Transformation of the Built and Lived Environment

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Abstract The built environment is like a reason and solution for different ongoing societal and environmental change processes. On the one hand, it may enable societal progress, ensure people's health, and is a precondition for our modern society's working and productivity environment. On the other hand, the built environment is a crucial driver of carbon emissions, and a significant driver of climate change improvements in manufacturing processes, (re)use of structures, and reduction of energy consumption are requirements. Obviously, researching possible solution paths for changing boundaries requires a variety of interdisciplinary resources and expertise. Everything mentioned interferes and significantly depends on the economic opportunities the different societies can spend for the transition and how willing they regard the expected changes. The growth area "Built and Lived Environment" (BLE) of RWTH Aachen University aims to provide such kind of interdisciplinary research playground. Different ongoing methods and examples emerging from the growth area BLE and specific solutions of transformative research in the described field are presented.

Keywords Built environment · Lived environment · Transformative research

1 Introduction

The societal challenges the world community faces due to global warming, the necessary energy transition, geo-political system rivalries, and the associated economic tensions could hardly be more significant. There is also no question that, on the one hand, rapid and targeted technical innovations are required to deal with these pressing questions of the future. On the other hand, society actively supports the necessary

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change and the inevitable hardships. The creation and implementation of new technologies, the evolution of habits in the light of changing conditions over a period—"it is nothing less than a new moral revolution that humanity must successfully complete if it does not want to seal its own end" (Appiah 2011).

The patterns of such significant societal change follow a routine that stems from ignorance via recognition of action. After a successful transformation, former societies looked back in disbelief and questioned why action was not taken sooner. Examples of such historical changes in Western societies are the abolition of slavery and the introduction of women's suffrage (Schneidewind 2018). Concerning environmental and demographic challenges, the Club of Rome report in 1972 (Meadows 1972) is the first, primarily ignored warning call. After numerous climate protection conferences and increasing climate protection commitments, humanity is heading towards a phase of action—but we are still at the very beginning. Today, it is scientifically undisputed that the challenges mentioned at the front are so urgent due to the limitations of resources and the expected consequences of climate change and that the warning of 1972 is manifesting in the climate change crisis we face. Most people can already feel that hesitant changes are no longer justifiable and demand corresponding political measures. The transformative achievement that political decision-makers need to demand from society and the economy cannot be distributed over several decades in doses. Instead, the immediate implementation will affect the current and future generations with exceptionally high intensity.

The built environment, which has always been intended to protect people from natural phenomena and external dangers, is of direct importance for the well-being of humankind. The residential development provides such protection and is essential for physical and mental health. The built infrastructure represents the basis for our current economic activity, without which the prosperity achieved and the opportunities for technical innovation would hardly be possible. One example is the successful invention and mass production of vaccines in the wake of the corona pandemic, which was ultimately only possible, thanks to the available research and infrastructure resources. At the same time, however, the construction sector is also significantly involved in artificial climate change. The manufacture and operation of buildings are responsible for around 40% of global CO_2 emissions (Chen 2015, Moran et al. 2018) . It thus becomes clear that the moral revolution must take place to a considerable extent within the construction sector—but at the same time, the aspects of well-being cannot be neglected so that the socio-ecological change can also be accepted and supported.

In this context, the "double decoupling" (Weizsäcker et al. 1996) should be mentioned, a fundamental principle of sustainable management. It expresses that, due to technological advances, there is a decoupling of the economy and environmental consumption (green economy), which takes place in the existing economic order. According to the principle cited, however, this alone is no longer sufficient (among other things, due to rebound effects), so the quality of life must also be decoupled from economic growth. This means it is also particular about the definition of prosperity and quality of life—ultimately, a social issue primarily about justice.

And not only climate change and its risks to natural hazards require an interdisciplinary confrontation about the usage, materialization, construction forms, and

compositions of buildings, quarters, and cities in the future. People are nowadays much more aware of the interference between living spaces and human health. The exterior air quality is mainly affected by industrial and traffic pollution; however, the built environment can positively influence the micro-climate by planting, green facades, and a meaningful building arrangement. The interior air quality can be further improved based on restorative materials, ventilation, and building technology. In the context of increasing heat, aspects like urban heat cells, drought, and microparticles will also be more relevant in the future. The corresponding trends require a reflection of sustainability ambitions and suitable solutions, such as labour market, mobility of residents, and their desired prospective way of life—likewise in modern urban centres, in suburbs of developing countries, and in rural areas. Predictions, analyses, and recommendations need manifold expertise, including profound knowledge of specific local boundary conditions.

In Fig. 1, the interfering aspects of transformation are visualized. It is believed that different trends, such as climate change, digitization, mobility, and the higher expectations of people towards individualization and health are inducing stress into the built and lived environment, demanding adjusted solutions. The interdisciplinary group Build and Lived Environment (BLE) at RWTH Aachen University has declared its goal to advance thematic research in the context of these tendencies. All those involved are aware that the solution approaches also involve interactions at different levels of the built and lived environment (mutual adaptive solutions). For this reason, the development of research projects is organized in thematically appropriate research groups, with a significant focus on the inclusion of young scientists. As a side effect of this joint research work, it is expected that the individual disciplinary research of the actors involved will also benefit, as there should be a coordinated exchange of methods, data, and approaches (cross-cutting issues).

The uniqueness of BLE lies in the interweaving of different perspectives. For instance, when it comes to the prediction of flood events and the implementation of construction measures for their containment in civil engineering, architecture can develop an assessment scale for the preservation or protection of culturally significant buildings. Economics can conduct cost–benefit analyses to assess the macroeconomic impacts, while the science of transformation can facilitate necessary changes through communication with policymakers and the general public. This example illustrates that an isolated handling of the complex issue can completely disregard the overall interests of society. That is why collaborative work on thematic aspects is now being pursued.

Like flooding (aggravated by climate change), all trends illustrated in Fig. 1 benefit from joined effort. The disciplinary research of the respective fields remains unaffected and provides necessary expertise and methods to tackle the multifaceted research questions.

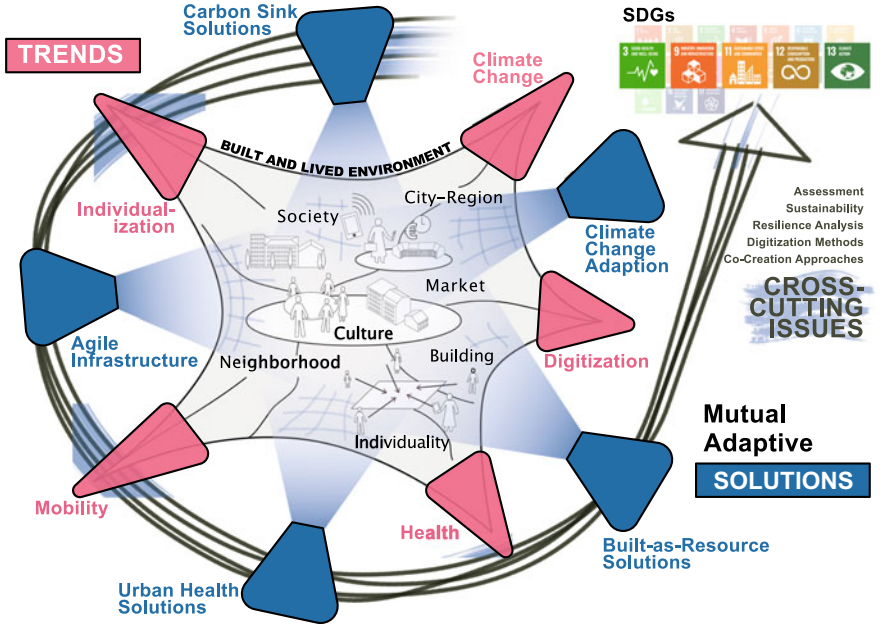

Fig. 1 Built and lived environment (BLE) is exposed to trends—a successful transformation towards the SDGs needs mutual adaptive solutions in various fields with overarching impacts

2 Inter- and Transdisciplinary Methodology

Regarding the built environment and our future life within it, these considerations result in very concrete starting points, which are intended in this sense regarding technological advances and social and societal aspects. The "future art" that is now necessary, with which the Wuppertal Institute describes "the understanding of the character, the course and the rhythm of social change processes", can only succeed in an interdisciplinary manner given the challenges mentioned above—there can hardly be any doubt about that either. This future art must be paired with accompanying technical innovations that cushion the effects of technological change on society as far as possible. For future buildings, people's well-being needs to be the main focus. Regarding the materials used, the manufacturing processes, the durability, and versatility, as well as their operating expenses, they must succeed in such a way that suitable concepts are made possible for the needs of affluent societies as well as for growth and poor communities.

Interdisciplinarity is also to be underpinned by spatial knowledge. In this regard, space is not only seen as a resource, offering materials and areas for building. Space is also integral to the built environment, setting a robust framework for implementing new technologies more systematically (Seto et al. 2014). This means taking ecological issues into account, but also economic and societal ones. Moreover, the successful development of living labs in the last years has underpinned the idea of space as a

medium for transdisciplinary research and space as a method to engage stakeholders by co-design or co-production of a built environment.

Technologically innovative ability and social art of the future are the challenges that the growth area "Built and Lived Environment [BLE]" of the RWTH Aachen University is taking on. It is primarily about transformative research to support change actively. This contribution focuses primarily on the interdisciplinary approach and the addressed focus levels and provides examples of successful ongoing projects within that framework. BLE gathers multidisciplinary knowledge from different fields: mainly architecture, civil engineering, economics, socio-technical sciences and medicine.

RWTH Aachen University acknowledges BLE as a "growth area", incorporating the field within its excellence strategy. The university supports its profiling towards interdisciplinary cooperation in core areas with this format. Notably, BLE will be the first RWTH core research area that does not focus on producing new technologies in a narrower sense (hardware, software) but takes a broader approach with also "orgware solutions". This approach is based on the hypothesis that sustainable solutions—especially in the built environment—will also be found on changing mindsets and behaviours and cultural sufficiency practices. The related influence domains and fields of action are shown in Fig. 2. The BLE initiative addresses the multidimensionality of the topics by considering the various scales inherent to building-specific issues, as the solution approaches inherently span across different scales. Particularly, questions related to individuality, mobility, and health are primarily addressed at the neighbourhood, district, or superregional scales. Regarding decarbonization, material research is required, and construction processes must be adapted or questioned. But the necessary transitions will also need to be discussed in the context of urban planning and the overall utilization of landscapes. Other overarching and spatially related issues, such as mobility or digitization, similarly extend across the entire range of scales. This is another distinctive feature of the BLE initiative: it encompasses expertise across all the aforementioned scales.

Following such an actor-oriented research approach, BLE makes its research effective by setting up living laboratories. Hypotheses, methods, and products will be developed, tested, and verified in cooperation with actors and user groups (a triad of co-design, co-production, and co-evaluation). Many existing initiatives and experiences can be built on here, such as the Living Labs of the RWTH ("RRI Hub" and "Living Labs Incubator"), the dialogue platform ("REVIERa") developed by the RWTH as part of the structural change in the Rhenish Revier. and the "ACademie for collaborative urban development". The living laboratories are designed as a network so that heterogeneous actors can get involved in the research process in the sense of "open science", and socio-technical innovations can be developed problem-oriented. At the same time, living laboratories—in addition to classic formats such as conferences, publications, and digital media—serve bidirectional scientific communication.

The living laboratories will also nurture the interdisciplinary research of the scientist involved as they reveal the need for new methods and analysis for complex and interfering systems. Involved researchers reflect and iterate datasets, procedures,

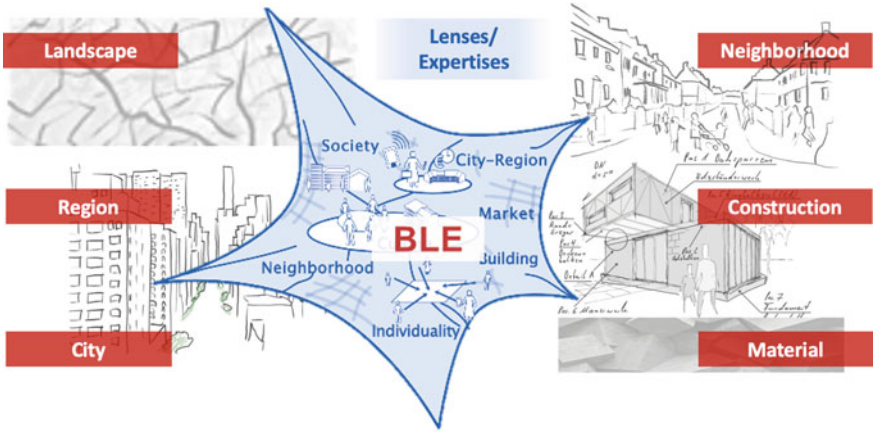

Fig. 2 Influence domains and levels expertise in different scales (lenses) for the growth-area "Built and Lived Environment" (BLE)

and criteria to find well-balanced solutions. Likewise, such scientific substantiation provides a base for political decisions and social participation.

3 Core Areas of Research

The transformation of the built environment is related to a necessary adaptation (climate change and natural hazards), mitigation of climate change effects (fewer carbon emissions, more efficiency, usage of building stock), and sustaining a healthy living environment. As these aspects are interdependent, scientific efforts must focus more on the overall consequences leading to the main reason for the drafted inter- and transdisciplinary approach. In the following sections, we describe the core research areas and some superordinate aspects to illustrate the thematic cross-relevance.

3.1 Decarbonized Buildings

The reduction of harmful greenhouse gases is a global challenge for society. The operation of buildings and the construction industry causes almost 40% of global CO_2 emissions. BLE is dedicated to this problem and researches socio-technical solutions on different levels. Central to this is the design and technical development of long-lasting, adaptable, and recyclable supporting structures made from naturally renewable and artificial building materials and a holistic implementation based on life cycle assessment instruments (Svirejeva-Hopkins et al. 2004). On the manufacturer side, the controlled use of materials, research into new composite materials

and the use of additive and energy-saving manufacturing processes are addressed. Regarding the sustainable operation of buildings, the focus is on decarbonization, resilient energy supply, and security of supply (e.g. through improved energy efficiency and direct use of renewable energy), which both new technologies as well as standards and usage practices, as well as the consideration of district-related solutions, for example regarding municipal heating networks.

11% of the carbon emissions of the construction sector is directly attributed to the manufacturing of building materials, e.g. cement, steel, etc. The growing world population and increasing global demand for comfortable living spaces further magnify the problem. The current demand for housing and infrastructural development consumes more than 40 billion tonnes of material annually, mainly primary ones. On the other side, ~ 33 billion tonnes of waste result annually, out of which the majority is handled by landfilling and incineration (Creutzig et al. 2015). There must be more innovative ways to close these circularity and carbon gaps. We must search for material solutions that utilize co instead of emitting even more. Improved design principles enable material-minimized structures. Alternative material streams, novel co-processing pathways, and new construction technologies may pave the way towards net-zero or climate-positive construction strategies. In any case, individual silo approaches are not an option for the future. Only a collective synthesis of integrated interdisciplinary viewpoints will provide more circularity, less materiality, and novel carbon sink solutions. Specifically, the following aspects require deeper consideration and implementation:

- New materials as enablers for a decreased resource and carbon footprint in the construction
- Circularity in construction (less primary, more secondary materials)
- Novel design principles and manufacturing technologies for material-minimized structures
- New approaches to assessing sustainability and materiality of construction
- Treatment and utilization of wastes, e.g. from dumps and landfills.

3.2 Preservation and Activation of the Building Stock

The excessive amounts of energy invested in existing buildings and the bound socio-cultural values, on the one hand, and the high consumption of materials and energies in new buildings, on the other, render existing building stock the most precious resource. Therefore, it is important to focus on built-as-resource solutions and establish and profile them as an interdisciplinary field of research and practice. Planning and construction solutions must be developed to protect, redevelop, and/or adapt existing buildings to promote socio-ecological transformation in our cities and regions. These solutions should consider historical, cultural, social, and design practices, which enable and condition new forms of careful use, as well as considering engineering, economic, and environmental science issues.

An essential aspect in this regard is the preservation and activation of the current building stock: Instead of "building with resources", it is, therefore, necessary to understand "what is built as a resource". BLE is consequently looking for planning, structural, and procedural solutions for how the existing building can be valued and adapted given the enormous socio-ecological and economic transformation requirements and which cultural points of contact and practices allow and promote new forms of use. In doing so, the limits of stock development must be explored from an energetic-ecological, economic, and normative-cultural point of view. It is crucial to develop an interdisciplinary, indicator- and value-based model for measuring the building stock as a resource while testing new planning instruments with which the supply is sustainable, and future proof can be designed. Handling and weighing of all mentioned aspects require analytical tools to evaluate and enable optimization. For this aim, a concept of values and correlative dependencies needs to be established, which objectifies individual building situations.

The confrontation with the existing settlements and urban fabrics is central here, as these require causally integrated, i.e. inter and transdisciplinary approaches. Current debates point at the built and lived neighbourhoods as the vital arena, where measures for shaping sustainability and resilience transitions are assumed particularly effective. Built and lived communities also comprise multiple forms of cultural heritage, constituting a valuable yet often side-lined resource in resilience and sustainability debates. At the same time, however, considering built and lived districts as urban heritage still poses manifold and essential conceptual, methodological, and practical (instrumental and procedural) challenges, how integrated transitions towards sustainability and resilience could be informed, initiated, and steered.

3.3 Climate Change and Crisis Adaptation

Climate change requires the rapid adaptation of spatial structures, infrastructure, and buildings, but also of socio-cultural structures (usage behaviour) and individual transformations (physical and psychological, acceptance of measures restricting use). The rapid succession of crises in recent times (pandemic, floods, heat waves, energy supply) raises additional questions as to how agile the built structures can react and how they can be set up in the future. These aspects must be mutually analyzed and operationalized, which requires, e.g. integrated approaches to climate impact modelling and the identification of suitable climate adaptation measures as well as the consideration of health-related aspects. BLE investigates how construction can be linked more closely to the functionality of ecosystems and the ecosystem services they produce. While traditional building defines natural processes as a risk of damage, BLE takes up the potential of "nature-based solutions", for example, to regenerate material flows, cool air, regulate floods, cope with dry phases, but also to create socio-cultural added value (well-being, identity, …).

The consequences of climate change can be observed worldwide in similar patterns: slower variations of weather events cause more prolonged phases of rain

and heat, leading to more frequent occurrences of flooding and drought, respectively. Extreme events of precipitation, windstorms, and heat waves tend to occur with shorter return periods and locally with higher amplitudes. In brief, the natural equilibrium and the ability to balance weather phenomena tend more and more to reach and exceed their limits.

For instance, in July 2021, a flood disaster occurred in the western part of Germany. The flooding incident was caused and aggravated by multiple factors: prolonged and intense heavy rain, topography, soil saturation, and soil conditions in the areas of rainfall—but also by interventions in natural river courses and peripheral buildings. Unexpectedly, buildings that were supposed to offer protection were in flooded areas. More than 180 citizens lost their lives. Besides extreme precipitation, severe wind events can also cause significant damage to the built environment and put humans at risk. This year, a tornado hit the city of Paderborn, with 43 people injured. Examples like these can be observed worldwide and with increasing frequency of occurrence.

While it is still not clear to what extent such severe events might increase in frequency or severeness due to climate change—it is likely that both features will be affected in an unfavourable way in the future, and the mentioned examples painfully demonstrate the possible impact of climate change to us. Therefore, climate change adaptation is a key topic for planning our future living environment and infrastructure. The construction sector is relevant, as it contributes significantly to carbon emissions (and thus offers potential for savings). Still, it also promises to provide opportunities for adaptation and solutions to gain resilience. Both aspects are closely interwoven with social, economic, and cultural issues. Due to this complexity, the topic demands us to bring together knowledge from different disciplines to stimulate new scientific interactions. The threat of natural disasters, the resilience of the built infrastructure, and the weighing up of security requirements and life risks in the areas of society, economy and culture should, therefore, also be included in future planning processes and receive more awareness among decision-makers. Some specific questions that need to be addressed in this context are:

- How can we predict and guarantee structural and infrastructural safety in the future?
- How must we adapt our built environment to climate change tendencies?
- How can reliable infrastructure consider reduced carbon emission goals?
- How do we need to modify planning processes?
- How can we moderate transformation processes and gain the support of politics and society?
- How must we develop higher education to raise the right experts?

Hence, technical, planning, and societal aspects require an outbalanced discussion of safety, reliability, and material efficiency.

3.4 Healthy Environments

Much of the building sector's contribution to global warming comes from providing healthy and comfortable thermal, visual, olfactory, and acoustic conditions indoors, where we humans spend 90% or more of our time. At the same time, people living indoors and in urban areas are among those most affected by climate change, as this is where the adverse impacts of climate change are exacerbated (e.g. synergistic interactions between heat waves and urban heat island effects). Climate change, demographic change, and scarcity of resources are therefore increasingly challenging health and well-being—in addition to this, there are the consequences of the COVID-19 pandemic. Given the continuing urbanization, the city as a living space has a decisive role to play. Since the built stock characterizes European cities, solutions are needed for a sustainable and healthy transformation. Due to the complex interactions between people and space, solutions to increase the resilience of urban spaces, interiors, and their occupants require multidisciplinary and multiscale approaches. BLE focuses on the multidimensionality of existing cause-effect relationships. For this purpose, in addition to social and creative aspects, medical-physical (e.g. thermal, visual, electromagnetic, and acoustic exposures) and health-psychological aspects are increasingly being examined.

Urban spaces and buildings are among the most important contributors to greenhouse gas emissions. Research suggests that energy-intensive solutions accelerate climate change (and further degrade outdoor environmental quality), harm human health, and reduce human resilience. Therefore, Urban Health Solutions (UHS) addresses the core of BLE: the interactions between space and people—between the "built" and the "lived" environment. Due to the complex interactions between people and space, solutions to increase the resilience of urban spaces, indoor environments, and their inhabitants require multidisciplinary and multi-scalar approaches. UHS stakeholders present their work related to one or more of the following four scales:

- component and interior
- house & ensemble
- site & neighbourhood, and
- city & region. Altogether, these contributions consider: (I) multiple modalities, (I) interactions between environment and user, and (III) quality and value.

Multimodality includes consideration of multiple sensory modes (e.g. thermal, acoustic) and disciplinary backgrounds and targets (e.g. architecture and medicine; aesthetics; and health). Interaction and role of the user consider people in the urban context as active designers: indoors through their interactions to ensure comfortable environmental conditions and in the urban context for the co-design of transformation processes towards health-promoting urban districts. Quality and value represent the objectives of research and action defined on different scales and differentiated according to the disciplines. Good research questions include the effect of physical stimuli on human behaviour and health and the relation to energy use and

sustainability. Methodologies reflect the diversity of approaches and have (a) new/mixed methods within laboratory environments, real buildings, and the urban context, including thoughts on understanding health in line with the salutogenic model and (b) theoretical approaches to healthy cities and regions.

4 Specific Approaches Towards the Support of Transformation

As the alert reader may have noticed, the general programme of BLE encompasses multiple issues related to transforming the built environment. Such an approach must depict all relevant interrelations and challenges when starting interdisciplinary cooperation. Therefore, BLE has elaborated several focus projects as test beds for collaboration among the scientist involved. This serves as a kind of starting point to subsequently explore the complex field of topics in a step-by-step manner. The projects presented below are all based on specific collaborations with local and regional stakeholders, thus addressing questions that have an immediate prospect of realization. Furthermore, they offer the opportunity to establish regional and cross-regional networks, which not only support the concept of thematic research but actually demand it.

4.1 Competence Network Space-Water-Construction

The flood disaster of July 2021 demonstrated society's dependence on flood and disaster control, land use, and infrastructure and settlement development. Sustainable solutions must be anchored in actor-oriented processes much more than in the past, beyond technical flood protection. To this end, BLE will bundle expertise from various specialist areas of the network (e.g. climatology, hydraulic engineering, urban water management, urban planning, and urban development) and combine a wide range of methods, e.g. safeguarding cultural heritage, climate impact modelling, land use planning, and process design. The aim is to set up the previous advice to public institutions (e.g. politics, administration, and associations) more concertedly and to bundle it with other partners from science and administration to form a competence network.

4.2 Cooperation Area Net Zero City Aachen Living Laboratory

The city of Aachen has been given special access to national and European funding by being named a "Net Zero City" by the EU. The goal formulated therein ("a happy, just, healthy, climate-neutral city") coincides with the research ambitions of BLE. In this respect, it was agreed to set up a joint living laboratory even more: to understand the entire city as a "real city of research" and to work together intensively in application-oriented research. Common events are planned for autumn 2022, at which the urban planning is to be compared with the BLE expertise and the EU funding agendas, and a roadmap for further action is to be developed from this. The aim is to research innovative methods and technologies for climate protection and climate adaptation in the city, also with the involvement of the RWTH campus development, and to implement them in pilot projects. Quality of life, health, and social balance are essential criteria.

4.3 Human-Building-Quarter Experimental Space

While the relevance of indoor spaces for health and well-being has already been recognized, the interactions between people, buildings, and the outdoor areas of the neighbourhood have yet to be researched. However, the pandemic has clearly shown how much health is being challenged by changes in living, working, and leisure behaviour and the associated socio-spatial behaviour. Likewise, climate change and the associated overheating of inner cities and rooms in summer cannot only be countered by technical adaptations of internal rooms. Holistic approaches are required here that consider the district's climatic interdependencies and behavioural patterns. For this purpose, BLE is building the experimental space Man-Building-Quartier, an interdisciplinary and transdisciplinary platform for researching the interaction between man and space using real (existing and experimental buildings), virtual and modelled spaces. This leads various BLE expertise together, including building technology, occupational and environmental medicine, climate impact modelling, district research, urban development, and open space planning. In addition to generating health-related knowledge, methodological questions are answered, such as the replicability of reality and its transferability to laboratory and simulation environments, especially regarding the inclusion of individual and social behaviour.

4.4 "Growth" Strategy

In addition to this research strategy, BLE has also developed a strategy of dissemination and engagement of further experts and stakeholders, e.g. a yearly conference

is scheduled to show the BLE approach and expertise to a broader audience. To this end, in 2021, an online conference highlighted the summer flooding crises around Aachen. By showcasing the link to climate change and the multiple reasons for this disaster, BLE could shed light on its approach and engage further stakeholders in its work. In 2022 a follow-up will focus on the critical issue of RWTH campus energy supply—again to sensitize for the BLE approach but also to find hands-on answers through interdisciplinary discussions among RWTH researchers. According to the strategy, in 2023 the dissemination of BLE's work will address a national and international audience. Within a unique RWTH format—the Kármán-Conference—it is planned to gather experts from all over the world in Aachen to discuss the subject of "built-as-resource". The conference should facilitate knowledge exchange and discussion in this field and enhance the visibility of BLE in general.

As a "growth area" BLE is trying to engage Junior Principal Investigators (JPIs). To this end, several funding schemes are applied for, among them a call on "Profilbildung" launched by the federal state of NRW. The aim is to form a post-doc group that can boost BLE by its own research, support the work in focus projects, and engage PhD students across the faculties involved. JPIs have also been the focus of a BLE Science Day that was conducted in June 2021. Taking place in an inspiring environment—a so-called pop-up Campus funded by the BBSR—many JPIs can allocate their research to BLE core arenas, present their work, and exchange with peers. As a follow-up of the BLE Science Day (Day 2022), more than 20 JPIs gathered recently in two science workshops conducted by the RWTH excellence initiative. The workshops focus on successfully writing research proposals but also serve as a unique opportunity to team up for further interdisciplinary BLE research.

4.5 Perspective

A sustainable anchoring of the initiative at RWTH Aachen University seems promising. Funding from the state of North Rhine-Westphalia was approved as part of the Profil.2022 programme, which enables structured development. In particular, scientific employees (post-doc level) are funded for the core areas presented in Sect. 3, so that the research questions can be worked out in the form of concrete sub-projects. It is expected that this will allow other young scientists to be integrated into the core areas at short notice via project plans. The principal investigators of the participating faculties, who previously acted as the nucleus for the growth area, will continue to support the initiative and the sub-projects to be developed in an advisory capacity and by contributing their own resources. The timeframe for funding is from 2023 to 2026. After that, the initiative should be so deeply rooted that it can support itself through thematic funding.

5 Collaborative Teaching

Interdisciplinary teaching is part of the strategic development of RWTH Aachen University in the context of the "Exzellenzinitiative". Concerning buildings and the lived environment, different formats have been established in recent years, especially between the faculties of architecture and civil engineering. I might sound a bit offbeat to term such collaboration as "interdisciplinary",—but in fact, it is. The way of teaching, research, methods, and solutions differs significantly between architecture's more art-oriented discipline and civil engineering's more analysis-oriented discipline. While architects primarily work on a project base, civil engineers enjoy a traditional, fundamentally oriented education. Nevertheless, graduates from both disciplines need to work together and find standard solutions for factual project-oriented work in professional careers. Bringing together the fields in early stages and facing the contrast of education, responsibility, and the areas of influence are suitable to widen the view towards future problems and the openness for interdisciplinary collaboration.

In the framework of BLE, education can also significantly benefit from the other involved disciplines. It is aimed at establishing interdisciplinary projects with student groups of all parties which address topics of the BLE agenda. Student interviews underline that the young generation is very interested in such project work. Furthermore, a significant acceptance or rather an expectation for such ways of education can be especially observed for female prospective students. This could be a pivotal solution to increase the interest in technical study programmes for women.

The faculty of civil engineering (supported by the architecture faculty) is currently planning a new international master's programme, "Resilient Civil Engineering". This study programme tries to combine analytical, method-oriented teaching with specific projects. Lectures from both faculties plan the curriculum and will be part of the curriculum. Within the framework of the jointly designed projects, the scientific-technical approaches of engineering are combined with planning methods. The necessary intersections for joint research should also arise from this collaboration, and students should be introduced to thematic research in the field of BLE and its core areas. Student work in the master's programme can also be specifically integrated into project initiation or execution. Such collaborations are an essential starting point for a potential future study programme, "BLE".

6 Conclusion

A transformation in the built and lived environments is necessary due to various changing boundary conditions to reach sustainability development goals (SDG). Due to complex interactions, this process needs interdisciplinary efforts, methods, and expertise. The challenges and opportunities have led to establishing of a multi-disciplinary platform at RWTH Aachen University—the growth area "Built and

lived environment" BLE. An essential part of the inter and transdisciplinary methodology is the cooperation in core areas aiming towards sustainable solutions alongside changing mindsets and behaviours and cultural practices of sufficiency. The needed transformation of the built and lived environment is a significant demand to our society, and it needs support by research and transformative moderation to guide as direct as possible towards SDG goals.

The core areas of BLE (decarbonized buildings, preservation and activation of the building stock, climate change and crisis adaptation and healthy environments) are essential to reach societal and economic goals in the longer run. In each of these areas, transdisciplinary research is ongoing and further strived in the future. Specific approaches based on living labs, competence networks, and experimental spaces give an insight into the transformative process of the growth area BLE and its growth strategy. Finally, transdisciplinary capacities are visible in the collaborative teaching approach, where new generations of students and lecturers learn based on interdisciplinary cases.

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