. For example, it is standard practice to switch on ventilation systems in meeting rooms only when they are in use, but beyond that to also base the periods of operation and volume of air movement on the pollutant concentration (CO_2 levels of the air in the room). As I said: any wish can be fulfilled and so the question of how sophisticated you want the technology to be is ultimately a question of common sense and how much money you are willing to spend.

Another limitation – in fact a serious limitation – is posed by the lack of sufficiently experienced professionals. Unfortunately, there are only a few people who have the right qualifications to understand all the aspects of what are sometimes very complex situations and then translate them into error-free programming.

What role does building automation play now that Germany is transitioning to a new energy era?

When talking about this new energy era – or Energiewende – we have to distinguish between sometimes very hi-tech, well-equipped functional buildings, on the one hand, and housing on the other. Since our buildings are usually one-offs, it is difficult to achieve something like series production for building automation. And that is reflected in the high costs of setting it up. That is why there is usually no individually programmed building automation system in residential buildings.

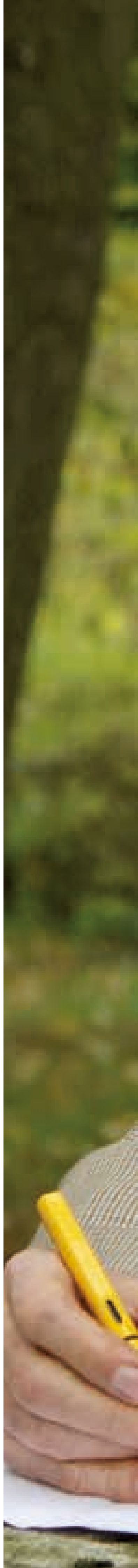
Instead the individual components (such as the heating system) have fairly highly developed control systems, but it is quite complicated and expensive to integrate them into an overall energy management system along with the other building automation components. But that is what has to happen in order to operate the fixed building services in a way that saves energy.

Apart from the different standards of automation technology in different buildings, another problem with operating fixed building services is that there is a serious lack of skilled professionals. That means that the potential for energy saving simply cannot be fully harnessed.

Are there any strategies to offset that problem?

In larger functional buildings it is standard practice to place building automation under a management level known as building management systems. This makes it possible to generate graphic views of processes and operating status, identify any deviations from normal operation and introduce measures to counter them.

In further developing building management systems we are trying to upgrade the systems so that people without any academic training can more easily identify malfunctions. You can see an example of this in the graphic on page 69. This shows a heating circuit which is part of an extensive system. It has been depicted using standardised symbols. You see the pipes, the circulating pump, a control valve and the relevant system temperatures. On the right is a graph showing the heating curve of the control unit. This heating curve shows how the temperature of the hot water in the heating system should be adjusted to match the outside temperature.



"The aim is to make it possible to detect malfunctions in the building services sooner. That will make a crucial contribution to further reducing energy consumption."

Kurt Speelmanns

To detect malfunctions the operating personnel would have to be able to see the relationship between the supply temperature and the outdoor temperature and compare that with the actual value. We have relieved the operator of the need to perform this calculation by entering the actual value on the diagram in the form of a green dot. If everything is working properly the green dot is on the red line. This is not the case in the example shown, which means the operator has to try and find the reason for the deviation.

How can we expect this technology to develop further?

As part of the Zukunft Bau research initiative, we are currently funding a project looking at automatic detection of that kind of malfunction in building control technology. The aim is to make things easier for operators of these systems and make it possible to detect malfunctions sooner. That will make a crucial contribution to further reducing energy consumption.

What is the situation in residential buildings like?

Comprehensive building automation is found only rarely in residential buildings. The reason is that there is a lack of inexpensive solutions that integrate all the technology involved. Examples that have been installed and presented within the industry are based on appliances and procedures that we are familiar with in functional buildings or from process automation. Consequently, the costs are so high that they are completely disproportionate to the economic benefits. And once more there is the additional problem of the availability of properly trained personnel. So if we want to achieve a breakthrough in energy management in Germany's homes, of which there are over 20 million, the technology has to become affordable and easy to install.

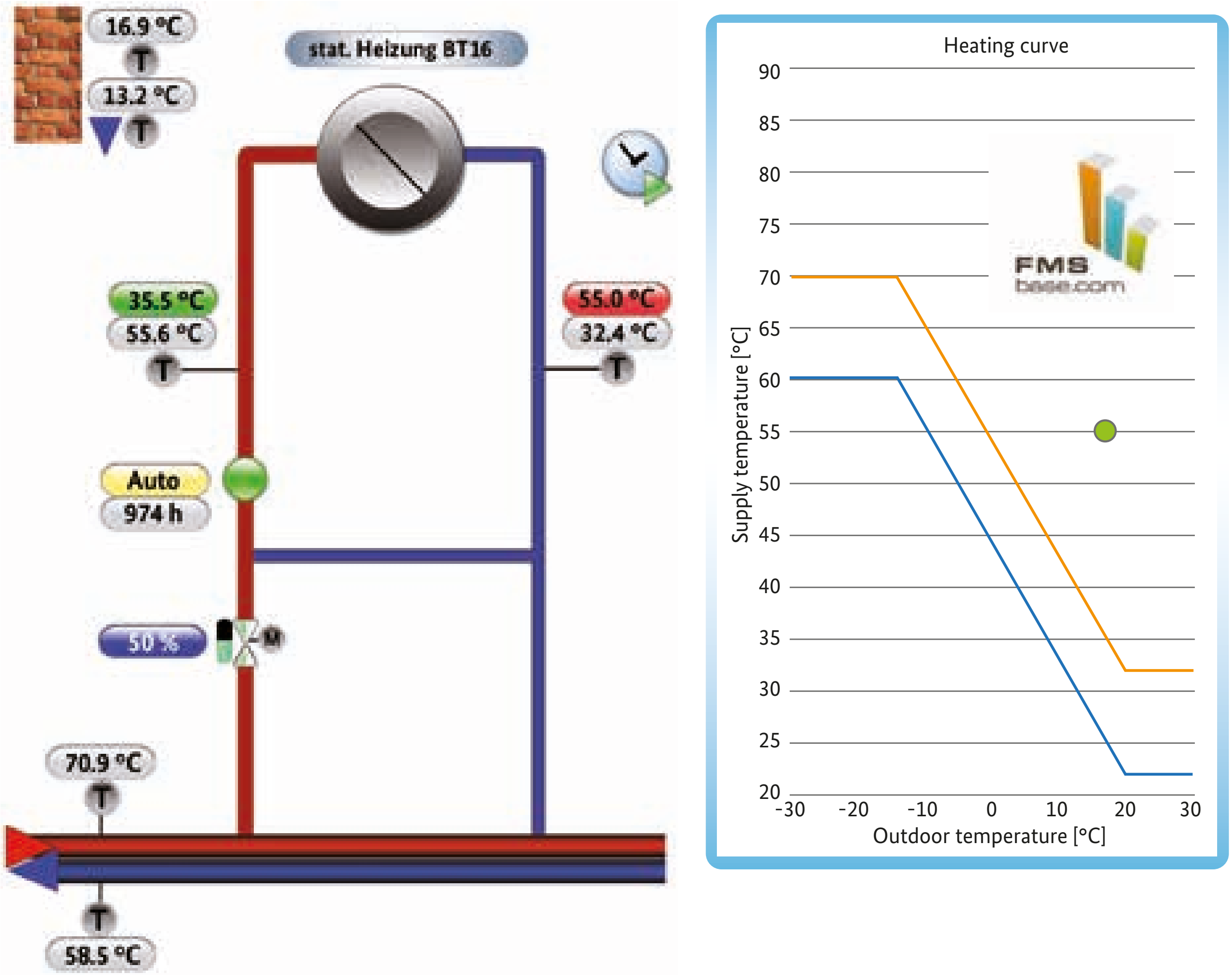
What is building research doing to make that happen?

Our institute is taking a two-pronged approach. On the one hand, we are involved in a DKE initiative (German Commission for Electrical, Electronic & Information Technologies) which aims to use the smart meter gateways that are to be installed in every home in the future for purposes that go beyond merely transmitting data from the electricity meter. The aim is to collect and transmit all other consumption data (heating costs, water, gas), and also information to do with smart homes and the Ambient Assisted Living programme (AAL) through to telematics in the health service through this interface. The data protection profiles developed by the Federal Office for Information Security (BSI) will be complied with and the homeowner will have to have direct access to all information. That also depends on it being an open system, i. e. not subject to a monopoly. In view of the huge number of users, we are anticipating an urgently needed innovation push to develop software solutions to enable laypersons to be able to gain an overall picture of the technical systems in their home without too much difficulty.

The second area we fund is research into “web services” that facilitate communication in all areas of building services engineering. It has become evident that this technology is the only way that low-cost plug-and-play approaches can be implemented and BSI's protection profiles complied with.

What is your home like?

My wife and I live in a semi-detached house that was built in the 1980s. After our children moved out and it was just the two of us again we adapted the house accordingly and also made a number of improvements. To improve energy efficiency, we replaced the windows and installed a thermal solar system to assist the space heating system. Everything is controlled and displayed by a process automation system which I adapted and programmed myself. ■



Building management systems make it easier to detect malfunctions.

Energy-efficient multi-pane insulating glass – less is more

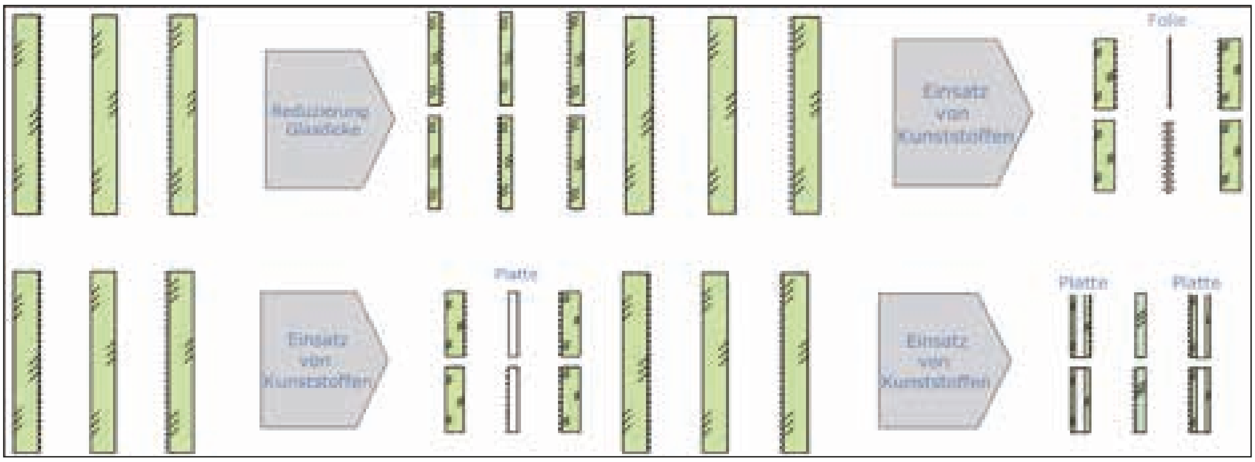
Norbert Sack, ift Rosenheim

Since the energy performance specifications that a building envelope has to meet are becoming even more stringent, triple insulating glazing in windows and French doors can be expected to become standard in the near future. Similarly, requirements regarding noise insulation, burglary protection, fire resistance and other performance features will also increase. Contemporary architecture is reinforcing the trend towards larger openable windows/French doors and facade elements. Floor-to-ceiling elements such as French doors are being increasingly used in private sector housing construction.

The developments mentioned are causing the weight of the multi-pane insulating glass used – and consequently the weight of the entire building component – to increase significantly. The research project therefore aimed to study the technical measures that might reduce the weight per unit area of multi-pane insulating glass and what effects that would have. The following design measures were studied with this in mind:

1. use of thinner glass
2. use of transparent plastic in the form of films
3. use of transparent plastic in the form of sheets

Use of glass in buildings to increase energy efficiency and as an architectural design element



Basic options for reducing weight per unit area

Calculations for examples of possible weight reduction options

	Configuration	Weight per unit area	Relative
2 times MIG reference	4/16/4	20 kg/m²	100 %
3 times MIG standard	4/12/4/12/4	30 kg/m²	150 %
3 times MIG thin glass	3/12/3/12/3	22,5 kg/m²	112,5 %
	3/12/2/12/3	20 kg/m²	100 %
3 times MIG plastic sheet	4/12/PC2/12/4	22,5 kg/m²	112,5 %
3 times MIG plastic film	4/12/PET0,1/12/4	20 kg/m²	100 %
3 times MIG combination of thin glass + film	3/12/PET0,1/12/3	15 kg/m²	75 %

The investigations were intended to provide answers to the following questions:

- What influence do measures to reduce weight per unit area, in particular the use of thinner glass, have on the validity of dimensioning rules for multi-pane insulating glass?
- What influence do measures to reduce weight per unit area, in particular the use of plastic films or sheets, have on the durability of insulating glass? Factors to take into account would be compliance with specifications regarding rate of gas loss or moisture absorption of the desiccant.
- What influence do the measures have on other performance characteristics such as heat transfer coefficient (U value), solar heat gain coefficient (g value), airborne sound insulation, light transmission?

The project addresses these questions primarily through experiments. This was true of the questions concerning durability, material compatibility, airborne sound insulation, light transmission etc.

Where it was possible and made sense to do so, the experiments were backed up by numerical simulations.

The studies produced the following findings:

Multi-pane insulating glazing with thin glass

Dimensioning rules:

- For external loads (wind): the non-linear theory produces significantly lower values for tension and sag. For large-format insulating glazing, wind load is usually the crucial load.
- For internal loads (climate): the non-linear and the Kirchhoff theory produce similar results. Using the non-linear theory has no advantages. For small-format insulating glazing climate load is usually the crucial load.
- For long narrow formats: the non-linear and the Kirchhoff theory produce similar results. Using the non-linear theory has no advantages.

Need for toughening:

- For panes with a short edge of less than about 65 cm, both 4 mm and 3 mm thick panes need to be toughened.

- For thin panes the need for toughening is not significantly higher than for 4-mm float glass because they are designed for wind and climate loads.
- It is possible that a need for toughening may also occur due to handling of the panes or thermal stresses.

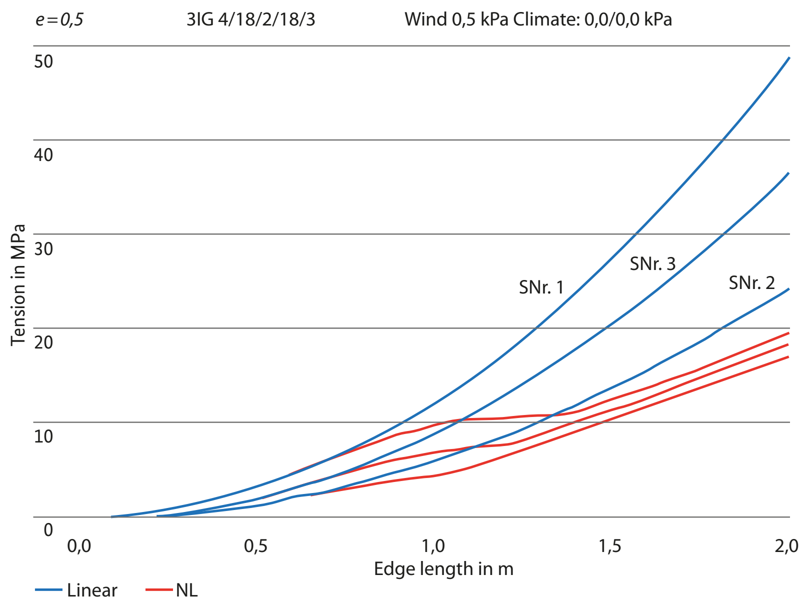
Radiometric properties:
- For insulating glazing with thermally toughened glass panes, the spectral transmission and reflection values of non-toughened float glass can be used as a basis.

Multi-pane insulating glass with film
- Structures that use film as a substitute for the middle pane are complex systems. The qualification process for film/sealant/spacer combinations requires the use of several test methods.
- Although the test specimens studied by the research projects did not individually meet all the requirements of EN 1279 in terms of rate of gas loss and moisture absorption, overall the results ascertained indicate that it is basically possible to comply with all the requirements.
- No fogging occurred, not even at higher test temperatures.

Multi-pane insulating glass with plastic sheet
- Plastic sheets used as a middle pane require a special mount, which allows for thermal stretch of the sheets, without adding stress to the edge seal. In the test units studied a special profile was integrated into the edge seal, which created a floating mount for the plastic sheet.
- With both types of plastic used – polycarbonate and PMMA – no fogging occurred, not even at higher test temperatures.

Test specimens prepared for an experiment on the deformation behaviour of multi-pane insulating glazing made of thin glass

- When using plastic sheets as a middle pane, it is essential to take into account that the plastic may release moisture into the cavity between the panes. Either the plastic sheets must be dried before installation or the amount of desiccant must be adjusted accordingly.
- The test units studied by the research project that had an edge seal with better thermal properties had a rate of gas loss that slightly exceeded the limit defined by EN 1279-3. The limit for moisture absorption stipulated in EN 1279-2 was significantly exceeded; this could, however, have been caused by moisture release from the plastic sheets (see previous bullet point). A conclusive assessment of the system tested with regard to compliance with the requirements of EN 1279-2 and -3 is therefore not possible.



Asymmetrical configuration of the multi-pane insulating glazing, tension of the individual panes under wind load

Test specimen with film in the cavity between the panes following a pull-out test; the film adheres to the secondary sealant on both sides.

Performance characteristics

Energy performance:

- The heat transfer coefficient, solar heat gain coefficient and light transmittance of those units studied in the project that have lower weights per unit area are comparable to those of conventional triple insulating glazing.

Airborne sound insulation:

- Thin glass panes in a symmetrical configuration always reduce airborne sound insulation, as a result of their lower mass, especially in the standard 4/12/4/12/4 configuration. This disadvantage can, however, be offset by ensuring the multi-pane insulating glass has an asymmetrical configuration (4/12/2/12/3).
- The shape of the middle pane – whether thin glass, film or plastic sheet – has no significant effect on airborne sound insulation. ■

Weight per unit area for multi-pane insulating glass

Research institute	ift Rosenheim
Project leader	Norbert Sack
Project partners	Bundesverband Flachglas e. V., represented by Isophon glass GmbH, Southwall Europe GmbH and Winterglas GmbH.
Overall costs	€ 158 520
Federal government grant	€ 90 075
Term	up to December 2012

Self-compacting lightweight architectural concrete, slump flow of 680 to 700 mm

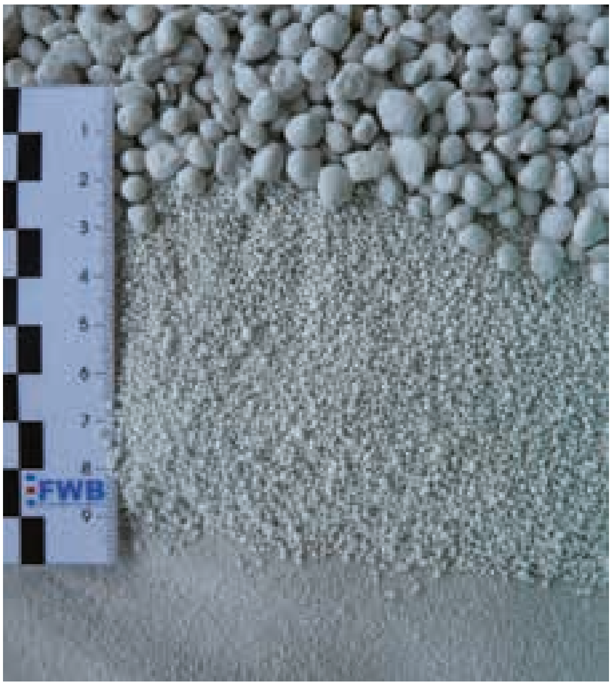
Solid fairfaced concrete external building components made of lightweight architectural concrete with high thermal insulation properties

Wolfgang Breit, TU Kaiserslautern

The combination of lightweight concrete with high thermal insulation properties and the visual characteristics of architectural concrete makes it possible to create buildings that unify the appearance of concrete with the energy performance standards that external building components have to meet. At TU Kaiserslautern a building was constructed in a new lightweight architectural concrete, allowing information acquired in the laboratory to be put to the test under the normal conditions a building is exposed to.

The aim of the research project was to develop solid external building components made of fairfaced concrete with high thermal insulation properties. In order to meet sustainable building standards, the project also aimed for them to be manufactured from recyclable building materials and cement with an optimal life cycle assessment.

Solid external building components made of thermally insulating lightweight concrete have a low-density porous structure that makes them susceptible to ingress of moisture and media that can cause corrosion. Furthermore, full compliance with the specifications for properties of fresh concrete and also the mechanical requirements is crucial, while at the same time a high standard of fairfaced concrete must be achieved. The solid building component has to meet the specifications of the Energy Saving Ordinance (EnEV) 2009 without any additional insulation. Combined with mineral foam core insulation it must achieve a U value of 0.2 W/(K•m^2). To this end, appropriate core insulation materials were used, which particularly take into account the aspects of sustainable building and recyclability of the entire structure.



Recycled blown glass granules for lightweight architectural concrete

The blown glass granules being tipped from big bags into the mixer truck

Wall of the experimental building with mineral foam core insulation

The aim was to use lightweight architectural concrete with the following specifications:

- high-quality fairfaced concrete with a dense surface
- Wall complies with the specifications of the Energy Saving Ordinance (EnEV) 2009.
- Materials used meet sustainability requirements.
- fresh concrete: good compactibility, mix stability
- hardened concrete: compressive strength LC 8/9, bulk density < 750 kg/m3
- adequate resistance to gas and water ingress

Lightweight architectural concrete building following completion of the concreting operation

Composition of the lightweight architectural concrete with high thermal insulation properties

The composition of the concrete had to meet conflicting requirements, such as adequate compressive strength yet low bulk density and low water absorption despite foamed cement matrix.

Since lightweight architectural concrete has low thermal conductivity, blast-furnace cement CEM III/B 32.5 N was used as a binder because the heat of hydration develops slowly. The required water absorption and thermal con-

Concreting operation in progress

ductivity were achieved using blown recycled glass as a lightweight aggregate. Different glass fractions were used in granule sizes of 0.25/0.5 mm, 1/2 mm and 4/8 mm. The self-compacting flow characteristics without segregation were achieved using a PCE plasticiser in combination with a stabiliser. The low dry-bulk density desired (< 750 kg/m³) made it necessary to use a foaming agent for the cement matrix. To improve durability, a shrinkage reduction and hydrophobic additive was also used.

Typical values for the lightweight architectural concrete

The self-compacting composition of the concrete used for the experimental building had a slump flow of 680–700 mm. The fresh concrete bulk density was 720–740 kg/m³. With dry bulk density markedly below 700 kg/m³, a 28-day compressive strength of 6.3 MPa (56 d: 8.7 MPa; 90 d: 9.2 MPa) and a modulus of elasticity of about 3.5 GPa were measured after 28 days. Despite the foamed cement matrix, gas permeability was in the order of magnitude of normal concrete whereas, as a result of the hydrophobic additive, capillary water absorption was below the average for normal concrete.

The most important requirements the lightweight architectural concrete had to fulfil were its thermal insulation properties. To date a thermal conductivity value of about $\lambda = 0.15$ W/(m•K) has been achieved. Mineral foam core insulation was added to one of the walls of the experimental building; here a U value of 0.2 W/(K•m²) was achieved.

Constructing an experimental building made of lightweight architectural concrete

The lightweight architectural concrete for the 7 m x 5 m x 4 m experimental building was manufactured in a ready-mixed concrete facility, with the different blown glass fractions being added directly to the mixing trucks. After the cement paste had been added, all the constituents were thoroughly mixed in the mixer truck and the self-compacting lightweight architectural concrete was poured without further compacting. Currently measurements to evaluate the temperature and moisture changes are being recorded and analysed in order to be able to make a prediction about the actual thermal insulation properties and durability of lightweight architectural concrete under natural weathering conditions.

The lightweight architectural concrete made of blown glass and blast-furnace cement, which was developed with sustainability in mind, complied with high standards in terms of its properties both as fresh and hardened concrete.

With a dry bulk density of less than 700 kg/m³, a thermal conductivity value of $\lambda = 0.15$ W/(m•K) was achieved. The transferability of the laboratory findings to an actual building was demonstrated by constructing a lightweight concrete building. Ongoing measurements of the changes in temperature and moisture using multiring electrodes installed in the building make it possible to assess the actual thermal insulation properties and durability of the lightweight architectural concrete. ■

Fairfaced concrete external elements made of lightweight architectural concrete

Researchers/project leader	Prof. Wolfgang Breit Technische Universität Kaiserslautern, Fachgebiet Werkstoffe im Bauwesen Gottlieb-Daimler-Straße 60 67663 Kaiserslautern
Project leader	Prof. Wolfgang Breit
Overall costs	€ 148 500
Federal government grant	€ 68 400
Term	up to December 2013

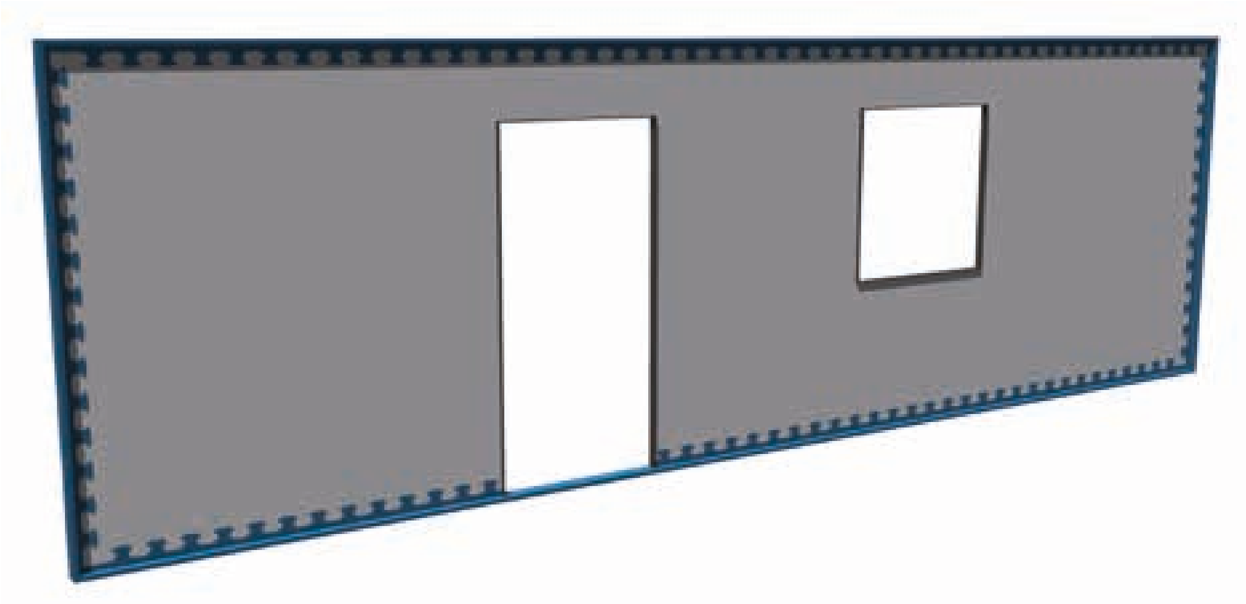


Figure 1: UHPC wall element using stud rail connectors

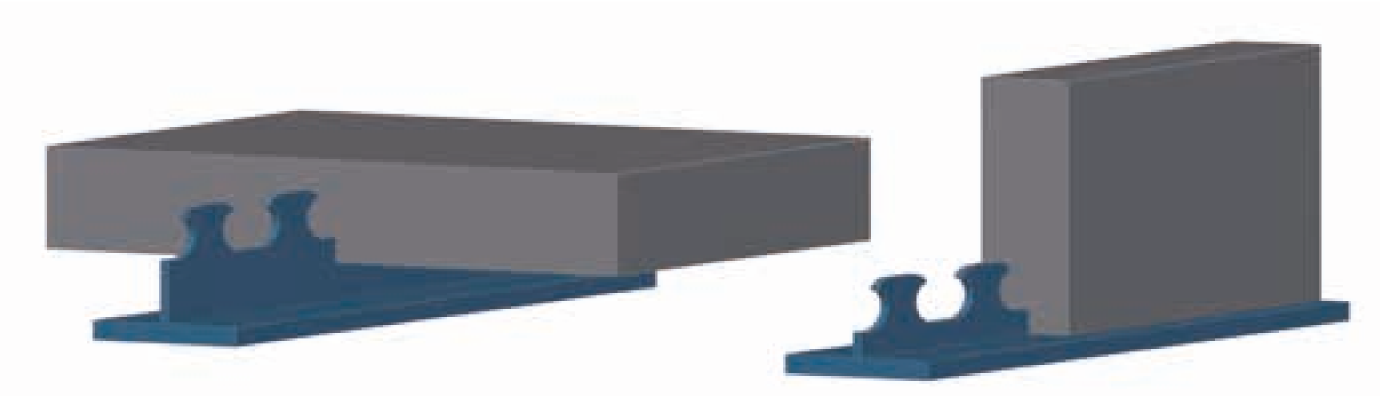


Figure 2: Vertical use of stud rails in slabs (left) and horizontal use in wall elements (right)

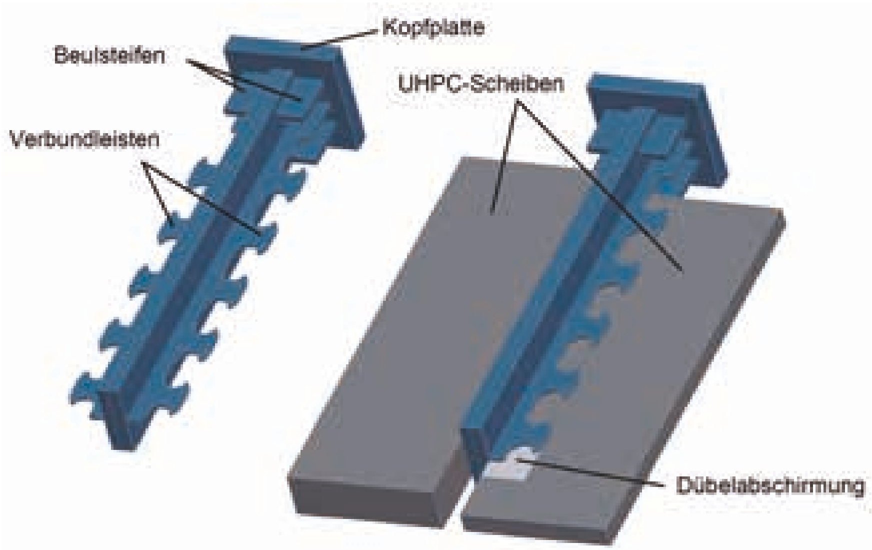


Figure 3: Prefabricated steel element and cutaway push-out test objects to test the load deformation behaviour

Development of thin-walled structural components made of ultrahigh performance concrete and suitable methods for connecting them

Thomas Lechner, Technische Universität München (TUM)

The development of ultrahigh performance concrete (UHPC) has great economic and environmental potential for use in slender wall elements between 4 and 6 cm thick. However, before they can be used in practice it is necessary to investigate how these prefabricated wall panels can be connected to other building components and to establish the stability of such slender elements.

Using UHPC with compressive strength in excess of 150 N/mm^2, more slender panels can be created with smaller cross-sectional dimensions than are possible with normal concrete. Thin-walled structural building components can be used to significantly reduce the cross-sectional dimensions and increase durability while maintaining the same load-bearing capacity. In the case of slender UHPC wall elements (see Figure 1), this means that the connections made on site between the usually prefabricated elements and other building components (columns, floor slabs etc.) must be equally slender. Furthermore, the stability (bulging or buckling) of such slender wall elements is a key aspect to be considered to ensure that this prefabricated construction method can be used safely and economically in the future.

In order to develop slender wall elements and appropriate ways of connecting them to other building components, a range of different fastening techniques such as adhesive joints or mechanical fasteners were first of all studied. For more detailed examination of the load-bearing capacity in thin UHPC elements, clothoid-shaped stud rails were selected. They are already cast into the UHPC wall elements in the factory and the connection to other building components is made by welding, bolting or using an interlocking system. Early tests on stud rails in UHPC slabs ("vertical" application) showed that stud rails in ultrahigh performance concrete not only have high load-bearing capacity but also outstanding deformability. Tests on the load-bearing capacity of stud rails in thin UHPC wall elements with only a few centimetres of lateral concrete cover ("horizontal" application) had not previously been carried out (see Figure 2).

Extensive experiments were carried out to test the load-bearing and deformation behaviour of clothoid-shaped "horizontal" stud rails in thin ultrahigh performance concrete elements. Push-out tests (see Figures 3 and 4) were conducted to test stud rails with a maximum thickness of 10 mm in concrete panels with a maximum thickness of 60 mm. One of the factors considered was the influence of the thickness of the concrete and the thickness and quality of the steel on the load-bearing behaviour. The maximum lateral concrete cover was less than 30 mm in all the test specimens.

The test results show that horizontal stud rails in thin ultrahigh performance concrete elements can achieve shear resistance up to 1 250 kN/m, if the quality and thickness of the steel are high enough. In cases like this, the cause of the failure is usually brittleness due to the concrete splitting. But if the steel has appropriate properties, shear forces of up to 800 kN/m can be transferred even if there is ductile failure in the steel. The dimensioning for this possibility can be based on that for stud rails in normal concrete. Brittle failure of the UHPC as a result of splitting should be avoided.

Using the results of tests on buckling of thin UHPC walls available in the literature, the stability behaviour of the wall elements was compared to buckling in steel plates. As a result, a dimensioning proposal was developed based on DIN EN 1993-1-5:2010. The UHPC buckling tests were then recalculated using materially and geometrically non-linear FE simulations. In addition, experiments were carried out on fixing UHPC wall panels. Here loads were exerted on the top edge of the panels in the vertical plane and the stud rail was firmly fixed (see Figure 5). After these tests had also been numerically simulated, an appropriate FE model was used to assess the influence of openings on the buckling behaviour of wall elements.

In addition to the structural tests, the research project also compiled physical specifications and requirements

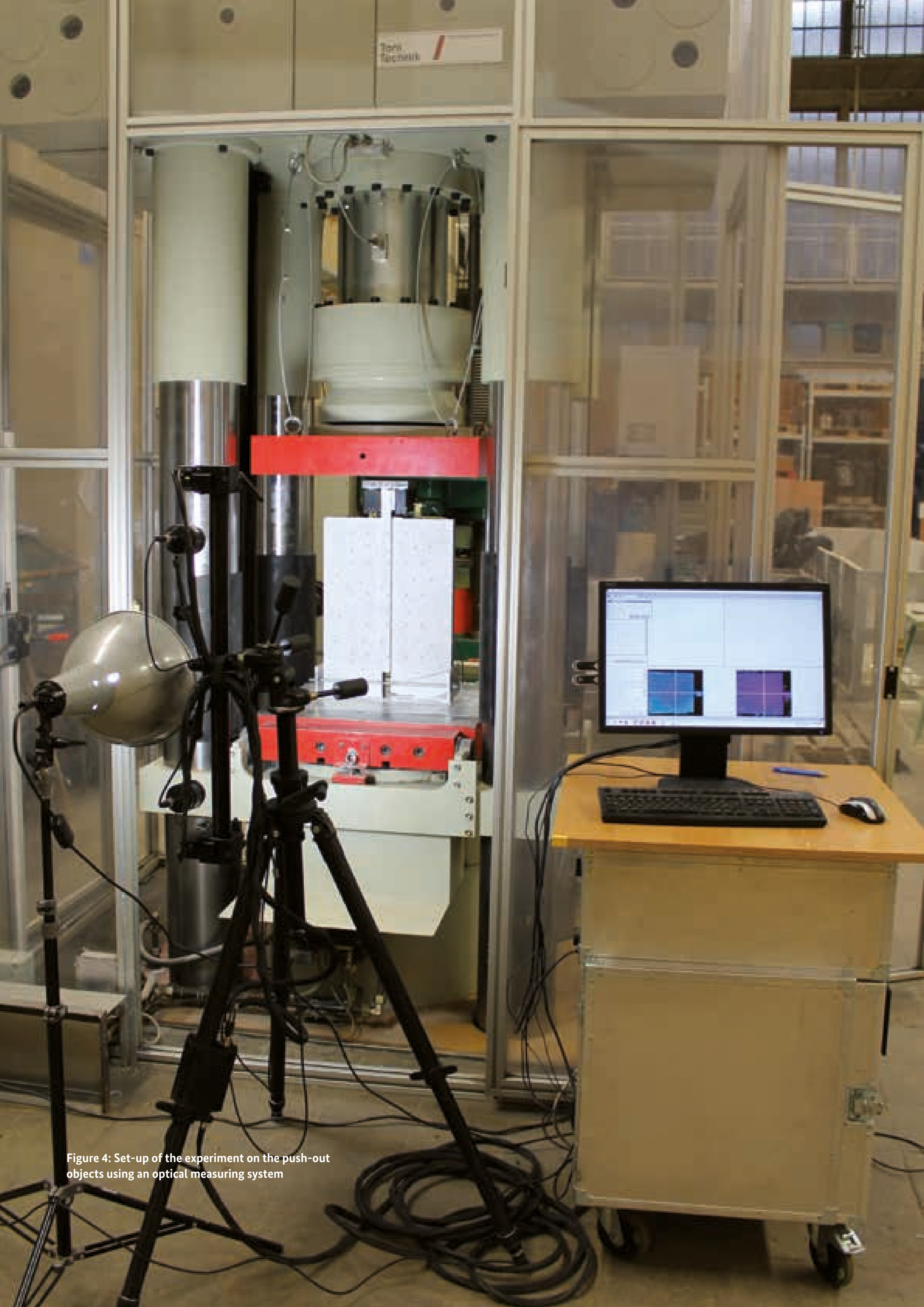


Figure 4: Set-up of the experiment on the push-out objects using an optical measuring system

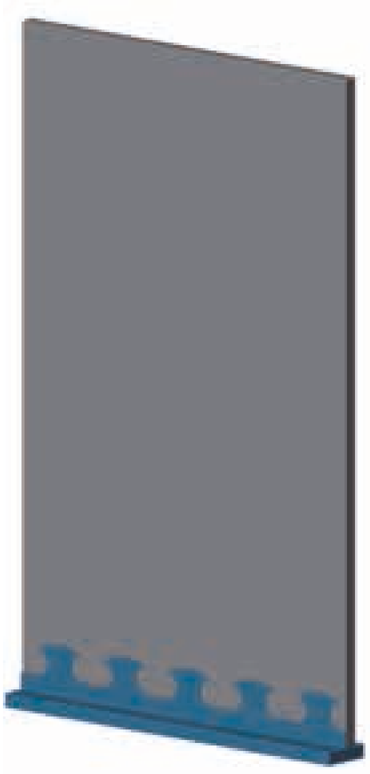


Figure 5: Test objects to determine clamping (depicted with a cutaway UHPC panel)

regarding building services, which the wall elements would have to meet in the proposed applications for new build or refurbishment activities. Furthermore, proposals for detailing the wall elements and for ways of taking into account the physical aspects and the fixed building services were developed.

Stud rails can be used in slender UHPC wall elements as connectors. The dimensioning of the stud rail can be based on the same approach used for normal concrete, although care must be taken to prevent the thin UHPC panels from splitting.

The stability design of the slender wall elements can be based on the specifications for steel structures in DIN EN 1993-1-5:2010, ignoring the restraining effect of the concrete in the stud rails.

To optimise use of slender wall elements in the future, further modular UHPC components must be developed in order to be able to create a modular system using the wall elements described. ■

Wall elements made of ultrahigh performance concrete

Project leader/researchers	Chair of Concrete and Masonry Structures, Technische Universität München (TUM) Chair of Metal Structures, Technische Universität München (TUM) SSF Ingenieure AG/Chair of Concrete and Masonry Structures
Project leader	Prof. Oliver Fischer
Overall costs	€ 322 800
Federal government grant	€ 232 300
Term	up to February 2014

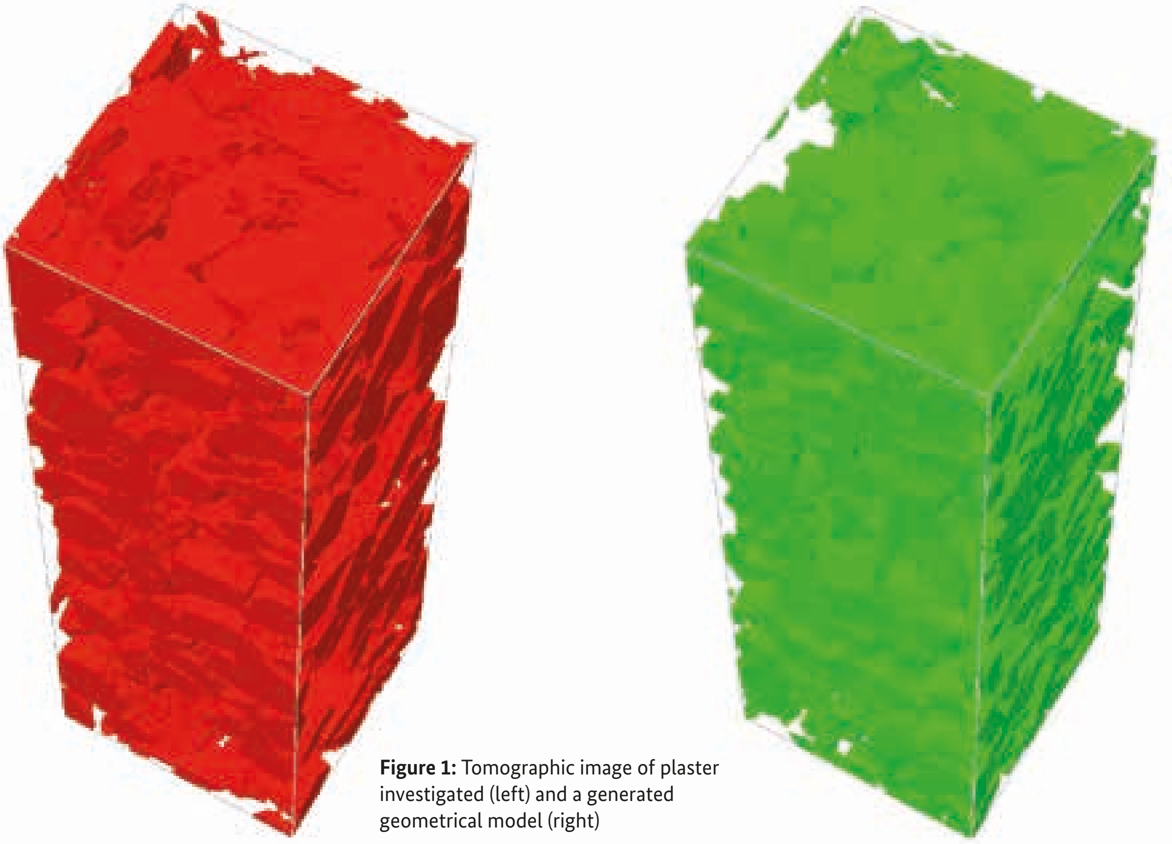


Figure 1: Tomographic image of plaster investigated (left) and a generated geometrical model (right)

Market-oriented acoustic plaster systems with high thermal efficiency

Horst-Albert Drotleff, Fraunhofer Institute for Building Physics (IBP), Stuttgart

Ceilings in office buildings are increasingly being designed to be multifunctional. However, smooth uniform surfaces that conceal the numerous technical installations are the preferred aesthetic option. Seamless plaster appears to be the material of choice to achieve this look. But highly contradictory physical specifications would have to be fulfilled to create a ceiling with both acoustic and thermal functions.

To absorb sound, plaster has to be porous, but that reduces thermal conductivity and therefore compromises its heating and cooling qualities. The project set out to analyse the microstructure and identify acoustically suitable pore morphologies, which permit thin coats of plaster to be used while also creating satisfactory thermal conductivity.

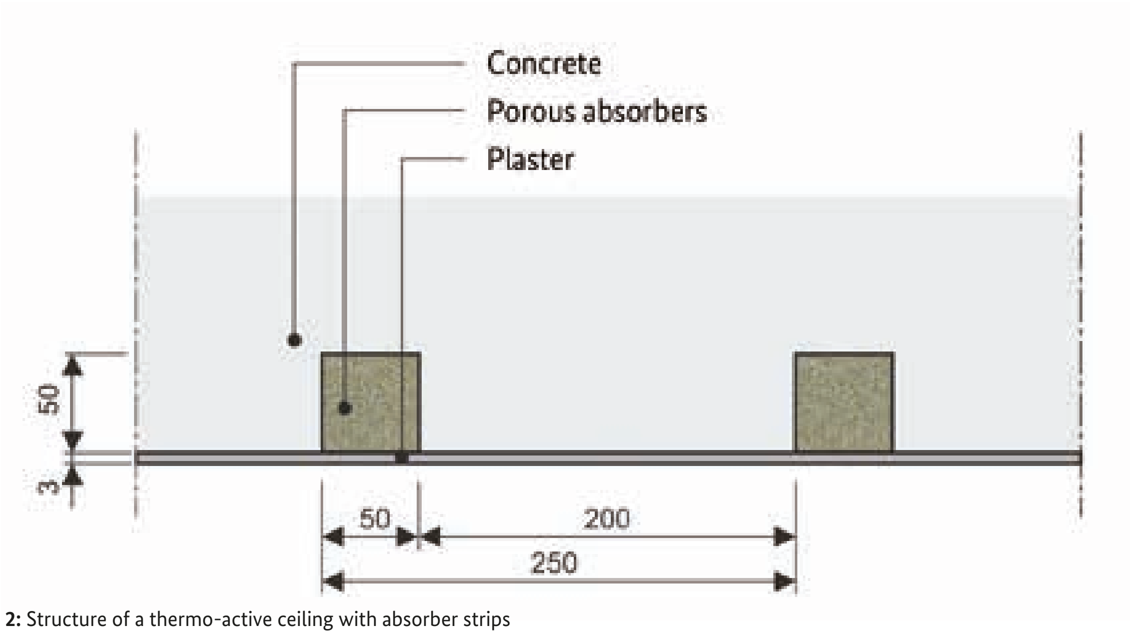


Figure 2: Structure of a thermo-active ceiling with absorber strips

Two cooling ceiling systems were investigated: thermo-active concrete ceilings with flush-fitted sound absorption strips at regular intervals (see Figure 2) and suspended acoustic cooling ceilings. Since the acoustic properties of these two options are very different, the plaster systems had to be designed separately. Computational studies on the absorption capacity of the plaster systems produced optimum ranges for the acoustic parameters of the material. Calculations for the suspended ceilings were based on commonly used methods for layering porous absorbers; for the ceilings using absorption strips, an existing calculation model was expanded to include additional full coats of plaster.

A crucial element of this approach was the theoretical modelling of the sound propagation in the plaster. In preparation for this, sound absorption coefficients were measured for a wide range of samples. The project partner Sto AG was given samples taken from three different plaster systems, in which the coats of plaster were of different thicknesses and had been applied differently. They had also been applied to different kinds of substrate and onto foils. The best results were from plaster that was separate from the substrate. Arranged over layers of air of different thicknesses, it was possible to investigate the absorption capacity in various spectrums across a wide frequency range. Classic models of porous sound absorbers proved to be suitable. The input data needed was indirectly ascertained to provide the best fit to the absorption spectrums.

In addition to this, a new method of analysing and carrying out a parametric synthesis of the pore morphology was used. The aim was, firstly, to calculate the input data for the absorber model directly from the microstructure. The second aim was to infer acoustically favourable pore structures by varying the geometrical models. To do this,

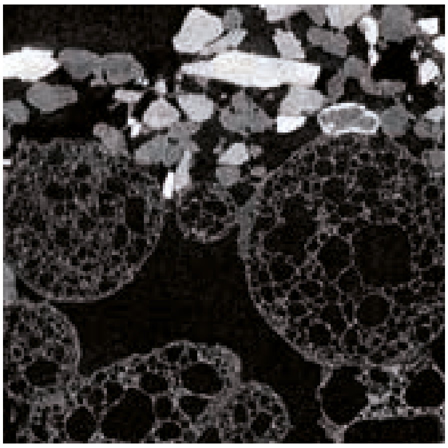


Figure 3: Tomographic image of a single coat of plaster on plasterboard made of blown glass granules

microtomography images of the plaster samples for which acoustic measurements had already been established were made and evaluated using integral geometry (see Figure 3). The analysis also provided characteristic parameters, such as the grain size distribution of the reconstituted granules, for which a direct correlation with the manufacturing parameters could be established. These parameters were used to generate a geometric model for plaster with a non-porous grain, which can be easily varied (see Figure 1). In the resulting pore volumes, flow and diffusion fields were then simulated, from which all the necessary data needed to calculate absorption coefficients can be obtained.

The thermal aspect is based on calculations using the finite elements method. This included calculating efficiency specific to the building components by comparing the average surface temperatures of the plastered and unplastered structures. This made it possible to identify acoustically and thermally favourable combinations of the thickness of the plaster and its thermal conductivity and to obtain indications of appropriate additives for the plaster (see Figure 4).

The aim was to develop plaster systems for sound absorbing cooling ceilings, which achieve sound absorption spec-

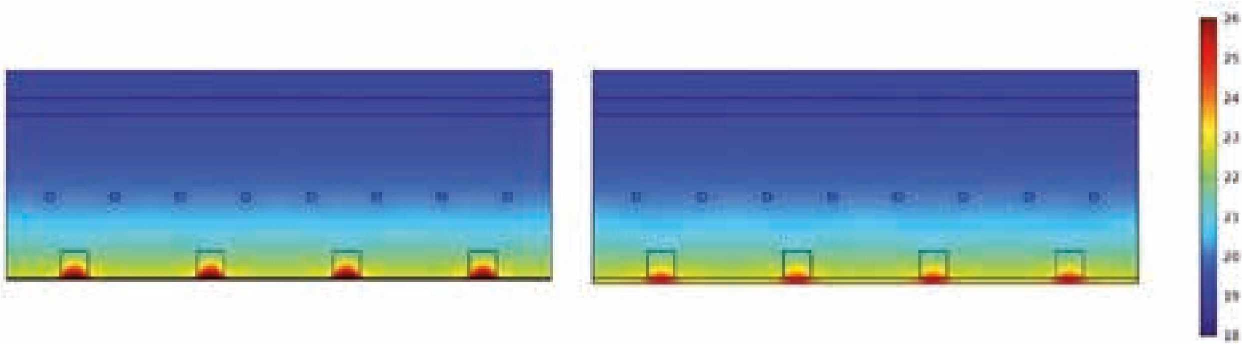


Figure 4: Simulation of temperatures of components in degrees Celsius in a ceiling with absorber strips and plaster of different thicknesses and thermal conductivity

trums that are fit for purpose without seriously compromising thermal efficiency. The following recommendations were developed for the two types of system: due to the relatively low thickness of the plaster, its acoustic properties are primarily determined by open volume porosity and flow resistance. Porosity should be set at about 40 % for all types of plaster. Higher values have no acoustic benefit and reduce thermal conductivity. The linear flow resistance can be approximately estimated on the basis of the grain size of the aggregates, assuming sphere packing. Solid aggregates only should be used, due to their significantly better thermal performance. No acoustic benefit could be established for porous aggregates in the types of ceiling studied.

In the case of ceilings with absorber strips, the plaster coat should be kept to the technically feasible minimum and grain size increased only to an extent that does not compromise properties such as workability or strength. For suspended ceilings the optimum flow resistance is significantly higher than for ceilings with absorber strips. They can be achieved by using solid aggregates only that have a diameter that is significantly less than one millimetre. ■

Market-oriented acoustic plaster systems with high thermal efficiency

Researchers/project leader	Fraunhofer Institute for Building Physics (IBP), Nobelstr. 12, 70569 Stuttgart
Project leader	Horst Drotleff
Overall costs	€ 150 000
Federal government grant	€ 95 000
Term	September 2011 to May 2013

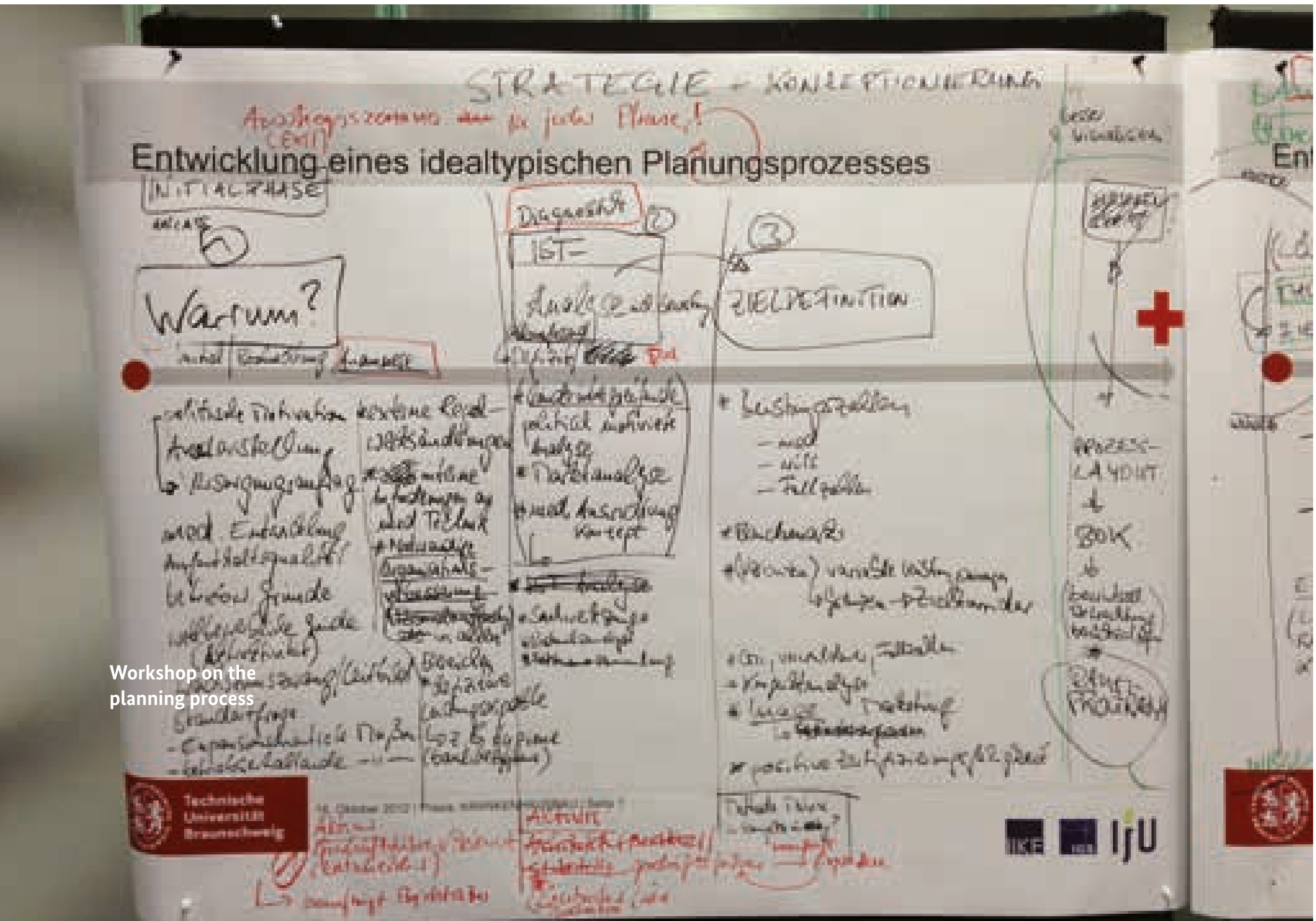
Hospital design in practice

An interdisciplinary research project at TU Braunschweig is developing viable solutions for organising the design process and building structure for hospitals, which also offer ways of approaching design and management of other complex major projects in the future.

Wolfgang Sunder, TU Braunschweig

The German hospital landscape is of international repute, highly regarded for its medical excellence. However, a chronic shortage of money, political narrow-mindedness, tough competition and obsolete structures often tarnish the clinics' image. If hospitals in future are to plan, operate and work more efficiently, i.e. guarantee quality health care, they have to tackle these challenges.

Hospital design plays a key role in this. Many hospital operators are therefore working flat out to improve their resource efficiency and organisational procedures, but with many existing hospital buildings they have very little scope for achieving the increase in efficiency needed and in many cases the building structures need to be adapted. An interdisciplinary research team made up of experts in construction, process planning and energy design at TU Braunschweig and led by the head of the Institute of Industrial Building and Construction Design (IIKE), Prof. Carsten Roth, is exploring this subject in a research project on hospital design in practice, which started in May 2012, looking in particular at how design processes could be optimised and consequently how new building structures could be made efficient and sustainable.

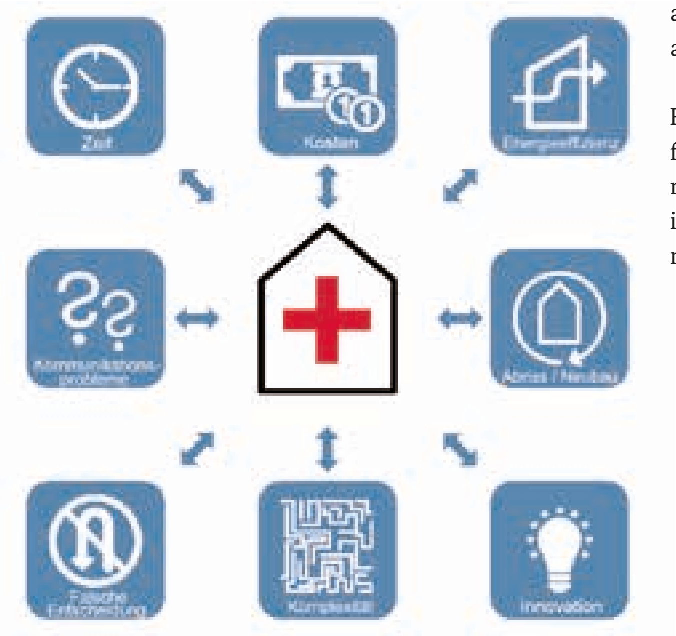


Workshop on the planning process

Shortcomings in hospital design and in the design process

In preparation for the start of the project in mid-2012, the research team worked closely with the project partners, exploring in workshops (see the photograph on page 86) which issues are important to hospital operators and designers. As a result the following shortcomings in hospital design and in the design process were identified:

- Innovations in medical technology and new forms of treatment exert enormous pressure for change and need adaptable, efficient building structures and procedures.
- The effects of inadequate quality of buildings and the opportunities for efficient long-term use that flexible buildings hold are often recognised too late by hospital operators.
- Hospital buildings are often designed for a short lifetime and operated on that basis (demolition instead of refurbishment). This focus on economic aspects means that hospitals often lose sight of their function as a place of healing and a workplace.
- High time and cost pressure often causes hospital providers to take the wrong decisions. Furthermore, the expertise of interdisciplinary teams (such as architects and process and energy designers) is integrated into the hospital design process too late.
- In most cases, hospitals used fixed building engineering services that are not energy-efficient and cannot respond to changing needs. Due to the rising energy costs, the pressure on hospital operators to drive forward saving in this area is increasing.



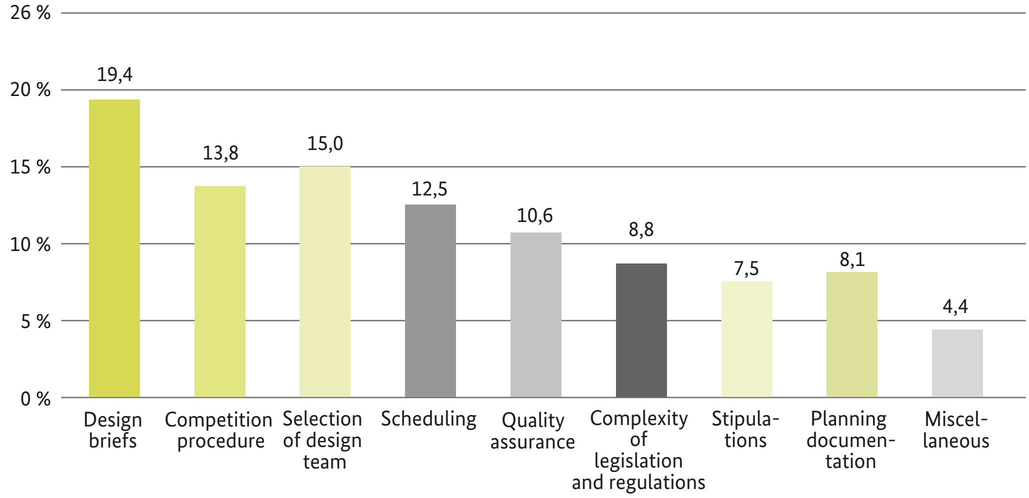
Challenges in hospital design

Future challenges

A nationwide online survey was carried out to look more closely at the shortcomings in hospital design listed above. The aim of the survey was to acquire a practice-based picture of what requirements hospital design has to fulfil. During the survey period from August to October 2012, over 800 people were asked for their views on a number of areas: process, buildings and energy in hospitals. The survey was addressed, on the one hand, to users (doctors and nursing staff) and, on the other hand, to planning experts in the health sector.

In this way, key issues for hospital design and the design process were developed. In terms of process, the respondents saw design briefs as the most important aspect in need of further optimisation. In this context, a design brief involves methodically establishing the client's needs. They also believed that not enough attention is paid to selecting a design team capable of meeting these needs.

From this, the conclusion can be drawn that there is scope for potential to be leveraged both by further developing methods and tools in preparing design briefs and also in the cross-cutting functions of design, such as project management.



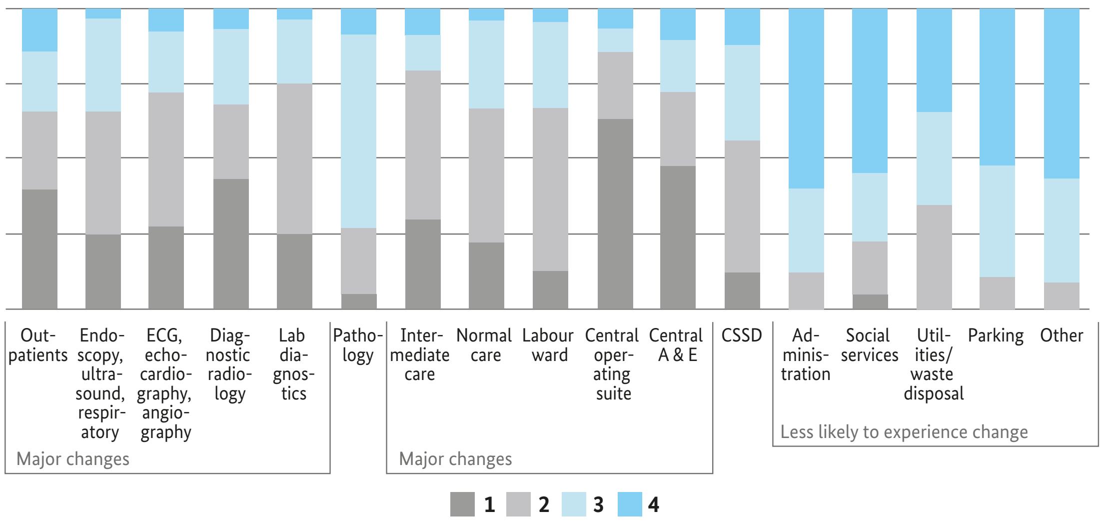
Online survey: Which aspect of the design process would you like to improve?

With regard to buildings, designers were questioned about future developments, restrictions and potential. Four areas were identified where the respondents believed a great deal of flexibility needs to be demonstrated. In this context, flexibility refers to the potential to adapt a building's structure quickly and cost-effectively. The areas included, for example, a hospital's central operating suite and accident and emergency department.

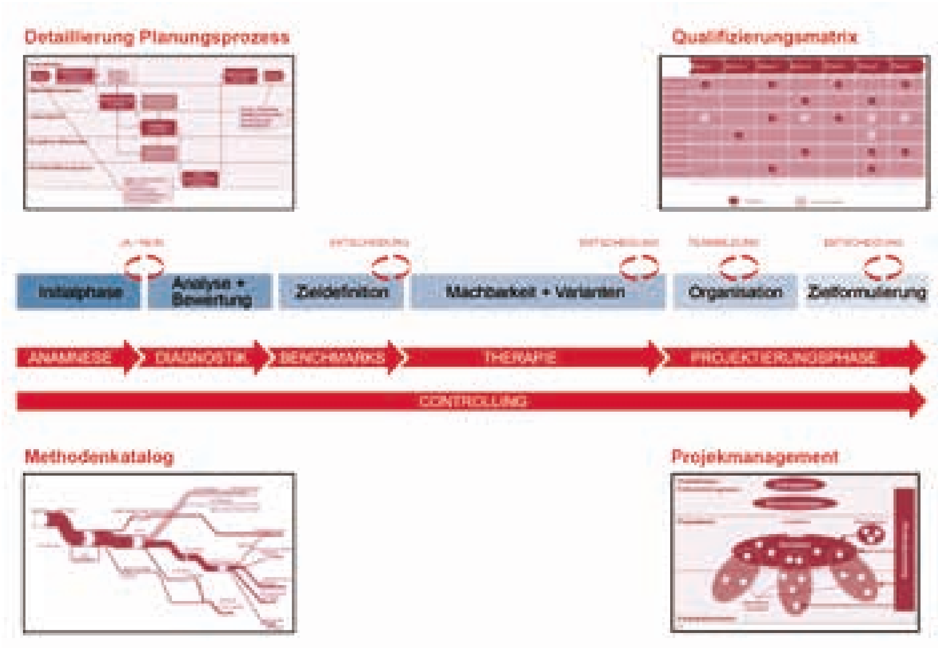
The solution: optimisation and quality assurance in strategic planning

In the next stage of the project, the team of researchers worked in conjunction with the research partners to develop a strategic planning process to be used before the first work stage defined in HOAI, the German architects' scale of fees. The phases essential to strategic planning from the initial phase through to formulating objectives were developed in greater detail using a matrix to which the necessary information was added.

Leading on from there, the next task was to define how methods and tools for the three disciplines – process, energy and building – could best support the design process in acquiring information. To this end, a comprehensive catalogue of methods and tools was compiled, which describes their use in practice and lists advantages and



Online survey: Which areas of the building will change most in the future?



Design process for hospital buildings that are fit for the future

disadvantages. To be able to achieve objectives such as flexibility and sustainability that make hospital design future-proof, the efficient and correct use of skills is crucial. To address this, the team of researchers developed a quality profile, detailing skills that everyone involved in the design process needs to enable them to carry out certain activities. The profile comprises technical, methodological and social skills.

Stuttgart 21, BER airport, Elbphilharmonie Hamburg

The issues addressed in the previous phases of work were reviewed against a number of different hospital projects. The chronological arrangement of documentation and its transfer into the design system developed (target/actual comparison) proved to be workable. Particularly the ability of the matrix developed to provide a simplified visualisation of problem areas proved convincing for everyone involved in the research project.

The research project's findings have had an innovative impact and have already been incorporated into the design activities of the research partners. However, at the same time, numerous ideas have been generated regarding how the findings might be applied to large-scale public and private building projects, which in the past have jeopardised the good reputation of Germany's construction industry in that they often ran way over schedule and massively over budget. ■

Hospital design in practice

Researchers/project leader	Research team at Technische Universität Carolo-Wilhelmina zu Braunschweig, IIKE – Institute of Industrial Building and Construction Design (project leader), Prof. Carsten Roth, Wolfgang Sunder, Jan Holzhausen Institute for Building Services and Energy Design (IGS) Prof. M. Norbert Fisch, Philipp Knöfler Institute for Advanced Industrial Management (IFU) Prof. Uwe Dombrowski, Christoph Riechel
Project partners	Bauunternehmen Wolff & Müller Holding GmbH & Co. KG, Dräger Medical Deutschland GmbH, Katholischer Hospitalverbund Hellweg, Miele & Cie. KG, Architektengruppe Schweitzer & Partner, Rhön-Klinikum AG, Schön Kliniken Verwaltung GmbH, Städtisches Klinikum Braunschweig gGmbH, Unity AG
Overall costs	€ 439 768
Federal government grant	€ 197 568
Term	up to May 2014

The authors work in the team researching hospital design in practice at TU Braunschweig. In the following article they talk about their experience from the development of the research idea through to preparing the funding application.

From an idea through to a research project – preparing a successful application

Jan Holzhausen, Wolfgang Sunder, TU Braunschweig

The process involved in getting a research project approved depends on many individual factors. It is important that these factors be seen as an opportunity rather than as some kind of chaos that has to be mastered. The gradual emergence of the core issue, the composition of the research team and recruiting industry partners are what make the application stage interesting. These factors determine the research project's punch and therefore its likelihood of attracting funding.

At the beginning of each research project there are always lots of very different angles in evidence. There are also very personal reasons for which topic is actually taken through to the application stage. Which topic interests me at the time? Does it fit the profile of our institute? Can I build on knowledge that the institute has already acquired? Do we want to explore new areas? And last but not least: is the subject we are interested in even eligible for funding?

The Federal Institute for Research on Building, Urban Affairs and Spatial Development uses a clever instrument that looks at the own funding/external funding split. With this it has developed an indicator of whether there is a need in practice for the subject under consideration. The proportion of external funding enables us to clearly see how urgent the research topic is and how willing the industry partners involved are to provide funding.

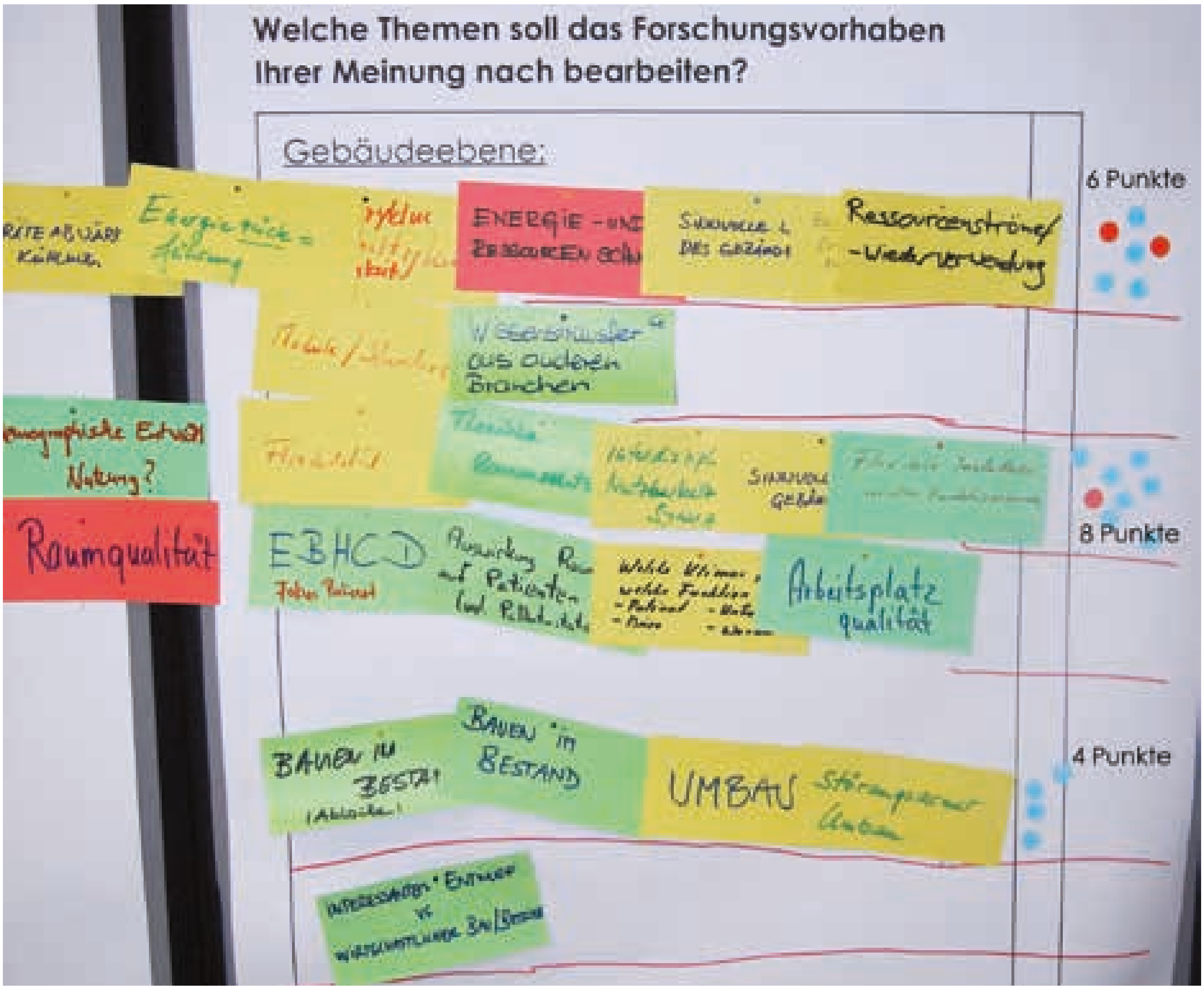
For this reason, the practice of contacting possible research partners at a very early stage in the process has established itself. Of course, we first of all look at the different departments of our own university and institutes in other establishments we are on friendly terms with. Once we have put together the academic part of the research team, we turn our attention to industry partners. Here we architects who think ourselves above these things may just have to pick up the phone and start looking for backers. In these first phone conversations you very quickly get a sense of the necessity of the subject in the reality of construction practice and not just from the ivory tower of academia.

We have also developed something that has proven extremely useful and that is to organise an initial kick-off meeting long before we start preparing an application. Here we bring together everyone who is interested in the topic. The meeting enables us to get to know each other and to begin to narrow down the research topic.

We do this using a moderated process for analysing the deficits of the possible topic. After that topics are clustered and ranked. The results of this workshop enable us to hone the application and at the same time reflect the potential for optimisation in industry.

The participants at the meeting are also able to better assess whether it makes sense for them to be involved as a partner in the research project. Even at this first meeting a certain dynamic usually develops among particular groups of people who then go on to become decisive driving forces in the subsequent research project.

When analysing the funding landscape, it is also advisable to get in touch with the project coordinators at BBSR early on to coordinate the application with them and thus increase the application's chances of success.



Workshop with research partners from industry in the application phase to narrow down the range of possible topics

Before we submit the application we also incorporate the topic under consideration into our teaching practice at the university. This enables us to develop the fundamental aspects in collaboration with our students and generate unorthodox, or sometimes even naïve – and therefore fresh – angles on the subject.

In our experience, our industry partners really like this unconventional thinking on the part of students who are not weighed down by a sack full of conventional and empirical knowledge that hampers their creativity. In fact, as the project progresses, our industry partners repeatedly seek out their input.

All the measures we have described take time. Just the process of recruiting industry partners and incorporating them into the application submission can take a year or more. For us that means that once an application has been approved we have to get the next one underway.

Of course, the best thing is when new topics evolve naturally from completed ones, which means that research partnerships can continue.

The initial idea for a research project does not take much time and an experienced academic can draft the application for funding in a couple of days. But it is setting up the complete structure, the framework for the research project, that makes it unique and therefore eligible for funding. Timetables, work schedules and budgets can be conscientiously drawn up but it is getting a research team together to work on honing the subject that will make the difference between victory and defeat at the application stage. ■

Code of practice for accessible building design

Rachel Barthel, Federal Institute for Research on Building, Urban Affairs and Spatial Development

The much needed changes that are taking place in society are creating an inclusive society. In the future, the percentage of older people with impairments is set to rise. We all want to be able to use buildings without assistance if possible, including in our old age. Buildings must therefore be accessible and usable for everyone. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has commissioned important research projects to look at how buildings can be made accessible. A new code of practice provides guidance on making public buildings and workplaces accessible.

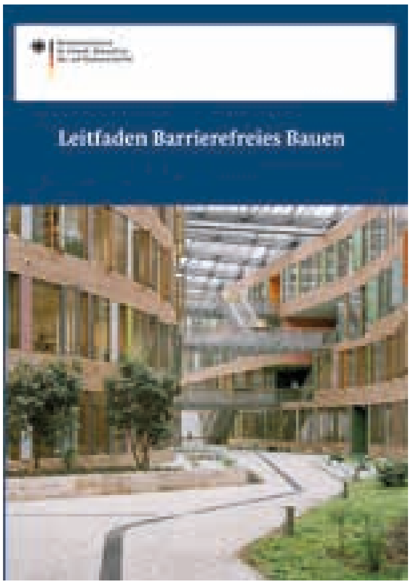
Accessible building design is an important research area and since 2005 a range of commissioned research projects on the subject have been carried out in BBSR. The development of a code of practice for accessible building design has been one of the focal areas of research for several years. The code of practice is intended to make it easier to implement the accessibility requirements for public buildings as stipulated in the federal government's Equal Opportunities for People with Disabilities Act (BGG). The highest building authorities will receive a guidance document detailing how the federal government's commitment to ensuring accessibility, as called for by Section 8 of the Equal Opportunities for People with Disabilities Act (BGG), can be implemented. This stipulates that accessibility standards must comply with the generally acknowledged state of the art in all new civilian buildings and all large refurbishment and extension projects. The Act does not apply to small-scale building work on existing buildings costing less than € 2 million. The spirit of DIN 18040-1 must be complied with for existing buildings. The code of practice for accessible building design also recommends considering which individual building measures might be appropriate for small-scale refurbishment and extension work.

In DIN 18040 "Construction of Accessible Buildings – Design Principles – Part 1: Publicly Accessible Buildings" of October 2010, stipulations to be complied with in publicly accessible buildings were made for the first time, which are designed to include the needs of people with sensory impairments. DIN 18040-1 does not, however, apply to places of work. The Technical Rules on designing accessible workplaces are made more specific by ASR V 3a.2, for example. It is therefore important to establish which areas of a workplace are publicly accessible and which are not because they have to comply with different requirements under public law. A guidance document is needed to help government building authorities deal with the complexity of the law and various technical standards relating to buildings and components. Furthermore, during the course of building activities, responsibilities and competence in the design process and procedures set out in the Federal Construction Guidelines (RBBau) must be observed.

Ensuring that buildings are accessible calls for an integrated design approach. The BMUB's code of practice for accessible building design aims to integrate accessibility into the design process for all public building projects. The overall objective is that as far as possible everyone should be able to use public buildings and public areas of workplaces. Thus, new public buildings and workplaces have to be built to certain accessibility standards and obstacles to accessibility have to be eliminated in existing buildings. The code of practice for accessible building design is directed at designers, building owners, operators and users of public buildings and workplaces.

The code of practice is divided into four parts

Part A describes with references the generally acknowledged state of the art regarding accessible building design. An easy-to-understand explanation is given of which key legislation, directives, regulations and agreements apply when. Short sections deal with aspects of accessible building design that relate to architectural heritage and conservation, to sustainable building design and economic considerations. For building work on existing buildings it describes measures and the search for individual solutions based on cost-effectiveness.



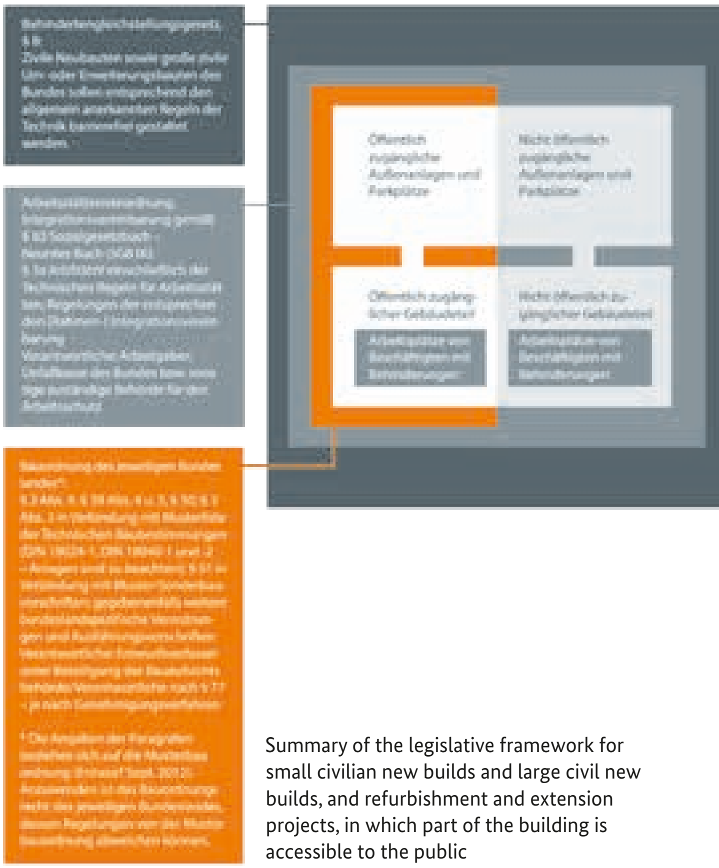
Cover of the code of practice for accessible building design

Part B of the code of practice gives guidance on the design process following the procedures of the Federal Construction Guidelines

The sensory requirements for buildings accessible to the public set out in DIN 18040-1 take into consideration the needs of people who are visually impaired, blind, or have a hearing impairment (people who are deaf, deafened or hard of hearing). A number of requirements are also intended to make buildings easier to use for elderly people and people with cognitive impairments.

Part C explores the needs of people with impairments. Based on the structure of DIN 18040-1, the stipulations are categorised into 22 fields of action based on the requirements they need the built environment to fulfil. The fields of action are divided into four groups: overall concept (urban integration and orientation and guidance systems), circulation (including alarm systems and evacuation), fixtures and fittings and rooms.

Part D uses the example of an idealised hypothetical project to illustrate how decisions on accessible building design can be documented. It includes a section entitled "accessibility concept" and another entitled "demonstrating accessibility" to give an example of how to demonstrate compliance with the requirements in drawing up a decision paper and design documentation.



Summary of the legislative framework for small civilian new builds and large civil new builds, and refurbishment and extension projects, in which part of the building is accessible to the public

At a future date, a written instruction currently being prepared by the BMUB will make the code of practice for accessible building design a mandatory requirement

In the initial planning stages of a project, it would be important to be able to estimate the costs of compliance with accessibility requirements. It should be possible to estimate and incorporate costs of ensuring accessibility in large-scale new builds, extensions or refurbishment projects as early as the brief for building design. To date, the experience needed to appropriately include these costs when drawing up budgets for government building activities was lacking. A research project on economic aspects of accessible building design developed a methodology for establishing the additional costs of accessible building design from the outset. Based on this methodology, the additional costs are the sum total of the individual measures required. The additional costs for each individual measure are determined using typical values for specified reference standards. To ascertain the additional expense, the number

Verfahrensschritte nach RBBau	Einbeziehen Barrierefreiheit	Zuständigkeit
ES **ES-Bau (Entscheidungsunterlage-Bau)** → vgl. HOAI: LP 1 und teilweise LP 2		
Bedarfsplanung nach Ziffer 2.21 Abschnitt E RBBau	Prüfung der Anforderungen an die Barrierefreiheit in der Bedarfsplanung	**Nutzer** (Beteiligung Maßnahmeträger, Bauverwaltung)
Variantenuntersuchung zur Bedarfsdeckung nach Ziffer 2.22 Abschnitt E RBBau	Prüfung der Anforderungen an die Barrierefreiheit in der Variantenuntersuchung	**Maßnahmenträger** (Beteiligung Bauverwaltung)
Qualifizierung zur ES-Bau nach Ziffer 2.23 Abschnitt E RBBau	Erstellung: KONZEPT BARRIEREFREIHEIT	**Bauverwaltung**
EW **EW-Bau (Entwurfsunterlage-Bau)** → vgl. HOAI: LP 2,3 und 4 und teilweise LP 5		
nach Ziffer 3 Abschnitt E RBBau Vorentwurfs-, Entwurfs-, Genehmigungsplanung	Erstellung: NACHWEIS BARRIEREFREIHEIT	**Bauverwaltung**
A **Ausführungsplanung** → vgl. HOAI: LP 5 und 6		
nach Ziffer 4 Abschnitt E RBBau Ausführungsplanung Leistungsverzeichnisse	Fortschreibung: NACHWEIS BARRIEREFREIHEIT	**Bauverwaltung**
Bauausführung → vgl. HOAI: LP 7 und 8		
nach Abschnitt G RBBau Vergabe Bauüberwachung	Kontrolle Einhaltung: NACHWEIS BARRIEREFREIHEIT Dokumentation notwendiger Abweichungen im Rahmen der Ausführung	**Bauverwaltung**
Bauübergabe und Dokumentation → vgl. HOAI: LP 9		
nach Abschnitt H RBBau Dokumentation	Erstellung: Bauübergabe und Dokumentation Barrierefreiheit	**Bauverwaltung**

Accessibility in federal buildings
Procedures specified in the Federal Construction Guidelines (RBBau)

Integration of a platform lift into a historic stairway in Albrechtsburg in Meissen: As a means of preventing anything from getting trapped, a sensor strip has been fitted around the platform lift, which automatically switches off the motor.

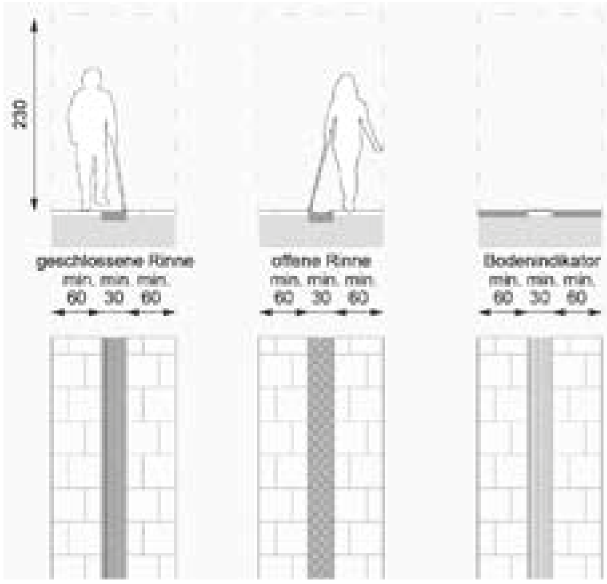
and type of measures needed to achieve accessibility are established for each project. Nine of the 22 fields of action of the code of practice for accessible building design which incur most of the extra expense were studied. It was found that the assumption that the additional costs as a percentage of overall costs decreases as the size of the project increases is not true for all fields of action. A linear correlation with the size of the building was confirmed only for ramps (exterior), lifts compliant with the code of practice for accessible building designs and foyer/entrance. The findings are based on generally applicable values, such as building costs per square metre of floor space, and therefore make it possible to take the costs of ensuring accessibility into account from the outset. A follow-on project aims to ascertain project-specific additional costs of accessible building design.

A research project to digitalise the code of practice for accessible building design is currently being funded by the Zukunft Bau initiative. It is creating an online version of the code of practice. It includes a user-friendly online tool that can be used to generate project-specific accessibility schemes and documentation that follows the structure of the code of practice for accessible building design.

The fundamental human right to participation should be assured for all users of new public buildings. For public building activities, the code of practice for accessible building design is a crucial milestone for the implementation of the UN Convention on the Rights of Persons with Disabilities, the German Equal Opportunities for People with Disabilities Act (BGG) and DIN 18040-1.

The code of practice gives designers a tool – that goes beyond minimum requirements – to base their thinking on and design buildings for the benefit of everyone who uses them.

The code of practice for accessible building design can ensure that accessibility is an integral part of all stages of the building design process. Decision-making and design processes are structured and documented. The code of practice is both a reference work and a source of ideas. ■



An example of floor indicators and alternative schemes using other kinds of guidance elements

Code of practice for accessible building design

Project leader/researchers	Technische Universität Dresden Prof. P. Schmieg und Prof. I. Lohaus, Sárka Vorísková
Project leader	Rachel Barthel Federal Institute for Research on Building, Urban Affairs and Spatial Development in the Federal Office for Building and Regional Planning Orders: publikationen@bundesregierung.de/Download: www.nachhaltigesbauen.de
Overall costs	€ 95 288
Term	October 2011 to April 2014

Digital code of practice for accessible building design

Project leader/researchers	Technische Universität Dresden Prof. P. Schmieg und Prof. I. Lohaus, Sárka Vorísková und OnlineNow! Gesellschaft für elektronisches Marketing mbH, Dr Hoyer
Project leader	Rachel Barthel Federal Institute for Research on Building, Urban Affairs and Spatial Development at the Federal Office for Building and Regional Planning
Overall costs	€ 99 960
Term	December 2013 to March 2015

Economic aspects of accessible building design

Project leader/researchers	Technische Universität Dresden Prof. P. Schmieg und Prof. I. Lohaus, acting Prof. Mickhan, Sárka Vorísková
Project leader	Rachel Barthel Federal Institute for Research on Building, Urban Affairs and Spatial Development at the Federal Office for Building and Regional Planning Orders: publikationen@bundesregierung.de/Download: www.nachhaltigesbauen.de
Overall costs	€ 49 980
Term	October 2012 to August 2014

The increasing aging and loss of mobility of the population in rural areas is being accompanied by growing centralisation of services. A multiuse building, which can be used for different purposes on different days, can create an economically feasible and attractive hub for services and community activities in villages. It works on the same principle as car sharing: service providers and other users share the building by contributing to the basic rent and running costs.

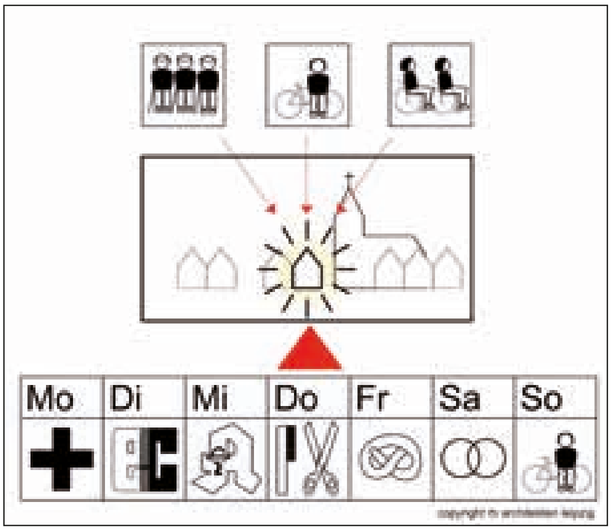
Setting up multiuse buildings in the Stettiner Haff pilot region – evaluation project

Jana Reichenbach-Behnisch, Leipzig

The idea of the multiuse building, which the authors first outlined back in 2008 for rural areas and then developed to a point where it could be put into practice as part of an initial research project, has now been implemented for the first time in five villages in the Stettiner Haff region of Mecklenburg-Western Pomerania. The second report published in April 2014 documents the project's active facilitation work from the first multiuse building and creation of a network in five neighbouring villages with meetings and user workshops right through to the beginning of the remodelling phase. The next generation of multiuse buildings will benefit from this. The work of evaluating and documenting the catalogue of problems and possible solutions included not only legal reports and performance audits but also developing a logo and establishing a quality assurance tool, drafting up-to-date catalogues of needs and criteria and making recommendations for action aimed at local authorities and other decision-makers.

Covers of research reports

Covers of research reports



The buildings are used for different purposes on different days

Das Multiple Haus. Die neue Dorfmitte.

Logo for the multiuse buildings

All tidied up, but still a building site: the multiuse buildings Alter Dorfladen in Hintersee, Alte Schule in Altwarp, Alte Mühle in Ahlbeck, Alte Schule in Vogelsang-Warsin and SeeSalon in Rieth (from top left to bottom right); as at: April 2014. Joint inauguration scheduled for autumn 2014

A modular furniture system consisting of storage, seating and counter elements was designed and is ready to be installed in the multiuse buildings. An interactive website with calendar was developed as a management tool. The central website will now also support the imminent creation of a network extending beyond the region with options for sharing ideas about solutions to problems and facilitating communication among the buildings. But first and foremost it will act as an advertising platform promoting public awareness.

These practical examples of space-sharing models, and in particular the nationwide approach, are likely to be of interest to many people, not just the private sector sponsors such as RWE, who will support the first multiuse buildings and their operating cost calculations with its smart home power control system. The aim of a future project offering training and support is to empower committed local stakeholders and decision-makers to set up and manage a multiuse building.

Since the evaluation project was launched in one village only, it can be seen as a particular success that the first network of multiuse buildings in five neighbouring villages has now been set up. ■
www.multiples-haus.de/www.multiples-haus-stettiner-haff.de (online from May 2014)

Alte Dorfschule m. H. – setting up multiuse buildings

Researchers/project leader	Jana Reichenbach-Behnisch
Project leader	Jana Reichenbach-Behnisch
Overall costs	€ 139 100
Federal government grant	€ 106 000
Term	July 2011 to April 2014

Meisenheim, Schlosskirche, tenon joint with clear signs of maceration

Maceration of wood in historic roof structures

Developing and trialling methods to reduce and control damage (MATEKUR)

Insa Christiane Hennen, building research and conservation expert, Wittenberg

The roofs of almost all the major Medieval churches and other historical monuments in the former German Reich were treated with flame retardants between 1942 and 1945. As a result, numerous historic wooden structures in Germany, the Czech Republic, Austria, Slovakia, Luxembourg, Belgium and Poland, are affected by maceration damage. The project is evaluating existing refurbishment approaches and developing and testing new methods.

The cause of the maceration, which is a fraying of wood surfaces that leaves the wood with a furry appearance, are salts from fire retardants, which have penetrated about 10 mm into the timber. In many cases, the flame retardant treatments were repeated at short intervals and biocides such as DDT and lindane were also applied, so that the maceration produced contaminated dust. The damage has been progressing over decades; the extent depends on climatic factors.

To date, it had been assumed that the salts in the timber absorb water from the atmosphere, which would produce acids and/or cause the timber to swell. In dry periods, the salts crystallise again, which is also detrimental to the structure of the wood. The extent of the maceration varies, depending on whether fluoride, phosphate or sulphate compounds were used.

Halle, Moritzkirche, view into the church's roof space

Naumburg, cathedral, maceration of the surface of the wood

Since 1990 a range of different restoration approaches – some of them experimental – have been used. The aim is to study their effectiveness and evaluate the cost and benefits. The starting values of 17 restored buildings were compared with current salt levels, the appearance of the wood was described and any flanking measures carried out on the buildings, such as improvements to the ventilation of the roof space, were documented.

Cleaning the wood is not generally speaking sufficient, because in the medium-term salts from deeper levels migrate to the surface and cause fresh damage. Removing the damaged wood in its entirety is out of the question because it would mean serious reductions in cross-section and would totally remove any traces of historical workmanship. This, however, is also often the case after thorough cleaning.

The relatively frequently used "masking" method, which involves a coating that virtually hermetically seals the surface of the wood, prevents the salts in the wood from absorbing water from the atmosphere and seems to at least halt the corrosion process over a longer period of time. However, undesired changes to the appearance of the wood have been observed and the salts remain in the wood.

Meisenheim, Schlosskirche, testing whether the wood can be cleaned with a rotating brush

Meisenheim, Schlosskirche, surface of the oak structure after cleaning with a rotating synthetic brush

Chemical buffers, which were used to stabilise the damp in the part of the wood close to the surface, are no longer effective after ten to 15 years so that the effects of maceration are visible again.

In spring 2013, test areas were established in the roof of Naumburg cathedral, which were then observed over the course of a year. All the surfaces were mechanically cleaned using a range of rotating brushes. Washing processes were also tested. One test area was masked using a new substance, which does not hermetically seal the surface of the wood and does not cause any changes to its appearance. Substances to convert the salts in the wood into stable chemical compounds and compresses of the kind used to remove salts when restoring natural stone were also trialled.

The test areas are checked regularly, their appearance described, the humidity of the wood measured and compared with untreated wood. The effectiveness of the treatment methods is checked by comparing the sulphate and phosphate content after treatment with the values before treatment.

A laboratory experiment to model the damage process has been running since May 2012. Test specimens that have not been treated and others that have been treated with fire retardant salts are placed in a desiccator cabinet and exposed to different hygric conditions, alternating every 12 days between 92 % and 35 % relative air humidity.

Other laboratory experiments were carried out to verify the recently developed restoration method. The inactivation of

Synthetic brush used to clean the wood

Naumburg, cathedral, testing whether the wood can be cleaned using an extraction cleaner

sulphate and phosphate ions in wood at risk of maceration is difficult to document stoichiometrically, since the inhomogeneous nature of wood as a substrate and the uneven application of fire retardants preclude exact mathematical recording. In addition to the experimental and empirical approach on site, the reaction kinetics were ascertained using precisely doped test specimens. Although the desired conversion into inert, non-water-soluble alkaline earth compounds is a matter of elementary, non-reversible reaction mechanisms, the practical implementation is fraught with numerous uncertainties and problems, which means that the method will have to be gradually optimised.

Simulation of maceration processes could succeed for the first time. After 88 changes/44 cycles the first loosening in the structure of the wood has been observed. The effectiveness of using compresses to remove salts was demonstrated both in the laboratory and in practice. This method could be used, for example, for valuable wood joints or surfaces with joint marks etc. The results achieved to date in converting the salts into inert compounds are promising.

The aim is to produce a manual by the time the project is concluded at the end of 2014, which would present the different possibilities for using and combining different methods, taking into account the economic aspects of tackling maceration. ■

Developing and trialling methods to reduce and control damage (MATEKUR)

Project leader/researchers	Dr Insa Christiane Hennen (building research and conservation expert, Wittenberg) Uwe Kalisch (IDK Halle) Hans-Norbert Marx (SVB Marx, Bühl-Vimbuch) Holger Niewisch (Büro Niewisch, Berlin) Udo Tostmann M.A. (Büro für Bauwerkerhaltung, Berlin)
Project leader	Dr Insa Christiane Hennen
Overall costs	€ 237 582
Federal government grant	€ 97 582
Term	up to November 2014

3D mapping of deformations and damage in building structures

Christiane Maierhofer, BAM Braunschweig

3D mapping is a key factor in ensuring the safety and reliability of buildings in that it provides a three-dimensional and time-resolved image of damage to buildings. The aim of the project was therefore to develop visual and thermographic methods for 3D recording of cracks and delamination. With this new approach, the mapped images can be directly transferred to virtual 1:1 models.

Digital 3D scanning of surfaces of components and damage makes virtual representation of buildings possible. If the examinations are repeated at regular intervals, the changes to the building over time, such as deformations, torsion, increase in the size of cracks, and bulging plaster can be depicted virtually. Since larger sections of buildings can already be recorded effectively using 3D laser scanners and photogrammetry, the detection of damage near the surface – especially cracks – with a high spatial resolution was the project's priority.

To carry out 3D mapping of cracks a simple to operate scanning probe was developed, which is run manually along a crack; its position and orientation are recorded by a tracking system (see Figure 1). This system is usually used to record human movements in motion capturing applications. A further development of the system made it possible to achieve the significantly higher measuring accuracy needed here in the sub-millimetre range. Cracks, plaster edges and transitions between different materials can be classified during data capture (see Figure 2).

To record and depict markings in the plaster in Magdeburg cathedral dating back to the Middle Ages, a stereophotogrammetric method was optimised in which high-resolution surface topologies can be extracted on the basis of two digital images. To obtain 3D data to measure objects with a large surface area in the resolution needed, several images have to be combined. This process made it possible to achieve for the first time a vivid depiction of the markings in the plaster that had never been possible before from photographs (see Figure 3). To depict the results of depth mapping the area, an averaged reference level was first added to the 3D data set. The difference from the original

Figure 1a und 1b: Crack tracking system with scanning probe (a) and camera system (b)

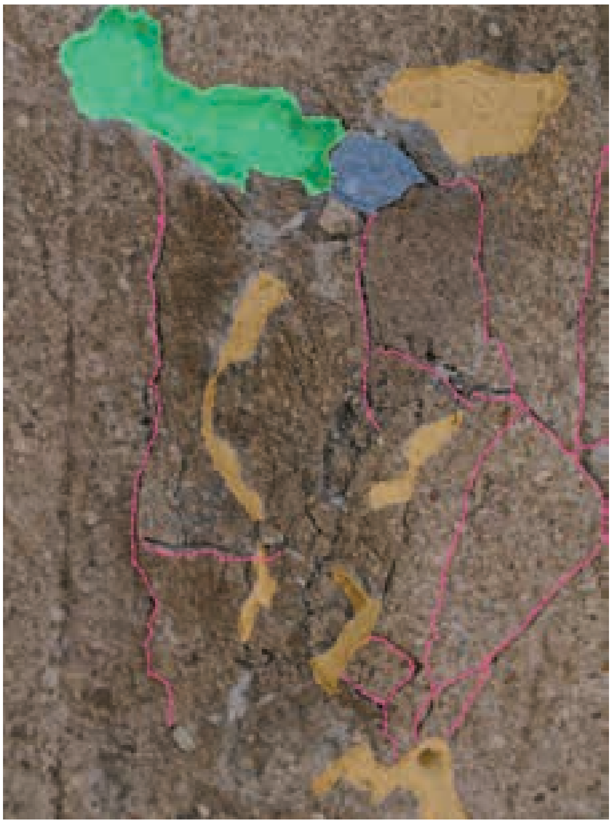


Figure 2a und 2b: Photo (a) and 3D mapping of cracks using the tracking system (b) of a hollow in the markings in the plaster in Magdeburg cathedral

Figure 3: 3D depiction of markings in the plaster using stereophotogrammetry

data set was calculated on that basis. The result is shown in Figure 5a. Both bulges out of the plane and depressions and indentations become visible.

Active thermography was also used, a process by which non-stationary heat transfer processes resulting from solar irradiation, shading or artificial heat sources can be made visible by measuring the temperature distribution on the surface. Fan heaters or infrared lamps, for example, can be used as artificial heat sources. After having been heated, an infrared camera is used to record with good temporal and spatial resolution the cooling of the surface of the building component (see Figure 4a). By evaluating the change in temperature over time, it is possible, for example, to achieve good visualisation of the markings in the plaster and flaking plaster around larger cracks (see Figure 4b). Hollows and flaking plaster can also be easily identified on the thermographic image as hotter areas (see Figure 5b). In conjunction with the depth map it is possible to determine, for example, whether bulges are due to plaster beginning to

Figure 4a: Recording thermography sequences on the surface of the plaster in Magdeburg cathedral following artificial heating

flake or whether they are patches of thicker plaster. Cracks that are vertical or diagonal to the surface can also be visualised using active thermography. In the case of diagonal cracks, information on the angle of the crack and possibly also its depth can be obtained.

To test the new high-resolution 3D mapping techniques, they were used in conjunction and in combination with other techniques (including ultrasound to measure the depth of cracks, manual mapping of cracks, crack sensors) in two case studies, one mapping cracks and damage to Giebichenstein bridge in Halle, which is flanked by two concrete animal sculptures acting as icebreakers, and another to visualise markings in the plaster at Magdeburg cathedral and also map damage to the surrounding facade. The development of the measuring techniques and the measurements taken during the course of the case studies were carried out in close collaboration with restoration and conservation experts. They can be put into practice at relatively low cost. The project produced four leaflets about the techniques it developed and about using ultrasound to measure the depth of cracks. A catalogue was produced, giving an overview and classification of the different methods for surveying cracks.

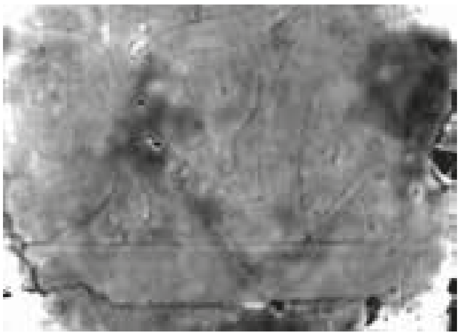


Figure 4b: Thermography phase image of recently uncovered markings in the plaster: Marking, cracks and flaking in the area around the crack can be easily identified.

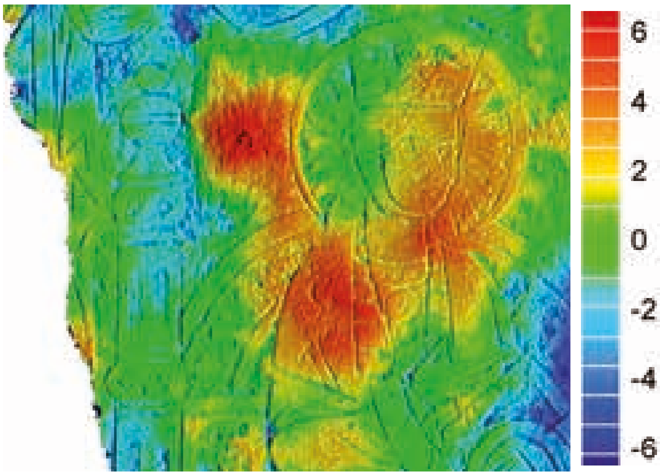


Figure 5a: Depth mapping of an area of the plaster with markings to show the deviation from a reference plane: Bulges are red, indentations are blue. All measurements are in in mm.

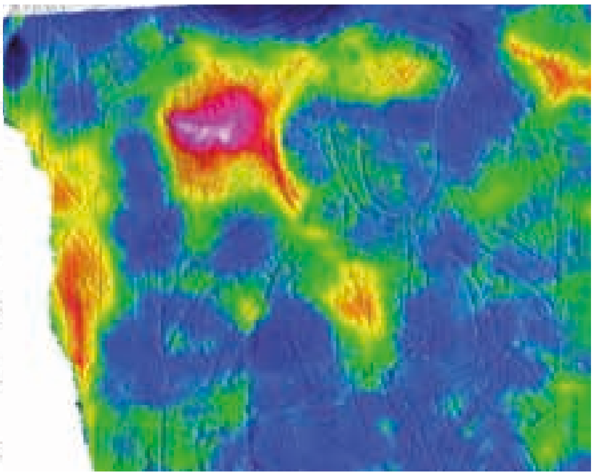


Figure 5b: The visualised markings in the plaster superimposed on the thermographic image: Hotter areas are shown in red, cooler areas in blue.

The aims of the project were

- to develop 3D methods for characterising cracks,
- to further develop active thermography for characterising cracks,
- to examine larger building component structures to classify damage,
- to develop a 3D mapping system with a measuring, visualisation and monitoring tool.

The following innovations were achieved:

- a new method for measuring cracks based on 3D tracking
- optimum visualisation of cracks in plaster using 3D photogrammetry
- further development of active thermography for effectively mapping cracks
- using thermography sequences to map defective areas on larger facades
- efficient 3D mapping system for depicting the results of individual methods ■

3D mapping

Research institute/researchers	Federal Institute for Materials Research and Testing (BAM), FB 8.4, Dr Christiane Maierhofer Fraunhofer Institute for Factory Operation and Automation IFF, Dr Rüdiger Mecke Institut für Diagnostik und Konservierung an Denkmalen in Sachsen und Sachsen-Anhalt IDK e.V., Uwe Kalisch Thomas Groll
Project leader	Dr Christiane Maierhofer
Overall costs	€ 283 330
Federal government grant	€ 189 740
Term	January 2011 to June 2013

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3		Federal Minister Dr Barbara Hendricks	Federal government, Sandra Steins
6		Cover photo of the Guideline for Sustainable Building	BBSR
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7	Top right	BNB assessment scale	BBSR
7	Bottom	Federal Minister Dr Barbara Hendricks	BBSR, Deck bar Photographie
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8	Centre	Foyer of the primary school in Hohen-Neuendorf	IBUS architects
9	Top	Extension to the Federal Environment Agency in Dessau	BBR
9	Bottom	Model of the extension to the Federal Environment Agency in Dessau	BBR
11		Federal Minister Dr Barbara Hendricks at the stand displaying the BMUB's Zukunft Bau research initiative	BBSR, Deck bar Photographie
12–13		Background image of concrete	BBSR
13	Top	Screenshot of eLCA	BBSR
13	Bottom	Screenshot of eLCA	BBSR
14–15		Background image of rock wool	BBSR
15		Screenshot of eLCA	BBSR
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