Leibniz Institute of
Ecological Urban and
Regional Development

Research Programme
2022 – 2028

We research for the sustainable transformation
of neighbourhoods, cities, and regions

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DRESDEN concept

Leibniz Institute of
Ecological Urban and
Regional Development

Research Programme 2022-2028

Leibniz-Institute of Ecological Urban and Regional Development (IOER)

Research Programme 2022-2028

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1 Concept and Approach

The IOER Research Programme 2022-28 builds on the long-term orientations provided by the institute's statute and its *Leitbild* (mission statement). It reflects the position of the IOER in the German science system and the European Research Area as well as peer organisations and research networks globally with a view to ensuring both the distinctiveness and connectedness of the institute's research agenda. Additionally, it takes into account the crucial timeframe to 2030 for the achievement of societal transformation goals and for setting priorities to meet preconditions and address leverage points.

The programme provides a multiannual framework for **advancing and implementing spatial sustainability sciences** at the IOER. It establishes the institute's overall research subject and objectives as well as its research and transfer approach, research ethics and organisational structure. Further detailed programming is drawn up for the four IOER Research Areas (*Forschungsbereiche – FB*) as well as for key cross-cutting areas including the Knowledge Integration Hub (KIH), the IOER research data infrastructures as well as the institute's engagement in science and society networks and the promotion of young scientists.

Challenges

The world faces unprecedented challenges in the 21st century. A planetary **human-environmental crisis** is unfolding along our current development path. Anthropogenic drivers are creating severe threats to the Earth system and its dynamics that have already caused substantial disruptions. The current degree of environmental change and degradation exceeds planetary boundaries and poses risks to livelihoods, wellbeing and prosperity. It is shaping novel patterns of unsustainability and even questions the integrity of nonhuman nature and human lives, as well issues such as equal opportunities and justice goals. It is against this unsettling backdrop that the IOER formulates its research agenda for the next seven years, targeting interfaces between the Earth system and the anthroposphere with a focus on their **critical spatial dimensions**.

Current scientific evidence underlines the **urgent need for socio-ecological transformations in spatial terms** in order to achieve fundamental sustainability goals. Human activity exerts spatially differentiated pressures on ecosystems at all scales. Processes of demographic change, economic and technological development as well as changes in land use drive excessive local or telecoupled environmental pressures, with major regional variation in growth dynamics and sustainability impacts (UN SDSN, 2021; Elmqvist et al., 2018; UN DESA, 2019). This has led to negative impacts such as climate change, ecosystem destruction, species extinction, resource depletion and environmental pollution (IPCC, IPBES, UNEP, WBGU). In turn, human settlements are increasingly exposed to diverse natural hazards with highly irregular geographical distributions (CRED & UNDRR, 2020; IPCC, in press). In all of these matters, technologies and especially digitalisation play an ambivalent role since they can both reinforce or indeed alleviate pressures and risks while modifying spatial structures, understandings and perceptions (WBGU, 2019; Evans et al., 2019; Schwab, 2016).

Despite political commitments at all levels, current systemic structures and paradigms have so far resulted in **spatial developments of declining sustainability and resilience**. While this reflects basic conflicts of interests, power asymmetries and social exclusion within societies, it also points to multiple fragmentations along territorial, hierarchical, sectoral or action domain boundaries as well as a lack of meaningful stakeholder involvement, thereby impeding knowledge integration, empowerment and responsible place stewardship (Cars et al., 2018; Stissing Jensen et al., 2019).

Research Subject

In view of these major societal challenges and with particular regard to their spatiality, we investigate the features, patterns and dynamics of multi-scalar **socio-ecological-technological spatial configurations**. We understand these to be produced and reproduced through complex spatial relations and processes, linking diverse societal and material factors. Drawing on current debates in the sustainability sciences (Clark/Harley, 2020; Fang et al., 2018) and contributions that emphasise the need to forge connections between research engaging with either socio-ecological or socio-technical system transformations (McPhearson et al., 2021; Markolf et al., 2018), we are particularly concerned with the **diverse ways in which spatiality plays out** in this. Therefore, our research focuses on landscapes, land use, the built environment as well as spatio-economic interactions to explore their **development and transformation** in the territorial context of urban neighbourhoods, cities and agglomerations, urbanised and rural areas, as well as regions and countries – including cross-border aspects. We examine key environmental factors such as the regional climate, ecosystems, biodiversity, resources and natural hazards. As corresponding physical factors of society, we study technologies, materials and energy. Ultimately, our principal focus is the spatial coevolution of these factors with societal institutions, cultures and practices and the **capacities** available to influence the scope, direction and speed of developments regarding **sustainability, resilience** to environmental risks and **planetary justice**. This entails considering the role of different individuals and actors, their intersectionality and interactions as well as society as a whole in co-shaping spatial change. We thus define our overall research subject as **spatial sustainability transformations**, namely exploring the ways in which different spatial configurations enable or constrain deep and encompassing societal change towards sustainability (see Figure 1).

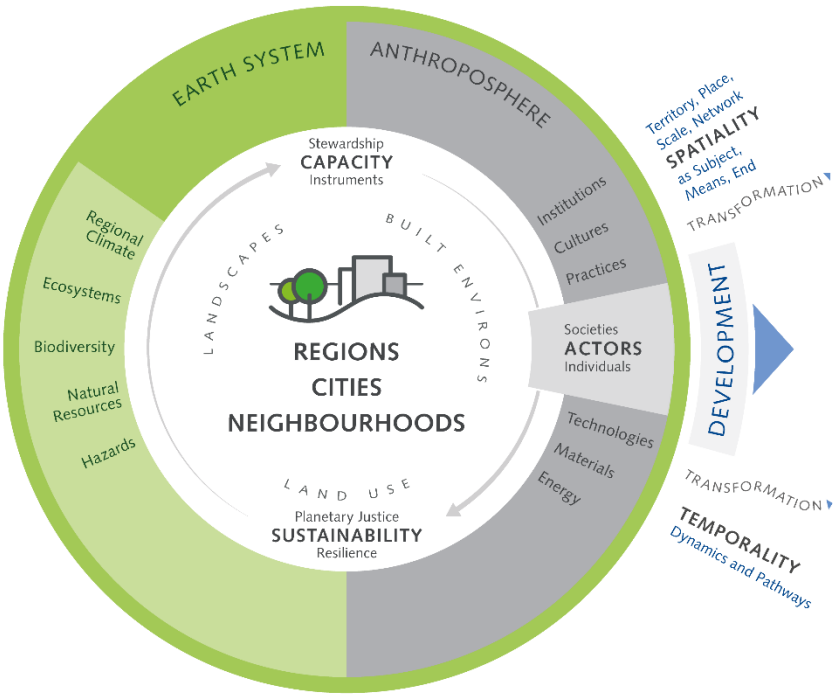

Figure 1: The IOER research perspective – We examine the development and transformation of neighbourhoods, cities and regions. In so doing, we include factors of the natural and man-made environment across scales as well as social structures and practices. Our main interest is the spatial interaction of these factors and the ability to influence their sustainability and resilience effects.

Guiding Objectives

Our research results support the achievement of **key societal goals linked to spatial development** including the UN and EU Urban Agendas, EU Territorial Agenda, Leipzig Charter and Basque declaration as well as the UN SDGs and related international environmental commitments such as the UN conventions on climate change (UN FCCC) and biodiversity (UN CBD). Moreover, these research results are intended to enable stakeholders in the public, private, civil society and third sector at all levels to move beyond compliance with established goals and to jointly leverage transformative change in human-nature relations and develop collective stewardship of sustainable and resilient places. At the same time, we aim to **contribute to pertinent scientific debates** in and across a broad range of disciplines through novel concepts, insights and methods.

More specifically, our guiding objectives are to:

- Advance the scientific understanding of spatial sustainability transformations, their characteristics, dynamics and geographies;
- Elucidate socio-ecological-technological spatial configurations and assess their sustainability and resilience;
- Develop cross-scale spatial information, analytical tools and knowledge as well as policy- and planning instruments that enhance adaptive and transformative capacities in urban and regional systems;
- Contribute to societal agenda-setting and implementation processes that shape sustainable and resilient regions, cities and neighbourhoods;
- Support a spatial development that enables people to thrive within ecological boundaries while ensuring planetary justice.

Research and Transfer Approach

We draw on the spatial, environmental, social, economic, planning, law and engineering sciences, using notions of **spatiality as a shared reference**. These range from physical-material space to conceptions of space as relational and socially constructed, to subjective experiential and inner space, as well as digital space. Given the complexity and dynamics of our subject, we create and apply integrated **disciplinary** as well as **inter- and transdisciplinary research** approaches. In particular, we develop interdisciplinary research designs while adopting disciplinary perspectives in order to scrutinise individual aspects and promote comprehensive understanding. Furthermore, together with public, private and civil society stakeholders, we co-design transdisciplinary research approaches such as living labs or citizen science to enable knowledge co-production and co-creation. This ensures a degree of reflexivity regarding our role as scientists in a given spatial development context. In summary, therefore, IOER research essentially corresponds to the conception of **application-oriented research** outlined by the German Science and Humanities Council (*Wissenschaftsrat*) (WR, 2020) or "use-inspired basic research" (Stokes, 1997), following co-evolutionary processes and combining multiple modes of knowledge (co-) production with a view to developing results of high societal relevance *and* to pushing the frontiers of science.

Based on this approach, we generate **knowledge of spatial configurations**, their past and present, and of their changeability as well as possible and desirable futures. We derive alternative spatial development pathways and the conditions, approaches and interventions required to foster transformative change. Accordingly, we also develop concepts, methods and tools for science and society to understand, assess and purposefully shape spatial change as well as the role of spatiality as

a subject, means or end of sustainability transformations. In particular, this work encompasses spatial data collection and analysis, monitoring, foresight and modelling approaches, formal and informal policy- and planning instruments in the spatial and environmental domains as well as reflexivity formats concerning individual or community orientations and practices.

As a structural measure of overarching importance, the institute plans to reinforce its research data infrastructure and capacities by establishing the **IOER Research Data Centre** (IOER-RDC) in the period of this Research Programme, thus also following recommendations of the Senate of the Leibniz Association (2018). Building on the established research data infrastructure (IOER-Monitor), the IOER-RDC will be anchored in all four research areas of the institute, thereby enabling novel interdisciplinary approaches and applications in terms of spatial data collection, sharing, integration, analysis and interpretation (see Section 3.2).

Knowledge Transfer

Given our basic concern about the societal relevance and impacts of our research, **transfer** forms an integral part of the IOER's scientific approach. In line with Gottfried Wilhelm Leibniz's scientific ideal "theoria cum praxi" and the transfer mission statement of the Leibniz Association, we understand transfer as "target group-specific and quality-assured translation of scientific findings and, conversely, the integration of socially generated issues into research projects" (Leibniz Association, 2019).[1]

Our overall **transfer goals** are to impart knowledge, to ensure understanding, to identify and work on information needs, to respond to current issues, and to find and shape new spaces for transfer – ultimately with a view to strengthening the decision-making and actions of stakeholders as well as developing adaptive and transformative capacities for sustainable and resilient neighbourhoods, cities and regions. Central **target groups** are political decision-makers, public administrators, planning practitioners, the private sector, the third sector and civil society actors as well as intermediaries.

Our **transfer topics** build on the activities of all research areas. They relate to three **forms of knowledge** that are particularly relevant for spatial sustainability transformations: 1) Systems knowledge on the genesis and possible further development of problems as well as on problem interpretations in the real world; 2) Target knowledge to determine and explain the need for change and desired goals; 3) Transformation knowledge on possible means of action that aim to transform existing realities and introduce desired ones (Hirsch Hadorn/Pohl, 2007, p. 36; cf. WR 2016).

The key design principles for our transfer activities are to make them dialogue-based, target group-oriented, context-related, transparent, evidence-based and open-ended. Based on these orientations, we combine three essential **transfer approaches**:

- **Communication** aims to achieve exchange between science and society. It seeks to transfer scientific knowledge into society so as to inform about research activities, issues, results, and options for action but also to raise awareness, to foster empowerment and to trigger participation. Equally, such communication should open up feedback channels to ensure that non-academic knowledge can be integrated into research activities.
- **Consulting** focusses on contributions to decision-making processes, e.g. in writing or through participation in advisory boards, expert panels or networks. This serves to support formal and informal processes of planning and policy-making, standardisation or regulation as well as decisions in the private, civic and third sector. Consulting activities are frequently

[1] Translated by IOER

embedded in research projects. They strongly benefit from the establishment of long-term strategic partnerships with stakeholders at all levels.

- **Application** aims to facilitate the usage, uptake and implementation of research results including, for example, data, information, tools, procedures or proposals for design, policy or regulation in the pertinent decision-making contexts. Furthermore, transdisciplinary research approaches such as living labs or citizen science enable knowledge co-production and co-creation involving various target groups.

These approaches essentially correspond to the **transfer pathways** currently under discussion among Germany's scientific organisations.[2] In addition, based on the corresponding Leibniz Guidelines for Career Development (Leibniz Association, 2020), the IOER also engages in transfer "via people" by providing comprehensive support for career development at all stages, including through the Dresden Leibniz Graduate School (DLGS).

To operationalise the integration of transfer across research activities and foster synergies, the IOER will also develop a **transfer strategy**. In particular, this will include the formulation of overarching **transfer themes**, tying together the specific topics addressed by each research area and sharpening the IOER profile towards the needs of its target groups. It will also define the practical approach for planning and designing transfer activities within research projects, drawing on the conception of **transfer chains** (which link the intended impact and outcome to the input, process and output required to achieve them). This will also enable the establishment of standards for the **monitoring and evaluation** of transfer activities.

The specific transfer goals, target groups, topics and approaches specified in this Research Programme for each research area are detailed in Section 2.

Research Ethics

Our research aligns with the principles of **good scientific practice**, following guidelines adopted by the IOER and the corresponding Code of Conduct of the German Research Foundation (*Deutsche Forschungsgemeinschaft – DFG*) (DFG, 2019). We adhere to the **LeNa guidelines** (*Leitfaden Nachhaltigkeit*) for responsible sustainability research (Fraunhofer-Gesellschaft et al., 2016) and orientations for **Responsible Research and Innovation** (RRI) promoted by the European Commission (Wilford et al. 2016), thus striving to anticipate and assess possible implications of our research for science, society and the environment. Correspondingly, we also promote **gender equality and diversity** in our research designs and organisation. In terms of environmental ethics, we adopt the guiding principle of **strong sustainability** as a reference for researching normative orientations, positing the non-substitutability of natural capital *and* attributing intrinsic value to nature (Ott, 2016; Dedeurwaerdere, 2014) while also incorporating this principle in our research structures and operations.

Organisational Structure

Following the adoption of the *Leitbild* in July 2021, the IOER has also revised its organisational structure to align with the principal research orientations defined therein. Moreover, interdisciplinary

[2] Relevant transfer pathways for IOER are: a) the communication of science (including public relations, active involvement of citizens, scientific advisory services); b) via people; and c) infrastructure services.

cooperation has been further strengthened to address specific challenges. As a result, the institute now features four **Research Areas** (*Forschungsbereiche – FB*) with the following thematic focus:

- **Transformative Capacities** (FB T) including:
  - Interdisciplinary Centre for Transformative Urban Regeneration (IZS)
  - Research Group Sustainable Economic Dynamics and Innovation
- **Landscape, Ecosystems and Biodiversity** (FB L) including:
  - Research Group Urban Human-Nature Resonance
- **Built Environment – Resources and Environmental Risks** (FB R) including:
  - Research Group Anthropogenic and Natural Resources
- **Spatial Information and Modelling** (FB M) including:
  - IOER Research Data Centre (coordination)

The Research Areas are the principal organisational units responsible for the conception and implementation of the Research Programme. Contributions from the respective Research Groups are fully integrated into their planning. In addition, there are four cross-cutting areas of overarching importance for the mission of the institute yet with different organisational structures (see section 3). These are the **Knowledge Integration Hub** (KIH), the IOER **research data infrastructures**, the engagement of the institute within **networks in science and society**, as well as its continuous **promotion of young scientists** – including through the Dresden Leibniz Graduate School (DLGS).

2 Research Areas

2.1 Transformative Capacities

(including the Interdisciplinary Centre for Transformative Urban Regeneration and Research Group Sustainable Economic Dynamics and Innovation)

In this Research Area, we investigate transformative change in neighbourhoods, cities and regions with a view to understanding its preconditions, pathways and sustainability impacts. Drawing on insights regarding patterns and dynamics of socio-technical, social-ecological and socio-institutional transformations, spatial development and urban/regional economic change, our focus is on bridging disciplines and (co-)producing knowledge to conceptualise, assess and develop transformative capacities in urban and regional systems. This requires inter- and transdisciplinary research in selected geographic contexts, spatial configurations and across scales. Our overall aim is to co-design spatially informed governance approaches, instruments and methods that are able to initiate, navigate, accelerate and stabilise transformative change towards sustainability.

Societal Challenges and State of Research

In today's world, societies lack the knowledge and tools to drive and perform deep and path-deviant transformations (Ehnert et al., 2018; Augenstein et al., 2020) from unsustainable patterns and dynamics towards sustainable ones. Over the past decade the critical importance of geography and spatiality in this has been increasingly recognised, with many scholars highlighting their diverse enabling and constraining influences on sustainability and transformation (Elmqvist et al., 2021; Horlings et al., 2020; Binz et al., 2020). Especially **urban and regional transformative capacities**, defined as abilities to transform systems across different scales (local to global) and spatial configurations (e.g. large and small cities, urban and rural areas, growing and shrinking regions, cross-border regions) have been identified as key for societal transitions towards sustainability (Ziervogel et al., 2016; Hölscher/Frantzeskaki 2021). Beyond the capabilities of individual actors, this refers to a range of characteristics embedded in places and their relational socio-material configuration (Wolfram, 2016). Characteristics of particular importance are participatory governance modes and empowerment, system awareness, the co-production of knowledge, vision building and foresight practices, socio-ecological-technological experimentation and social learning, approaches to innovation and exnovation as well as intergenerational and interspatial justice. However, there remains a large gap between scientific disciplines and between science and practice in the ability to develop such capacities. This gap has three different aspects:

First, a variety of current policy and planning approaches address **sustainable urban and regional development** and are implemented in practice around the world (e.g. land use planning and spatial development strategies, urban development and regeneration concepts, urban climate concepts). These approaches are well informed by insights from spatial research such as on the sociology of space (Löw, 2001), identities with places and spaces (Paasi 2004), the construction of space (Otto, 2015), soft spaces and fuzzy boundaries (Allmendinger and Haughton 2009), territorial cohesion (Davoudi, 2005; Faludi, 2007) and strategic spatial and collaborative planning (e.g. Albrechts, 2004; Davoudi, 2009; Healey, 1997; Wiechmann, 2008). However, the corresponding institutions, actors, objectives, instruments and processes are not designed with a view to transformative capacity and consequently have thus far demonstrated limited success in initiating transformative change towards sustainability (Wolfram, 2018; von Wirth/Levin-Keitel, 2020; BBSR, 2020).

Second, from the **spatial economics viewpoint**, the development of cities and regions takes place under conditions of competition between different economic actors for market access and resources. On the one hand, conflicts between individual and societal goals related to sustainable development have been addressed by various market and non-market instruments and control mechanisms (e.g. renewable energy subsidies or CO_2 taxes). Current literature on ecological economics also discusses more far-reaching approaches that aim to influence the entire economic system (Jacob/Edenhofer, 2014). These are intended to change economic incentives and thus resolve conflicting goals (Ostrom, 2015), although their impacts on the spatial distribution of economic activities are often unclear. On the other hand, it is important to better grasp the ability of cities and regions to generate **sustainability innovations** from the bottom-up. In particular, we note a lack of understanding of factors influencing the emergence and spread of sustainability innovations (de Silva et al., 2017) and their importance for the design of respective policy instruments.

Third, informed by **sustainability transition and transformation research**, a variety of approaches have emerged to address transformative change (e.g. Transition Governance, Transition Management, Strategic Niche Management, Transformative Innovation Policy) and have in part also been tested (Loorbach, 2009; Roorda et al, 2014; Schot/Steinmüller 2019). Moreover, scholars have further specified different leverage points for systems change (Leventon et al., 2021; Abson et al. 2017; Meadows 1999), which can inform priority setting and policy mixes to initiate transformative change. Hence, these studies provide a rich knowledge base for identifying key components to enhance the capacities available for the transformation of urban and regional systems (e.g. Wolfram et al., 2019). Nevertheless, most studies on transformative change and transformative capacities lack an explicit spatial lens (e.g. spatial patterns of the existing built and natural environments, socio-demographic conditions or spatially-oriented actors and institutions) (Truffer et al., 2015).

Clearly, there is a lack of understanding of how urban and regional transformative capacities can be conceptualised, empirically identified, assessed/compared and increased in current governance systems based on a systematic interlinkage of knowledge from spatial, urban and planning studies, transition- and transformation research as well as insights from spatial and ecological economics.

In order to address this gap, an inter- and transdisciplinary perspective (Fazey et al., 2020) is required to understand patterns and dynamics of transformative urban and regional change, to identify leverage points, synergies and trade-offs across systems and to practically increase the available transformative capacity. From a methodological viewpoint, this can be achieved by supplementing existing modes of knowledge production in the academic sector through the co-creation of knowledge with actors from the non-academic world as well as transformative research settings (e.g. real world labs, transition experiments) (Schäpke et al., 2018; von Wirth et al., 2019).

Guiding Questions

(1) How can the transformative capacities of urban and regional systems be understood and conceptualised?

(2) How can the transformative capacities of specific urban and regional systems be identified, assessed and compared?

(3) How can governance approaches, instruments and methods be designed to increase the capacity to initiate, navigate, accelerate and stabilise transformative change in cities and regions?

Research Objectives

The overall objective is to systematically link and integrate knowledge from three research strands, namely sustainability transition and transformations, urban and regional economic studies, and

planning and spatial sciences, as well as to further co-develop these insights with stakeholders in order to simultaneously conceive and build transformative capacities. Our focus will be on urban and regional systems, selected with a view to their spatial characteristics and sustainability impacts (e.g. land use, blue-green infrastructures, ecosystems, food, the built environment, mobility, energy).

Specifically, we aim to advance the following aspects:

First, we will work to build a **conceptual foundation** of a spatially and economically sensitive framework of transformative capacities and a sound understanding of its individual components and their interrelations. Our conceptual work will be informed by studies on patterns and dynamics of sustainability transitions, specifically elucidating the roles of different actors, institutions and structures as well as the emergence, scaling and embedding of innovations that promote sustainable ways of production and consumption in urban and regional systems. We will focus on how these aspects play out in different spatial configurations, e.g. in large cities and metropolitan regions, small and medium cities as well as rural and peripheral areas with their geographical, cultural, demographic and socio-economic peculiarities while considering gender specific aspects and implications. Particular emphasis is placed on the question of how spatial aspects (e.g. physical infrastructures, land use patterns, shared spaces, place attachment, proximity or spatial visions) and different conceptualisations of space (e.g. administrative space, relational space, physical space) can inform an advanced understanding of transformative capacities.

Second, we aim to develop a set of **criteria and indicators** to empirically assess and compare the transformative capacities available for different urban and regional systems as well as to monitor changes over time. The identification of differences and similarities across diverse spatial configurations, scales and political contexts in Germany, Europe and the world will allow us to collect evidence for an advanced empirical underpinning of transformative capacities, to inform context-specific approaches of capacity building and to collect evidence for an improved conceptual understanding. Cases that either face similar transformation challenges, show differences or similarities regarding their spatial configurations or have demonstrated progress or failure in capacity building (e.g. based on specific governance approaches, instruments or methods) are of particular interest.

Third, we intend to **(co-)design governance approaches, instruments and methods** that effectively increase the transformative capacities of urban and regional systems in order to help resolve key societal challenges that require transformations (e.g. climate neutrality). In this regard, emphasis is placed on the role of formal and informal (spatial) planning approaches (actors, institutions, instruments, processes, content and regulations) and the interplay of different actors from civil society, public administration, politics, science and the business community as well as intermediary actors navigating between these worlds. Moreover, we aim to design governance approaches that foster the emergence, scaling and embedding of sustainability innovations with special attention given to the derivation of economic incentives and mechanisms to increase the transformative capacities of urban and regional systems and to direct creative destruction towards sustainability.

Methodologically, our research is informed by an interdisciplinary perspective. Moreover, we will implement, reflect and further develop **transdisciplinary and transformative research** approaches for both knowledge co-creation and as a governance approach to increase transformative capacities in cities and regions (e.g. real world laboratories, living labs, experimentation and citizen science). In the context of the IOER Research Data Centre, we will investigate how spatial data science (e.g. data-driven scenarios, foresight, modelling, visualisations and digital tools) can inform participatory governance approaches in cities and regions, e.g. the co-production of visions, transformation pathways, agenda setting and experimentation as well as joint reflection and learning.

Knowledge Transfer

Transfer goals

Our aim is to transfer non-academic knowledge into science and scientific knowledge into different parts of society in order **to increase its ability to achieve transformative change towards sustainability in cities and regions over the long term** (impact). In particular, **we address local and regional authorities** and therein predominantly planning actors, as well as policymakers and public administrations dealing with environmental issues, sustainability and urban and regional development at the level of municipalities, counties and regions or federal states (especially the Saxon State Ministry for Regional Development), at national level (especially the Federal Ministries for the Environment, Interior and Research), at European level (DG R&I, DG Environment, DG Regio) or within international organisations (especially the United Nations) and networks (especially ICLEI, Eurocities). Together with these actors, we will **(co-)design governance approaches, instruments and methods** (outcomes) tailored to their specific contexts that increase their capabilities **to transform urban and regional systems**. These outcomes will entail specific outputs from our project, e.g. sustainability visions, transition pathways, experiments, process designs, data driven tools and scenarios, best practices and policy briefs as well as recommendations for actions stemming from our projects (outputs). Moreover, we will exchange and co-create knowledge for and with **organised civil society and citizens** in order **enhance their participation in and foster their empowerment for sustainability transformations** (outcome), supporting a just transformation based on democratic principles. Specifically, we will develop process designs, tools and methods for citizen engagement in transdisciplinary research settings as well as in urban and regional development policies (outputs).

Transfer topics

We communicate and disseminate our knowledge to societal debates on a broad range of thematic fields, primarily regarding the governance and planning of transformative change, urban experimentation, the scaling and embedding of sustainability innovation and the participation and empowerment of citizens. Further specific contributions will address ways of creating sustainability visions and utopia, the role of scenarios and pathway creation for sustainable futures, revitalising urban regeneration and regional structural change.

Transfer approaches

Our knowledge transfer builds on a diverse set of approaches, formats and methods that acknowledge the different channels and ways societal actors interact, inform themselves and learn from each other, using their language and terminology.

- Wherever possible, we involve stakeholders directly in the creation of knowledge and the design of outputs, as this increases their feasibility. Hence, transdisciplinary settings (research projects) that incorporate knowledge and experiences from multiple actors from the non-academic sector constitute a crucial pillar of our transfer activities.
- In the specific cases of Dresden and Görlitz (locations of IOER and IZS), we are building up long term partnerships with local administrations in these two cities (formal cooperation agreements), which ensure a continuous exchange of knowledge with policy-makers and public officials (regular meetings, joint event series such as the *"Denksalon"* and "Back or Future") and allow us to create, test and learn about urban transformations in different spatial configurations (real world labs, transition experiments).
- We cooperate with strategic partners from non-academic networks and institutions that deal with urban/regional development and sustainability (e.g. ICLEI, Transition Town Network, political and private foundations), exploiting their events, projects and networking

activities (e.g. Informed Cities Forum) to transfer knowledge to other cities and regions in Germany, Europe and around the world.

- We use established approaches to transfer knowledge to political arenas across scales (local to international), e.g. through tailored policy briefs, presentations to parliamentary committees, workshops and conferences, memberships in advisory boards or the dialogue format "Leibniz in the Bundestag".
- To ensure knowledge transfer to civil society and citizens, we cooperate with the organised civil society using their experiences, languages and formats, e.g. presentations, workshops, exhibitions, video competitions, crowd voting and storytelling.

2.2 Landscape, Ecosystems and Biodiversity
(including Research Group Urban Human-Nature Resonance)

Our research focuses on the analysis and evaluation of processes of landscape transformation as well as the development of strategies, concepts, (legal) instruments and incentives for their orientation and navigation. This also entails the investigation of the role of landscapes within transformative change. We deal with the natural environment from the perspective of landscapes, ecosystems and biodiversity, with particular emphasis placed on a socio-ecological view of open and green spaces in regions, cities and urban districts. Key concepts are ecosystem services (ESS), nature-based solutions, blue-green infrastructure and human-nature resonance. Our overall objective is to ensure sustainability through the development of attractive and viable landscapes along with the maintenance and improvement of ecosystems and biodiversity as well as their intrinsic, relational and instrumental values.

Societal Challenges and State of Research

The huge scale of anthropogenic environmental change over the last decades has caused an **acceleration in the degradation of landscapes and ecosystems as well as a loss of biodiversity**. To address these pressing challenges of the current global human-environmental crisis, spatial research is required at and across the diverse scales of regions, cities and urban districts (ARL, 2021), linking these through approaches focusing on landscapes, ecosystems and biodiversity. Based on such an integrative perspective, we conceptualise, analyse and evaluate the external and internal transformative change of landscapes, ecosystems and biodiversity in terms of steering and governance instruments and our internal mindsets regarding such change. In so doing, we address the need for further sustainability research on internal-external sustainability (Wamsler et al., 2021).

In a first line of research, the key challenge to be addressed is the achievement of **purposive landscape transformation** for greater sustainability (Zhou et al., 2019). Referring to the European Landscape Convention, "landscape" is understood as "a zone or area as perceived by local people or visitors, whose visual features and character are the result of the action of natural and/or cultural (that is, human) factors" (CoE 2000). This notion of landscape encompasses ecosystems and biodiversity to enable a holistic and integrative perspective addressing their interrelations at a larger regional spatial scale. We understand landscapes not only as the sum of their ecosystems but also – for the purposes of land system science – as culturally and socially-influenced spaces and places (Switalski/Grêt-Regamey, 2020). While landscapes have always been subject to autonomous change, they are also impacted by human factors such as agriculture and forestry, urbanisation (Artmann et al., 2019), resource consumption and energy production, changing land usage (cf. Lintz/Wirth, 2020) as well as shifting ideas of environmental and nature conservation. In recent decades, however, the repercussions of change induced by human activities and the accompanying

"great acceleration" (Steffen et al., 2015) have intensified in a particularly negative way. There is clear evidence of widespread landscape degradation (Wende et al., 2020), for which the overuse of modern technical systems/infrastructure and demographic developments (among other things) creates a catalysing effect (cf. WBGU, 2020). As a result, landscapes are impaired by land consumption, increasing fragmentation, homogenisation and pollutants. Furthermore, landscapes do not describe a gender-neutral reality: the feminisation of environmental issues (e.g. Bauhardt, 2016) recognises that spatial structures have become polarised through spatial functionalities (working, living, recreation, transport) that separate the spheres of paid production and unpaid reproduction. Therefore, landscape research must also show concern for gender implications.

A key challenge for landscape transformations from the regional to local level is the **protection and sustainable transformation of ecosystems**. This is also underlined by the UN Decade on Ecosystem Restoration 2021-2030, which was designed to highlight the need for significantly increased global cooperation to successfully restore degraded and destroyed ecosystems. A set of ecosystems together with social-ecological factors constitute landscapes. The term "ecosystem" is a guiding concept for the integrative consideration of ecological units. The sustainable protection and pluralistic valorisation of ecosystems demands a paradigm shift in our growth-oriented society, which currently assigns largely instrumental, monetary values to non-human nature and does not perceive itself as part of nature. In the course of this, we must critically examine the links and contradictions between concepts which follow a utilitarian representation of human-nature interconnections, such as ESS (Grunewald et al., 2021) and relational sustainability discourses calling for a morality of care towards nature and its intrinsic values (Muradian/Gómez-Baggethun, 2021). It is vital to comprehensively reflect on the contradictions but also the unifying aspects of various scientific concepts describing human-nature relations and their potential contribution to the strengthening of sustainability transformations. With regard to the challenge of increasing degradation of ecosystems, future research must focus on collecting and assessing data as well as developing and testing concepts, models and indicators (cf. Bonn et al., 2020) to capture the complexity as well as dynamics of ecosystems. In this regard, the *external* responses to the ecological crisis (e.g. the capacity of planning agencies (Hossu et al., 2021)) as well as the role of *inner* transformation (e.g. the shift of worldviews and values towards non-human nature (Artmann et al., 2021; Ives et al., 2020)) should be taken into account, considering in particular sustainable urban human-food relations (Sartison/Artmann, 2020).

A third challenge for landscape transformations is the **rapid decline of biodiversity**. Biodiversity is an integral and stabilising element of both landscapes and ecosystems, addressing an additional urban-rural and local demand for space. Biodiversity refers to the range of habitats, species and genetic variability, whereby targeting the first two components is key for spatial research. The Convention on Biological Diversity (CBD) already recognises the intrinsic value of biodiversity as well as its ecological, social, economic, cultural and aesthetic value (UN, 1992). The IPBES Global Assessment Report states that of eight million plant and animal species around the world, about one million are at risk of extinction (IPBES, 2019), thereby threatening the stability of ecosystems. The same threat is valid at a national biodiversity level (BfN, 2020). To reverse these negative trends by 2030, the UN, the EU and the German government want to strengthen the protection and restoration of nature. This is to be achieved by improving and expanding the network of protected areas and by developing an EU nature restoration plan (COM 2020). The EU Commission sees it as vital to introduce a European governance framework and concrete legal restoration targets for biodiversity (COM 2020). However, it is still not known how these targets can be achieved and be broken down at the national, regional and local planning levels (cf. Mathey et al., 2018, 2020). With regard to biodiversity, the urban realm is also currently becoming the focus of research and policy. In cities,

well-designed blue-green infrastructure is an important prerequisite for a healthy living environment, successful adaptation to climate change as well as the conservation and development of biodiversity (eu2020.de, Hemingway et al., 2019, Mathey et al., 2015). Additionally, it is still unclear how conflicting objectives between resource use and biodiversity conservation can be resolved.

Guiding Questions

The primary guiding questions for Research Area L in the period 2022-2028 are:

(1) How can the concept of sustainable landscapes, ecosystems and biodiversity transformation be theoretically grounded and practically operationalised?

(2) How can landscapes, ecosystems and biodiversity along with their services and relational/intrinsic values be methodologically framed to enable permanent protection and development?

(3) Which strategies and (planning) instruments can help to protect, restore and qualitatively enhance landscape, ecosystems and biodiversity in different geographic contexts?

Research Objectives

The primary goal for the period 2022-2028 is to conceptualise the transformation of landscapes, ecosystems and biodiversity to secure sustainable land-use structures and land systems. To this end, landscape, ecosystems and biodiversity will be placed into relation with one another and across different scales.

We will apply disciplinary as well as inter- and transdisciplinary approaches to investigate how forms of **governance, spatial planning and its instruments can be realigned to support sustainable landscape transformations**. For this, landscape scenarios will be devised and practical steps identified to ensure the further development and digitalisation of legal tools such as spatial and landscape planning at national level. We will investigate the endogenous and cultural potentials of landscapes for structural change and post-mining areas in selected world regions (Asia, Central and Eastern Europe). We also aim to continue to design other instruments such as strategic environmental assessments suitable for application in the context of sustainability transformations and land system sciences. Questions of environmental and landscape justice within planning will be operationalised with regard to physical access to landscapes as well as to improved participation of citizens, power relations and gender issues in decisions on land use. In the international context, we will explore phenomena of multiscale telecoupling and its (adverse) environmental impacts.

We also aim to assist in the **protection and sustainable transformation of ecosystems**, viewed as integral elements of the landscape. Further national/international indicators for ESS will be generated in the period up to 2028. Moreover, ontologies of non-human nature will be investigated that serve to overcome its utilitarian representation and take into account various ethical and moral implications for (inner) change towards sustainability. This includes the conceptualisation and evaluation of different individual and collective human-nature relationships in the city and their governance, such as the approaches of human-nature resonance (linking the resonance theory by Rosa (2019) with sustainability science), sustainable urban agriculture and human-food relations. Yet as we need not only concepts for the protection but also the restoration of ecosystems, these will be developed especially at the European level. Innovations for nature-based and multifunctional solutions to create new blue-green infrastructure and restore ESS in the context of spatial and landscape planning will be identified along with likely trade-offs.

To realise the goal of **preserving biodiversity as an integral component of ecosystems**, we will reflect on and develop innovative guiding principles such as local protection and enhancement

strategies following a human-nature partnership. We will also analyse, evaluate and generate new steering approaches, for example in governance processes for municipal biodiversity strategies. In this context and due to the frequently high demand for land use, special attention must be paid to brownfields as well as to small plots of land using a strategy of "urban environmental acupuncture". We will analyse potentials for and barriers to the restoration of biodiversity (Biodiversity Restoration/Offsets) as well as its qualitative improvement (Biodiversity Net Gain) in the European context. Further, we intend to identify strategies and instruments for the sustainable development of high-quality biodiversity tailored to the respective rural and urban habitats. Analyses will also be conducted on urban-rural interlinkages (with a particular focus on Asia) and on planning and political steering options for biodiversity protection. In the context of the IOER-RDC, new qualitative subjective ecosystem/biodiversity indicators, benchmarks, assessment tools and landscape scenarios will be designed. We aim to show how urban-rural interactions can be practically shaped with a view to meeting ESS and biodiversity objectives as well as how we can contribute to an urban development exnovation based on eco-sufficiency. Proposals for a reversal of trends in land use and land consumption (as a driver of biodiversity loss) will be developed together with the other research areas.

Knowledge Transfer

Transfer goals

Our aim is to jointly generate system analyses, scenarios and transformation knowledge for key target groups as well as to trigger learning processes among the various actors. In the medium term, we intend to inform and influence the actions and decision-making of individuals and corporate actors in a bidirectional way (e.g. urban and regional planning in Dresden, Saxony and/or Germany, NGOs such as BirdLife Europe). Here the focus will be on environmental and spatial legislation, planning, corporate environmental management and school, vocational or university education. In the long term, our aim is to raise the awareness of the general public and key stakeholders of the significance of open spaces and blue-green infrastructure in urban settings for sustainability as well as for the maintenance of ESS and the protection of biodiversity. We will also pursue knowledge transfer at the international scale by targeting selected contexts (e.g. within the EU as well as to China and Russia).

Transfer topics

We will highlight the role of open and green spaces in regions, cities and urban districts in discussions about the future. Here a central role is given to landscape scenarios that are designed to support a sustainability transformation. Additionally, the concept of ESS and the intrinsic and relational values of nature will be anchored more strongly in public discourse. The contents, goals and opportunities of these abstract concepts need to become broadly understood, accompanied by the development of positive narratives for sustainability transformation. This will be done, for example, in the context of general concerns such as health and quality of life. Finally, we will draw attention to the protection and restoration of biodiversity. Significant contributions will also be made here by the Urban Human-Nature Resonance research group, which explicitly investigates the inner and external connections between human and non-human nature.

Transfer approaches

- Policy-making is addressed through advisory formats such as expert groups ("epistemic communities", think tanks). One particular target are governmental ministries, encouraging them to integrate biodiversity aspects into the environmental economic accounts;
- Expertise is also exchanged with policymakers and administrations through consultations, the IOER Forum, or *Leibniz in the Bundestag*;

- Guidance for administrations is provided in the form of manuals, e-learning tools, policy briefs as well as commentaries on laws and brochures. We also address cities and their green space agencies to develop manuals for setting up local biodiversity strategies;
- Civil society is involved co-creatively through formats such as real-world laboratories and citizen science, and addressed through our work in public relations;
- We engage in new experimental approaches to share and discuss evidence, e.g. through *"Raumbilder"*, exhibitions, comics, videos, games, social media and collaboration with artists (formats that "touch" people and research subjects that can be touched). For example, we work with artists to develop exhibitions that raise awareness of issues such as urban sufficiency or landscapes.

2.3 Built Environment – Resources and Environmental Risks
(including Research Group Anthropogenic and Natural Resources)

We investigate the use, development, materiality and environmental risks of the built environment and its spatial relations with the natural environment. In this work, we understand the built environment as one element of a complex socio-ecological-technical system, the physicality of which includes buildings, infrastructures and anthropogenically modified open spaces. Our particular focus is on anthropogenic and natural resources and their use and impairment as well as risks to the persistence and usability of the built environment due to natural hazards and resource depletion, which are intensified or caused by climate change and urbanisation. Furthermore, we explore social and technical innovations that enable regional and sectoral mitigation as well as adaptation to changing environmental conditions. Our research is oriented towards achieving sustainability and climate protection goals such as carbon neutrality and dematerialisation as well as the resilience of the built environment, which also represents a key anthropogenic resource.

Societal Challenges and State of Research

The **built environment refers to human-made spatial environs** broadly encompassing buildings, infrastructures and open spaces. Its development faces major challenges due to the deepening global ecological crisis, in particular with regard to resources and environmental risks.

Resource use for the built environment accounts for 35-45 % of global material flows (Mhatre et al., 2020). At the same time, the built environment is an enormous anthropogenic resource stock, releasing 30-40 % of the world's waste. However, **material flows in the built environment system** are today predominantly organised in a linear way (Ruiz et al., 2020). This leads to diverse environmental impacts that are locally and spatially decoupled (telecoupling) in terms of climate (grey emissions) (IRP, 2020), land, landscapes and biotopes (Maus et al., 2020; Göswein et al., 2021, EEA & FOEN 2020). While a transformative solution would be to develop circular systems (European Union 2020), a basic prerequisite for this is to know and understand the composition and dynamics of the anthropogenic material stock in the built environment (Schiller et al., 2017). Industrial ecology research has made valuable contributions here, relying on a comprehensive set of methods of material flow analysis (MFA) (Ortlepp et al., 2016; 2018; Augiseau et al., 2017), while the ongoing trend of digitalisation is opening up new options for mapping the materiality of cities and regions within a specific spatial context using corresponding material cadastres. (Haberl et al., 2021; Lanau et al., 2020; Schiller et al., 2021). Moreover, existing concepts of continuous MFA serve to interconnect various approaches such as the consideration of urban metabolism, settlement structures and process chains (Schiller et al., 2017). This could be further linked to analyses of technical and social innovations, identifying pertinent stakeholder actions and ultimately specifying business models

throughout the entire development cycle of the built environment (Carra/Magdani, n.d.). A resource- and climate-related perspective on the built environment does not stop at the city boundaries but must take into account all sources and sinks in a regional context, including cities and the urban hinterland (Schiller et al., 2020; Schiller et al., 2018).

Regarding the role of environmental risks, there is no doubt that climate change and urbanisation are increasing the **susceptibility of the built environment to environmental hazards and crises** (IPCC, 2021) and thus its usability if we consider the negative consequences of extreme events such as flooding or periods of excessive heat (Hutter et al., 2021a). Many changes in the climate system are already revognised as irreversible for the next few centuries if not millennia due to past and future GHG emissions, and will become even greater if global warming is not halted (IPCC, 2021). This includes the increased frequency and intensity of extreme heat, heavy rainfall events or droughts. For example, from the start of the industrial era up to the year 2020, average global temperatures rose by 1.2 °C; indeed, the decade 2011-2020 was the "hottest" on record (Masson et al., 2018). The negative repercussions of such environmental risks include, on the one hand, threats to the health and safety of the population and, on the other, losses of property and assets as well as losses of value creation (Kron et al., 2019; Koks et al., 2019). Accordingly, the **analysis and management of environmental risks** (also taking into account stakeholder action and legal frameworks) are among the most important goals in the sustainable development of cities and regions (e.g. Hedelin et al., 2017).

It is clear, therefore, that we must enhance the **resilience of local urban and regional systems** to environmental risks (Hutter et al., 2021b). The concept of resilience is becoming increasingly applied worldwide to help cities and regions deal with the risks and uncertainties associated with hazards in the context of climate change (e.g. Coaffee et al., 2016; Meerow et al., 2016; Elmqvist et al., 2018; Hutter et al., 2021a). Especially with regard to adaptation strategies and measures, there are significant disparities in our state of knowledge of the different types of environmental risks. Hence, while more research is needed on environmental hazards such as heat or drought, there already exists a substantial international body of knowledge on flooding, especially riverine flooding (e.g. Ruangpan et al., 2020). In particular, adaptation, resistance or evasion are generally accepted concepts to ensure that buildings have sufficient resilience to flooding (Schinke et al., 2016). Here it is vital that studies move beyond individual risks to consider cascading hazards as well as pathway dependencies resulting from their interactions. Appropriate solutions in terms of adaptation could be, for example, multifunctional land use or nature-based solutions (NBS), including blue-green infrastructure. Furthermore, it is essential that the built environment be adapted to already occurring and unavoidable climate impacts while also taking account of climate protection and justice (incl. gender) in the process (Schünemann et al., 2020; Ortlepp et al., 2021a), for which sufficient adaptation capacity is a prerequisite (Bohensky et al., 2010).

Ultimately, transformative solutions must both mitigate negative environmental impacts and enable adaptation to rising environmental risks, thereby increasing **socio-ecological-technical resilience**. Resource problems and environmental risks for the built environment are also tightly interwoven. Long-term resilience and usability are essential if we are to appreciate the **built environment as an anthropogenic resource** beyond its current use. Here, three factors are of particular importance: First, the need to ensure resilience to environmental risks can engender conflicting goals with regard to resource use. Examples can be found in structural protection measures against summer heat, earthquakes or flooding, which generally lead to an increase in the demand for resources. Hitherto, such trade-offs have rarely been addressed (Ortlepp et al., 2021b; Schiller et al., 2019). Secondly, the heady pace of urban expansion is outstripping the sourcing of new land and materials for the construction of settlements and infrastructures. This is leading to supply shortages, land use conflicts and massive interventions in the natural environment. Current discussions

are starting to face up to this challenge, exploring resource substitution possibilities in the building sector with feedback to the supply of local raw materials (Ortlepp, 2021; Schiller et al., 2019). However, a broader debate on material supply in the context of urban resilience is not yet apparent. Thirdly, we see the temporal dimension of the usability of the building stock and the associated deceleration of the material cycle as crucial links between the topics of resources, risks and resilience. While these links have not been previously addressed, it is essential that they be explored in order to identify potential synergies.

Research on the above-mentioned topics addresses a number of novel challenges. **Resource and risk issues are all embedded in socio-ecological-technical spatial configurations** with particular (local) characteristics that can form significant drivers and barriers to a sustainability transformation. However, this has so far neither been addressed in transformation research nor in corresponding studies of the built environment (Köhler et al., 2019; Meerow et al., 2016). To adequately grasp this embeddedness, both physical and social concepts of space have to be taken into consideration (Levin-Keitel et al., 2018). Moreover, while current research focuses predominantly on technical systems, little attention has hitherto been paid to the potential of social innovations, although these are needed urgently in order to achieve the ambitious goals that have been set (e.g. IRP, 2020). Last but not least, while the issues of resources, risks and resilience in relation to the built environment are already highly complex in themselves, an integrative approach necessarily adds to this. Understanding the dynamics of the complex socio-ecological-technical system of the built environment and unpacking its materiality, environmental effects and risks is therefore a prerequisite to enable its transformation towards sustainability and resilience. Systemic approaches can make important contributions here, not only to reduce complexity but also to support the necessary inter- and transdisciplinarity of this research (Schünemann et al., 2021).

Guiding Questions

(1) How can concepts of resilience, resource conservation and circularity be developed and combined into an integrative overall approach that guides a transformation towards sustainable and regenerative built environment systems in different geographic contexts and across spatial scales?

(2) How can the built environment be developed towards a circular system that maximises resource conservation and minimises material-induced emissions by exploiting potentials from technical and social innovations as well as new policies?

(3) In the face of environmental hazards, urbanisation and resulting environmental risks, caused or intensified by anthropogenic influences including climate change, how can the resilience of the built environment be increased by novel adaptation and mitigation approaches?

Research Objectives

We generate approaches, methods and indicators on the basis of which circular and resilience-oriented developments of the built environment can be specified in their socio-ecological-technical parameters.

In particular, we develop **digital material cadastres for cities and regions** in order to quantify the material stocks of existing settlement structures and their changes, which may occur, for example, as a result of settlement policy decisions or technical/social innovations in the provision and use of buildings and infrastructures. This base data is combined with **continuous material flow analysis** approaches to link potential anthropogenic resources from demolition with demand for construction materials along process chains. From such analysis, we can assess impacts in terms of **resource**

consumption, grey emissions and indirect land use. Based on this system knowledge, we aim to identify business models to implement circularity in the built environment, considering both physical and social spaces (e.g. networks or territories). Different spatial characteristics, for example regarding urbanisation, geological conditions, wealth, norms and standards, are taken into account in order to provide transformation knowledge and approaches for the development of "circular spaces" (i.e. spatial configurations enabling the circularity in the built environment). Furthermore, we create **methods for analysing environmental risks**, **vulnerability and damages** in cities and regions. These are applied to assess the impacts of environmental hazards such as heat, heavy rain, floods or drought on various receptors of the built environment, i.e. buildings, blue-green infrastructure, agriculture and transport infrastructure, as well as on people of diverse genders and social status who occupy or use these spaces. For this purpose, we use object type-based approaches, which we combine and integrate with social science approaches in novel ways. On this basis, we derive **adaptation measures and strategies** at the level of object and settlement structure, tailored to the environmental hazards affecting them.

In the context of the IOER Research Data Centre (RDC), we intend to link approaches from building simulation and GIS tools to **develop model chains and indicators for decision support**. The goal is to generalise the aforementioned approaches and typologies to enable their transferability to different geographic contexts, including the consideration of climate change scenarios as well as cascading hazards. On this basis, we want to generate transformation knowledge and propose actions to strengthen the resilience of settlement structures to environmental risks, while giving attention to their adaptive capacities. Further, we intend to integrate and generalise approaches to material flow, vulnerability, damage and risk analysis and the underlying object and settlement structure typologies. The aim is to **link object type-based modelling approaches with GIS-based spatial approaches** across scales in order to answer questions relating to material stocks, resource efficiency, environmental risks and resilience at regional up to national level with a high, object type-specific resolution. These object types will be implemented in a new **"Information System Built Environment"** as part of the IOER Research Data Infrastructure. We will develop spatial indicators of the built environment by means of cause-effect relationships of settlement and material flow dynamics as well as risk assessments. On this basis, we will carry out scenario analyses in the RDC for virtual realities of settlement development using parameterised models.

In summary, we are exploring the extent to which a transformation towards a regenerative built environment can be supported by bringing together resilience, circularity and resource conservation approaches in a comprehensive manner. In so doing, we pursue a **systemic understanding of the built environment**. We describe it both qualitatively and quantitatively as well as across scales as a socio-ecological-technical system (with its various elements, relationships and influencing factors), simulate its change dynamics and evaluate effects on resources, climate and people. This also includes the consideration of **trade-offs and synergies between resilience and efficiency concepts** and an examination of how the securing of construction materials and urban expansion represents a novel risk type.

Knowledge Transfer

Transfer goals

Our overarching transfer goal is to enable stakeholders to effectively develop a sustainable, adaptable, climate-neutral and resilient built environment. This requires a shared understanding of the necessary changes, which encompass the minimisation of natural resource consumption and grey emissions and a reduction in vulnerability to environmental risks as well as increased knowledge of options for action. Beyond awareness-raising, we thus strive to co-produce such knowledge and

support the required skills for implementing circularity and measures to improve the resilience of the built environment while lowering the resistance to costs, effort or image change shown by stakeholders.

More specifically, we want to embed new resilience, circularity and resource efficiency approaches in a transdisciplinary manner, targeting formal and informal processes of planning (e.g. regional, environmental, urban, construction and environmental planning), standardisation and legislative processes as well as decision-making in the private sector and civil society (e.g. resource-saving entrepreneurial business models, climate-adapted user behaviour). We will explore and test novel ways of adopting new knowledge within corresponding processes. This includes co-producing a comprehensive understanding of systems as well as the initiation of cross-actor groups and cross-sector processes to allow the embedding of information systems into business models.

Transfer topics

We address the CO_2 neutrality and circularity of cities and urban regions, thus contributing to the policy discourse on carbon-neutral cities and post-carbon cities, among other topics.

Another focus is the adaptation of the built environment to weather extremes such as heavy rain, heat and droughts and their repercussions. Specifically, we not only address constructional precautionary and adaptation measures but also behavioural precautionary and adaptation measures as well as legal requirements. This necessitates methods to integrate planning for risk reduction (e.g. by adopting multifunctional, nature-based solutions) as well as greater awareness of the necessity and effectiveness of private preventive measures.

A key topic is also circular construction and management from a spatial perspective. Here our focus is on highlighting technical and social innovations towards a circular economy in order to promote a sustainable, resource-conserving or circular building culture. Among other things, this addresses the policy discourse on the protection of resources in the building industry. We also foreground the tensions and goal conflicts between the action fields of climate change mitigation, adaptation and resource protection, thus bringing together all of the above transfer topics.

Transfer approaches

- We address all stakeholders through transdisciplinary projects and action research that include the concrete implementation of experimental measures such as pilots, real world laboratories or capacity building.
- We prepare target group-oriented formats and events (e.g. user training, IOER Forum) to interact with selected (groups of) stakeholders on specific topics.
- We use expert groups and advisory boards to convey proposals for regulation and policy designs, e.g. at national, regional or local level.
- We cooperate with different stakeholders such as planners or policy-makers but also with civil society initiatives or private sector actors (e.g. construction and recycling industry, real estate developers and managers) within the framework of joint transdisciplinary projects.
- We complement this with diverse creative transfer formats such as participation in campaign days and support for civil society initiatives (e.g. “Architects for Future”).

2.4 Spatial Information and Modelling
(including coordination of the IOER Research Data Centre)

We are developing data-intensive and data-integrating approaches on a multi-scale and high-resolution basis to investigate trends in settlement areas and open spaces, and to evaluate these for spatial monitoring. Our focus is on innovative research domains such as Spatial Data Science and Geospatial Artificial Intelligence to generate socially robust knowledge and provide transformative decision support in cooperation with stakeholders. We integrate processes of co-design to create digital tools and alternative future scenarios of spatial developments. A particular aim is to establish a Research Data Centre (IOER-RDC) based on the existing "Monitor of Settlement and Open Space Development (IOER-Monitor)", which will be networked with national and international research data infrastructures. The overall goal is to understand complex spatial relationships and dynamics through the action-oriented exploration and interpretation of rapidly growing and heterogeneous data.

Societal Challenges and State of Research

Sustainable land use is understood as one of the key factors for a "Great Transformation" towards sustainability (WBGU 2020). The difficulty in dealing with processes of non-sustainable spatial development calls for **multidimensional approaches in modelling and simulation** of bio, physical, social, economic, legal and ethical aspects (cf. Geels, 2011; Tolk et al., 2021). In order to identify and activate leverage points (Abson et al., 2017), it is necessary to examine the causes of unsustainability in more detail and to develop solution-oriented approaches for transformative change. There must be a dialogue between society and science as well as inter- and transdisciplinary collaboration in order to better exploit the potential of spatial indicators (Turnhout et al., 2007; Heink/Kowarik, 2010; Krüger et al., 2013), modelling approaches and simulations to generate socially robust knowledge (Scholz/Steiner, 2015) for transformative decision support.

Up-to-date and valid information and empirical knowledge are basic requirements for **evidence-informed planning and policy decisions** (Behnisch et al., 2018; Jehling et al., 2021). Diachronic research approaches are needed to explore unsustainable development forms and their interdependencies, to generate trends and alternative futures for settlement and open space development, and to derive appropriate assessment standards (Lambin et al., 2001; Verburg et al., 2004). The automated information extraction and data publication of prior settlement and open space development are essential key requirements for multidimensional, multiscale and multi-temporal analyses, modelling and simulations (Fuchs et al., 2013; Leyk/Uhl, 2018). Especially in the context of Land Change Science (Rindfuss et al., 2004; Turner et al., 2007), these offer the opportunity to illustrate development pathways, to estimate correlations between land use vs. other earth system parameters, and to identify undesirable development trends (business-as-usual scenarios) (cf. Herold, 2021). New data sources and improved quality of data allow us to enhance spatial scientific knowledge and target group-oriented data preparation. Some examples of such recent comprehensive and emerging datasets – which are freely available – include official geodata products such as 3D building data, earth observation data (satellite imagery, areal images, laser scanning data), pan-European products of the Copernicus Land Monitoring Services (soil sealing, forest, grassland, water and wetlands) and global datasets (e.g. Global Human Settlement Layer (GHSL), World Settlement Footprint (WSF)) as well as user-generated data from VGI platforms, citizen science activities and social media networks.

The key methodological challenges are to successfully **analyse, link and visualise ever-larger and more complex datasets and to jointly process these** (Lee/Kang, 2015; Robinson et al., 2017). Innovative approaches to big data analytics, data mining, knowledge discovery and deep learning are thus becoming central, and need to be further developed to deal more effectively with issues of land use (Behnisch/Meinel, 2018; Behnisch et al., 2018; Hecht et al., 2020). In particular, the structure and dynamics of cities and regions are major concerns in terms of land use, land cover, settlement density, building stock as well as blue-green infrastructure. When performing fusion tasks with various data sources (e.g. user-generated data or official geodata), it is necessary to be able to quantify the respective data uncertainties, to take them into account in the processing procedures and to visualise them. One promising approach in this regard is Uncertainty Modelling (Herold, 2018). In addition, user group-specific and interactive cartographic visualisations for easy-to-understand communication of the complex facts and analysis (Taylor, 2005) are an essential support for evidence-informed action towards transformative change. In this context, heterogeneity and specific data qualities must also be taken into account in visualisation (MacEachren et al., 2005).

To fulfil the requirements of networked cross-disciplinary empirical research, it is becoming increasingly important to **create standardised research data products**, ensuring data storage, archiving and persistent data publication in networked, FAIR-confirmed geodatabases, and the operation of a corresponding research data infrastructure and their integration into national and international research data infrastructures (Bernard et al., 2014; Gray et al., 2018; Brand et al., 2019).

Guiding Questions

(1) How can relevant information on settlement and open space development at different spatio-temporal scales be derived from heterogeneous spatial (including socio-spatial and user-generated) data?

(2) Which spatial characteristics, patterns, processes and cause-effect relationships of settlement and open space development can be elaborated and evaluated, and how can alternative scenarios of potential future spatial developments be generated from these?

(3) How can data, information and tools be made widely available and usable for science and society within the framework of a research data centre to advance sustainability transformations?

Research Objectives

Spatial information processing and modelling are crucial to achieving sound knowledge and decision support on the characteristics, patterns as well as current/future trends and tendencies in settlement and open space development and to making these available in digital form.

We develop **new approaches for the automated extraction of information on spatial development at different scales from heterogeneous data** such as basic official digital geoinformation and domain-specific geodata, remote sensing data, sensor data, prior topographic maps as well as user-generated and socio-spatial data. The use of AI-based geospatial analysis further refines the previously developed data collection, monitoring, analysis, and visualisation methods through **extensive application as well as new use cases**.

This includes, in particular, the **high-resolution geometric and semantic description of the settlement and open space structure** in terms of land use and land covers, building stock and blue-green infrastructure as well as the identification of **development patterns in robust time series** while taking account of uncertainties. We apply the concepts and methods of Spatial Data Science and Geospatial Artificial Intelligence (GeoAI) to the problems of spatial sustainability transformations as well as sustainable land use to create the **empirical foundations for evidence-informed decision**

making for policy, planning and society. We focus on the development of spatial indicators (including changes in building stocks, building density, green infrastructure and provisioning, and ecosystem services), spatial analytics (interdependency and land-use conflicts), alternative scenarios of settlement and open space development (new land consumption and urban sprawl), and assessment concerning sustainability goals, including gender equity, together with the other research areas.

We **publish spatial data and products and visualise these** using cutting-edge geospatial technology and cartography (e.g. Web Mapping, Story Maps). The uncertainties of spatial information are also taken into account as well as transparency in the publication of contents for easy communication to specific user groups.

The acquired **data, information and tools developed are made publicly available through the IOER Research Data Centre** (IOER-RDC). The initial focus is on the existing IOER-Monitor, which will be extended in compliance with the FAIR research data principles (findability, accessibility, interoperability and reusability) supplemented by prior time-series and information on grey, blue and green infrastructure, and expanded to include applications for data use and decision support. To enable a comprehensive use of the results in other scientific disciplines and the application of data science approaches in collaboration especially with earth system science, environmental science, social science, and economics, the IOER-RDC will be **interlinked into the emerging national (NFDI) and international research data infrastructure (EOSC)**. The country-wide high-resolution data collection for Germany will be supplemented by international case studies within the framework of third party-funded research to enable comparative studies of trends.

Knowledge Transfer

Transfer goals

We aim to provide and facilitate data-intensive basic knowledge and decision support for sustainable development and transformation of the settlement and open space structure. Particular target groups are actors in the domains of land use, soil, urban greening and climate adaptation/protection (especially policy-makers), spatial planning (state, regional, municipal/urban planning, landscape planning), relevant sectoral planning (including environment, green space, soil protection, transport), civil society as well as smart city actors and scientists. In the medium term, the above-mentioned target groups can use our published information and developed tools to strengthen an awareness of problems and to empower civil society as well as to provide goal-oriented support for data use in the context of digitalisation (outcome). In the long term, the aim is to guide strategic development and implementation at various levels (impact).

Transfer topics

The focus of our transfer topics is on diverse innovative data integration, in particular: information and analyses on land use, settlement density, building stock and urban green development; trends and scenarios of settlement development; cumulative spatial impact analyses of plan implementations; and monitoring technologies integrating user-generated data as well as tools for local and regional applications (e.g. inner-development potentials, green provision and accessibility). In addition, we are developing digital planning tools (urban sprawl, building-integrated PV potentials, accessibility, site suitability assessment) to shape future spatial development paths. Through citizen science, knowledge transfer and decision support, we are helping to change spatial development processes. We provide indicators on material stocks as well as on land productivity. Furthermore, we are extending the availability of indicators on biodiversity and ecosystem services while addressing the quality and perception of urban green spaces as well as the urban heat island effect.

Transfer approaches

- The transfer of results will be ensured, in particular, by the implementation of the IOER Research Data Centre with standard data products and analysis potentials, the publication of an IOER Land Use Report, a metadata collection on land use policy and statistics as well as the visualisation of alternative scenarios of future settlement development.
- FB M organises the annual Dresden Land Use Symposium (DFNS), which gives scientists the opportunity to present their research results and discuss these with practitioners. Held every two years, the DFNS also provides an international scientific platform for the exchange of knowledge and results.
- Other formats include an annual expert workshop “Towards better land-use statistics”, indicator workshops and thematic dialogue formats with stakeholders of sustainable settlement development as well as the IOER Forum.
- Our data and indicators of land use will be interlinked with the data of other providers such as the NFDI consortia NFDI4Biodiversity, NFDI4Earth, KonsortSWD, BERD, and in the European Open Science Cloud EOSC. In addition, local and regional planning tools are developed together with practice partners.

3 Cross-cutting Tasks

3.1 Knowledge Integration Hub

The IOER's Knowledge Integration Hub (KIH) helps generate theoretical and methodological foundations for a better understanding and co-shaping of spatial sustainability transformations. The focus is on the identification and investigation of basic inter- and transdisciplinary issues of overarching relevance for the institute's research, as well as on the reflection and advancement of concepts, methods and practices for inter- and transdisciplinary knowledge integration. To this end, the KIH involves all research areas and engages with pertinent research networks.

Knowledge integration is an essential element in the study of sustainability transformations. The scientific investigation of such multi-faceted and dynamic processes of real-world change towards societal goals requires the use of knowledge from a number of disciplines as well as from different societal groups in an inter- and transdisciplinary manner. In view of today's global environmental crises, it is essential to improve our shared understandings of spatiality in sustainability transformations, both from the perspective of scientific innovation as well as due to the high societal relevance. Yet while sustainability science has rapidly gained resonance over the past decades (cf. Clark and Harley, 2020; Fang et al., 2018), its grasp of the complex roles of spatiality is still at an early stage (cf. Binz et al., 2020; Levin-Keitel et al., 2018; Wolfram et al., 2016). Specific avenues of knowledge integration are needed to be able to consider the dimensions and phenomena of spatiality in terms of biophysical junctions, spatial configurations and relations, scales as well as temporal dynamics (e.g. Eräranta & Mladenović, 2021; Zhou et al. 2021). Such research depends on overarching and crossover theoretical and methodological foundations beyond thematic and empirical studies (e.g. Tretter and Simon 2018). It tackles the interrelations between originally distinct and heterogeneous theoretical and methodological approaches in goal-oriented processes and results to create emergent new knowledge structures (cf. Berggren et al., 2011; Nagy et al., 2019). Regarding the spatiality of sustainability transformations, this demands insights from the natural, engineering and social sciences, the humanities, as well as from real-world perception and experience.

Research aims

In the period 2022-2028, the Knowledge Integration Hub is pursuing the following overall research aims in close collaboration with the institute's research areas:

- To identify concepts, methods and practices suitable for knowledge integration concerning the spatiality of sustainability transformations;
- To adopt and advance ontologically and epistemologically integrative heuristics for spatial sustainability transformations, particularly considering systems and assessment approaches;
- To reflect normativity at the science-policy interface of spatial sustainability transformations;
- To elaborate perspectives on the generation of transformation knowledge for selected socio-ecological-technological spatial configurations.

Approach

Questions of knowledge integration have played an essential role in the inter- and transdisciplinary research of the IOER from the outset and are addressed continuously although separately within

the research areas and their respective thematic fields. To tackle knowledge integration systematically, it is necessary to focus on the three knowledge types underpinning transdisciplinary and transformation research (system-, target- and transformation knowledge) as well as their interrelations, taking into account concepts, methods and practices of principal relevance for spatial sustainability transformations. The Knowledge Integration Hub takes up this perspective and strives to deepen and gradually expand the available expertise through an evolutionary approach so as to ensure flexibility and facilitate innovation. It builds on previous works of the institute such as literature analyses and explorative studies on system approaches (e.g. Schanze et al., forthcoming) and cross-thematic framework concepts (e.g. Müller et al. 2020, 2021) to investigate selected theoretical and methodological questions of relevance for the entire institute. It will then strive to sequentially gain further insights regarding the above research aims, combining bottom-up activities initiated by researchers of the institute with strategic research and networking. To ensure relevance as well as uptake and usability for the various thematic fields, activities of the KIH will be continuously coordinated with the institute's research areas, including the IOER-RDC.

Three principal formats characterise the activities of the KIH:

- Targeted exchange between researchers from multiple disciplines in formats that foster creative dialogue;
- Strategic collaboration with leading associations, networks, and virtual centres;
- In-depth research on selected topics through research projects of the institute and its partners.

Knowledge transfer

Concepts, methods and practices for knowledge integration across disciplines, sectors, levels and territories offer a high potential to support societal decision-making and behavioural change. For this reason, the KIH explicitly prepares key findings from inter- and transdisciplinary research on knowledge integration for transfer and societal uptake. The resulting impacts together with scientific progress on knowledge integration will significantly enhance the institute's positioning as a think tank for spatial socio-ecological-technical research in general, and spatial sustainability transformations in particular.

While results of the KIH appear to be generally relevant for all stakeholders, explicit and hence more systematic consideration of knowledge integration questions is especially pertinent for certain actors playing a crucial role in spatial sustainability transformations such as *intermediaries* (individuals and organisations), *policy designers* and -*innovators* as well as *policy consultants* and -*advisors* in the public, private and civil society sector. Accordingly, the KIH adopts knowledge transfer approaches tailored to these target groups, from the local to the international level. The following will be of particular importance:

- Dialogue and co-creation formats involving various target groups to raise awareness of the opportunities for advanced knowledge integration and to provide contexts for direct uptake;
- Policy briefs, guidelines, procedures and outputs of knowledge integration for (diverse aspects of) spatial sustainability transformations;
- Press releases, media briefings and interviews additionally inform the interested general public.

3.2 Research Infrastructure

IOER Research Data Centre (IOER-RDC)

The IOER Research Data Centre (IOER-RDC) *(IÖR-Forschungsdatenzentrum)* develops and provides **digital information tools and applications** for a sustainable land transition as well as transformative urban and regional development.

The IOER-RDC intends to close a critical gap in the German and international research landscape by providing an integrated view on the complex socio-ecological-technological dynamics of spatial and settlement development and by supporting actors to effectively contribute to sustainability transformations. We will elaborate and provide research- and decision-relevant information on land use and settlement structure as well as realise and enable cross-scale and cross-disciplinary spatial analyses, modelling and simulations. This requires the integration of heterogeneous data sources and 3D geodata products as well as the use of novel approaches in spatial data science and geospatial artificial intelligence (GeoAI). Possible applications range from the reconstruction of historical developments and the current, high-resolution description of the status quo to the creation of alternative scenarios for future development paths.

To this end, the IOER-RDC bundles **expertise in geoinformatic science and technology with work from all our research areas** (e.g. ecology, engineering, planning, economics) and thus drives the interdisciplinary development of innovative data collection, analysis and interpretation methods. At the same time, it strengthens knowledge transfer by establishing and operating a comprehensive spatial research data infrastructure and by providing digital tools and methodological innovations.

Monitor of Settlement and Open Space Development (IOER-Monitor)

The starting point for the IOER-RDC is the "Monitor of Settlement and Open Space Development" (IOER-Monitor), which is a product of interdisciplinary research. The IOER-Monitor provides **web-based open data and services** for the observation and analysis of **spatial and settlement development** in Germany. It integrates multi-temporal datasets at different spatial resolutions and enables indicator-based assessments and interpretations. The IOER-Monitor is accredited by the German Data Forum (RatSWD) and will be part of the emerging National Research Data Infrastructures (NFDI). It will be further developed by expanding data stock and indicators for the grey, blue and green infrastructures in close cooperation with all IOER research areas.

Within the period of this Research Programme, we will further conceptualise and realise the IOER-RDC in **compliance with the FAIR principles** (findability, accessibility, interoperability and reusability), with its core components and services (IOER-Monitor, databases on buildings and other structures, geo services and processing services, tools, etc.). Apart from analyses, scenarios and visualisations as key results this includes also knowledge transfer measures (user trainings, website, IOER-monitor report, public outreach). The data products, indicators, tools and analyses will be further complemented through joint developments involving all IOER research areas.

Infrastructure tasks particularly relate to: (i) the ongoing operation, indicator additions and functional extensions of the IOER-Monitor including its FAIR-compliant expansion; (ii) persistent provision and publication of research datasets; (iii) further development of new services for the simplified use of social science survey results (SOEP, GESIS, among others) for spatial science research (SoRa App); (iv) provision of databases and tools; (v) services such as the IOER-Monitor report, *IÖR-Flächenportal*, analyses/scenarios, visualisations, e-learning offers, user training, public relations; (vi) integration of the IOER-Monitor into emerging National Research Data Infrastructures (NFDI) and the European Open Science Cloud (EOSC).

IOER Information System Built Environment (ISBE)

Germany's total **stock of buildings and infrastructure** can be viewed as a material repository that changes every year due to new construction as well as renovation and demolition work. At the same time, it is exposed to significant environmental risks. Our "IOER Information System Built Environment" (ISBE) as part of the IOER-RDC assists scientists, urban, regional and environmental planners, industries and politicians by providing them with information on the physical characteristics of the built environment in terms of its materiality and resilience.

This information is based on reference values obtained **empirically from selected individual objects** of the built environment (representatives) and structured along a **typology of buildings and infrastructures** such as residential/non-residential buildings, transport infrastructure and supply and disposal infrastructures.

Objectives for extending the ISBE during the period of 2022-28 include: (i) expansion of the existing database to include basic data on building types, taking into account innovative construction methods (e.g. low-carbon construction methods), innovative building materials and building elements (e.g. carbon concrete-based), and expanding the evidence base for existing typification approaches for built environment elements; (ii) integration of continuous assessment modules (linking dimensions such as material, raw materials, construction and demolition waste, emissions and land use) as well as extension of the functionality of the information system (topic-related query mechanisms); (iii) development of transfer interfaces, e.g. for indicators of instruments used in planning practice such as the supply of input data to urban material cadastres as well as for the IOER Research Data Centre, e.g. providing input data for virtual realities.

3.3 Scientific Network

Leibniz Association

The IOER is a member of **Section B "Economic and Social Sciences, Spatial Sciences"** and an associate member of **Section E "Environmental Sciences"** of the Leibniz Association. Of particular importance for our interdisciplinary research are strategic cross-sectional collaborations in the context of **Leibniz Research Associations (LRA)** and Leibniz Research Networks (LRN), and we proactively engage in their formation and development. Currently this includes (see details below):

- Leibniz Research Alliance "Infections in an Urbanizing World – Humans, Animals, Environments"
- Leibniz Research Network "Knowledge for Sustainable Development"
- Leibniz Research Network "Spatial Knowledge for Society and Environment"
- Leibniz Research Network "Integrated Earth System Research"
- Leibniz Research Network "Biodiversity"
- Leibniz Research Network "Environmental Crisis – Crisis Environments"

The IOER also regularly takes part in the annual **Leibniz competition** within the framework of the Pact for Research and Innovation. In addition, we participate in various **working groups** of the Leibniz Association such as Citizen Science, Knowledge Transfer, International Networking, European Affairs, Central and Eastern Europe, Sustainability Management, Research Data Management, Libraries, Equal Opportunities and Diversity as well as Administration.

LRA "Infections in an Urbanizing World – Humans, Animals, Environments"

The LRA combines expertise from 15 Leibniz partner institutions across four Leibniz Association sections, three non-Leibniz institutions, two Leibniz Networks and two other LRAs to develop and implement a strong interdisciplinary and cooperative infection research agenda. It is committed to generating long-term research synergies to help tackle the global health and societal challenge of infectious disease transmission. Specifically, it focuses on the spread of antimicrobial resistant (AMR) microbes in an urbanising society to advance current knowledge, to contribute to the development of countermeasures and to provide tailored policy recommendations. The aim of the IOER as Leibniz partner is to conceptualise and investigate the spatial conditions and configurations of societal threats due to environmental AMR microbes. This involves the identification of spatial human-environmental conditions influencing the occurrence, transmission and threats of AMR microbes. Based on this, the biophysical and socio-spatial factors for developing adaptive capacities and collective stewardship regarding AMR infections and their transmission are analysed to enable risk reduction.

LRN "Knowledge for Sustainable Development" (SUSTAIN)

Established in 2020, the LRN aims to connect, bundle and further develop research competencies in the sustainability sciences in the Leibniz Association, thereby improving the effectiveness of sustainability-oriented research and its contributions to societal sustainability transformations while strengthening the overall profile of Leibniz in this regard. Alongside conceptual and methodological advances, the network also promotes reflexivity and change within the science system and research policy regarding the requirements of sustainability science. To this end, the five core members together with associated members organise a number of tailored formats of varied scope and scale involving other Leibniz institutes as well as external partners from science and society, including Future Dialogues, Synthesis Workshops, Summer Schools and an International Conference. Professor Wolfram, Director of the IOER, is co-founder and co-spokesperson of the network.

LRN "Spatial Knowledge for Society and Environment" (Leibniz R)

The oldest network in the Leibniz Association (formerly 5R-Network), Leibniz R gathers together the principal spatial research centres in Germany. It focuses on analysing social, ecological and economic processes and their interactions in their spatial contexts and identifies space-related options for action. In this way the network helps to anchor spatial knowledge more broadly in society and politics and to make it more usable. Particular aims of the network include sharpening the national and international visibility of spatial research in the Leibniz Association, promoting young scientists and strengthening the communication of science as well as knowledge transfer. The network organises a biannual Spatial Research Colloquium (*Raumwissenschaftliches Kolloquium*), providing an important forum for scientists and practitioners to discuss current issues of spatial development, as well as summer schools and a journalist-in-residence programme. The LRN members IOER, ARL, IRS, ILS and IfL also jointly publish the renowned journal *"Raumforschung und Raumordnung | Spatial Research and Planning"*, offering open access to contributions in English and German. Two further Leibniz institutes (ZALF and IAMO) joined the network in 2020.

LRN "Integrated Earth System Research" (iESF)

iESF aims to gain knowledge about people in the Earth system of relevance to society's actions. It addresses the increasing human influence of the Earth system and visible signs of the "Anthropocene". The ecological carrying capacities of the Earth system are to be determined and sustainable development paths derived from these. On the one hand, the network develops innovative principles of integrated Earth system research; on the other, it adopts the perspective of the Earth system to investigate the oceans (along with their use), freshwaters, biodiversity and land systems as well

as potentials for a bioeconomy, urban-rural interlinkages and environmental migration. Climate change is considered throughout. The IOER contributes to approaches for the theoretical and methodological integration of interdisciplinary Earth system knowledge as well as to empirical studies on freshwaters, biodiversity, land systems and urban-rural interlinkages. Professor Schanze, senior scientist of IOER, is the network's spokesperson.

LRN "Biodiversity"

The LRN Biodiversity bundles the skills of Leibniz institutions in environmental-, social-, life-, spatial- and economic sciences to draw up recommendations for sustainable solutions. Scientists from research institutes and research museums record and document biodiversity, research topics of major social relevance, inform the public competently and advise policy-makers on the development and implementation of biodiversity goals. The strategic aim of the network is to develop a concept for interdisciplinary cooperation in a future Leibniz Research Alliance on Biodiversity. Within the framework of the network, initial participation in national and EU-wide collaborative projects in this thematic area should be made possible, thus making the project-oriented networking expertise visible across different sections. The network thus creates the conditions for further anchoring inter- and transdisciplinary biodiversity research as a unique selling point of the Leibniz Association. It also supports the transfer of knowledge into political discourses and society as a whole through conferences, projects, policy briefs, etc.

LRN "Environmental Crisis – Crisis Environments"

The LRN combines perspectives of the environmental and social sciences and humanities from Leibniz institutions of four Leibniz sections. Cutting-edge interdisciplinary research and user-oriented knowledge transfer aim to reap significant insights on the emergence of environmental crises and their societal treatment by a wide range of actors from individuals to global governance. The network focuses on frictions and opportunities in the perception and action of dealing with sudden and creeping environmental change in governance approaches. Expected outcomes of the collaborative work will foster innovations for sustainability transformations through effective multi-level governance of environmental crises. The IOER especially contributes to the inter- and transdisciplinary knowledge integration for the further conceptualisation and operationalisation of environmental crises. Moreover, it addresses thematic fields of environmental crises with its expertise on spatial sustainability transformations.

DRESDEN concept – Science and Innovation Campus

At its location in Dresden, the IOER is closely integrated into the DRESDEN-concept (DDc) **network of scientific institutions**. In particular, we are engaged in a long-term strategic partnership with the **Technische Universität Dresden (TUD)**. This is expressed through the Interdisciplinary Centre for Transformative Urban Regeneration (IZS), the Dresden Leibniz Graduate School (DLGS) and in **joint appointments of professorships** at the Faculties of Environmental Sciences, Architecture and Business and Economics as well as an honorary professorship at the Faculty of Arts, Humanities and Social Sciences.

- Chair of Spatial Development and Transformation
  (Prof. Dr. Marc Wolfram)
- Chair of Ecological and Revitalizing Urban Transformation
  (Prof. Dr. Robert Knippschild)
- Chair of Economics, esp. Environmental, Urban and Regional Economics
  (Prof. Dr. Artem Korzhenevych)

- Chair of Environmental Development and Risk Management
  (Prof. Dr. Jochen Schanze)
- Chair of Urban Development
  (Prof. Dr. Wolfgang Wende)
- Honorary Professor for Environmental and Planning Law
  (Prof. Dr. Gerold Janssen)

The IOER is currently also preparing further joint appointments together with the TU Dresden to head IOER research areas. One professorship for "Spatial Information and Modelling" will be set up at the Faculty of Environmental Sciences starting in 2023. Another professorship linked to the research area "Transformative Capacities" is also in planning, most likely at the School of Humanities and Social Sciences.

Furthermore, we cooperate with the TU Dresden as well as other DDc partners in numerous **research projects**, including within the framework of selected **emerging fields *(Potenzialbereiche)* of the university's Excellence Strategy**. For instance, the TU Dresden is currently implementing the measure "Disruption and Societal Change" (TUDiSC) as a new interfaculty research centre in the context of the emerging field of "societal change". The IOER contributes here in one of five projects ("The disruptivity of the others: An interdisciplinary analysis of the co-constitution of outsiders and disruptions in transformation processes" - .DOT), which connects closely to our agenda on urban experimentation and transformation. We also continue to participate in strategic long-term research activities such as the project "ScaDS.AI – Competence Center for Scalable Data Analytics and Artificial Intelligence" (funded by the BMBF – Federal Ministry of Education and Research) and play a proactive role in DDc network formats, for example in several Scientific Area Networks (SAN) such as "Future of Cities and Rural Areas" and the Scientific Area Committee (SAC) on "Culture and Societal Change". The IOER also actively engages in the "PRISMA – Centre for Sustainability Assessment and Policy", the Administration/Infrastructure Committee, or the Working Group on Research Data (together with partners beyond DDc). In addition, the institute contributes substantially to postgraduate teaching at TU Dresden, especially in the Master's programme in Spatial Development and Natural Resource Management (cf. Chapter 3.4).

Another important area of work is our cooperation with the **Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES)** of the United Nations University. The **Dresden Nexus Conference (DNC)**, which is organised jointly by IOER, UNU-FLORES and TU Dresden, is at the heart of this cooperation. It takes place every two years as a globally-oriented scientific event with close links to policy and society. In the interim years between each conference, the DNCi innovation platform addresses regional stakeholders from science and practice. Moreover, starting in 2023, UNU-FLORES together with IOER and TU Dresden will also launch a new joint PhD programme on the "Resource Nexus for Sustainability Transformations" (NEXtra), funded by the DAAD (Development-Related Postgraduate Course – EPOS). This 10-year programme will be linked to the Dresden Leibniz Graduate School (DLGS).

Interdisciplinary Centre for Transformative Urban Regeneration

The Interdisciplinary Centre for Transformative Urban Regeneration (IZS) is a **joint research facility of the IOER and TU Dresden, located in Görlitz**. At the university, cooperative activities are carried out in particular by the International University Institute (IHI) Zittau, a central academic unit of TU Dresden. The management of the centre is linked to a joint appointment of the IOER and TU Dresden on "Ecological and Revitalising Urban Transformation".

In the sense of a **real-world urban laboratory**, the IZS deals with the transformation of historic cities as well as small and medium-sized towns in peripheral locations that are caught between the conflicting demands of ecological development and demographic change as well as those of revitalisation and the protection of historical monuments. The IZS's location in Görlitz ensures its international approach to this topic. In particular, we have strong ties to Polish and Czech partners.

Part of the IOER Research Area "Transformative Capacities" (FB T), the IZS is in fact closely linked to all our research areas through project co-operations, publications, conferences and transfer services. The annual ***"Denksalon"* workshop** and discussion series on transformative urban regeneration plays an important role for academic and societal exchange. Another format for transfer at the IZS is the *"Europastadt-Gespräche"* (European City Talks) as a German-Polish oriented, regional discussion platform.

In the coming years, the function of the IZS as an interface between science and practice will be further expanded. Thematically, our focus is on **transformative responses to ecological, demographic and social challenges** for existing structures and buildings, especially **in small and medium-sized towns in peripheral locations** and in regions affected by structural change. Together with the IHI Zittau of the TU Dresden and other partners, research-based policy advice for transformative change will be developed, especially at the location in Görlitz and the surrounding border region. With the centre we are pursuing a transdisciplinary approach in which the identification of research needs, the production of knowledge, the pilot application of new solutions as well as their reflection and further development take place together with stakeholders of urban and regional development.

European and International Network

The IOER and its researchers are actively involved in multiple **international scientific and transdisciplinary networks of strategic importance** for the Institute's research. Specifically, these include:

- **Association of European Schools of Planning (AESOP):** AESOP is a network of Europe's planning schools. It provides its expertise to ongoing debates and initiatives regarding planning education and promotes its agenda with professional bodies and key stakeholders in spatial and urban development. IOER is a long-standing affiliate member and contributes to AESOP annual conferences and other formats.
- **European Forum for Geography and Statistics (EFGS):** Encompassing representatives from more than 40 states and territories, EFGS promotes spatial statistics built on well-integrated geographical and statistical data. It is relevant for the development of the IOER-RDC.
- **European Spatial Data Research Network (EuroSDR):** EuroSDR links national mapping and cadastral agencies with research institutes and universities in Europe for the purpose of applied research in spatial data provision, management and delivery as well as for the development of research infrastructures. We intend to further expand our involvement in EuroSDR and its partner organisations such as ICA, AGILE, ISPRS.
- **Ecosystem Service Partnership (ESP):** ESP is a worldwide network designed to enhance science, policy and the practice of ecosystem services for conservation and sustainable development. The IOER aims to become an official partner in this network, which will help us to research on and develop new ecosystem services assessment methods, e.g. in the context of ecosystem services accounting.
- **Local Governments for Sustainability (ICLEI):** ICLEI is a global network of more than 2,500 local and regional governments committed to sustainable urban development. It is a key

partner for the IOER in the co-production of transdisciplinary knowledge on urban sustainability transformations as well as for the communication, dissemination and exploitation of our results to local policy-makers and public officials.

- **International Society of City and Regional Planners (ISOCARP):** ISOCARP is a non-governmental global association of professional city and regional planners and related scientists with over 700 individual and institutional members from more than 85 countries. It provides a vital science-practice forum for exchange and innovations in the professions and disciplines linked to spatial planning.
- **International Society of Industrial Ecology (ISIE):** ISIE promotes industrial ecology as a way to address sustainability challenges and achieve a circular economy. The science of industrial ecology applies a systems perspective to explore how material and energy are used by society, thereby seeking solutions to complex environmental problems. ISIE is a key network for IOER in the sharing and development of knowledge about industrial ecology.
- **International Sustainable Development Research Society (ISDRS):** ISDRS is the leading global network aimed at advancing the sustainability sciences. It provides a platform for debate across all disciplines, also involving practitioners. IOER engages here especially in organising two topic groups (urban and regional transformations; urban and regional resilience), and through the board membership of Prof. Marc Wolfram.
- **Regional Science Association International (RSAI) / European Regional Science Association (ERSA):** RSAI is an international community of scholars interested in the regional impacts of national or global processes of economic and social change. It is a crucial global community for the IOER to interact with in the fields of urban and regional economics and economic geography research.
- **Research Data Alliance (RDA):** RDA is an international network committed to unlocking the value of research data by building the requisite social and technical bridges to enable the sharing and re-use of data. The IOER-RDC team will actively participate in networks and thematic working groups within the national rda-deutschland.de and international Go-FAIR communities. This will provide an opportunity to achieve key competences in research data services as well as to network with other research data providers.
- **Society for Urban Ecology (SURE):** SURE exists to foster and develop knowledge and to implement urban ecology worldwide by strengthening contacts and enriching the dialogue between researchers and practitioners. The IOER not only holds an institutional SURE membership, thereby strengthening our research on urban ecology in the context of sustainability transformation, but is also represented on the board of SURE (Dr. Martina Artmann). These close connections ensure joint research as well as transfer activities and events.
- **Sustainability Transitions Research Network (STRN):** STRN is an international network of scholars interested in sustainability transitions which aims to advance transition scholarship through a programme of knowledge building, education, exchange and outreach. For the IOER, it is the most important community with regard to the study of changing socio-technical-systems and transition governance. It also hosts the thematic group on Urban Transitions and Transformations (UTT), co-founded by Prof. Marc Wolfram.

The IOER also organises various major events and formats for international exchange, solely or together with different partners and linked to joint research and knowledge transfer activities. Notably, this includes regular biannual formats such as the Dresden Nexus Conference and the International Land Use Symposium, both of which were launched in 2015. In addition, since 2021 the IOER

also runs its own **annual conference** as an inter-/national science and practice forum under the heading of **"Space & Transformation"**.

Our **empirical work in the international arena** primarily concerns European countries, especially Central and Eastern Europe (including Russia) as well as East-, South- and Southeast Asia. In this respect, we are linked to numerous universities and research institutions as well as to spatial planning and development practice through project cooperations or institutionalised agreements. In the European context, we are involved as a coordinator and partner in EU-funded collaborative projects (Horizon Europe and Interreg) and thus maintain close relations with scientific and practice partners in numerous European countries as well as with relevant professional associations at EU level and beyond (e.g. Eurocities, ICLEI). Of increasing importance in the global context is also the cooperation with the German Centres for Research and Innovation (DWIH) at various locations.

National Network in Science, Practice, Business and Civil Society

In the national context, we cooperate (beyond the Leibniz Association and Dresden-concept; see description above) with numerous **universities and research institutions** in projects and networks and are involved in joint projects of the BMBF and other programmes. Our staff are involved in various networks, academies and professional associations such as the *Akademie für Raumentwicklung in der Leibniz-Gemeinschaft (ARL)* (Academy for Territorial Development in the Leibniz Association), *Vereinigung für Stadt-, Regional- und Landesplanung* (SRL) (Association of Town, Regional and State Planning), *Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV*) (Working Committee of the Surveying Authorities of the German Länder), *Deutsche Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation (DGPF)* (German Society for Photogrammetry, Remote Sensing and Geoinformation), *Deutsche Gesellschaft für Kartographie (DGFK)* (German Society for Cartography), *Deutsche UVP-Gesellschaft* (German Environmental Impact Society), *DWA – Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall* (German Association for Water, Wastewater and Waste), *Deutscher Verband für Wohnungswesen, Städtebau und Raumordnung* (German Association for Housing, Urban and Spatial Development), *Stiftung Umwelt und Schadensvorsorge der SparkassenVersicherung* (Foundation on Environment and Damage Prevention).

With our "IOER Monitor" and the IOER Research Data Centre, we are also involved in the development of **National Research Data Infrastructure (NFDI)**, which is intended to systematically develop, secure, make accessible and network scientific data resources in Germany. This concerns the consortiums BERD@NFDI, NFDI4Biodiversity, NFDI4Earth and KonsortSWD, which have been confirmed by the Joint Science Conference (GWK).

The IOER also has many years of experience in close **cooperation with practice partners**. An important element of cooperative activity is here the collaboration with specialised ministries and departmental research institutions of the federal and state governments (e.g. German Environment Agency, Federal Agency for Nature Conservation, Federal Institute for Research on Building, Urban Affairs and Spatial Development), with associations in the fields of spatial and environmental development, with municipalities and regions as well as with representatives from business and civil society. In this way, we lay the foundations for transdisciplinary research. Constant dialogue between science and practice in a spirit of trust is a prerequisite for generating the knowledge needed for transformative, sustainable development.

With the **Dresden Land Use Symposium**, we have been organising the most significant German-language exchange platform in the field of land use and land-saving settlement development since 2009. Together with the city of Dresden and actors from local civil society, the Institute runs the knowledge series "Back or Future?" in the context of the Future City Initiative of the BMBF. The

annual *"Denksalon"* (Workshop on transformative urban regeneration) in Görlitz is a communication forum with an open atmosphere to facilitate dialogue between science and practice. We are also an active partner of the Saxony Centre for Building Culture (ZfBK), contributing to its events and exhibitions.

Within the framework of existing strategic partnerships, the **urban regions of Dresden and Görlitz** function as **"real-world laboratories"**, forming an important context for our research questions. Cooperation agreements connect the IOER to both cities and provide the basis for transdisciplinary research, knowledge transfer and mutual learning.

Visiting Scholars

We offer outstanding scientists from all over the world the **opportunity to spend a research period at the IOER** – to promote professional exchange and joint work on projects and publications as well as to establish international cooperation. Likewise, we make it possible for staff members of the IOER to spend time as **guests at other institutions**. A prerequisite for guest stays is some thematic connectivity to the research or transfer topics of the Institute and the potential for mutual inspiration. In connection with the objectives of a guest stay, it can have a duration ranging from a few days or weeks to several months or a year.

Short stays typically encompass expert discussions, lectures, workshops with experts from the IOER and our networks, or, if necessary, an individual visiting programme. Target groups are primarily established scientists or experts in the field. For long-term stays, we offer intensive collaboration on topics that are relevant to both sides. This includes individual professional support by IOER staff members. The target group of longer stays are primarily younger scientists seeking further qualification, usually funded through structured programmes.

In cases where suitable content and motivation are given, we support the applications of visiting scholars and our own IOER researchers for a scholarship through professional exchange and organisational coordination. The IOER has **extensive experience as a host for fellows** of the Alexander von Humboldt Foundation, the German Federal Environmental Foundation *(Deutsche Bundesstiftung Umwelt – DBU)* and the Erasmus+ programme. We also welcome fellows of the Marie Skłodowska-Curie Action of the European Commission as well as fellows in other relevant programmes. We intend to further expand our activities in this regard.

3.4 Promotion of Young Scientists

The promotion of young or next generation researchers has been an important concern of the IOER for many years. This aim has been supported by an **institutional agreement** since 2003, which was revised in 2007 and 2018. Within the framework of our research, we promote outstanding doctoral students, postdocs and those working on their habilitation. With the internationally oriented Dresden Leibniz Graduate School (DLGS), jointly run by the IOER and TU Dresden, we also promote independent PhD students, thereby expanding our research profile.

Structural Support of Doctoral Students

The IOER offers a stimulating scientific environment and extensive **structured support for doctoral candidates**. Special supporting structures and processes ensure the qualification and completion of excellent and relevant dissertations.

The central plank of structured support for doctoral candidates is the **individually composed supervisory board**, which serves to discuss the doctoral project and ensures mentoring. The participation in a training programme, among others in **cooperation with the Graduate Academy of the TU Dresden**, enables the targeted further qualification of doctoral candidates. Other special discussion formats are the regional PhD Day and an **international Autumn School**. To support the networking of doctoral candidates, we finance, for example, the participation in national and international conferences.

We offer various positions for doctoral candidates, including those allowing the candidate to focus entirely on the doctorate. Furthermore, doctoral students at the IOER can also be funded within the framework of the Dresden Leibniz Graduate School.

Dresden Leibniz Graduate School (DLGS)

The Dresden Leibniz Graduate School (DLGS) is a **joint interdisciplinary facility of the IOER and the Technische Universität Dresden**. It hosts international doctoral candidates and invites applications from all disciplines selected in a competitive process, with an opportunity to be supported by a full-time scholarship for a period of three years.

The DLGS strives to develop **novel insights and approaches to face the challenges of spatial sustainability transformations**. It encourages and supports pioneering studies across a broad range of disciplines. The aims of the DLGS are to prepare the next generation of transformative leaders in spatial sustainability sciences. It strives to foster the academic and professional skills required to meet the diverse challenges related to spatial change dynamics and the global human-ecological crisis.

With the DLGS we offer a programme that encompasses **diverse formats for developing theoretical, methodological and practical knowledge**, featuring compulsory and elective academic modules as well as informal events. DLGS scholarships are advertised once a year (June to September) with an initial cohort of usually three candidates in the following spring (March). Students with own funding can apply for admission all year round as well as temporarily. Additional scholarships will become available from 2023 through the “Resource Nexus for Sustainability Transformations” (NEXtra) programme with UNU-FLORES and TUD.

Promotion of Postdocs and Habilitations

The IOER offers **postdoctoral positions for independent research** within the framework of our Research Programme. We also support postdocs from programmes of the DFG, the EU (e.g. Marie Skłodowska-Curie Actions) and various foundations. The concrete support of a postdoc researcher is defined in individual target agreements. A support programme is compiled based on the needs and goals of the individual postdoc.

Postdocs work in one of our four research areas and are supervised by a mentor. They are also expected to support doctoral candidates at the IOER and DLGS. In addition to the cooperation within the Institute, networking with scientists from other research institutions and universities in Germany and abroad is encouraged.

The IOER also supports **habilitations as a special step of qualification** for staff members working towards a professorship. For this purpose, we encourage individualised career development pathways.

Academic Teaching

Strongly committed to teaching, the IOER offers students a **variety of opportunities for additional qualification**. It is possible to work at the IOER as a **student or research assistant** and thus gain experience in various disciplines. Likewise, students can write up **qualification papers and final theses**, which are supervised by IOER researchers. Students are also invited to attend events at the IOER and to use our library.

The close connection between the TU Dresden and the IOER is particularly forged through **joint appointments** (see Chapter 3.3). The cooperation with various faculties of the "University of Excellence" (one of only 11 such universities in Germany) shows the disciplinary range in which we support the academic education of students. The IOER's teaching services focus on the **Master's programme in Spatial Development and Natural Resource Management** as well as Master's programmes in the fields of geography, architecture, landscape architecture, economics and water management at the TU Dresden. Furthermore, we participate in the international education programme of the **Centre for International Postgraduate Studies of Environmental Management (CIPSEM)**. In addition to the TU Dresden, members of the Institute's staff also teach at other universities in Germany and abroad.

IOER Projects

(Projects funded by the institutional budget of the IOER)

Research Area "Transformative Capacities" (FB T)

(including the Interdisciplinary Centre for Transformative Urban Regeneration and Research Group Sustainable Economic Dynamics and Innovation)

Transformative planning for sustainability transformations

Planned duration: 01/2022 – 12/2024

Research area(s): FB T (in cooperation with FB L, FB M, FB R)

Project management: Dr. Markus Egermann

The main objective is to assess the ability of the German planning system with its formal and informal institutions, actors, legislation, instruments, concepts and processes to enhance the transformative capacities in cities and regions. The project focuses on urban and regional spatial as well as sectoral planning as part of a multilevel governance system (federal, national and European). The project will identify opportunities and bottlenecks of the existing planning system to enhance the transformative capacities of urban and regional systems. Also based on scientific and practical knowledge and experience from planning worldwide, the project will develop ideas on how to advance the capabilities of the German planning system to initiate and navigate transformative change towards sustainability.

Knowledge transfer: Planning system, Capabilities, Transformative change, Cities, Regions

Urban regeneration and transformative capacities – Concepts, references, synergies

Planned duration: 01/2022 – 12/2025

Research area(s): FB T

Project management: Prof. Dr. Robert Knippschild

The aim is to foster knowledge building on relationships between urban regeneration and transformative capacities. To this end, the project will integrate and relate findings from studies on: a) the influence of characteristics and dynamics in small- and medium-sized cities on the development of transformative capacities; b) the interrelations between transformative capacity building and regional structural change processes; and c) the ability of established and innovative formal and informal planning instruments as well as urban experiments to unleash transformative capacities. Knowledge created within the project, in particular on the effects and design of governance approaches, will be transferred into policy advice and the co-productive development, testing and reflection of solutions.

Knowledge transfer: Regeneration of small- and medium-sized cities, Urban and regional governance, Regional structural change, Urban experiments

The role of spatial interlinkages for the development of regional transformative capacities and for sustainability innovation

Planned duration: 01/2022 –12/2025

Research area(s): FB T (in cooperation with FB M)

Project management: Prof. Dr. Artem Korzhenevych

The project focuses on innovations (both technological and social) that help to reduce the resource intensity of production and consumption activities. At a regional scale of analysis, the objects of investigation are various spatial factors that influence the emergence and spreading of sustainability innovation (e.g. agglomeration effects, interregional production and knowledge networks, trade and labour mobility, infrastructure and accessibility). While research methods are mainly quantitative, using secondary data, statistical analysis and economic modelling, more qualitative analysis and case studies are also employed. The goal is to formulate recommendations for the design of instruments and methods to foster transformative innovation policy, in particular concerning relevant economic incentives.

Knowledge transfer: Regional structural change, Transformative innovation policy, Economic incentives, Scaling of sustainability innovation

Research Area "Landscape, Ecosystems and Biodiversity" (FB L)

(including Research Group Urban Human-Nature Resonance)

Conceptualisation of Landscape, Ecosystems and Biodiversity Transformation

Planned duration: 02/2022 – 12/2025

Research area(s): FB L

Project management: Prof. Dr. Wolfgang Wende, Dr. Juliane Albrecht, Dr. Martina Artmann, Dr. Alejandro de Castro-Mazarro, Dr. Karsten Grunewald, Dr. Neelakshi Joshi, Dr. Gerd Lintz, Dr. Juliane Mathey, Dr. Ralf-Uwe Syrbe

The primary objective is to conceptualise the transformation of landscapes, ecosystems and biodiversity to secure sustainable land-use structures and land systems. To this end, landscape, ecosystems and biodiversity will be placed into relation with one another and across different scales. The concept of sustainable landscape, ecosystems and biodiversity transformations will be theoretically grounded and practically operationalised. The outcome of the project will then serve as a baseline for any further development of methods, strategies and instruments for protection and enhancement.

Knowledge transfer: Landscape, Ecosystems, Biodiversity transformation concepts, Theory, Role of open and green space, Scenarios

Methodological Framing and Strategic Orientation of Landscape, Ecosystems and Biodiversity Protection and Development

Planned duration: 06/2024 – 12/2027

Research area(s): FB L

Project management: Prof. Dr. Wolfgang Wende, Dr. Juliane Albrecht, Dr. Martina Artmann, Dr. Alejandro de Castro-Mazarro, Dr. Karsten Grunewald, Dr. Neelakshi Joshi, Dr. Gerd Lintz, Dr. Juliane Mathey, Dr. Ralf-Uwe Syrbe

The FB L will methodologically frame landscape, ecosystems and biodiversity along with their services and relational/intrinsic values to enable permanent protection and development and/or enhancement. New assessment methods and (subjective) indicators will be developed. Innovative spatial strategies and (planning) instruments such as biodiversity restoration will be evaluated and developed, thereby helping to protect, restore and qualitatively enhance landscape, ecosystems and biodiversity in different geographic contexts.

Knowledge transfer: Assessment methods, Spatial strategies, Planning instruments, Indicators, Restoration

Urban human-nature partnerships for sustainability transformation

Planned duration: 01/2022 – 12/2024

Research area(s): FB L

Project management: Dr. Martina Artmann

Despite an increasing awareness that the intensifying social-ecological crisis is harming human life around the planet, current collective and individual responses are still failing to achieve a significant turnaround. Due to the physical and mental distance to nonhuman nature, the impact of the global crisis such as biodiversity loss, resource depletion, climate change and social injustice are only slowly becoming apparent in the everyday life of urban Western populations, although awareness is steadily rising. This project aims to identify how individuals and collective actors (e.g. in their professional lives) are externally and internally affected by nonhuman nature and the threats to the urban context caused by human activities. A special focus is placed on the need for internal transformation as a lever for sustainable transformation. To this end, the project will look at the role of the inner worlds of urban individual/collective actors as well as their worldviews and environmental values that consider nonhuman nature as a sentient and intelligent subject of intrinsic value having the right to flourish in human-nature partnerships in cities and beyond.

Knowledge transfer: Human-nature resonance, Cities, Internal transformation, Social-ecological transformations

Research Area "Built Environment – Resources and Environmental Risks" (FB R) (including Research Group Anthropogenic and Natural Resources)

Integrative concepts on resource conservation, climate protection and resilience (IntR²)

Planned duration: 09/2022 – 08/2026

Research area(s): FB R

Project management: Dr.-Ing. habil. Regine Ortlepp, Dr.-Ing. Georg Schiller

IntR² aims to consider resilience, circularity and resource conservation approaches in a comprehensive manner. The project will examine the extent to which a shift towards a regenerative built environment (BE) can be supported by such a systemic understanding. The objective is to describe the built environment both qualitatively/quantitatively and across scales as a socio-ecological-technical system with its elements, relationships and influencing factors, thereby facilitating a deeper understanding of its dynamics and enabling an assessment of its impacts on resources, climate and people. This will include an investigation of trade-offs and synergies between resilience and efficiency, among other factors.

Knowledge transfer: Urban resilience, Climate adaptation, Circular construction, CO_2 neutral city, Governance

Circular Spaces

Planned duration: 01/2022 – 12/2025

Research area(s): FB R

Project management: Dr.-Ing. Georg Schiller

The aim of the project is to understand, virtually describe and foster circular spaces. Digital material cadastres for cities and regions will be developed to quantify material stocks of existing settlement structures and their changes due to settlement policies and technical or social innovations. Methods such as continuous material flow analysis (MFA) will be developed further and combined with process chain and environmental assessment methods to pinpoint impacts on materials, resources, emissions, waste and land use at regional scale.

Knowledge transfer: Circular construction, CO_2 neutral city, Social innovations

Knowledge-integrative synthesis of methodological bases for risk analysis (Method R)

Planned duration: 01/2022 – 12/2025

Research area(s): FB R

Project management: Dr.-Ing. habil. Regine Ortlepp

Method R aims to combine and generalise approaches to vulnerability, damage and risk analysis and the underlying object and settlement structure typologies across scales to enable their transferability to different geographical contexts, including consideration of climate change scenarios as well as cascading hazards. The objective here is to answer questions on environmental risk and resilience at regional to national scales with a high, object type-specific resolution. This will entail the development of spatial indicators of the built environment based on cause-effect relationships.

Knowledge transfer: Risk provisioning, Urban resilience, Climate adaptation

Information System Built Environment (ISBE)

Planned duration: 09/2021 – 12/2028

Research area(s): FB R

Project management: Dr.-Ing. habil. Regine Ortlepp, Dr. Georg Schiller

ISBE aims to expand the existing database to include basic data on building types while taking into account new construction methods as well as innovative building materials and building elements, thereby increasing the evidence base for existing typification approaches for elements of the built environment. Continuous assessment modules and the interlinking of dimensions such as material, raw materials, construction and demolition waste, emissions and land use will be integrated in a stepwise manner. Overall, our objective is to extend the functionality of the information system. This also includes the development of transfer interfaces to instruments of planning practice such as urban material cadastres as well as to the IOER Research Data Centre, e.g. as input data for virtual realities.

Knowledge transfer: Circular construction, Risk provisioning, Structural adaptation, Data and services

Research Area "Spatial Information and Modelling" (FB M)

(including coordination of the IOER Research Data Centre)

Data-driven and user-generated spatial information acquisition (DaSIA)

Planned duration: 01/2022-12/2025

Research area(s): FB M (with inputs from FB R, L, T)

Project management: Dr. Robert Hecht, Dr. Hendrik Herold

In DaSIA we are developing innovative approaches for the automated extraction of information at different scales ranging from heterogeneous data such as (open) geospatial data, remote sensing data, sensor data and historical topographic maps to user-generated and socio-spatial data under the application of geospatial artificial intelligence (GeoAI). In particular, this includes the high-resolution geometric and semantic description of settlements and open spaces in terms of land use and land cover, grey infrastructure and blue-green infrastructure as well as the identification of trends over robust time series while taking uncertainties into account. The focus of research is on the data quality of different open and VGI geodata, new methods for classification, semantic enrichment and change detection of buildings as well as methods for urban green mapping and for extracting multi-temporal settlement masks. This forms the basis for the activities in TrIAM for indicator development, analytics and modelling as well as a transfer-oriented provision of the data and methods via the IOER-RDC.

Knowledge transfer: Public provision of data, Methods and code for free re-use in science, Practice and civil society (Geo Data Worlds, Open Science), Involvement of citizens in information gathering (Future Cities, Citizen Science)

Transformative Indicators, Analytics and Modelling (TrIAM)

Planned duration: 01/2022-12/2025

Research area(s): FB M (with inputs from FB R, L, T and KIH)

Project management: Dr. Martin Behnisch, Dr. Mathias Jehling

TrIAM seeks to refine spatial data and information for the development of Transformative Indicators as well as in Analytics and Modelling. Concepts and methods of Spatial Data Science are applied to problems of societal transformations to help realise sustainable land use. Through analysis, empirical results are obtained to support transformative solutions (transformative decision support). Collaborative formats such as transdisciplinary indicator workshops and the generation of hypothesis models will enhance the conception and implementation of spatial indicators, analytics and modelling. Trends and cause-effect relationships, assessment standards as well as scenarios for alternative futures are of particular interest and support the stakeholder-oriented integration of the IOER-RDC.

Knowledge transfer: Trends and scenarios for the development of settlement structures, Local and regional tools to analyse urban sprawl and densification, Potentials for PV and greening on roofs and façades, Sustainable development of the building stock, Foundations of indicators on transformative capacity and urban green spaces

Conception, development and operation of the IOER Research Data Centre (IOER-RDC)

Planned duration: 01/2022-12/2028

Research area(s): FB M (with the support of all research areas and the KIH)

Project management: Dr. Gotthard Meinel, Dr. Tobias Krüger, Dr. Sujit Sikder

This project will conceptualise and realise the IOER Research Data Centre (IOER-RDC) in compliance with the FAIR principles (findability, accessibility, interoperability and reusability) with its core components and services (IOER-Monitor, land portal, databases on buildings and other structures, geo services and processing services, tools, etc.), deliverables (IOER-Monitor report, results of analyses and scenarios, visualisations, user trainings), measures for public outreach and transfer (website, user advisory board, national and international cooperation) as well as joint project developments with the other IOER research areas (data product, indicators, tools, analyses). Functioning as the heart of the IOER-RDC, the IOER-Monitor will be further developed by expanding the data stock and indicators for grey, green and blue infrastructures in close cooperation with the IOER research areas. Up-to-date data together with retrospective information will enable the generation of alternative scenarios. Usability will be improved by integrating the data of the IOER-RDC into other user contexts through the creation of Application Programming Interfaces (API). This includes the continuous development support and integration of the SoRa-App services for enhanced interoperability of social science survey results (SOEP, GESIS) with spatial data. The IOER-RDC will also integrate the results of the other FB M projects DaSIA and TrIAM as well as the other IOER research areas (FBs). Furthermore, IOER-RDC will be networked and integrated with the emerging National Research Data Infrastructure (NFDI) and the European Open Science Cloud (EOSC).

Knowledge transfer: Data and results of analysis on land use, settlement density, building stock and urban green development, cumulative spatial impact analyses of plan implementations, visualisation of alternative scenarios of future settlement developments, IOER-Monitor report, Digital planning tools for the design of future spatial development paths (inner development potentials, green provision and accessibility, urban sprawl, fragmentation), Provision of indicators and thematic layers on material stock and land productivity, Biodiversity, Ecosystem services, Knowledge transfer and decision support for the transformation of spatial development processes

Knowledge Integration Hub (KIH)

Systems and assessment approaches for knowledge integration in contexts of spatial sustainability transformations (SAKI)

Planned duration: 01/2022 – 12/2025

Research area(s): KIH

Project management: Prof. Dr. Jochen Schanze

The project aims to adopt and advance concepts, methods and practices of knowledge integration relevant for an enhanced understanding and practical consideration of spatiality in sustainability transformations. The focus is on ontologically and epistemologically integrative heuristics, particularly considering systems and assessment approaches. The latter appear to be especially significant when dealing with the complex subjects and multi-faceted normative tasks of spatial sustainability

transformations in science and society as well as at their interface. The research comprises the identification, review as well as further development and testing of selected approaches. In principle, KIH addresses societal, technical and ecological interrelations, their dynamics as well as management and governance interventions for selected configurations of spatial sustainability transformations. An incremental and explorative research strategy involves all of the Institute's research areas, external scientific partners and practitioners in multi- and transdisciplinary dialogues.

Knowledge transfer: Sustainability transformations, Spatiality, Knowledge integration, System thinking, Sustainability assessment, Decision support, Environmental management and governance

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