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Expanding Boundaries:
Systems Thinking for the Built Environment

NEST – EXPLORING THE FUTURE OF BUILDINGS

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Abstract
Energy and climate challenges require a fundamental change regarding the footprint of the Swiss building stock. The living lab NEST is designed to foster the needed acceleration of the innovation process by bringing academia and industry together. NEST consists of a backbone with 2'500 m2 of innovation area where 12 to 16 research and technology transfer units can be built. Each unit is addressing different challenges such as lightweight construction, adaptive façades, digital fabrication or office of the future. People will live and work in these units to deliver feedback to accelerate the market readiness of new technologies. The units are connected by a multi-energy grid to an energy hub in order to maximise the harvesting and use of renewable energy on site and a water hub to investigate new urban water management solutions. The first two units will go live in spring 2016 and six more units are already under planning and will be completed within the next 2 years.

Keywords:
Living lab; innovation process; energy and buildings

1 INTRODUCTION

As many other countries, Switzerland has established ambitious goals regarding the future development of the energy consumption and the emission of greenhouse gases. These goals can only be reached if the environmental footprint of the Swiss building stock is dramatically reduced. Presently, more than 40% of the end energy in Switzerland is used in buildings, approximately 40% of the CO_2 emissions are caused by buildings and around 1 t of construction materials are used per capita and year [1]. These numbers are similar to the situation in other developed countries with a comparable climate [2].

Research teams in academia and industry are developing new materials, systems and concepts that have the potential to contribute to the goals mentioned. However, transferring results from research into products is a huge challenge in the construction sector and time to market is typically in the order of 10 years and more. Driving such a long term process needs a lot of dedication, financial resources and proper market conditions. As this is not always the case, many good ideas are abandoned despite the fact that they could be game changers.

A number of reasons are contributing to the slow innovation speed in the construction industry. The sector is highly fragmented with many small companies which have little or no capacity at all to invest into new developments. The current price pressure also seems to affect more the quality of work than the search for new solutions. Current low energy prices inhibit new business models. Probably the most important reason is the risk aversion of clients, especially in the area of buildings. This behaviour is perfectly reasonable since the construction of a building is a very costly investment and the building should last for decades. The use of a new component that has not fully proven its performance under real life conditions is therefore very unlikely.

This paper describes a new approach on how to accelerate the technology transfer from research into the market. This is achieved thanks to a close collaboration between academia and industry in a living lab situation where new ideas and prototypes can be evaluated and made market ready in a holistic approach under close to real life conditions.

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2 NEST – A DYNAMIC LIVING LAB

The modified concept of technology readiness levels (TRL) as proposed recently by EORTA [3] is well suited to identify the steps in technology transfer which represent the most critical hurdles (see Table 1). Conventional pilot and demonstration programs as the one operated by the Swiss Office of Energy in the area of energy efficient buildings [4] usually start at TRL level 7 or later. However, after the invention phase, the TRL levels 3 to 7 including concept validation, prototyping and incubation are difficult to pass. They need an early involvement of potential industrial partners and one has to pay attention to the added complexity if a new material or component has to fulfil its function not isolated in the lab but in combination and interaction with all other components of a building. On top of that, the role of the user is critical for the validation of many building parts, especially in cases where topics such as energy or comfort are addressed. Typically experiments covering this range are expensive and risky and can therefore not be executed within real construction projects where concrete user demands have to be met.

#	Original TRL class	EARTO
1	Basic principles obsereved	Invention
2	Technology concept formulated	
3	First assessment feasibility concept & technology	Concept
4	Validation integrated prototype in lab environment	Validation
5	Testing prototype in user environment	Prototyping & incubation
6	Pre-production product	Pilot production & demonstration
7	Low scale production demonstrated	
8	Manufacturing fully tested, validated and qualified	Initial market introduction
9	Production and product fully operational	Market expansion

Tab. 1: TRL levels according to EARTO [3].

The research and technology transfer platform NEST (Next Evolution of Sustainable Technology) was created in order to address this challenge: NEST is a living lab where technologies at a low TRL level (4-8) are implemented in so called research and innovation units. People will live and work in these units to deliver feedback to accelerate the market readiness of new technologies.

Another important feature of NEST is the flexibility to tackle different challenges from business and research over time. NEST consists of a central structure, the “backbone” with three free standing platforms that can host 12 to 16 different units on a total area of 2’500 m^2 (see Fig. 1). In addition, the backbone provides the necessary media (electricity, water etc.) for the units. Each unit is planned by a consortium with partners from academia and from industry around a specific topic of interest such as lightweight construction, adaptive façades or digital fabrication. So called innovation objects are added to the different units depending on the interest and challenges of the consortium responsible for the unit.

Once built, units will be scientifically evaluated by the partners and they serve as platforms for new research and innovation projects. All units are designed in such a way that most of the new components can be improved over time as new knowledge is gained from the operation. Once the unit has reached a level of maturity where the key questions have been answered and the technology is ready to be implemented in the market, the unit will be dismounted and replaced by a new unit with a new topic and new challenges.

Fig. 1: Empty NEST backbone.

NEST is connected to the Energy Hub Demonstrator on the campus in Dübendorf. The Energy Hub aims at optimizing energy management at district level and evaluating its influence on the overall energy system. Especially the temporal mismatch between supply of renewable energy and energy demand for buildings and mobility will be addressed. In this respect NEST can be viewed as a vertical district with a number of buildings with different energy systems, demand and load profiles.

A water hub operated by Eawag, the Swiss Federal Institute of Aquatic Science and Technology is also part of NEST and each unit is connected to the water hub. The aim of the water hub is the development of promising solutions to curb water consumption and make use of various substances found in wastewater.

NEST is operated by Empa but it is an open research and technology transfer platform for national and international partners from academia and from industry.

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3 RESULTS

The NEST backbone is close to completion and first units are already under construction. NEST will start operation in May 2016 and units will be constantly added over the coming years. The key features of the first wave of units is described in this part.

3.1 Meet2Create

Meet2Create is an office unit and will serve as a laboratory for collaboration and work processes. It focuses on the interplay between humans, space and technology. The consortium is led by the competence centre for Typology and Planning in Architecture at the University of Applied Science Lucerne. Industrial partners are coming amongst others from the area of HVAC, office furniture, façade systems, lighting and communication. It is the first unit constructed in NEST and will be ready for operation in May 2016.

The office unit will have three different areas each addressing a specific question related to offices. In the first area, options are explored to reduce the use of HVAC systems to an absolute minimum. This includes the use of sorption based long term energy storage systems. The temperature in this area might fall in winter bellow the normally accepted values. In cooperation with the users, it will be investigated how such a room could still be used for certain activities of knowledge workers. It might well be that for brain storming sessions and interactive workshops lower temperatures might even be beneficial and activate the team members.

In a second area, the question of personalized local climate will be addressed. It is well known since the ground breaking work of O. Fanger that the individual preferences regarding the indoor climate have a rather broad distribution. As a consequence, no matter what settings are selected for the indoor climate, a certain percentage of people in an office will feel uncomfortable. Small and decentralized HVAC components have theoretically the potential to provide an individualized local climate according to the preferences of the person working at this specific place. In Meet2Create, the feasibility of this approach will be evaluated and besides the economic cost also the energetic balance of such an approach will be investigated. Theoretically, this could be even more energy efficient since users develop counter strategies if their needs are not fulfilled and usually these strategies are very energy intensive.

The daily activities in offices are very diverse in nature. They range from concentrated individual work to one to one meetings both physically and virtually, workshops with numerous people and presentations. Meet2Create will explore the potential of new office furniture to support this variety of activities and to make a specific office a multifunctional room. Furthermore, new ways are explored to foster the collaboration between teams which are physically located at different places. The goal is the reduction of the need of travelling which is time and energy consuming.

In addition to these focal points many other things will be included in Meet2Create such as acoustically active panels or energy harvesting systems in façade elements.

3.2 Vision Wood

Vision Wood is a living unit for three persons developed under the leadership of the Laboratory of Applied Wood Materials at Empa and the Chair of Wood Materials Science at ETH Zurich in collaboration with industrial partners from the wood sector. The unit is expected to be operational in spring 2016. Vision Wood is promoting wood as a natural resource for the building industry by adding a new flavour to this material thanks to completely new functions added to wood and the improvement of properties of wood based materials.

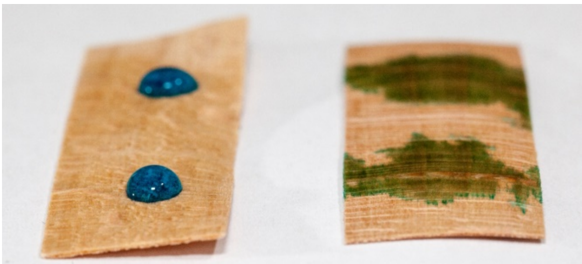

Fig. 2: Hydrophobized (left) and untreated (right) wood.

One of the most critical properties of wood is the interaction with water. The uptake of water leads to dimensional changes and it can trigger and/or accelerate the decomposition of the material. The standard solution up to now is the application of coatings but they change the natural appearance of wood and the durability is limited. I. Burgert and his team found a way to make not only the surface of wood hydrophobic but the complete bulk material (Fig. 2) [5, 6]. This opens completely new applications of wood in living rooms, especially in wet areas. The bathrooms will be equipped with sinks made out of hydrophobized wood and also in the kitchen area applications are envisioned.

Other new functionalities that were added to wood in the research groups lately are magnetic wood [7], wood surfaces which are antimicrobial and mineralized wood [8]. All of them will be upscaled for the first time in Vision Wood in order to create tangible objects. Magnetic wood will be used in the kitchen to hold knives on the wall. Wood with an antimicrobial surface [9] can be left untreated otherwise and keeps the pleasing natural appearance of wood. Handrails and similar objects will be fabricated in this manner. Mineralized wood is less prone to fire and

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therefore adds to the safety of timber based buildings when critical elements of the construction are made out of this material.

Beech wood is today mainly used for energetic applications and not in building structures due to the strong swelling and shrinking of the material upon changes in relative humidity. Vision Wood is using glued laminated timber elements made out of local beech wood to prefabricate large parts of the unit. This will potentially considerably enlarge the market for beech wood and foster the use of a renewable material at large scale in buildings.

This is only a small part of the long list of innovation objects which will be implemented in Vision Wood. Presently, the work focuses on the upscaling of the laboratory processes in order to produce large scale objects. In the use phase aspects of durability will be in the centre of the work as well as acceptance by the users. Furthermore, the unit is designed in such a way that continuously single components made out of new materials can be added into the unit and depending on the results first products will appear soon on the construction market.

3.3 HiLo

HiLo is a two story living unit exploring the potential of ultra-lightweight concrete shells, adaptive façades and automated occupant-centred building systems [10]. The consortium is led by the chairs of Architecture and Structures and Architecture and Building Systems at ETH Zurich.

The double curved roof system of HiLo is extremely lightweight and thin and at the same time it is a multifunctional structure. Flexible thin film solar cells will produce electricity, high performance insulation materials will guarantee the necessary thermal insulation and a hydronic low temperature heating and cooling system will be used to deliver the needed comfort in the unit.

The same concept of multifunctionality and lightweight is used for the floor system. Funicular vaulting allows for a 70% reduction in weight compared to conventional solutions and at the same time buildings systems for heating and cooling and other services can easily be integrated in the system without adding to the floor height (Fig. 3). The floor system consists of prefabricated elements which can be easily assembled on site.

Fig. 3: Integrated funicular floor system [10].

An adaptive solar façade with thin film photovoltaic modules with soft pneumatic actuators for solar tracking and daylight control is part of HiLo as well as an energy concept which aims at zero emissions in operation while providing the highest comfort to the user at the same time. The construction of HiLo will start in the second half of 2016.

3.4 Solar Fitness and Wellness

Fitness and wellness constitute a growing need in our society but at the same time they contribute to the ever raising energy demand. The unit Solar Fitness and Wellness has the ambition to provide the services required without relying on fossil energy. The team lead by researchers at Empa and NTB Buchs developed a concept where high temperature services required in a sauna are delivered mainly by renewable energy.

The core idea is the use of a high temperature CO_2 heat pump which is able to provide the heat for the sauna and steam room around three times more efficiently than conventional systems. Furthermore, the heat is subsequently used for services with lower operation temperature: sauna at 90°C, bio sauna at 55°C, steam room at 45°C, warm water for showers at 45°C and finally low temperature heating of the unit around 30°C. This cascade adds to the overall energy performance of the unit.

The unit will also become a role model for sustainable water management. Rain water will be used where appropriate, grey water is recycled in a controlled way and nutrients will be recovered from urine. All of this will be part of the water hub operated by Eawag. The unit is expected to go live towards the end of 2016 and it will add to the quality of life on the campus.

4 CONCLUSIONS

The challenges that the building stock is facing can only be met if the innovation speed accelerates dramatically in the future. This can be achieved if the time used to pass the intermediate TRL levels from 3 to 8 is decreased. NEST offers this opportunity by bringing partners from research and practice together and let them develop, validate and improve new materials,

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systems and concepts in a close to real life environment. Key assets of NEST are the possibility to take far higher risks than in a conventional construction project, the scientific evaluation of all projects and the integration of users in the process.

Although NEST will only become operational in spring 2016, a first evaluation of the basic concept turns out very positive. Four research and technology transfer units will be constructed in 2016 and four more units are already under planning in the area of urban mining, digital fabrication, solar office and assisted ambient living. This clearly shows the interest of partners from academia and industry in such a platform. Furthermore, the network of NEST partners proves to be an extremely valuable asset for all individual partners. NEST is a platform where new ideas are openly discussed and new partnerships evolve.

The final proof will be made once NEST becomes a flagship for innovative ideas in the construction sector and more and more products are introduced into the market which were realized for the first time in NEST.

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