EFI Network Fund Report

Research Agenda

– Biocities of the future

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Executive summary

This Research Agenda has been developed as part of the European Forest Institute (EFI) Network Fund call for the preparation of a *Green Book of Biocities* and a *Research Agenda for Biocities of the Future*. The Research Agenda is intended as a foundational document for further research and initiatives to be undertaken by the new EFI Biocities Facility launched in 2022 in Rome (Italy).

A number of conditions, developments and critical notions form the backdrop to this study:

- the continuing pattern of migration to cities globally, and related urbanization patterns and processes;
- the interrelationships of cities and the urban realm to global problems (and global solutions);
- the fact that cities are inherently complex, that the urban issue is multifaceted, and that solutions are by consequence interrelated and demand interdisciplinary attention;
- that the cities of tomorrow face an increasing number of challenges, and are of an increasing diversity;
- that cities have been, and are expected to remain, crucibles of development and innovation in areas of technology, economics, culture, society and politics;
- that forests, greenspace and the natural world can become central to a paradigm shift in understanding, ordering and acting in the (bio)city of the future;
- that the notion of a Biocity resonates with similar initiatives such as eco-urbanism, nature-based solutions and green cities, but aims to critically extend and enlarge on these concepts through the involvement of more diverse branches of research and practice, their effective integration and contextualization, and through the exploration of novel cross-cutting perspectives.

The overall objective of the agenda is to contribute towards transforming existing cities to Biocities and provide a framework for new urban developments. Biocities can be defined from the perspective of 'desirable futures' (based on a vision developed by the parallel work of another project consortium on the *Green Book of Biocities*). Critical variables that impact future pathways towards Biocities and point towards areas for further action and research include:

(i) degrees of political stability; compatibility of political systems to principles; political commitment to principles; flexibility and adaptability of regulatory and legislative systems; degree of inclusion and participation of communities;
(ii) volatility of economic conditions internationally, nationally and locally; predisposition of communities and governments to expand value concepts beyond the monetary;
(iii) willingness and capacity of urban communities to adapt to systemic changes required of certain principles; awareness of motivations behind transitions to various principles; migration patterns, the future of work, demographic trends;
(iv) development of necessary technological innovations; uptake of technology;
(v) availability of natural resources; speed of anthropogenic impacts on planetary boundaries.

On the basis of these critical variables, scenarios reveal to what extent the Biocity goals may be reached, resulting in a first set of overarching research challenges, which include: reconciling different perceptions by getting and keeping interest groups involved; interoperability between green space management and urban development; funding and implementation; impacting culture and behaviour towards transformation.

Learning from these overarching themes, five key topic areas are identified as a framework for elaboration of a research agenda to facilitate the transition to Biocities: (1) circular bioeconomy, (2) climate resilience, (3) governance, (4) social and human environment, and (5) biodiversity. Our results show that

various challenges arise from different perspectives in these topic areas, such as life-cycle management, cultural change, prioritisation of sustainable approaches, urban carbon storage, infrastructural adaptation, bio-resilience, participation, cross-sectoral planning, systemic integration of health and wellbeing, and spatial sustainability.

Further, several knowledge areas and research gaps emerge that need to be addressed from the social sciences and humanities, as well as from ecology, civil engineering, architecture and spatial planning and design. Examples include: conceptual research on the circular bioeconomy and urban biodiversity; modelling of the urban microclimate, local health impacts and global supply chain effects; methodologies and standards for impact assessment and participatory planning; historical and contextual research on green, blue and grey infrastructure across cities. For the implementation of greener, cooler and more resilient cities, further knowledge is needed on urban innovation, transition, participation, inequality, inclusiveness management, health and human wellbeing, suitable policies and strategies and the science-policy interface.

The implementation of the Research Agenda will require five pathways: (i) an international coordinated research effort, (ii) interdisciplinary networks, (iii) integration of other initiatives, (iv) conceptual capacity building and (v) support for emerging disciplines. The implementation of the Research Agenda is expected to contribute to the Sustainable Development Goals in an urban context, as well as to support the Green Deal Strategy of the European Commission and the promotion of One Health.

1. The need for a Biocities Research Agenda

Today urban areas have become home to much of the European population. This situation is reflected across the globe, the result of a combination of migration from rural areas and world population growth (United Nations 2018). As a result, an expected 68% of the world population will be living in urbanized environments by 2050 (United Nations 2018). Migration to cities and continued population growth will have a matching effect on patterns and processes of urbanization globally. Depending on the location and context, existing cities will expand and transform, smaller towns and cities will grow, and new cities will appear. The global environmental impact of a burgeoning world population concentrated in more numerous and larger cities is becoming increasingly clear and urgent. The fact that cities are traditionally catalysts for economic activity, and that associated patterns of production and consumption have reached many of the limits the planet can sustain, presents a real and present challenge for the built environment. To complicate matters, increasing urbanization presents challenges in matters of human health and wellbeing, community interaction and social justice. Compounding this task is the fact that cities are inherently complex and that the urban issue is multifaceted, with solutions demanding trans- and interdisciplinary attention. There are an increasing number of urban challenges – and of an increasing diversity – which will need addressing.

In this context, initiatives such as the United Nations Sustainable Development Goals (SDGs) present valuable and useful frameworks for actors from research, government, industry, and society involved in urban futures. Whether these frameworks are focused enough to guide urban development towards meeting these multiple challenges is the question. For cities to become sustainable, resilient and liveable it is necessary to quickly move beyond current paradigms and practices via an innovative, accelerated response encapsulated in a grand narrative. This Agenda sets out such a step. It brings to the fore forests, greenspace and the natural world as guiding themes in a paradigm shift in understanding, ordering and acting in the city of the future. The city of the future is a Biocity. The notion of a Biocity resonates with similar initiatives such as nature-based solutions and eco-cities but aims to critically extend and enlarge on these concepts through the involvement of more diverse branches of research and practice, their effective integration and contextualization, and through the exploration of novel cross-cutting perspectives.

To be able to pursue a holistic framework and to reach this paradigm shift towards Biocities, current knowledge must be expanded with new and context-specific knowledge on urban transformations and sustainable solutions. The Biocities concept calls for a rethinking of current cities in a holistic way, taking a trans- and multidisciplinary approach and going beyond administrative boundaries. For instance, peri-urban areas, defined as areas that are in some form of transition from strictly rural to urban[1], are of central significance to assess and manage the external effects of future urban growth, as well as the external drivers of a city's liveability and wellbeing. Through the assimilative and supporting capacities of their ecosystems, peri-urban areas can buffer risks of natural and anthropocentric disasters and support climate change mitigation. At the same time, if not properly planned and managed these areas can have negative impacts on cities. Therefore, a holistic perspective that takes into account ecosystem services and disservices is crucial in the development of future cities.

Similarly, economic, ecological and societal perspectives need to be integrated to identify synergies and let cities thrive. Simultaneously, innovative ways of integrating and transferring existing knowledge into practice are needed. Therefore, academics and practitioners from a variety of backgrounds are invited to support the European Forest Institute's Biocities Facility in establishing the knowledge basis for transforming current cities into Biocities in Europe and beyond. Coming from a European perspective, the following research agenda sets out the first steps in this journey.

1 https://inspire.ec.europa.eu/codelist/SupplementaryRegulationValue/7_1_4_7_PeriUrbanAreas

2. Biocities definition

Fundamental to the development of a Research Agenda for Biocities is defining what a Biocity is. Our definition is elaborated via a set of principles which consider the concept from various operative perspectives, specifically focusing on how a future Biocity should look and function. Ten basic principles developed in the parallel initiative 'Green Book on Biocities' (Scarascia-Mugnozza et al. 2023) form the basis for this definition. These principles proceed from the stance that natural systems form a normative basis for the Biocity, and that specific elaborations and iterations of natural systems emerge in cities in response to various political, economic, social, technological, legal and environmental conditions. Each principle builds on key findings from relevant disciplinary fields.

Principle 1: The Biocity as a forest
The Biocity has no net emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) but rather net absorption, as a forest ecosystem does (Harris et al. 2021). The Biocity interacts intentionally with trees and forests within and without the urban boundary to benefit from the goods and services they sustainably provide both during life and whilst incorporated within building materials.

Principle 2: The self-sufficient Biocity
The Biocity produces locally the derivative resources it needs for its operation. It produces energy through its own renewable systems, extracts water from its own natural basins or subsoils, and grows food and biomass (in the Biocity or the associated Bioregion) for its own population (Guallart 2014).

Principle 3: The multi-level Biocity
The Biocity must be organised so that each of its levels, from the subsoil to the ground, the main building and the roofs can develop different, mutually reinforcing functions and provide resources using elements of green, blue, brown and grey infrastructure to service the Biocity as a whole (Silva et al. 2020).

Principle 4: The healthy living Biocity
The Biocity is not just a collection of human settlements, instead people are understood to be part of an ecosystem. Since Biocities are necessarily urban areas that promote a wide spectrum of life (bios), human wellbeing and biodiversity are fostered by the same multi-scalar strategies as in natural ecosystems. This is achieved by using biodiversity to aid the provision of ecosystem services (ESS) (Brockerhoff et al. 2017).

Principle 5: The circular bioeconomy Biocity
Circular and evolutionary bioeconomies make the Biocity a vibrant, regenerative system featuring dynamic governance approaches which enhance interlinked hierarchies of activity. These are in a state of constant reinvention, and spawn ample aligned job opportunities through the use and development of local biobased materials and recycled materials to manufacture, maintain and improve the products required for the proper functioning of the Biocity (Silliman and Angelini 2012).

Principle 6: The low-mobility connected Biocity
The low-mobility Biocity promotes changes in the habits of its population. Through functional reorganisation of an urban area, all basic services necessary to live are made readily available within the radius of a 15-minute walk or cycle (Moreno et al. 2021). The connected Biocity enables individuals to exchange goods and information and enables society to function, flow and progress together in the most sustainable, efficient and ecological manner (Simard et al. 2012).

Principle 7: The urban-rural balanced Biocity
Soft, blurred, gradated, fluid and reciprocal boundaries between discrete natural ecosystems (ecotones) optimise health and function. Similarly, unbiased symbioses and dialogues between the urban Biocity and its corresponding rural Bioregion enable urban systems to work in harmony with the natural systems of their territorial environments. This balance thus fuels both the urban and rural economies, through the growth of thriving, regional biobased value chains (Yahner 1988).

Principle 8: The local culture Biocity
The Biocity is not only adapted to its local climate and environment, but also promotes a material, cultural and social identity based on its unique local history and traditions, via continuous exchange with the broader world through physical and information networks. Through an integrated governance ecosystem incorporating top-down and bottom-up decision-making with communal rights, local residents and communities are proactively engaged in self-determining the realities and networks of influence of their Biocity.

Principle 9: The timeless Biocity
In a mature Biocity, publicly accessible urban blue and green nature in the forms of forests, meadows etc. provide a diverse population of citizens with life opportunities. Such public and accessible places provide democratic spaces in accordance with the justice perceptions of all affected stakeholders and globally accepted standards for human rights. In doing so, they perpetuate the value of past human and natural heritage, as well as secure the infrastructures which will be required to meet the challenges of tomorrow.

Principle 10: The universal Biocity
Within the Biocity, biodiversity is prioritized not only in terms of sheltering a variety of species, but also in terms of maximising accessibility for all citizens, regardless of ability, age, race, ethnicity, religion, occupation, gender, income or education, whilst undermining forced displacement from gentrification. The involvement of citizens is natural at all levels. Ultimately, the universal Biocity will eliminate systemic and structural environmental inequalities and injustices.

3. Critical variables, overarching themes and key research fields

3.1 Barriers and drivers

The Research Agenda was developed in four steps, as explained in Annex 1 of this document. A first step in agenda development was the identification of critical variables, which are assumed to impact future pathways towards Biocities, both as drivers and/or barriers in the transformation process. These variables point to new areas for further necessary action and research. Through the analysis of the abovementioned principles based on the PESTLE[2] (political, economic, social, technological, legal and environmental) analysis framework, the following critical variables were revealed:

- Degrees of political stability – compatibility of political systems to principles; political commitment to principles; flexibility and adaptability of regulatory and legislative systems; degree of inclusion and participation of communities.
- Volatility of economic conditions internationally, nationally and locally; predisposition of communities and governments to expand value concepts beyond the monetary (such as biobased value chains).
- Willingness and capacity of urban communities to adapt to systemic changes required by certain principles; awareness of motivations behind transitions to various principles; migration patterns, the future of work, demographic trends.
- Development of necessary technological innovations; uptake of technology.
- Availability of natural resources; speed of anthropogenic impacts on planetary boundaries.

3.2 Overarching research themes

Based on the critical variables above, three scenarios for Biocities were developed to understand to what extent the Biocity goals may be reached. These scenarios revealed the following set of overarching research themes relevant to the transition to Biocities:

Reconciling different perceptions

Different stakeholders such as academics, citizens, governments and industry might have diverse and even contesting ideas, perceptions, and interests in the development of Biocities. The challenge is to integrate this diversity of stakeholder opinions into the Biocities vision. Therefore, it is necessary to set common grounds of understanding on the topics and concepts around Biocities and their implementation.

Part of the difficulty in setting common grounds is the *definition of the Biocity boundaries of influence*. This definition is challenging as it depends whether you take an administrative or systems-based perspective. Limits in the administrative realm are relevant in defining by whom and how Biocities are governed and, therefore, who takes leadership in the transition and funding for it. Whereas from a systems approach, the management of the urban-rural interface gains particular importance and does not necessarily coincide with the administrative limits. To implement the Biocities concept considering these different perceptions, it is necessary to collaborate with current (e.g., New European Bauhaus initiative) and emerging (e.g., One Health) initiatives that have at their core the same aim as the Biocity concept: to develop sustainable, resilient and liveable cities. The main questions to be investigated are: *How and to*

2 https://pestleanalysis.com/what-is-pestle-analysis/

what extent can Biocities contribute to reaching Sustainable Development Goals (SGDs), and conversely how will strategies and action plans for reaching the SDGs affect Biocities? How does the conceptual framework for Biocities relate to other sustainability models, and how does this contribute to identifying vulnerabilities in the transition to Biocities?

Interoperability between green space management and urban development

It is not an easy task to integrate the frameworks and conditions that must be considered and addressed from a green planning perspective in the traditional design and planning of cities. This includes the integration of systems and cycles at a city planning level. Moreover, the lack of interconnectivity – i.e. existing silo thinking – across stakeholders and disciplines adds difficulty to the processes. Urban planning plays a central role in implementing strategies to support urban biodiversity, reduce natural resource use and mitigate climate change, such as greening cities and managing land-use conflicts. This is also related to the challenge of urbanisation processes generating shortages of land, segregation, as well as social inequalities in green space access and its related benefits for human wellbeing. The integration of green planning, green management, urban planning and urban design offers the opportunity that silo planning is changed to intersectoral planning, where different departments coordinate each other to reach the common objective of Biocities.

Funding and implementation

A number of challenges need to be addressed to secure funding for a transition to Biocities. Overcoming these challenges is seen as an important prerequisite for the implementation of the Biocities concept. These challenges include a lack of information, tools, and standards for quantifying, measuring, monitoring, and evaluating the diverse processes that lead to a transition at a city level. They also relate to the lack of understanding of benefits and conflicts that the use of a specific strategy might generate in diverse dimensions, such as the contrasting impacts of selected building materials on climate change, biodiversity and the urban socio-spatial aspects. Further, the sources of investments into Biocity solutions need to be considered. A special challenge is how to involve the private sector. The use of modern technology in the transition to Biocities as well as its availability, accessibility and affordability as key elements of the conceptual framework pose many challenges that need to be addressed. Furthermore, challenges may vary and act differently across the different scales of cities. So, the question of how the Biocities concept can be applied at different scales of cities and within different geographical and socio-political contexts needs thorough investigation. By extension, two fundamental questions need to be answered: *Can all cities become Biocities? Are there growth limits to Biocities?*

Getting and keeping everyone involved

On the one hand, engagement and empowerment in terms of co-creation, co-production, co-planning and co-governance of different stakeholders and more precisely of citizens is needed at all dimensions and moments of the transition. Engagement and empowerment bring the challenge of thinking of different, more cooperative and inclusive approaches of governance. On the other hand, there is a disconnect between researchers, practitioners, developers and decision-makers that results in a need for cooperation. The disconnect between departments and levels of government that need to work towards common goals adds difficulty to this issue. The challenge is the integration of different disciplines and their corresponding stakeholders from the beginning into the decision-making and planning processes and throughout its implementation and evaluation. Fostering participation as proactive engagement and empowerment of civil society represents the main challenge. This requires adequate information on the process, new (co-) creative participation methods and monitoring actions.

Impacting culture and behaviour towards transformation

Cultural and behavioural change towards values, mindsets and attitudes that support the transition is needed. This needs to be considered in education at all levels and requires finding strategies and tools for adequate communication with diverse audiences. Clear communication with stakeholders is essential to bridge the information gap between experts and citizens, which might signify obstacles for fostering change.

3.3 Key research fields

In step 2 of the development of the Research Agenda (see Annex 1), five research fields were identified as a framework for concrete elaboration of the Research Agenda to facilitate the transition to Biocities (Figure 1):

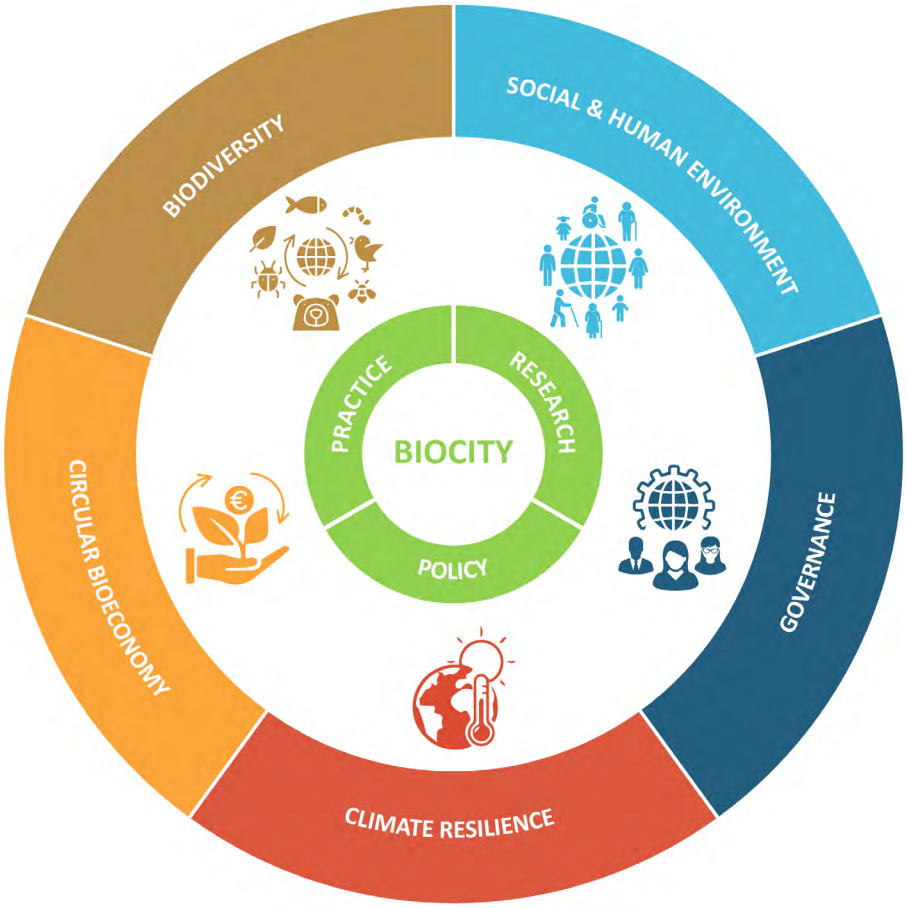

Figure 1. Research fields and branches of research used to develop the Research Agenda of Biocities. Source: own representation by the authors.

To elaborate on the challenges and perspectives specific to each of these research fields, the following branches of research, practice and policy were consulted in a series of webinars:

Circular bioeconomy: urban planning, urban design, architecture, materials sciences, forestry, environmental engineering, industrial ecology, ecological economics, econometrics, sustainability impact assessment, vocational education, innovation management, transition research and municipal governance.

Climate resilience: climate research, urban climatology, environmental sciences, urban hydrology, urban water resources, physical geography, greenspace planning & management, landscape architecture, urban design, architecture & built environment, forestry, biology, ecology, biogeography, transition design, resilience, social sciences and humanities.

Governance: environmental sciences, greenspace planning & management, greenspace planning and design, urban planning, forestry, urban forestry, urban greening, green space governance and policy, forest and green space goods and services, public involvement, social sciences and humanities.

Social and human environment: spatial planning, forest economy and health, sociology, forest administration, architecture, urban planning, forest planning and environmental economics.

Biodiversity: urban ecology, environmental sciences, biology, landscape ecology, biodiversity & conservation, sustainable development, urban planning, urban forestry and forest genetic resources.

4. Circular bioeconomy

4.1. Challenges and perspectives

The hazardous effects of fossil-fuel driven climate change and the depletion of fossil resources have been recognized (IPCC 2018; Meadows and Randers 2004). This demands that future cities should be based on renewable materials and renewable energies. To mitigate overexploitation of bioresources by the urban metabolism, such an urban bioeconomy should be complemented with circular economy principles. In the debate about the integration of emerging circular and bioeconomy approaches in urban practice and research, the following perspectives reveal important challenges that demand further research:

- From a **life cycle management perspective on biobased materials and products**, the increasing importance of *closing resource loops, slowing resource consumption, and enhancing the use of local biobased materials* is recognised to achieve a higher resource availability in cities and turn the built environment into a carbon storage facility. Challenging strategies that require further innovation and knowledge include the separation, consequent cascading and recycling of organic waste fractions; business models and information systems to enhance the urban mining and strategic sourcing of biogenic materials (e.g., construction wood) from stocks in the built environment; a reduction in food waste and the prolonging of building service lives through durable materials and maintenance; as well as the design of products for disassembly and a dematerialisation of construction with wood and other biomass-based materials.
- A **sustainable development perspective** highlights the importance of *identifying and promoting those strategies that maximise social, human and environmental outcomes*. Not all strategies associated with the circular bioeconomy necessarily contribute to sustainable urban development that supports a wide spectrum of life. Challenging from this perspective is the balancing of different capitals (e.g., natural, social, human) at different scales (e.g., urban, national, global) and the design of suitable guidelines.
- From a **cultural change perspective**, habits and mindsets of citizens and public institutions are key factors to guide *urban consumption patterns towards local produce*. Simultaneously, cultural change in supply and manufacturing is necessary to establish *circular design thinking* and to *ensure bioresource management aimed at maximising ecosystem services*. Strategies that might catalyse such change, but which require further investigation, include participatory planning, citizen science and engagement, communicating the everyday benefits of a circular bioeconomy at all levels, educating manufacturing professionals, setting standards, leveraging green public procurement and showcasing full value chain processes in cities.
- In terms of **spatial sustainability,** urban planning and design, architecture, urban agroforestry, and regional interconnectedness play a central role in implementing circular bioeconomy strategies such as *greening cities, managing land use conflicts, and introducing local biobased products into the market.* Research from this perspective should adopt a holistic approach integrating a portfolio of strategies and effects across the urban-rural interface to unveil interconnections and to clearly define the boundaries of a Biocity.

4.2. Knowledge areas and research gaps

Conceptual research – As the idea of a circular bioeconomy is only emerging in the context of cities, a clear definition and common vision is still to be elaborated by research and practice. This entails the identification of major actors that can drive the transition as well as the main target systems and related urban agendas such as climate action or local development policy. In this context, the conceptualisation of circularity by different actors and for different biomaterial value streams such as food production, organic

waste management and wood use is a major knowledge gap, especially when it comes to which new perspectives the circular economy framing can add to existing conceptualisations in bioeconomy sectors and how this might fuel further innovation.

To what extent are circular economy and bioeconomy visions already integrated in urban governance? How can an integration of the two approaches be fostered?

Social sciences and innovation research - A major gap in relation to the circular bioeconomy discourse is that of social innovation. Whereas technical innovation is well advanced, particularly in relation to biomaterial application and cascading, a lack of social system approaches to the circular bioeconomy is inhibiting the leverage of these innovations. Social innovations are needed, for instance, in the reconfiguration of social practices to encourage organic waste separation at the source, to maintain existing building stock, and to increase and foster the acceptance, understanding and adoption of solutions such as wood construction or material inventories. Future research should identify the desired functionality of the solutions, stakeholder values, and suitable communication tools and narratives.

Which soft infrastructures (practices, cultures, relationships and networks) advance circularity in the urban bioeconomy?

Civil engineering and architecture – Engineering and architecture have generated significant knowledge on the creation of new products from waste and the application of biobased materials. Further research is required to disseminate and concretise design for disassembly in the biobased construction sector, and the development of intelligent, accessible and secure inventories of distributed materials. Further, exploitation of organic waste fractions from unseparated waste is still a challenge to solve in order to access the basis for any further biorefining.

How can circular practices such as design for disassembly be adapted to and scaled across the biobased construction sector?

Science and data – The availability of data on urban material stocks and flows is crucial to advance circularity in cities. Material inventories such as building material passports would significantly improve the ability to connect material demand and supply, while improving the ability to assess the impacts of circular bioeconomy strategies.

How can intelligent, accessible and secure inventories of distributed materials and flows be developed to assess and manage complex, cyclical resource flows in cities?

Modelling and impact assessment – Impact assessment is crucial to prioritise those strategies and policies that maximize social, human and environmental outcomes. While current impact assessment models mainly focus on the global environmental and economic dimension, the elicitation of tangible local scale impacts such as employment, public health and urban land use is just as important to advance the adoption of the concept in municipal governance. Further, current models lack granularity to assess the impact

on different stakeholder groups, and the effect in different socio-economic and geographical contexts. Fundamental research as well as integration in impact assessments is required to balance evaluations of resource productivity with other ecosystem services including biodiversity, soil health or carbon sequestration. Assessments are especially required of the effectiveness of different municipal policy levers including those that aim to induce cultural change.

How can impact assessments holistically represent evaluations of resource productivity together with other ecosystem services including biodiversity, soil health, or carbon sequestration?

How can positive and tangible impacts on society be integrated in multi-impact assessment methods such as life cycle assessments?

Methodologies and standards – An actor-centric standardisation of the system boundaries of the urban material and energy metabolism particularly with regards to the urban consumption and production hinterland is indispensable to set the scope of action. Such a standardisation of the urban boundary would enable the generation of consistent and operational approaches for common quantitative impact assessments.

How can we standardise the system boundaries of a city and associated value chains to generate consistent and operational approaches for common quantitative impact assessments?

5. Climate resilience

5.1. Challenges and perspectives

Recognition and action on planetary boundaries (Stockholm Resilience Centre 2022) and the complex of challenges brought on by anthropogenic activity is the foundational driver of the field of climate resilience. The Biocity of the future is conceived as an accelerated response to this problem, specifically the problem of climate change. In discussions about both the impact of climate change on cities, and the impact of cities on climate change, the following perspectives emerge as important threads for future research:

- From a **mitigation perspective**, there is an acknowledged urgency for *lowering GHG emissions and energy consumption in cities*, as well as for *developing integrated carbon storage measures in and around urban centres*. In addressing these challenges, revisiting of approaches like Earth System Sciences as first proposed by von Humboldt in *Essai sur la géographie des plantes* in 1807 can be valuable, as well as the elaboration of further knowledge around strategies and measures such as developing greenspaces in and around urban centres to absorb much of the emissions a city produces, sourcing energy, water, food and building materials locally, and mobility efficiencies which lead to critical reductions in GHG emissions.
- From an **adaptation perspective**, challenges revolve around *physical measures to combat rising temperatures and heat stress, dealing with extremes in precipitation patterns causing droughts and flooding, and coping with sea level rise causing coastal erosion and flooding of low-lying areas*.[3] A guiding framework for adaptation measures is needed that considers different types of urban infrastructures in which various climate change-related cycles play out (and can be influenced). These include (1) green-blue infrastructures: private and public greenspace – in particular the urban forest – and all natural and built environment water systems and features; (2) grey infrastructure, including transport systems and elements, but also structures and buildings; and (3) the social infrastructure of cities, understood as the intangible system of practices, cultures, relationships and networks. Added examples of research attention in this perspective include strategies and measures linking built environment features both horizontally and vertically to optimize mitigation effects.
- A **resilience perspective** highlights the need to *help urban communities and their spaces, places and networks to co-exist with a natural environment undergoing radical change*, assuming that change will occur even if the most optimistic scenario for reduction of emissions is achieved. Resilience is understood as the agility of urban societies and ecosystems to effectively adapt and evolve in response to calamities. In addressing these challenges, the Biocities outlook proposes the adoption of existing resilience perspectives as well as the *notion of bio-resilience*, to include the resilience of other species found in cities. Other themes emerging in this perspective deserving investigation include fostering health and wellbeing through multi-scalar strategies, linking urban and rural economies to enable shock-resistant and responsive biobased value chains, integrated governance ecosystems enabling top-down and bottom-up decision-making which responds to change effectively and equitably, and accessible urban green-blue infrastructure building on existing green-blue networks particular to each city. At the same time research efforts need to be focused on *renewing human-environment and human-nature relationships*, with the intention to aid climate change mitigation through awareness and behavioural change.

3 Adaptation measures are considered necessary (and increasingly urgent) as, despite international commitments to eliminate net global greenhouse gas emissions by 2050, their concentration will continue to rise in coming decades, impacting global and local climates and weather patterns.

5.2. Knowledge areas and research gaps

Science and data – Adequate data on biophysical and biogeochemical[4] cycles in cities which form part of the climate change issue is a first and major research area. Data collection quantifying biophysical and biogeochemical cycles in cities is limited and, in most cases, non-existent. Where initiatives exist, information is rarely validated or correlated with data from other cities. More uniform and precise data on different biophysical and biogeochemical pathways in relation to built environments, at different scales, is needed. A specific knowledge gap also arises around (data on) the impact of green infrastructure such as green space and the urban forest on urban biophysical and biogeochemical cycles and depending on the environmental context (i.e. ecoregions). Leading on from here is the question of the value of related green-blue infrastructural elements such as public open spaces, water features, green facades and green roofs. Data on green-blue space on private land is also necessary. From a data management perspective, interactive databases and data platforms need to be developed and maintained so data can be stored, analysed, managed and disseminated.

What specific impact does green-blue infrastructure (urban forest, public open spaces, private gardens, green facades and roofs, urban water bodies) have on biophysical and biogeochemical cycles?

Modelling – A complementary gap in research is that of modelling tools. The majority of tools used to model biophysical and biogeochemical cycles are not tailored to the urban context or are otherwise outdated. New tools are needed to model various cycles and simulate changes in cycles at the tree/building, neighbourhood, district and city scale. The variability of climate change is an added problem, and models need to capture this variability at the city scale. Development of tools and modelling with microclimatic data is also needed. On the response end of the equation, more detailed physical models are needed, complemented by precise data. Specific modelling tools, such as those simulating the interrelationship of greenspace and water during heatwaves can be invaluable.

What kinds of modelling tools can be developed to simulate the impact of various components and configurations of greenspace on biophysical and biogeochemical cycles at building, neighbourhood, district and city scale?

Spatial planning and design – Knowledge gaps around climate change in urban territories demand spatial design research and innovation at various scales, including:

- *Element* (building, garden, tree, street, canal scale)
- *Area* (building complex, tree ensemble, neighbourhood, park, watercourse scale)
- *Network* (urban tissue, green ensemble, urban forest, water system scale).

These studies should elaborate spatial-physical innovations, from generic principles to specific typo-morphological, (bio)geographic and (micro)climatic conditions of cities. Input for these studies needs to come

4 Biophysical cycles include **atmospheric cycles** in relation to urban territories and mitigation challenges such as carbon emissions, energy consumption and sequestering, **hydrological cycles** in relation to urban territories and adaptation challenges such as drought, extreme rainfall and flooding, and **heat cycles** in relation to urban territories and adaptation challenges such as UHI and heat stress. A fourth cycle – **air pollution** may also be considered as part of a biophysical cycle. Biogeochemical cycles are pathways by which chemical substances are exchanged through and between the **biosphere, lithosphere, atmosphere** and **hydrosphere**, namely **carbon, hydrogen, nitrogen** and **oxygen,** and to a lesser extent calcium, mercury, phosphorus, selenium, iron and sulfur.

from a combination of earth, life and building science researchers. In relation to physical infrastructures, research gaps also exist in the linking of urban metabolic cycles and the urban layout to biophysical and biochemical cycles. Further research topics are the relation between above-ground and below-ground spaces.

How can interactions between earth, life and building sciences be better fostered in the design of new built environment 'templates' which mitigate greenhouse gas emissions and adapt the city to climate change?

What kinds of new built environment 'templates' can be developed which mitigate greenhouse gas emissions and adapt the city to climate change at different scales?

Engineering and building technology – A critical realm for research on climate change mitigation, adaptation and resilience in (bio)cities is the interrelationship of biophysical and biogeochemical cycles and grey infrastructure (understood here as not only transport infrastructure but also urban building stock). In terms of existing buildings, we need to better understand the interaction between biophysical and biogeochemical cycles and building 'technology' (facade, interior, structure etc) as well as with their day-to-day functioning and maintenance. In terms of building replacement and expansion, we need to review the raw materials, supply chains and construction processes in relation to their impact on biophysical and biogeochemical cycles. Much is becoming clearer in regard to differences in GHG outputs of various materials, and continued fundamental, applied and technical research is needed to substantiate these impacts further and to innovate related supply chains and construction techniques and processes.

What are the impacts of various raw materials, supply chains and construction processes on biophysical and biogeochemical cycles in cities and how can these be reduced?

Policy and governance – There are still many questions on what type of policies are crucial to avoid the catastrophic impacts of climate change: those promoting a move to renewable energy for electricity and transport, or those building nature-based systems into cities. This demands further research on how different policies and governance strategies can help to reach zero-carbon goals in cities, and at the same time promote adaptation and foster resilience. Particular attention is needed on the issue of risk management (fires, storms, floods, pests) and the need for adequate planning and greenspace management to deal with these risks.

What are the impacts of contrasting policy frameworks – specifically nature-based vs high-tech frameworks – in mitigation and adaptation goals around climate change?

Which kind of soft infrastructure (e.g., practices, cultures, relationships and networks in both urban communities and administrations) can mitigate socio-economic impacts and disservices of climate change?

Historical and contextual research – Realising adaptation measures and community resilience demands an in-depth understanding of the green-blue, grey and social infrastructure particular to each city. An understanding of the specific built greenspace, the 'DNA' of cities, is a prerequisite for spatial design research and innovation.

How can we realise mitigation and adaptation measures which take into account the existing green-blue, grey and social infrastructure particular to each city?

Monitoring and impact assessment – In the Biocity of the future, where green-blue and grey infrastructure is central to climate change mitigation and adaptation, it is vital that vegetation survives extreme weather events such as heatwaves, droughts and floods. These challenges require assessment, control studies and field research on the effects of various conditions on individual taxa and vegetation ensembles in relation to different urban microclimates, typo-morphologies and sub-surface conditions. These insights need to be matched by research and the development of responses to identified problems in these areas. The development of inventory tools to map and monitor green infrastructure at different scales is a must, and these need to encompass both public and private lands. Another issue for further studies is related to ecosystem services and which are the most important for cities depending on local, social, economic and environmental conditions and stakeholder perceptions.

What are the impacts of climate change on urban ecosystem services and which ecosystem services are most important for cities?

6. Governance

6.1. Challenges and perspectives

The holistic, transboundary nature of Biocities requires new forms of thinking about municipal governance, planning and participation. The need to go beyond silo thinking and to identify adaptable, resilient and co-creating modes of governance is driving research in this field, as well as the need to enhance cooperation between governments, private actors, planners, scientists and civil society, as well as their capacity to reimagine the city. In discussions about a transition to Biocities, the following perspectives emerge as important threads for future research:

- From a **governance perspective,** challenges revolve around *integrating different disciplines and enhancing collaboration between different departments* in a cross-disciplinary approach. In this context, the provision of capacity building at all levels – from institutional capacity to capacity of co-learning – is crucial. A further challenge is to ensure that the concept of Biocities is conceived as a global cross-sectoral model and that it is applied considering all or at least most principles proposed. In this context it is crucial to ensure inter-governmental cooperation to enable the implementation of the Biocities concept. Therefore, *reforming current investment mechanisms and ensuring the maintenance of necessary capacities* for the transition to Biocities will be a further challenge. In this context it will be important to find ways of (re)funding providers of services such as green spaces. Finally, proposing simple frames to tackle the complexity of the urban socio-ecological system will be a challenge.
- A **planning, design and management perspective** highlights the need to *rethink the way cities are planned* beyond current practices so that resilience, sustainability and quality of life are the cornerstones of urban planning, design and management. Therefore, *adapting regulations and allowing interconnections between different disciplines* (planning, design and management professionals) will be necessary, as well as adequate capacity building to secure the proper implementation of the concept. A further challenge from this perspective will be the need to secure land for the implementation of the Biocity. Finally, it highlights the importance of avoiding social inequalities at all levels of city planning, design and management in terms of technology use and access and gentrification.
- From a **participation perspective,** challenges revolve around the best methods to *involve a wide range of stakeholders and to integrate their perspectives and their expectations* into the vision of Biocities and the transition process. This requires a proper understanding of the role of these stakeholders in the governance process, and of the ways to raise their awareness of the Biocities concept, providing them with the necessary information and with financial and practical advice, and empowering them by giving self-respect. Additionally, understanding the needs of all stakeholders and addressing the aspect of long-term thinking in terms of environmental justice, ethics, and the recognition of the long-term benefits of Biocities will be crucial. This necessitates the integration of minorities in the participation process in a fully inclusive process. A further challenge is ensuring collaboration between all stakeholders involved (e.g., consultants, experts and implementing partners) at the different levels of the transition. Finally, preventing organisations (e.g., enterprises, NGOs) from becoming dependent on local governments pursuing the transition to Biocities will be a challenge to be tackled.

6.2. Knowledge areas and research gaps

Governance and Politics – Understanding the role of different stakeholders, such as the private sector and policymakers in initiating the transition to Biocities is a first and major knowledge area and research gap, as it is a cornerstone to support the transition to Biocities. This also entails understanding the role

of political leadership and the role of authorities at various scales and going beyond current (municipal) silo thinking. In this context, a further major research gap is understanding new forms of governance (such as adaptive and resilient governance approaches, co-governance, green hubs, community arrangements) supporting the transition to Biocities. On top of this, further research gaps include identifying ways to align and negotiate (political) agendas of diverse stakeholders supporting and hindering the transition and aiming to develop a common vision of Biocities, as well as finding ways to mainstream the concept of Biocities in political and professional discourses. To achieve this communication and narrative research will be necessary.

How can we align and negotiate agendas of diverse stakeholders towards a common understanding and vision in the transition to Biocities?

Who are the most relevant actors that can lead and initiate the transition to Biocities?

Which role do different actors (e.g., municipalities, businesses, citizens and national governments) play in this process?

Which factors foster and hinder cooperation of stakeholders towards Biocities?

Which conditions need to be in place to ensure that governance approaches balance trade-offs between different capitals (e.g., natural, social, human), different ecosystem services and different groups of people?

Which governance and planning structures can support mutual benefit between urban, sub-urban and rural areas?

Planning, design, management and monitoring – Major research gaps in planning, designing, managing and monitoring Biocities are understanding the interconnections between disciplines and avoiding social inequalities. This will require analysis of the types of policy instruments that are necessary to foster and support the transition, as well as understanding the policy levers that are most effective in ensuring the success of the Biocities concept. Additionally, land property rights and prices and the adequate recognition of the environmental role of agriculture in terms of food production and provision of ecosystem services in peri-urban areas will also favour the transition to Biocities. This will require understanding of their potential for the provision of nature-based solutions and green infrastructure.

Which policies are most effective to support the transition to Biocities?

How can we improve the integration of social and experiential (or socio-ecological) information in urban planning?

How can cities be planned in such a way, that inhabitants and nature are complementary and work together for benefiting both?

Which capacities (e.g., local authorities) need to be in place for the implementation of the Biocities concept within 20-25 years?

Finance and funding – Identifying ways to (re)fund local authorities and municipalities for delivering Biocities solutions (e.g., payments for ecosystem services) will be crucial for successful implementation. Thus, involving markets, financial institutions and the private sector with new financing models for planning and managing Biocities will be relevant. This will require an understanding of the role that the private sector can play in investing, implementing and supporting the transition to Biocities.

What are ways to (re)fund local authorities for delivering Biocity solutions such as urban green space?

Participation research – To foster the transition to Biocities, a major knowledge gap is understanding new and diversified and inclusive modes of participation. Additionally, finding enabling factors to unite people in a shared goal will be necessary, including finding terms shared by different disciplines and stakeholders which allow for a common mindset.

Which instruments (e.g., communication) ensure proactive, fair and transparent (informal) participatory procedures?

Science-policy interface – The transition to climate-proof Biocities and resilient urban communities calls for next-generation methodologies incorporating citizens, industry, science and administrations. These innovations require an academically developed design approach that is human-centred, iterative and integrated, in order to go back and forth between technological potential and human necessity. Specifically, new frameworks are required for planners, designers and greenspace professionals to benefit from values created by new technologies.

What type of platforms are necessary to pair necessities (e.g., practical knowledge) of stakeholders and share experiences and solutions across cities?

To what extent do transdisciplinary projects with public and private institutions increase the applicability of scientific knowledge in practice?

7. Social and human environment

7.1. Challenges and perspectives

The topics discussed in the Research Agenda are all embedded in the social and human environment, and thus the likelihood of the transition to a Biocity is bound to the successful change in the social system. The most important challenges of the transition to the Biocity are related to urban densification and risks of overcrowding, the need for more participation and involvement of inhabitants in planning and decision-making, as well as the aim to foster human health and wellbeing.

- From a **socio-cultural environment perspective**, challenges arise concerning the growing *urbanisation and densification of cities* that leads to a shortage of living and recreation space in and around cities. This has an effect on housing prices and consequently leads to segregation and increased inequalities (e.g., unequal access to different resources), deeper social and economic divide, and poverty. Further, current consumption trends (e.g., veganism, consumption of local food, urban gardening) linked to urbanisation and to food security and food sovereignty in the context of densely populated cities lead to challenges in land use policy, urban planning and design. "*Digitalisation*" and digital innovation (e.g., advances in social media, AI and digital connectivity) present both a challenge and an opportunity for the city of the future. Through migration and immigration caused by the climate crisis, cities become drivers in terms of lifestyles, values and attitudes. The *spectrum of diversity* is a challenge that cities have to tackle, as it needs adaptation of processes (e.g., translation of crucial documents for migrants). Finally, uncertainties concerning future events have severe impacts on society at different levels, and this poses challenges to both policymakers and society in general. Understanding how societies can *learn to cope with uncertainties* would be necessary.
- A **participation and involvement perspective** highlights the need of *participatory approaches* that are inclusive and methods that aim to propose a comprehensive stakeholder analysis, as well as ways of establishing co-production and two-way communication. Additionally, it highlights the necessity for *improved channels and tools of data collection* aiming for higher representativity in terms of *technology and digital innovation* in participative processes (e.g., social media, participatory GIS, online surveys etc.) to engage different stakeholders. Here, the challenge will be to determine the necessary *level of participation* for projects at different scales that are not costly, time-consuming, and that do not require special skills of planners.
- From a **health and wellbeing perspective**, challenges revolve around the *integration of more green infrastructure* in cities (as a way to reduce CO_2 emissions as well as air and soil pollution, improve air quality and walkability, foster private gardens for healthy food), the quality of the available green areas and equal access to green space. In this context providing *good transport infrastructure to promote physical activity for all* types of citizens in terms of abilities and disabilities will be crucial. Finally, a further challenge is to integrate health and wellbeing in *guidelines and regulations* for city planning. Simultaneously, a further challenge is the importance of defining *clear and legally binding indicators, as well as implementing more binding legal acts* concerning the amount and quality of green spaces, which affects the air quality in cities necessary to foster health and wellbeing of all citizens, particularly children.

7.2. Knowledge areas and research gaps

Innovation and transition research – A major knowledge gap is understanding citizens' attitudes and values and how they could be influenced in terms of interventions to foster environmental awareness. In this context, research on how to more effectively integrate citizens' attitudes and perceptions in the planning process through socially innovative and co-creative participatory processes in terms of research on new means of communication, tools and instruments (e.g., citizen science, urban living labs) will foster the transition. The concept of socio-technical systems in the context of sustainable urban development and smart urban development is an important knowledge area to foster the transition to liveable Biocities. The role of innovation and technology in general and digital innovation specifically are fields that need to be further researched.

How can we create the necessary awareness and willingness to change among stakeholders in order to make a participatory transition to the Biocity successful?

How can we reach stakeholders (e.g., silent voices) that benefit from a Biocity but are not easily identifiable and reachable through classical communication tools?

Inequality research and inclusiveness management – Major knowledge gaps are identifying ways to reduce inequalities in order to achieve green and socially just cities, as well as to provide inclusive growth and sustainable communities. Research on social movements related to sustainable urban development, sustainable lifestyles, urban food production, food security and sovereignty will foster the transition to sustainable cities. In this context, identifying tools and processes to facilitate the creation of Biocities is a further research gap. Understanding ways to involve a multitude of different stakeholder groups in a participative democratic process, proposing new governance approaches, monitoring and assessment of the processes will be crucial in fostering the transition to Biocities. However, the transition to Biocities (e.g., urban forest areas) could also bring along disservices if these are not adequately planned or managed, leading to danger to citizens and fear. In this context security issues are a further knowledge area to be considered.

Which housing policies effectively mitigate an exponential rise in housing prices as a consequence of the transition to more liveable cities?

How can Biocities cater to all citizens' needs and correct inequalities, by for instance, policies for affordable housing and providing ecosystem services through urban green space management equally throughout the city?

How can we foster inclusive and sustainable planning from the Biocity perspective that respects the needs of all people including persons with disabilities, young people with mental health problems and refugee groups?

Health and human wellbeing – In the context of urban densification, aspects of health and wellbeing require a stronger research focus, for example on environmental quality aspects such as noise and air pollution. The effect of both green and blue elements in the city should be included in future research with a stronger emphasis on the indicators of the impact of the urban environment on human health and wellbeing. The ongoing global pandemic of COVID-19 has highlighted the importance of research in the

epidemiological impact of the urban environment specifically in the context of population density and overcrowding, access to infrastructure (blue and green spaces, clean water and sanitation), and the overall environmental quality. Moreover, the quality of the indoor environment is equally relevant for human health and wellbeing and requires further examination.

What are the vulnerabilities associated with health in cities and how can these be addressed?

How can we ensure systemic integration of health and wellbeing in the urban planning system? For instance, how can we promote the use of Health Impact Assessment Plans for all city issues?

Which measures are effective in controlling and managing negative health effects of nature (zoonosis etc.) including green space management, protective clothing, vaccinations, information?

Behavioural and social change research – A major knowledge gap exists in relation to 'soft' infrastructure (practices, cultures, relationships and networks in both urban communities and administrations). Areas for investigation include developing tools and pathways for change, changing habits and practices in mobility, consumption, recycling and circularity, new synergies between administrations and community groups, and identifying socio-economic impacts and disservices.

How can we encourage and enable greater care and responsibility towards nature across all societies?

Spatial planning and design – Proposing innovative management approaches for green spaces in cities, providing a maximum benefit for residents and lowering the implementation and management costs, while avoiding damage to ecosystems (trade-offs between different ecosystem services) is a further relevant knowledge area. Research is needed on indicators showing the effects of green spaces on health and wellbeing and proposing binding legislation concerning these effects (defining e.g., a minimum of green space a city should provide). Inclusive planning and the necessity to have more specific instruments and procedures to integrate the SDGs and health issues in city planning is another relevant gap.

What are the opportunities that urban environments offer to society?

What is the role of mobility in this context?

How can these be improved when considering health and human wellbeing?

8. Biodiversity

8.1. Challenges and perspectives

Biodiversity is a key element of future Biocities. The need to conserve biodiversity is well recognised (CBD 2021). In discussions about the importance of biodiversity for the transformation to Biocities, the following perspectives emerged as important threads for future research:

- From a **stakeholder's perspective,** a central challenge is to *reach consensus on the understanding of biodiversity in a city*. Varying understandings of biodiversity make it difficult to reach a consensus about which biodiversity we want to preserve. Here, in particular, the awareness and understanding of biodiversity and its connection to ecosystem services by citizens plays a major role. A challenge in this context is a non-biased understanding of biodiversity which does not prefer certain more benign species over others. Therefore, communication and knowledge transfer are key elements to raise awareness about how natural solutions work as a strategy for biodiversity conservation and how they can be improved. Citizen involvement and awareness building should start in childhood, and not only focus on adults and public institutions with legislative power. Cultural influences on the understanding of nature and biodiversity in specific, levels of acceptance from citizens and how people appreciate nature-based solutions as a management approach to increase biodiversity needs further investigation. In order to apply any actions to protect, manage, and restore natural or modified ecosystems, citizen science and transdisciplinary approaches are needed.
- From a **policy perspective**, *monitoring and measuring the effectiveness of nature-based solutions on biodiversity* is crucial. However, conceptual clarity on nature-based solutions is still missing. Nature-based solutions could well be inspired by nature without benefiting biodiversity. For instance, a bioreactor based on algae is an effective carbon storage, but is not directly improving local biodiversity. At the same time, one strategy could enhance biodiversity in one area (e.g., roof-top garden can increase flora and insect diversity) but simultaneously create disservices in another one (e.g., breeding problems of birds in roof-top gardens). Further, the impact of nature-based solutions on biodiversity and ecosystem services could not only be direct. For, instance while a bioreactor itself has no influence on local biodiversity, its function as a space-efficient carbon storage might save land elsewhere for biodiversity conservation. Therefore, it is important to quantify both services and disservices from ecosystems when developing and implementing nature-based solutions. Overall, the application of nature-based solutions is not only influenced by their effectiveness but also by limitations such as acceptance by government and citizens, finance, scarcity of land and collaboration between stakeholders.
- From an **ecological perspective,** it is important to *preserve and improve connectivity between species within a cityscape* to support ecological and genetic links between cities' flora and fauna. Creating a stronger foundation for the ecosystem that supports biodiversity in general can foster functional connectivity between the city and the peri-urban and wider landscape in an urban-rural-nature continuum. Quantification of biodiversity and its habitat is not just a simple count of the richness of flora and fauna but must be considered in the urban context from a functional point of view that measures how different types of ecosystem services are linked to ecosystem structure and functions.
- From an **interdisciplinary perspective,** the *interoperability between urban biodiversity, landscape ecology and urban planning* at any governmental level is challenging. For instance, small municipalities usually lack ecology departments, but big cities have many different departments, which would need to collaborate to implement biodiversity strategies. Here, another big issue is how to homogenize interpretations from academia, practice and administration about biodiversity. In addition to this, there is a lack of connection between researchers and practitioners, and there is a need to transfer scientific knowledge and insights into practice, which is often impacted by economic or legislative constraints.

8.2. Knowledge areas and research gaps

Conceptual and fundamental research – The concept of biodiversity requires a holistic approach. To understand blue-green infrastructure and its relation to biodiversity enhancement (aquatic vs terrestrial realms) further research needs to be conducted. This will include understanding the grey and green environment of cities. This will enable the elaboration of the concept of biodiversity in the context of this new paradigm of Biocities. A major research gap is the identification of key species or groups of species that foster biodiversity. Furthermore, the purpose, benefits and side effects of applying concepts such as nature-based solutions need to be clear, as well as the notion of "greening" a city, as these are currently not fully aligned with biodiversity conservation. There is a further need to improve the connectivity between green spaces in an urban setting to ensure functioning ecological networks, e.g., by connecting fragmented urban landscapes and ensuring viable populations of species (gene pools).

What are the various ontological frames current in understanding (urban) nature, (urban) landscape and (urban) biodiversity, where do they come from, and which are the relevant (and effective) pathways to move forward with, in respect to the concept of Biocities?

How do cities and urban biodiversity interact with non-urban biodiversity patterns and principles and what kinds of complementarities and crossovers can exist?

What are generic theories, principles and guidelines for biodiversity (in Biocities) and what are city-specific ones?

What are the "good" and "bad" species or group of species fostering/hindering urban biodiversity?

How can we create, model and implement (genetic) connectivity between species in fragmented urban landscapes?

Historical and contextual Research – Realising biodiversity demands an in-depth understanding of the green-blue, grey and social infrastructure particular to each city and how it supports flora and fauna in multiple ways and scales. An understanding of the biodiversity 'DNA' of cities is a basis for future spatial design research, and implementation of a biodiverse Biocity.

How can we use existing patterns, features and principles within the existing green-blue, grey and social infrastructure of a city to enhance and elaborate a Biocity 2.0?

Monitoring and impact assessment – Currently there is not enough information about how much biodiversity exists in urban environments, which is why spatial modelling and mapping of biodiversity and habitats of cities should be further improved. To measure connectivity between species in fragmented urban landscapes, genetic models are required. Furthermore, assessment of ecosystem services and disservices need more research as well as the restoration, evaluation and monitoring of urban biodiversity focusing on how it changes with space (e.g., urban to rural gradient) and time (e.g., seasonal, annual, decadal). Additionally, ecosystem disservices could also be related to a biodiversity increase that is conflicting with human wellbeing. These conflicts need to be investigated and avoided through innovative and holistic planning approaches. A major research gap can be found in aquatic biodiversity which is the most undervalued, poorly surveyed and underreported area of biodiversity. There is more research required on how this field relates to urban green spaces and urban infrastructure.

How can ecosystem services and disservices from biodiversity be better assessed?

What are possible conflicts between biodiversity conservation and ecosystem services provisioning (human wellbeing)?

What is the effect of blue infrastructure on biodiversity?

Strategies and concepts – Research is needed to develop strategies for elaboration and uptake, for instance by understanding cities as novel ecosystems with people as a nexus in that ecosystem. By extension, how Biocities can be conceptualized, planned and managed as connected environments forms a parallel hiatus in the body of knowledge.

To what extent are positive rewards or incentives such as "green certificates (green points)" effective to encourage the private sector and the public to maintain and develop green spaces?

Which strategies can mitigate the impact of urban climate and morphological conditions on individual taxa and vegetation ensembles?

Science-policy interface and participation – There is a lack of a governance framework connecting science, citizens, and government planners in urban biodiversity conservation and management. The role of different stakeholders (citizens, scientists and policymakers) to protect or foster biodiversity through individual and collective actions needs more research in order to improve collaboration. In this regard there is a gap in how issues of concern are addressed differently from the point of view of academics and citizens. Usually, the former tend to think about high impact issues such as climate change, however, local interventions can be achieved by the community. To involve the community in city planning and design processes, methods such as charrettes (intense participatory planning processes) need to be applied, but it is important that the long-term benefits of preserving biodiversity are known by people and policymakers.

How can we increase awareness of the long-term benefits of biodiversity conservation and the problems connected with biodiversity loss among citizens and policymakers?

How can we design, value and implement conservation strategies that close the breach between theory and practice?

9. Priorities and cross-cutting research needs

To foster the transition to Biocities it is necessary to define the priority and cross-cutting research needs to be addressed in the coming years. Table 1 proposes a selection of priorities and cross-cutting research needs that were identified as relevant for this transition.

Table 1. Selected priorities and cross-cutting research needs allowing the transition to Biocities

	Governance	Circular bioeconomy	Climate Resilience	Social and Human environment	Biodiversity
Governance		Identifying sustainable practices, policies and SDG-action plans that effectively support the emergence of Biocities			
Circular Bioeconomy	Developing social innovations that support technical innovation and the transition to circularity		Understanding climate mitigation potential of circularity and technical innovation in engineering and building technology.	Identifying ways to make the urban circular bioeconomy truly inclusive and equitable in terms of social, economic and spatial aspects	Assessing the effects of circular strategies on biodiversity.
Climate Resilience	Identifying types of policies that are crucial to avoid catastrophic impacts of climate change.	Understanding the effect of climate change on bioeconomy resources.		Assessing the interlinkages between resilience, human health and biodiversity and identifying the levers to provoke sustaining loops.	Identifying strategies to mitigate the impact of urban climate on urban ecosystem.
Social and Human Environment	Identifying adaptive and co-creating governance models that promote inclusivity and social equity.	Developing social innovations and identifying drivers of cultural change to foster circular and sufficient practices.	Identifying soft infrastructures changing habits and practices in areas of mobility, consumption and circularity.		Identifying approaches to better assess services and disservices offered by biodiversity in urban ecosystems.
Biodiversity	Determining levers to raise the awareness of long-term benefits of biodiversity conservation among citizens and policymakers.	Balancing the impacts of circularity on biodiversity and other ecosystem services such as resource productivity.	Monitoring and assessing the impacts of climate change on the urban ecosystem.	Mapping and investigating the linkages between biodiversity and human wellbeing.	

10. Implementation

Implementing the research agenda of Biocities will require transnational and intersectoral coordination and cooperation. This assumes strong commitment from different stakeholders (from researchers to policymakers) at different levels (local to international) of implementation. To facilitate the transition, we propose the following five pathways for how the research agenda could be implemented (Figure 2).

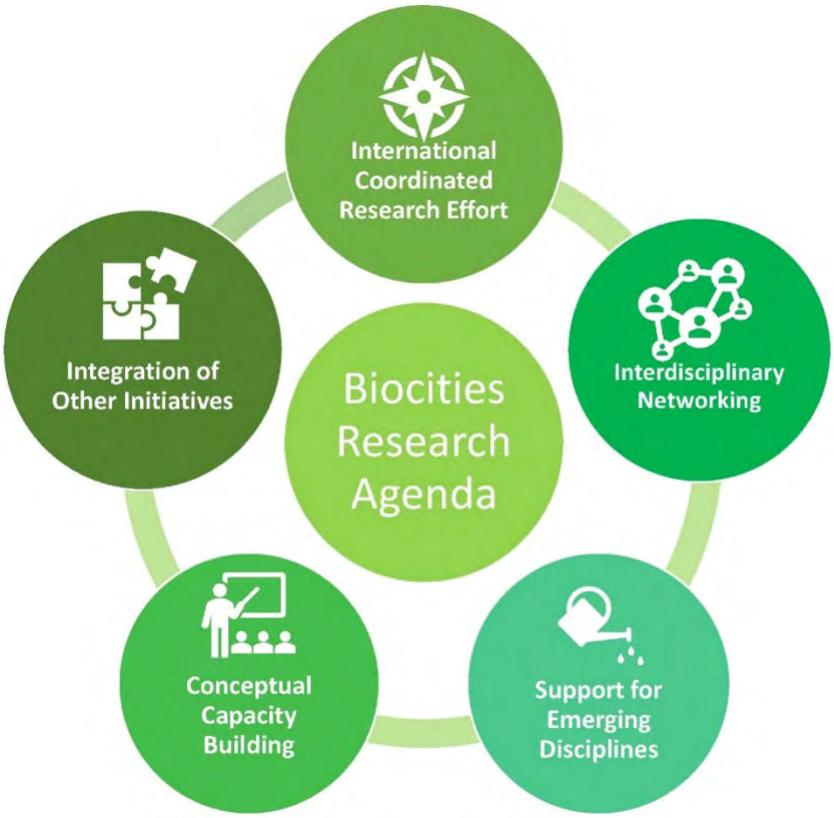

Figure 2. Pathways for implementing the Research Agenda of Biocities.
Source: own representation.

Firstly, a **coordinated effort** is needed between researchers at the international and national level to utilise in an efficient and effective way the international and national research funding resources available. To foster the coordinated effort, networks and committees integrating various stakeholders could be beneficial. At the same time, the funding resources need to be tailored to the specificities of Biocities topics, as elaborated in the Research Agenda. Therefore, understanding and awareness of policymakers towards the topic is a pivotal prerequisite. Furthermore, coordinated efforts by researchers and interested organisations to lobby for financial means to foster knowledge creation on the topic is needed.

Secondly, **networking activities** at the local, national and international level will be necessary between the different disciplines (from spatial planning, architecture, forestry to economy) contributing to the transition. A *commonly built digital knowledge platform* uniting the findings from different disciplines that address the research gaps outlined in this Biocities agenda could help to enhance and structure cross-disciplinary knowledge transfer and mutual learning.

Thirdly, **interdisciplinary and transdisciplinary research projects** involving adjacent and emerging disciplines are necessary and will be pivotal in promoting innovations to allow the transition to sustainable, resilient and liveable cities. Here, the proposed Research Agenda will facilitate finding interesting research topics to foster the transition and interdisciplinarity.

Fourthly, **capacity building** at all levels and disciplines will be necessary to promote the concept of Biocities and to gain momentum in relation to this concept. Here we see the need for building capacities from school level to universities, but also in practical organisation and decision-making bodies.

Finally, **coordinated efforts** with other initiatives at the local, national and international level as well as popularisation of the concept of Biocities will act as a catalyst. It is important to profit from these initiatives, as the Biocities concept only provides a frame that must over the years be further co-developed. As well as awareness raising of the concept within the research community and interested stakeholders, the popularisation of the topic with the public through various means of communication (traditional and social media) must be advanced. Here especially the active engagement of journalists, using different communication platforms and tools from blogs, exhibitions to awards could be utilized.

There are some limitations that will constrain the application of this Research Agenda. A first limitation is time. It will take some years, as well as personnel and financial resources to implement some of the research areas and research gaps identified in the Agenda. Second, the Biocities concept is dynamic, and it will need to be revised in a couple of years and with it the research priorities mentioned in this document. Lastly, coordination, collaboration and funding mechanisms will be strongly needed to implement this ambitious Research Agenda.

The EFI Biocities Facility founded in Rome in 2022 will promote the implementation of the Biocities Research Agenda, as result of ongoing consultations with all relevant stakeholders and research institutions. EFI, involving a network of more than 130 member organisations representing forest research, industry, forest owners, environmental research and international forest-related organisations from 40 countries, will act as a facilitator in stimulating implementation of the Biocities Research Agenda into projects and activities, facilitating the creation of research networks and identifying funding opportunities.

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Annex 1. Research methodology

The research agenda has been developed in four steps as shown in Table 2. Each one of these steps are described in detail in the sub-sections that follow.

Table 2. Steps of the research agenda. Source: Compiled by authors.

Methodology		**2020**		**2021**												**2022**	
Steps	**Activity**	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
Step 1	**Definitions, Drivers and Critical Variables**																
	Webinar I – Identifying visions and narratives and initial knowledge gaps				X												
	Webinar IIa – Identifying drivers, trends and uncertainties linked to visions and narratives					X											
	Webinar IIb – Formulating assumptions and scenarios for future Biocities					X											
Step 2	**White Papers for the Major Research Fields**																
	Climate Resilience – Focus Group discussion and white paper							X									
	Circular Bioeconomy – Focus Group discussion and white paper							X									
	Governance – Focus Group discussion and white paper							X									
	Social and Human environment – Focus Group discussion and white paper							X									
	Biodiversity – Focus Group discussion and white paper								X								
Step 3	**Identifying Trade-offs and Synergies Between the Research Field**																
	Webinar – Identifying trade-offs and synergies between Research fields in Step 2									X							
Step 4	**Validation**																
	Webinar – Identifying further knowledge areas and research gaps and prioritizing these											X					

Step 1 – Definitions, drivers and critical variables

Given the wide range of issues and challenges in the context of Biocities, the shaping of the Research Agenda needs to be made keeping a holistic view on future developments in the short, but also in the medium and long term. This is not only to ensure that important gaps in knowledge are identified at an early stage, but also to build resilience in forming the future of Biocities. Methods of future research can be helpful for such an approach (European Foresight Platform EFP 2010).

Scenarios can provide a wide range of perspectives on what might happen, "like a set of maps describing different aspects of a landscape" (Shell 2008). It can deepen our understanding of the driving forces affecting the future development of Biocities, and so contribute to identifying gaps in knowledge and suggesting areas of new research required to better understand driving forces (UK Government Office for Science 2017). The approach was based on the Generic Foresight Process Framework (Voros 2003) and on principles as formulated in the conceptual framework for Biocities ("Biocities Manifesto").

The draft conceptual framework of Biocities and a number of suggested relevant aspects were re-viewed and complemented in a first online workshop. The main task was to add critiques, comments and new ideas regarding the conceptual framework of Biocities and elements that affect Biocities.

To understand the dynamics of change, the experts were asked in a second workshop to identify driving forces that influence the trends of contemporary urban development, based on the PESTLE (political, economic, social, technological, legal and environmental) structure. A trend is understood as a general tendency or direction of a development or change over time. Drivers are defined as driving forces, factors or events influencing the trends and affecting or shaping the future. The most important drivers in shaping the future of Biocities are those with the most significant influence and the least certain outcome of their influence.

The third and last workshop centred around three pre-defined scenarios. Each scenario is based on the 10 principles of the conceptual framework of Biocities. 'Biocity Eden' corresponds to the 10 principles, whereas 'Gotham' forms a type of antithesis to Biocity Eden. 'Status quo' represents the business-as-usual development of cities. Discussing the assumptions and pathways in relation of the drivers to the three different scenarios allowed us to define further gaps in knowledge and thus research gaps.

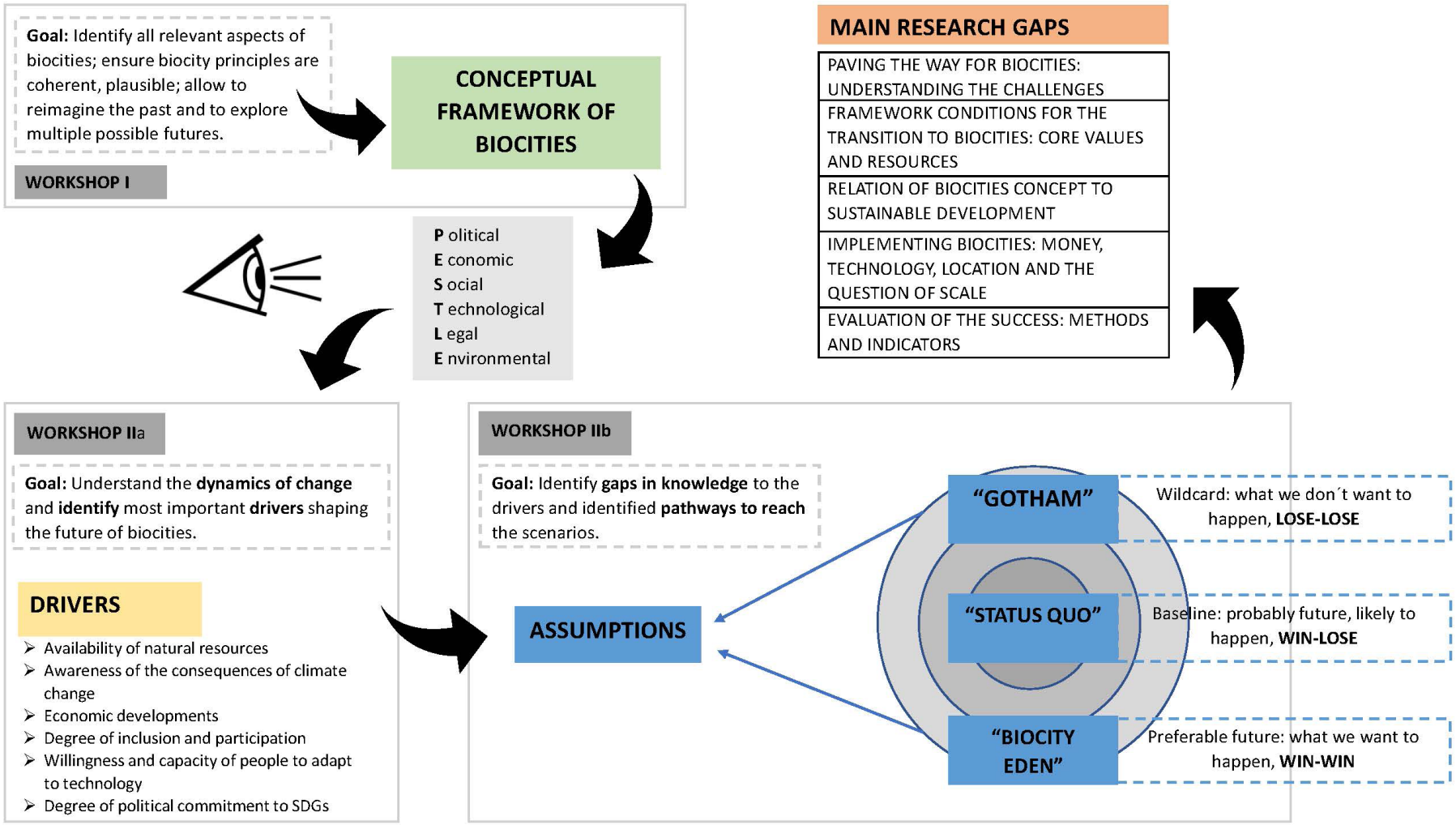

Figure 3. Graphical representation of step 1. Source: Compiled by authors.

Step 2 -White papers for the major research fields

Step 2 was carried out in seven sub-steps. To start with (**sub-step 2.1**), the basic principles, manuscripts and concept sketches available up to that point were reviewed and an initial thematic overview was drawn up. Based on this, the ReBio consortium then carried out a clustering in **sub-step 2.2**; this resulted in five thematic research fields: biodiversity, circular bioeconomy, climate resilience, governance, and social and human environment. A methodological framework was then developed (**sub-step 2.3**) for the conception and structuring of the corresponding focus group workshops. To prepare the workshops, research field teams were formed; these invited experts from different regions (Annex 2) and with different professional backgrounds (**sub-step 2.4**); about half of the experts came from practice and half from science. Thereafter, five thematic workshops were prepared and carried out in detail (**sub-step 2.5**). These workshops were recorded and transcribed, with each one resulting in approx. 30 pages of transcript. The collected data from this step was processed in **sub-step 2.6**; first, key word protocols were prepared; the teams analysed the data specifically with regard to research relevance and research gaps. Finally, in **sub-step 2.7** a synopsis of all results and arguments from all five workshops was elaborated; this served a basis and impetus for elaborating the research agenda and for writing the white papers.

The date of the focus group workshops and the sub-topics addressed in each research field are shown in Table 3.

Table 3. Dates of focus group workshops

Research Field	Focus Group	Sub-Topics
Governance	4 May 2021 5 participants	Governance for the transition to Biocities; Participation and networking: key elements for the transition to Biocities; Planning and design as key elements for the transition to Biocities
Circular bioeconomy	5 May 2021 8 participants	Life-cycle management of bioresources; Cultural change for circularity; Implementing spatial sustainability; Sustainability impacts
Social and human environment	11 May 2021 8 participants	Socio-cultural environment and challenges; Participation and involvement; Health and wellbeing
Climate resilience	18 May 2021 9 particpants	Urban biophysical and biogeochemical cycles; Physical and social infrastructures; Scales of investigation, development and action
Biodiversity	18 June 2021 5 participants	Biodiversity in the city: background, trends and challenges; Nature-Based Solutions (NbS) for biodiversity conservation in a spatial, temporal and taxa scale; Enhancement of ecological knowledge of biodiversity: urban biodiversity, landscape ecology and urban planning

Step 3 - Identifying trade-offs and synergies between the research fields

Step 3 was executed in four sub-steps. In the first sub-step, we finalised the five white papers from five research fields described above in Step 2. We identified challenges, knowledge gaps, and priority research areas that are cross-cutting to the research fields (Figure 4). After that, we distributed the whitepapers to the consortium members. In the second sub-step, all white papers were reviewed by the ReBio consortium members to identify synergies and trade-offs between trends in the research fields. The consortium members provided feedback to the leader of Step 3. After that, in the third sub-step, an online plenary discussion on identifying synergies and trade-offs was carried out on 16.07.2021. Finally, in the fourth sub-step, a draft research agenda was created including the challenges, knowledge gaps, priority research areas, synergies and trade-offs between research fields.

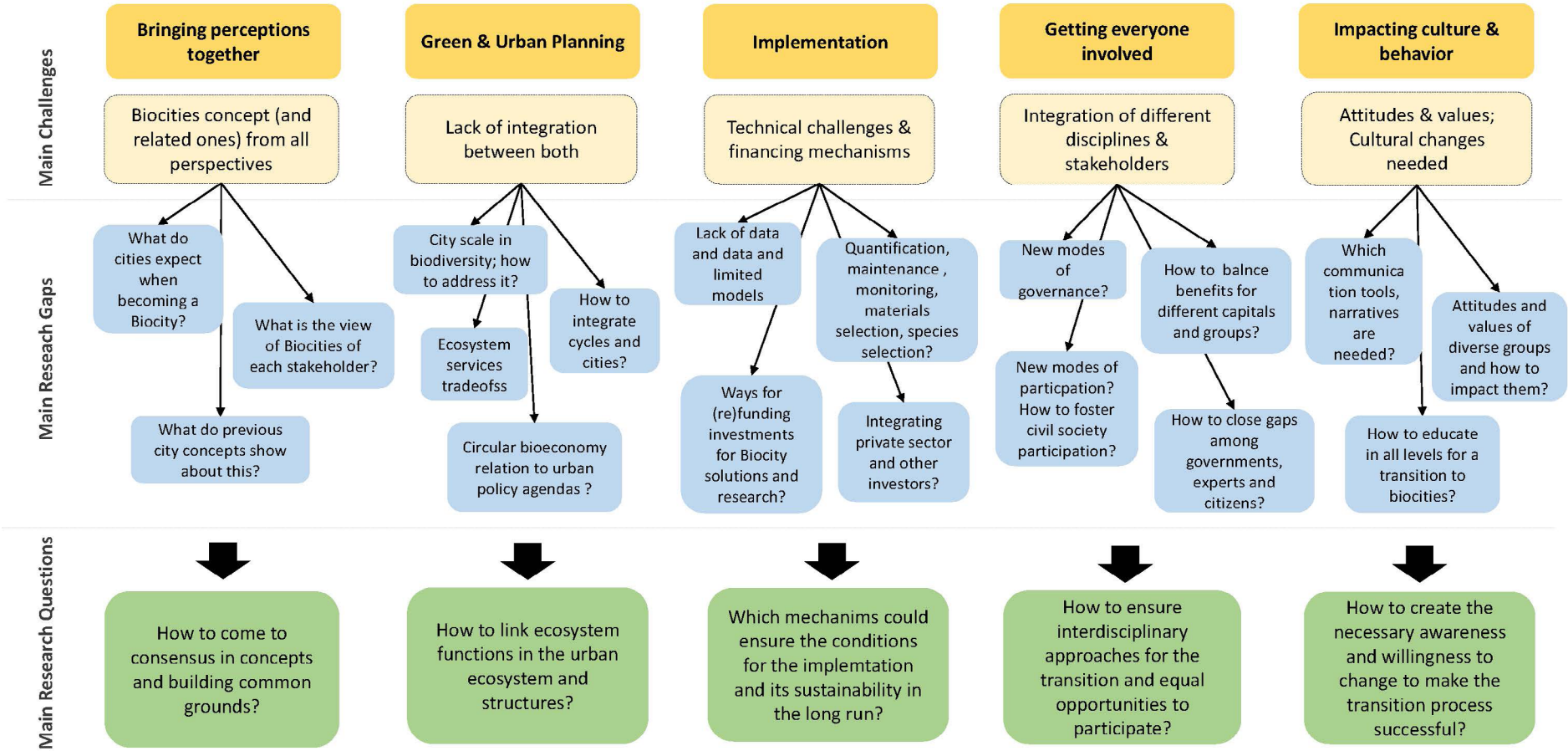

Figure 4. Diagram of the synthesis of five white papers to detect main challenges, major research gaps and critical research questions. Source: Compiled by authors.

Step 4 – Validation

The final step in developing the Research Agenda involved a review of the outcomes of various steps in relation to outcomes of related initiatives. Webinar sessions between members of the parallel project and the team leaders of each white paper were held, in which the ten principles developed for the Green Book on Biocities were used as framework to review the agenda. In a second step an overview of relevant agendas, reports, initiatives and papers was prepared, which were then reviewed using the following questions:

- What do other agendas/reports/initiatives/papers observe in regard to driving forces, critical variables and overarching themes for the future development of conceptual perspectives such as 'Biocity'?
- What do other agendas/reports/initiatives/papers see as challenges and perspectives in respect to various research fields identified and elaborated in step 2?
- What do other agendas/reports/initiatives/papers see as knowledge areas and research gaps in relation to the various research fields identified and elaborated in step 2?
- Which keywords arise in other agendas/reports/initiatives/papers which complement (or contradict) the keywords drawn from the 'landscape of arguments' prepared at the conclusion of step 2?
- What are the main implementation challenges emerging in other agendas/reports/initiatives/papers?

Following these reviews, additions and amendments to key areas of the relevant chapters of the Research Agenda were carried out, with the intention to be as comprehensive as possible with respect to the body of knowledge at the time of writing.

Annex 2. Participants list

Annex 2 gives an overview of all the people that have participated in the different steps of the development of the research agenda. Participants marked in grey are part of the ReBio Consortium responsible for developing the research agenda heading towards the transformation to Biocities.

Participants	Country	Institution	Type of Stakeholder	Step	Research Field
Alberto Bezama	Germany, Chile	Helmholtz Centre for Environmental Research -UFZ	Research	2	Circular Bioeconomy
Andreas Bernasconi	Switzerland	PanBern	Practice	3,4	Governance
Ana Mitic-Radulovic	Serbia	Centre for Experiments in Urban Studies - CEUS	Practice	2	Social and Human Environment
Anna Petit-Boix	Germany	University of Freiburg	Research	1	Circular Bioeconomy
Arne Arnberger	Austria	University of Natural Resources and Applied Life Sciences	Research	2	Social and Human Environment
Bart Muys	Belgium	KU Leuven	Research	4	Biodiversity
Cecil Konijnendijk	Spain	Nature Based Solution Institute - NBSI	Research / Practice	2	Governance
Chantal van Ham	Belgium	IUCN	Research / Practice	2	Biodiversity
Clémence Dirac	Switzerland	Federal Office for the Environment	Practice	2	Social and Human Environment
Constanza Parra	Berlgium	KU Leuven	Research	4	Governance
Daniel Ibañez	Spain, US	Institute for Advanced Architecture of Catalonia -IAAC, Harvard Graduate School of Design	Research / Practice	2	Circular Bioeconomy
Diana Tuomasjukka	Finland	European Forest Institute - EFI	Research	2	Circular Bioeconomy
Dijana Vuletic	Croatia	Croatian Forest Research Institute	Research	4	Biodiversity
Divina Gracia P. Rodriguez	Norway	Norwegian Institute of Bioeconomy Research - NIBIO	Research	2	Social and Human Environment
Evelyn Coleman	Switzerland	Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL	Research	1	Governance

Participants	Country	Institution	Type of Stakeholder	Step	Research Field
Elisabeth Karaca	Austria	University of Natural Resources and Life Sciences - BOKU	Practice	1,3	Governance
Fabio Salbitano	Italy	University of Florence	Research	1,4	Governance
Giovanna Ottaviani Aalmo	Norway, Kosovo[5]	Norwegian Institute of Bioeconomy Research - NIBIO	Research / Practice	1,2,4	Circular Bioeconomy
Giovanni Sanesi	Italy	University of Florence	Research	4	Governance
Giuseppe Scarascia	Italy	University of Rome	Research	1,4	Circular Bioeconomy
Irene Weinberger	Switzer-land	Quadrapoda	Practice	2	Biodiversity
Ivana Zivojinovic	Austria	University of Natural Resources and Life Sciences - BOKU	Research	1,3	Governance
Jelena Tomićević Dubljević	Serbia	University of Belgrade	Research	1,3	Social and Human Environment
Jerylee Wilkes-Allemann	Switzer-land	Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL	Research	1,3	Governance
Jessica Giron	Germany	Karlsruhe Institute of Technology - KIT	Research	3	Biodiversity
Lone Ross	Norway	Norwegian Institute of Bioeconomy Research - NIBIO	Research	4	Circular Bioeconomy
Lauren Cook	Switzer-land	Swiss Federal Institute of Aquatic Science and Technology - EAWAG	Research	2	Climate Resilience
Liisa Tyraväinen	Finland	Natural Resources Institute Finland	Research	2	Social and Human Environment
Liz O´Brien	UK	Forest Research	Research	2	Social and Human Environment
Maria Chiara Pastore	Italy	Politecnico di Milano	Research / Practice	2,4	Circular Bioeconomy, Climate Resilience
Marie-Reine Fleisch	France	Agroparistech	Research / Practice	4	Biodiversity
Mario Köhler	Germany	Gartenbauamt Karlsruhe - GBA	Practice	2	Biodiversity

5 In accordance with UN Security Council Resolution 1244, Kosovo is under the provisional administration of the United Nations (UNMIK).

Participants	Country	Institution	Type of Stakeholder	Step	Research Field
Michael Salka	Spain	Institute of Advances Architecture of Catalonia - IAAC	Research	1,4	
Mira Kopp	Germany	University of Freiburg	Research	1,3	Circular Bioeconomy
Mònica Ubalde	Spain	Institute for Global Health – ISGlobal	Research	4	Social and Human Environment
Nicolai Jacobi	Germany	ICLEI Europe	Practice	2	Circular Bioeconomy
Nicolas Picard	France	GIP Ecofor	Research	4	Biodiversity
Nicole Bauer	Switzer-land	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	Research	1,3	Social and Human Environment
Pedro Pinho	Portugal	Centre for Ecology, Evolu-tion and Environmental Changes - cE3c	Research / Practice	2	Biodiversity
Raffaele Gorjux	Italy	Keios	Practice	2	Governance
Renate Späth	Germany	Ministry for Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia	Practice	2	Social and Human Environment
Rene van der Velde	Nether-lands	Delft University of Technology	Research	1,3	Climate Resilience
Rik De Vreese	Belgium	European Forest Institute - EFI	Research / Practice	2	Governance
Robert Hostnik	Slovenia	Slovenia Forest Service - ZGS	Research	2	Social and Human Environment
Robert Mavsar	Finland	European Forest Institute - EFI	Research	4	Circular Bioeconomy
Roberto Tognetti	Italy	Universita degli Studi del Molise - UNIMOL	Research	4	Climate Resilience
Silvano Fares	Italy	Italian National Research Council - CNR	Research	2,4	Climate Resilience
Sina Leipold	Germany	University of Freiburg	Research	1	Circular Bioeconomy
Slavica Čepić	Serbia	University of Belgrade	Research	1,3	Social and Human Environment
Somidh Saha	Germany	Karlsruhe Institute of Technology - KIT	Research	1	Biodiversity
Thomas Randrup	Sweden	SLU	Research	2	Governance

Participants	Country	Institution	Type of Stakeholder	Step	Research Field
Tobias Stern	Austria	University of Graz	Research	2	Circular Bioeconomy
Vanessa García Otero	Germany, Colombia	University of Stuttgart and Urbanic Group Bogota	Research / Practice	2	Governance
Vanessa Zeller	Germany	Technical University of Darmstadt	Research	2	Circular Bioeconomy
Vicente Guallart	Spain	Institute of Advances Architecture of Catalonia - IAAC	Research / Practice	4	Climate Resilience
Wenche Dramstad	Norway	Norwegian Institute of Bioeconomy Research - NIBIO	Research	2	Biodiversity

Annex 3. Further knowledge areas and research gaps

In this annex additional research gaps are listed for each branch of research.

Circular bioeconomy

Conceptual research

- To what extent do existing urban policy agendas such as local development policy or climate policy entail the concept of circular bioeconomy?
- Where are the similarities and differences in the concept of circularity regarding different biomaterial value chains such as food production, organic waste management and wood use?

Social sciences and innovation research

- What are effective bioresource management strategies to mitigate and capitalise on disturbances such as forest fires?

Modelling and Impact Assessment

- Which new approaches can integrate environmental impact analyses with economic and social impact analyses to fully assess any type of Biocity intervention?
- How can the representation of contextual differences in social and environmental impact models be enhanced?
- In which way do effective circular bioeconomy strategies mitigate negative impacts and in which do they foster positive impacts across socio-economic and geographical contexts?
- What are the impacts of an increased use of renewable materials in cities for example construction wood and biofuels on global forest health and ecosystem services?

Climate Resilience

Science and data

- What are the baseline parameters and associated metrics of biophysical and biogeochemical cycles in cities?
- How are these spatially and temporally defined?
- How do these metrics vary from city to city?
- Which systems and platforms exist for data management, and how can these be developed to effectuate interaction and operability?

Modelling

- Which tailor-made tools can be developed to model urban biophysical and biogeochemical cycles at various scales?
- What kind of models can be developed to capture the variability of climate change in relation to the urban realm?

- Which elaborations of tools and modelling of microclimatic data can be developed?
- What kinds of models of the specific impact of green infrastructure and other built environment components on urban biophysical and biogeochemical cycles can be applied?
- What kind of modelling tools and inputs are needed to make decisions and manage trade-offs?

Spatial planning and design

- What is the impact of urban metabolic cycles on biophysical and biochemical cycles?
- What is the impact of urban morphology on biophysical and biochemical cycles?
- How do various biophysical and biogeochemical cycles (in relation to climate change) resonate in different forms of infrastructure?
- What are the problems, challenges and possible solutions in the relationship between above-ground and below-ground conditions in mitigating greenhouse gas emissions and adapting the city to climate change?

Engineering and building technology

- What is the interrelationship of urban biophysical, biogeochemical cycles and grey infrastructure (such as roads, bridges)?
- How do the biophysical and biogeochemical cycles interact with building 'technics' (facade, interior, structure etc.) as well as with their day-to-day functioning (and maintenance)?

Policy and governance

- How can we best involve society in climate resilience?
- How do different policies tackle all impacts of climate change?
- What type of policies are crucial and needed to avoid the catastrophic impacts of climate change?
- How can we reach zero-carbon goals in cities?

Monitoring and impact assessment

- What kinds of new inventory tools can be developed to map and monitor green infrastructure at different scales in mitigating greenhouse gas emissions and adapting the city to climate change?
- What are the impacts of climate change on vegetation behaviour and survival when facing extreme weather events such as heatwaves, drought and floods?

Governance

Governance and politics

- In which way does the Biocity concept relate to existing policy agendas such as local development or climate policy?
- Are some Biocity strategies better addressed through bottom-up approaches or through top-down approaches?
- Is this consistent from place to place or context-dependent?
- How have previous initiatives (e.g., citizen science) to implement urban change in a holistic way countered challenges of silo thinking and silo administration?
- How can we mainstream Biocities in the political and professional (e.g., planning, design, health care, management) discourses?

- What role do scientific knowledge and attitudinal change play in fostering the transition to Biocities?
- Which attitudes and values do decision makers such as politicians and urban planners have towards Biocities?
- How can this knowledge be used to steer participation and popularize the concept?

Planning, design, management and monitoring

- Which instruments and actors can encourage urban agriculture or non-motorized transport?
- What is the impact of different urban policy levers on the local level? Which policy levers are most effective?
- How can Biocities be conceptualised, developed and planned as connected environments?
- How can all elements of a Biocity become interconnected in a combination of the green-blue and grey networks?
- How can we transit from urban planning to city design (role of architects and planners, regulatory frameworks, and other instruments such as incentives, role of private landowners)?
- What are the relationships and boundaries between planning levels and areas (regional/local, hinterland of Biocities part of city) in the context of the Biocities concept?
- How can we prevent overcrowding of green areas? What are the challenges and opportunities for mainstreaming Urban Greening Plans?

Finance and funding

- What role could the private sector play in investing, implementing, and supporting research in the context of Biocities?
- How can we ensure involvement of markets and the private sector?
- How can we ensure that donor policies of financial institutions (e.g., World Bank, regional development banks) integrate Biocities in their strategies, particularly in the recovery efforts in the wake of the Covid-19 pandemic?
- What is the economic value of different ecosystem services and disservices?

Participation research

- How can we enable citizen engagement in the long run to ensure action under a shared goal, behavioural change, cooperation and implementation?
- How can participation of the civil society in legislation be strengthened?
- Which roles do social innovation and soft infrastructure (practices, cultures, relationships and networks in both urban communities and administrations) play?
- Which factors can explain the variation in stakeholder engagement?
- How can we ensure inclusive and just participation for all interested parties?
- How can we overcome the digital divide for citizen and stakeholder engagement?
- How can authorities learn to leave their (comfortable) expert role and allow for participation?

Science-policy interface

- How can lessons learned be transferred from one context to another?
- How can we ensure the transfer of latest knowledge and development from research to potential users?
- How can we bridge gaps between the concerns of research and practice through e.g., citizen science?
- How can the results of impact assessments be translated into policies and strategies?

Social and human environment

Innovation and transition research

- What are the best ways and tools to implement citizens' ideas in subsequent formal planning processes around Biocities themes?
- Which new approaches (such as online tools, citizen assemblies or charrettes) enable greater representation in participatory democracy and planning around Biocities themes?
- Which educational approaches effectively embed ideas of involvement and participation in the Biocity of the future from an early age?

Inequality research and inclusiveness management

- Which conditions are necessary for the Biocities concept to become truly inclusive (spatially, economically, and socially) instead of fuelling the Matthew effect and competition between and within cities?
- What policies are needed to reduce differences in life expectancy across Biocities?
- How can greater equity be achieved in education, opportunities, and access to urban resources to reduce inequalities?
- How does poverty evolve in urbanising cities under rising prices and the effects of the Covid-19 pandemic?

Health and human wellbeing

- Which indicators are suitable to measure the impact of Biocities and Biocity elements such as green space on human health and wellbeing? What role does residential knowledge have in assessing the impacts?
- What are the drivers of urbanisation and their effect on health and human wellbeing?
- How can we transform cities into healthy cities where it is easy to be active and access nature, and nature is embedded in everyday life and institutions in line with SDG 3?
- What is the (latest) knowledge on the effect of green spaces on health and on the different ecosystem services green spaces provide to society?
- What parameters or indicators are relevant to measure progress in the context of avoiding/reducing gentrification?

Behavioural and social change research

- Which kind of soft infrastructure (practices, cultures, relationships and networks) mitigate gentrification and promote environmental justice in cities?
- Which kind of soft infrastructure (practices, cultures, relationships and networks in both urban communities and administrations) is required to change habits and practices in the areas of mobility, consumption and circularity?
- How can we foster acceptance, understanding and adoption of new techniques and solutions such as organic waste separation or material databases? Which values, functionality of solutions, communication tools and narratives are needed?

Spatial planning and design

- What are the implications of the role of environment and access to nature in public health for urban planning and green space design?

Biodiversity

Conceptual and fundamental research

- Which indicators enable the assessment of the biodiversity potential of different species?

Strategies and concepts

- Which strategies properly address the urban island effect in biodiversity distribution and conservation?
- What is the role that new building, public space, and city models play in rethinking biodiversity?

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