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# Bionics: Applying Nature's Principles for Intelligent Building

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## Purpose

This issue brief reflects one of three topics the German research dialogue 'Futur' dealt with during its second phase between 2003 and 2005. The topic 'Bionic Building' was selected by the Ministry of Education and Research following a participatory process of topic generation. It aimed to define future research needs and possible research priorities to guide the German Federal Ministry of Education and Research in its future funding decisions. The process which comprised several workshops involved about twenty participants from architecture, urban planning, science, technology and research, both from the public and the private sphere. It resulted in the formulation of a theme paper on the topic and a scenario where a possible future of bionic housing is described vividly.

## Why Bionics?

Applying nature's principles for building and housing is a new notion for future research and development applying the concept of bionics to building and housing. Other than fixed architectural structures it includes the flexible and adaptive use of buildings or components that are able to be changed according to the changing demands of its inhabitants, thereby increasing the well-being of its inhabitants and minimizing the use of resources.

- Principles of bionic building are increased quality of living, sustainability, and marketability in the field of building and housing. The areas of research are urban planning, construction, technology development with respect to bionic housing and living, utilisation of individual buildings, clusters of buildings, urban structures, and infrastructure.
- The resulting products and processes are supposed to meet the criteria of adaptability, user friendliness,

autoregulation, appropriateness, reliability, and aesthetics.

The principle of bionics relates to structures and processes imitating nature's mode of organisation, optimization and adaptation, e.g. commonly known is the 'Lotus effect'. This does not only mean to imitate singular solutions but rather the application of holistic systems. Bionics implies using the most efficient solution while employing a minimum of resources.

## A Participatory Process

In general, the Futur process was supposed to complement the traditional agenda-setting in the Ministry of Education and Research with a participatory component. Up till quite recently, the decisions on new funding areas and research programmes were taken by way of a rather closed interaction between industry, research organisations, project managing agencies and ministry officials. Thus, Futur was set up to add



an open discourse of non-traditional stakeholders such as NGOs, small and medium-sized enterprises, scientists and others.

By using such a participatory approach, the Futur process sought to include the dimensions of future orientation and 'societal needs' into the conventional decision-making process of the ministry. This was expected to strengthen the demand-side of research priority-setting in contrast to the supply-side approach which had been used before exclusively. The Ministry expected to attain more future-oriented and innovative research agendas by this approach.

The Futur process was characterised by the following principles:

- Involvement of a broad variety of different stakeholders to ensure **interdisciplinarity**.
- High **transparency** of the process to ensure continuity, stability and traceability.
- **Reflexive learning** was an important aspect enabling to adapt the process if necessary.
- The process needed to include **demand-orientation** to guarantee that future needs of society are taken into account adequately.
- The process was supposed to be **open to results** meaning that it acted independently of current research areas or programmes in the Ministry.
- Finally, the process was supposed to promote **awareness-raising** in society and its results thus needed to be formulated in a way **understood by everybody**.

The Futur process was organised along several thematic workshops. Each topic was elaborated in four workshops by so-called 'Focus Groups' and resulted in a comprehensive theme paper and a scenario. The first workshop on the 'Bionic Building' topic was a so-called future workshop which was used to develop visions about the topic and possible ways for realising them by way of a creative and interactive process. Following, three Focus Group meetings were conducted. In the first two workshops, the topic was narrowed down and its aspects were discussed and defined within the working group. The last meeting was conducted as a scenario workshop to create input for a publishable scenario which was written on the topic. After the Focus Group work the Futur consortium finalised the theme paper and the scenario in autumn 2004.

The around 20 participants of the Focus Group came from various professional and thematic backgrounds. Among them were representatives from large as well as small and medium-sized companies, from science, universities and private institutes, dealing with construction, building, infrastructure, environmental, technical and design aspects of bionics and conventional building and housing.

## Overcoming the Limits of Conventional Building

Traditionally, housing, urban structures and respective infrastructures are built for long-time usage. Thus, the resulting structures are fixed and incompatible with changing living situations of its inhabitants who have to cope with changing living conditions, needs and requirements in a dynamic environment which is getting more and more complex and unpredictable. Facing the accelerating demographic change and the ageing of German society, future buildings will need to incorporate very different features than they perform today, meaning they might need to be dismantled and re-naturalized, or that they are subject to conversion or even deconstruction.

The concept of bionic building is not only to be applied to new buildings but also to the remodelling and conversion of existing buildings, urban structures and infrastructures. But creating entire urban structures following bionic principles seems to be a future vision. Challenges of today and tomorrow are the modernization of present buildings. This objective has been seen as a successive and invasive process, possibly integrating approaches using bionic principles from various starting points, slowly transforming housing concepts, urban structures and infrastructures – utilities as well as institutional infrastructures such as hospitals, kindergartens, work places etc.

### Economic Aspects of the Construction Industry

The construction sector makes up 4% of German GDP and accounts for 6% of employees. Together with the related industries and services along the whole value chain the construction sector is one of the most important sectors of the German economy - and it is one most depending on the business cycle. Since the construction sector is structured very traditionally and subject to a high degree of liability it does not react flexibly to changes and challenges. Besides, another problem German construction industry is facing are increasing costs. It would therefore be a challenge to create equally good construction solutions while decreasing costs. It thus seems to be about time for some fundamental modernization – especially given the fact that the globalization of the construction sector poses a severe threat to the German economy.

### Ecologic Dimensions of the Construction Industry

The traditional construction industry has a huge demand for resources. In Germany it accounts for nearly one third of the energy and material consumption and one third of the emissions. Other ecological problems are posed by the rising quantity of waste which accounts for some 40% of all waste in the country, not to mention the high demand of water, interference with the natural ecosystem and the consumption of space.

Thus, it is high time to apply an innovative approach to construction, building and housing such as bionics to counter the adverse effects mentioned.

## New Areas for Research

Bionic building is a striking new idea of creating and remodeling individual houses, clusters of houses, urban structures and infrastructures. It is therefore no surprise that this theme finds no academic equivalent, even though aspects touched by the concept of bionic building are researched in some established disciplines and funded in conventional research programmes, e.g. such as new energy technologies and materials. The holistic and systemic aspects of bionic building has, however, not been dealt with comprehensively yet. However, this field would offer the opportunity of a generic multi-disciplinary approach to science, research and development.

### The holistic approach

In order to apply bionic principles for future housing this new and innovative approach has to integrate three subsequent processes:

- **Planning:** definition of objectives by applying bionic principles which can be realized during the construction, operation and possibly the recycling phase; anticipation of alternative/multiple options for usage
- **Construction:** realization of the objectives by applying bionic principles, or optimization of existing structures through bionic principles
- **Operation:** solutions should be adaptable along with changing objectives and demands

## Combining Societal Needs with Principles of Nature

The three phases of constituting the holistic approach described above have to be designed according to criteria that grant maximum quality of life to the inhabitants of the building/urban structure while acknowledging the principles of natural efficiency and optimization. During the process of Focus Group meetings, six criteria were identified by the Focus Group participants:

- **Adaptability:** includes the possibility to adapt houses/urban areas to the changing living situations of its inhabitants (e.g. number of inhabitants, age, income) as well as to the changing conditions of the environment (e.g. day/night, seasons); this implies also the development of adequate information technologies and new materials.
- **User friendliness:** all applications should be easy to use by all inhabitants without any lengthy learning processes, but by intuition; furthermore, the application should be low in maintenance, easy to clean and offer options for dismantling and/or denaturalization.
- **Autoregulation:** implies the automatic regulation according to benchmarks set by the users of the house/urban structure that offer most comfort and a healthy climate; this might imply new IT applications and concepts of 'self-diagnosis' and 'self-healing'.
- **Appropriateness:** all functions of the house/urban structure should be applicable with the least possible effort and resources according to the principle: the simpler the better; changes that have to be made in order to adapt to alterations of life style or the environment should be realized by modular solution, e.g. enlargement, diminution.
- **Reliability:** all functions should be constructed in such a way that their reliability is guaranteed even in case of stress, e.g. natural disasters; this implies that some utilities have to be built in a very robust manner and/or in a redundant way, independent of overburdened networks that can be subject to severe external disruptions.
- **Aesthetics:** design that imitates or adapts natural and organic forms is usually considered pretty; therefore, this kind of design should be combined with optimized functionality according to bionic principles (form follows function).

## Options for Future Innovation

When measuring existing buildings against the principles of bionic building it becomes clear that a multitude of alterations would be necessary. Accordingly, the discussions of the Focus Groups resulted in the identification of the following options for future research related to bionic building:

### Optimizing the Utility Infrastructure

Innovation is needed with regard to increasing comfort and efficiency while using less energy and fewer resources. One challenge is the life cycle of existing conventional utility in-

frastructure which usually lasts several decades and is seldom renewed. It has thus to be assessed if future buildings can include semi-independent utility systems in order not to connect too much to the traditional ones if they are not appropriate. Related to this is the development of local and regional resource cycles.

### Light and Energy

The objective for further research is how to better make use of sunlight as a source of light and energy and how to adapt to natural cycles of lightness and darkness, thereby increasing the well-being of the inhabitants. This implies also the efficient usage of other renewable resources such as biomass, water,



wind and geothermal energy for local and regional energy cycles.

### Urban Structures

Social and functional structures are to be designed in such a way as to minimize the effort, time and energy to organize one's social life, e.g. short distances between home, work, school, business districts, including the adaptability and flexibility of transport systems to the needs of the inhabitants.

### Multi-functionality

The principle of multi-functionality applies to the changing needs of inhabitants of buildings, e.g. the changing size of families, the differences between young people with or without children and elderly people, and the possibility to house all these types of households in one building or one local urban area and to maintain a multi-cultural society. One additional

feature in this context is the adaptability to the changing acoustic environment. Different living situations or the increase of traffic may result in the demand to decrease noise either by applying dampening material or by constructing intelligent noise-absorbing buildings/components.

### Modularisation

Modularisation deals with the relation of size and functionality. Of what size can bionically constructed entities be in order to operate efficiently? How can they be altered once they have been integrated into a building to adjust to changing demand? How can different modules be combined in new constructions and in existing ones? Can specific appliances be pre-constructed or even mass produced? Is customized mass-production in combination with bionic principles an option for the sluggish German construction industry?

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## On the Verge of Implementation

The theme of bionic building has been accepted as candidate for a future 'lead vision' as a result of several voting processes by Futur participants and policy actors. Once the lead vision is passed by the Minister for Education and Research the theme is to become a priority for future funding programmes combining several disciplines of research. After the elaboration of the topic has been concluded by the Focus Group and the Futur consortium, the theme paper and the scenario have been passed on to the Ministry in autumn 2004. Following, the Ministry of Education and Research analysed all three theme papers which have been elaborated during this Futur phase, Bionic Building being one of them. Out of these three topics, the best one(s) will be chosen to officially become Futur 'lead visions'. These topics will then be used by the Ministry to

design and issue interdisciplinary research projects and programmes.

But up till now, no decision on the lead visions has been taken by the Ministry and as there will be national elections in Germany in September 2005, it is unclear if this will take place at all before these. Thus, no official implementation activities on the topic have taken place yet. The latest news on the topics pending and on their implementation can be found on the Futur website.

But in general, the interest in the subject of bionics and beyond has increased. In May 2005 the Ministry has issued a call on the innovative potentials of bionics to assess future options for research policy, funding programmes and economic prospects.

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## Sources and References

[www.futur.de](http://www.futur.de)

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<http://www.futur.de/Panorama-der-Zukunftsfragen/html/index.php>

As of August 2005, there is no official BMBF-publication on this Futur-topic yet.

Terminology and translation of key words are the official wording of the German Federal Ministry of Education and Research.

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