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# How to implement the urban bioeconomy: insights from Leipzig's current policy mix for transitioning towards a bio-principled city

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## Abstract

The bioeconomy is envisioned to play a decisive role in accelerating urban transformations towards greater sustainability and resilience. Integrating biological principles, such as metabolism, ecosystems and cycles, into urban planning and city life, and promoting a so-called “bio-principled city” provides significant potential for shaping more sustainable urban development. However, the future vision of a “bio-principled city” currently reflects more of a programmatic idea than a real political agenda. This study therefore draws attention to the existing policy mix of the city of Leipzig and evaluates in how far it already supports the city's transformation into a bio-principled city. For this purpose, we developed a proper conceptional framework consolidating different research methods to conduct a comprehensive policy mix analysis. The analysis shows that the current policy framework for a bio-principled city in Leipzig is complex, uncoordinated and lacks in definitive actions. Our analysis offers interested policy makers and scientists an example of how an incidental and thus patchy policy mix can look like in practice. By highlighting its strengths and corresponding limitations, we provide a starting point for deliberate interventions to further promote the vision of a bio-principled city politically and thus realize its implementation.

## Highlights

- Leipzig's current extended policy mix does not explicitly promote a transition to a bio-principled city.
- The current policy instrument mix consists of rather loose and poorly targeted measures.
- Mainly supra-national and national actors are explicitly involved in bioeconomy policymaking.
- German local governments' leeway in contributing to transitioning to a bio-principled city is relatively limited.

**Keywords:** Bioeconomy, Urban bioeconomy, Bio-principled city, Policy mix, Sustainability transitions, Urban transformations



## Policy and practice recommendations

- The federal state and local policy levels need to be more explicitly involved in shaping bioeconomy policy.
- Further assessment of the policy mix may provide guidance on how to adapt it and advance the transformation process.
- Narrowing down the vision to local strengths may help to identify targeted policy measures.

## Introduction

In recent years, the knowledge-based bioeconomy has consolidated as a strategy for reindustrialization and for implementing the Agenda 2030 for Sustainable Development. It holds great potential for significantly contributing to achieving the United Nations 2030 Sustainable Development Goals (SDGs), amongst others, to SDG 11 on sustainable cities and communities (El-Chichakli et al. 2016). A Delphi survey, commissioned by the German Bioeconomy Council, has shown that the bioeconomy is envisioned to play a decisive role in contributing to sustainable urban development. Integrating biological principles, such as metabolism, ecosystems and cycles, into urban planning and city life, and promoting a so-called “bio-principled city” was rated of very high relevance by participants in order to shape more sustainable urban development (Cuhls et al. 2015). Since the publication of the Delphi study in 2015, more and more concepts are being discussed in politics and academia similar to the “bio-principled city” concept, but framed under other terms, such as “urban bioeconomy”, “biocity” or “nature-based city”. All of these terms are associated with positive expectations for even more liveable future cities. They combine various bioeconomic approaches in urban spaces, such as biobased innovations for the recovery and recycling of wastes, residues and nutrients, new forms of energy production as well as innovative ways for urban greening and for promoting sustainable consumption and lifestyles (Schöbinger 2021).

It can be observed that cities around the globe are already taking up and implementing bioeconomic approaches. For example, in Paris urban farmers are trying a soil-free approach to agriculture that uses less space and fewer resources. In the southern 15th arrondissement, with 14,000 sq. metres, the world’s largest urban rooftop farm, called Nature Urbaine, has started to bear fruits (Thanh Thuy Schwertner 2019). In Italy, architects plan to regenerate a site of a Milanese district. The design of the mixed-used project, referred to as ‘pirelli 39’, involves the renovation of the site’s existing office tower, and the construction of a new residential high-rise that will include 1700 square meters of integrated vegetation (Platform 2021). New types of buildings are changing the way we build in cities. In the U.S., for example, the University of Maine recently presented the world’s first bio-based, 3D-printed house, called BioHome3D. It was built with the help of a large polymer 3D printer by using natural materials such as sustainably grown wood fibre. As a result, the house is fully recyclable and leaves almost no waste (Monteil 2023). Existing projects in the field of bio-inspired design solutions can be found, for example, in Hamburg, where the world’s first building was equipped with an algae

facade made of glassy bioreactors. This facade does not only produce heat and biomass; it also binds carbon dioxide through the photosynthesis of growing green algae (Glaswelt 2013).

At the same time, scientific initiatives are being awarded and public pilot projects are being funded at the national and supra-national level. In 2020, for example, the 13th German Sustainability Award for Research honoured for the first time an interdisciplinary project team in the area of urban bioeconomy. The team developed an open-source software to connect urban biological raw material flows of individual companies in an economically resource-efficient way and thus contributes to closing urban resource cycles (German Sustainability Award Foundation 2020). Furthermore, the European Commission aims at developing urban circular bioeconomy strategies in 10 European pilot cities. The focus is on turning urban organic waste into valuable resources to produce biobased products, rehabilitate brownfields, and applying bioeconomic processes and technologies within urban areas to diversify the sustainable sourcing of biomass and to create new business opportunities (European Commission 2018b).

These initiatives, under the guise of the bioeconomy, aim to accelerate urban transformations towards greater sustainability and resilience. However, the future vision of a “bio-principled city” currently still reflects more of a programmatic idea than a real political agenda. Our intention therefore is to explore the specific policy framework that accelerates a city’s transformation into a bio-principled city. This leads to the following research questions, which we want to explore in more detail: To what extent are the urban bioeconomy and the idea of a bio-principled city considered in current policy-making? What policy approaches currently exist to accelerate and implement such an urban transformation? And how can German local governments’ leeway in contributing to this transformation be strengthened?

The challenge for our investigation remains that urban transformations are highly complex processes encompassing all economic sectors, affecting different policy levels and involving multiple actors. This applies to the transformation towards a sustainable bioeconomy in general and a bio-principled city in particular. Bioeconomy experts from around the world recognised that steering the transition to a sustainable bioeconomy requires not only context-specific stimulus packages in the short-term, but also comprehensive policy frameworks and governance approaches that set-in motion transformative processes in the long-term (International Advisory Council on Global Bioeconomy 2020).

At present, the general pertinent scientific literature on transitioning towards a bioeconomy focuses on identifying possible transition pathways by questioning what is required to transform or how and by whom the transition is shaped. Scientific approaches therefore use scenario analyses (e.g. Wydra et al. 2021; Kalt et al. 2016), national perspectives (e.g. Imbert et al. 2017; Wreford et al. 2019; Holmgren et al. 2022; Heeren-Hauser et al. 2020), emphasize economic sector transformations (e.g. Ladu et al. 2020; Pannicke et al. 2015; Oriama and Pyka 2021), corporate power and the role of entrepreneurship (e.g. Bastos Lima 2021; Kuckertz et al. 2020) and transformative knowledge (e.g. Urmetzer et al. 2020), as well as general governance approaches and enabling technologies (e.g. Bosman and Rotmans 2016; Dietz et al. 2018; Laibach et al. 2019; Marvik and Philp 2020) to investigate criteria and enablers

for transition. This paper adds to the existing literature by investigating the transformation towards a bio-principled city. The focus of this study is to review the existing policy framework and evaluate in how far it supports a city's transformation into a bio-principled city.

For this purpose, the city of Leipzig has been chosen as a case study. With more than 600,000 inhabitants, Leipzig is the most populous city in the Free State of Saxony and the eighth largest city in Germany (Knupp 2021). With the formation of a bioeconomy working group within the cluster initiative of Leipzig's Economic Development Department in 2020, Leipzig is taking a pioneering role. The working group pursues, among others, to establish a platform to connect the city's and region's bioeconomy stakeholders, to find and test sustainable business models for the bioeconomy, to enable access to knowledge and research institutions and to design regional transformation approaches at the city and regional level (Netzwerk Energie und Umwelt e.V. 2020). At the time of investigation, such examples of bioeconomy activities at the city level were unique in Germany. Only in the recent past have further individual initiatives emerged that aim to anchor the bioeconomy at the municipal level. For example, the Ministry of the Environment, Climate Protection and the Energy Sector in Baden-Württemberg (UM) in Germany published the funding program "Municipal Bioeconomy - Bioeconomy Strategies for Urban Areas" at the end of 2022. It intends to support urban agglomerations or large municipalities in developing municipal bioeconomy strategies and implementing initial concrete measures (UM 2022).

In order to deduce how the transition towards a bio-principled city in Leipzig can succeed, we first look at the city's current policy mix. We then apply the extended policy mix concept for sustainability transitions proposed by Rogge and Reichardt (2016) to structure the analysis. By identifying and analysing the current policy mix supporting the development of a bio-principled city in Leipzig our findings shed light on the strengths and corresponding limitations of the current policy framework that arise for urban policy and practice to implement the vision of a bio-principled city. We aim to contribute important insights to the discussion on the transition to a bioeconomy in general and on the transition to an urban bioeconomy in particular as part of wider urban sustainability transitions. Recognising the lack of empirical studies on urban bioeconomy governance and also the lack of the use of the policy mix concept in this particular context, we intend to fill this research gap and generate novel applicable knowledge for theory and practise.

The remainder of the paper is structured as follows. In the [Theoretical anchoring](#) section, we provide an in-depth discussion of the emerging concepts of "nature-based city", "urban bioeconomy", "biocity" and "bio-principled city" and elaborate the role of policy mixes for urban transformations. In the [Methods](#) section, we introduce the conceptual framework of the paper. In the [Results](#) section, we synthesise the results of the analysis and summarize them in figures and tables. In the [Discussion & conclusion](#) section, we discuss critically in how far Leipzig's current policy mix contributes to the transition to a bio-principled city and conclude with a final reflection on how the vision of the bio-principled city can be used in the future.

## Theoretical anchoring

### Emerging concepts of the nature-based city, urban bioeconomy, biocity and bio-principled city

The ongoing global trend toward urbanization and the concurrent challenges of climate change have contributed to a general rethinking of how we want to build and manage our cities in the future, and how to promote sustainable urban development. While there is no universally accepted definition of a sustainable city, Cohen's (2017) literature review reveals that "The sustainable city minimizes its emissions of conventional air pollutants and greenhouse gases; uses as few non-renewable resources as possible; discharges effluents into waterways after treatment that removes the most harmful pollutants; uses energy and water as efficiently as possible; and attempts to reduce and recycle waste and minimize the impact of whatever waste disposal is needed." (Cohen 2018, p. 3). He further notes that in politics and business, the concept of the sustainable city was initially used with a view to create infrastructure for urban metabolism (i.e., sewage, water, energy, and waste management) (Cohen 2018). In the German context, the National Platform City (NPC) of the Future developed a vision on sustainable and future-oriented German cities and urban areas within the German government's High-Tech Strategy in 2012. The vision relates to "[...] a CO<sub>2</sub> neutral, energy and resource-efficient, climate-adapted, transformable, liveable and socially inclusive city of the future" (NPZ 2015, p. 3).

To develop economically, socially, and environmentally compatible and resilient living environments for current and future urban residents, concepts for sustainable urban development have emerged in the past that aim to bring back nature into cities by integrating natural principles and materials into urban planning. For example, the term "green city", which is already commonly known, reflects an umbrella framework for an energy- and resource-efficient city that contributes to improving a city's environmental performance and quality of life. It comprises the greening of different economic sectors, such as building and construction, transport and infrastructure, urban production and planning as well as public services. With the help of green and environmental technologies as well as smart information and communication technologies (ICT) greening a city is intended to contribute to green growth (Brilhante and Klaas 2018).

More recently, newer concepts such as the "nature-based city", "biocity", "urban bioeconomy" or "bio-principled city" have gained attention in politics and academia. Although these terms are often complementary used and have considerable overlap, they differ in scope and scale. Applications of nature-based solutions in cities and urban areas, for example, comprise measures that "(...) are inspired by, supported by or copied from nature (...)" (European Commission 2015, p. 4) and aim at maintaining, enhancing, and restoring biodiversity and ecosystems while improving air quality, energy efficiency and reduce temperatures (Kabisch et al. 2016). Accordingly, "nature-based cities" are cities in which, for example, the greening of existing infrastructure and the establishment of new green territories is promoted, including city parks and tree-lined streets, but also peri-urban farms and urban wetlands (UNEP 2021).

The term "urban bioeconomy" goes back to policy discussions at the EU level in 2018 which primarily revolved around the use of urban bio-based wastes and residual streams and to promoting an urban metabolism (Bezama et al. 2021). The concept has evolved

since then and today describes more an economic system within cities and their rural surroundings in which bio-based processes, materials and services are used to promote sustainable urban development (Yang and Yang 2022). Even though the focus is still on using synergies of resource flows and to promote resource circularity, further aspects have gained importance, such as promoting urban bioprospecting (i.e. extracting minerals, metals, nutrients and carbon from waste streams), adopting design principles from nature (i.e. urban greening or biomimicry urban solutions) and urban agriculture (i.e. converting under-utilised buildings and spaces into vertical farms, hydroponic indoor farms etc.) (Taylor Buck and While 2021).

The term “biocity” was recently defined by 10 principles (Wilkes-Allemand et al. 2022). Accordingly, the Biocity adopts the abilities of forest ecosystems (i.e. reduces emissions of carbon dioxide and other greenhouse gases), is self-sufficient, reinforces the functions of existing city infrastructures, uses biodiversity for ecosystem services and promotes health living, makes use and develops local biobased recycled materials, promotes low mobility, harnesses regional bio-based value chains, provides publicly accessible nature, and is socially inclusive (Wilkes-Allemand et al. 2022).

This research focuses on the term “bio-principled city” since it spans the range of the presented concepts and moreover, comprises additional elements that make the concept even more comprehensive. The original flagship vision developed by the German Bioeconomy Council assumes that “[t]he integration of biological principles into urban planning and city life has become a key element for the achievement of greener cities with high levels of self-sufficiency and quality of life.” (Cuhls et al. 2015, p. 14). Further characteristics of a bio-principled city include locally coordinated production, provision, use and recycling systems that ensure closed material and energy cycles in cities that contribute to minimized emissions, waste and losses. Moreover, urban farms provide economically and ecologically efficient high-tech food production, while innovative sustainable building designs and construction techniques are applied by referring to biological principles and renewable resources. Green areas also contribute to biodiversity, water regulation and filtration, air cleaning, halting soil erosion and desertification, mitigating temperature extremes and human recreation. Design solutions and functional materials make use of energy depots, natural lighting, wastewater systems and strategic planting to promote energy and water autonomy. In addition, the bio-principled city enables bio-inspired navigation and logistic systems as well as green industrial production that co-exists with residential living (Cuhls et al. 2015). An overview of the discussed concepts and their characteristics can be found in Table 1.

### **The role of policy mixes for urban transformations**

Before exploring the research questions in more detail, one should uncover what makes urban transformations towards more sustainability and resilience so special and how they differ to other transformation processes.

As Loorbach and Shiroyama (2016) emphasize, the role of cities in sustainability must be viewed in a differentiated way. On the one hand, they are places where unsustainable practices are developed, and which are particularly vulnerable to crises. On the other hand, they actively contribute to innovations for more sustainability and are thus direct scenes of transformations. However, the latter does not happen automatically. It rather

**Table 1** Overview on concepts and their characteristics

| Characteristics  | Bio-principled city | Biocity | Urban bioeconomy | Nature-based city | Green city |
|--|---------------------|---------|------------------|-------------------|------------|
| Reduction of emissions   | x                   | x       |                  |                   |            |
| Energy efficiency / renewable energy   |                     |         |                  |                   | x          |
| Establishment and recovering of territories for wetlands, forests, and green spaces by applying biological cropping techniques and environmental biotechnology | x                   |         |                  |                   |            |
| Reinforcing functions of existing city infrastructure  |                     | x       |                  |                   |            |
| High quality of life & human wellbeing   | x                   | x       | x                | x                 |            |
| Social inclusive and just  |                     | x       |                  |                   | x          |
| Urban greening (green buildings, green infrastructure, green transport, green technologies, etc.)  | x                   | x       | x                | x                 | x          |
| Self-sufficient, local production of food and energy (urban farms and forestry)  | x                   | x       | x                | x                 | x          |
| Local green industrial production  | x                   |         |                  |                   |            |
| Reduction of wastes and losses, circularity, value-chains based on cascading use of natural and renewable resources  | x                   | x       | x                |                   |            |
| Low mobility & integration and decentralization of spaces for recreation, production, services, work and living  | x                   | x       |                  |                   | x          |
| Designs solutions, logistic systems, functional materials and construction techniques adopting biological principled and renewable resources                   | x                   |         | x                |                   |            |
| Use and development of local biobased and residual materials as well as ecosystem services   | x                   | x       | x                | x                 |            |
| Urban-rural biobased value chains  | x                   | x       | x                |                   |            |
| Publicly accessible nature   |                     | x       |                  |                   |            |
| Using ICT to solve environmental problems while supporting high quality of life and inter-generational justice   |                     |         |                  |                   | x          |

requires targeted measures and new governance approaches that steer complex transformations in the long term and consider the large number of actors and interests involved (Loorbach and Shiroyama 2016).

The special nature of urban transformations compared to, for example, transitions in the areas of food, health, energy or mobility is that they extend across individual sectors and comprise multiple sectors at the same time. That in turn means that an analysis of urban transformations also needs to be adapted to this real-world context (Frantz- eskaki et al. 2017). Our research focus on the transition towards a bio-principled city in Germany makes this adaptation additionally complex. Not only does the urban bioeconomy penetrates the economy as a whole, an analysis of urban transformations further requires a multi-level policy perspective.

According to Köhler et al. (2019), policy mixes and the linkages between policy areas, processes and instruments play an especially important role in facilitating transition processes. Rogge et al. (2017), however, found out that while the majority of analyses have focused on national policy mixes so far, multi-level policy mixes have received less attention. Recognizing these insights, our research aims at filling

this gap by applying the extended policy mix concept for sustainability transitions proposed by Rogge and Reichardt (2016) to our case study. By providing an analytical framework for studying the link between policy and technological change in the context of sustainability transitions, the concept recognizes the complexity and dynamics of real-world policy mixes and assumes that they encompass more than just a combination of different policy instruments. It highlights three components: 1) *policy elements* that define the strategic direction through policy strategies and an interacting mix of instruments, 2) *policy processes* in which policy elements emerge and interact, and 3) the *characteristics* that describe the policy elements and processes (such as consistency, coherence, credibility and comprehensiveness) (Rogge and Reichardt 2016).

## Methods

To answer the research questions, we developed a proper conceptual framework consolidating different research methods to conduct a comprehensive analysis of the current policy mix for a bio-principled city in Leipzig (Fig. 1).

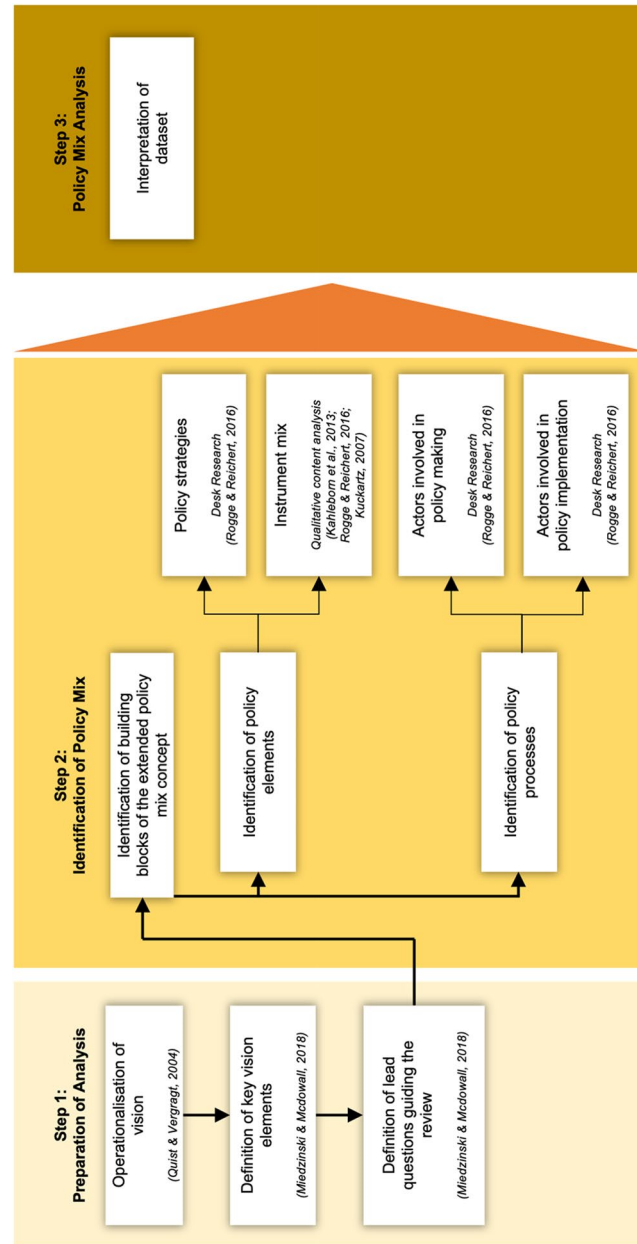
The research framework comprises three steps that are distinguished as following: In a first step we prepared the analysis and applied two existing visions on future cities as normative scenarios (Quist and Vergragt 2003). By operationalising these visions, defining vision elements and defining lead questions guiding the analysis we aimed at elaborating in how far the current policy mix addresses the vision elements of a bio-principled city. In a second step, we identified the current policy mix, including policy elements and policy processes. In doing so, we chose to conduct desk research combined with a qualitative content analysis to identify for our case study the building blocks of the extended policy mix concept for sustainability transitions as proposed by Rogge and Reichardt (2016). The third step included the policy mix analysis and the interpretation of the dataset.

### Preparation of analysis

#### *Operationalisation of existing visions*

The visions applied in this research included, firstly, the flagship vision of a bio-principled city developed by the German Bioeconomy Council. As argued in the [Emerging concepts of the nature-based city, urban bioeconomy, biocity and bio-principled city](#) section, it is more comprehensive than similar concepts. In addition, the National Platform City of the Future's vision on sustainable and future-oriented German cities and urban areas was chosen because it represents an overarching German vision for sustainable urban development and is thus also relevant for the selected case study. Furthermore, this vision contains additional elements such as CO<sub>2</sub> neutrality, climate adaptation and social inclusion. The focus of the operationalisation was on making the rather theoretical visions measurable. It provides the basis for the later content analysis and the resulting coding system. The first step of the operationalisation process is descriptive and its purpose is to capture the vision's main features and list them as vision elements (see Table 2, column 1).





**Fig. 1** Conceptual framework consolidation of different research methods

**Table 2** Inductive-deductive coding system

| Vision elements                                 | Definition of vision elements  | Questions guiding the analysis  | Deductive codes                                   | Inductive subcodes   | References in documents |
|---|--|---|---|--|-------------------------|
| CO <sub>2</sub> neutral, reduction of emissions | "Carbon neutrality means annual zero net anthropogenic (human caused or influenced) CO <sub>2</sub> emissions by a certain date. By definition, carbon neutrality means every ton of anthropogenic CO <sub>2</sub> emitted is compensated with an equivalent amount of CO <sub>2</sub> removed." (Levin et al. 2015)                     | In how far policy strategies are promoting CO <sub>2</sub> neutral urban planning activities?   | CO <sub>2</sub> neutral urban planning activities | General activities<br>Activities based on biobased innovations and solutions | 23<br>1                 |
| Climate adaptive                                | "Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change." (UNFCCC 2019) | Do policy strategies integrate climate protection and adaptation activities into long-term urban infrastructure decisions?  | Climate protection and adaptation activities      | General activities<br>Activities based on biobased innovations and solutions | 4<br>0                  |
| Energy efficient                                | "Energy efficiency, (...), describes the ratio between the benefit gained and the energy used." (Iirek and Thomas 2008)  | Do policy strategies promote biobased innovations and solutions to improve energy efficiency in cities?   | Improved energy efficiency                        |  | 0                       |
| Closed material and energy cycles               | "Circular economy is a sustainable development initiative with the objective of reducing the societal production and consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system." (Korhonen et al. 2018, p. 547)                        | Do policy strategies encourage the development of a sustainable urban circular bioeconomy?<br>Do policy strategies promote the establishment of urban biorefineries and/or comprehensive recycling systems? | Urban circular bioeconomy                         | Recycling of residuals, bio-waste & discards<br>Nutrient recovery            | 9<br>1                  |

**Table 2** (continued)

| Vision elements  | Definition of vision elements  | Questions guiding the analysis  | Deductive codes   | Inductive subcodes   | References in documents |
|--|--|---|---|--|-------------------------|
| Renewable resources, cropping techniques and biotechnology | "Establish and recover territories for wetlands, forests and green spaces by applying environmental biotechnology, optimized plants and biological cropping techniques." (Cuhls et al. 2015, p. 46)  | Do policy strategies promote the construction and recovery of wetlands, forests and green spaces in cities and urban areas by applying environmental biotechnology, optimized crops and organic farming techniques? | Construction/recovery of wetlands, forests and green spaces       |  | 0                       |
| Resource efficient   | "Resource efficiency means using the Earth's limited resources in a sustainable manner while minimizing impacts on the environment. It allows us to create more with less and to deliver greater value with less input." (European Commission 2019a) | In how far policy strategies are fostering the efficient use of resources in cities and urban areas?  | Efficient, resource-saving water, material flow & land management |  | 3                       |
| High quality of life                                       | "(...) quality of life does not only depend on a society's gross domestic product and individual incomes. People need access to important services like education, health and housing." (WGBU 2016, p. 7)  | Do policy strategies ensure an increasing quality of life in cities, and that people can make the most of their potential?  | Urban quality of life   |  | 0                       |
| Liveable   | "The concept of liveability (...) assesses (...) living conditions (...) across five broad categories of stability, health care, culture and environment, education and infrastructure." (EIU 2022)  | Do policy strategies contribute to making cities worth living in?<br>Do policy strategies support the well-being of urban residents?  | Liveability & well-being  |  | 0                       |
| Social inclusive   | "(...) Ensuring access to the resources and rights needed for participation in society, (...)." (European Commission Eurostat 2019)  | Do policy strategies promote comprehensive inclusion?   | Inclusion   | Political inclusion<br>Empowerment of the urban population | 2<br>1                  |

**Table 2** (continued)

| Vision elements  | Definition of vision elements   | Questions guiding the analysis  | Deductive codes                                  | Inductive subcodes  | References in documents          |
|--|---|---|--|---|----------------------------------|
| Greener cities   | <p>"Green cities are defined as those that are environmentally friendly. The greening of cities requires some, or preferably all, of the following: (1) controlling diseases and their health burden; (2) reducing chemical and physical hazards; (3) developing high quality urban environments for all; (4) minimizing transfers of environmental costs to areas outside the city; and (5) ensuring progress towards sustainable consumption." (Pace et al. 2016, p. 5)</p> | <p>Are policy strategies fostering urban green areas that provide retreats and contribute to biodiversity, water regulation and filtration, air cleaning, halting soil erosion and desertification, mitigating temperature extremes and human recreation? Do policy strategies promote sustainable lifestyles and sustainable bio-based consumption? Do policy strategies promote greening technologies, green spaces and green belts, as well as urban gardens, or the integration of existing allotment and home garden structures?</p> | Green areas                                      | <p>Urban gardens<br/>Rehabilitation of urban brownfields<br/>Green spaces<br/>Tree planting<br/>Green roofs &amp; walls</p> | <p>1<br/>4<br/>3<br/>2<br/>1</p> |
| Integration of biological principles into urban planning and city life | <p>"Navigation, traffic regulation and logistic systems that function on the basis of bio-inspired and natural principles." (Cuhls et al. 2015, p. 46)</p>  | <p>In how far policy strategies promote the integration of bio-inspired and natural principles in urban planning and city life?</p>   | Integration of biological and natural principles | 1   |                                  |
| Locally coordinated production, provision, use and recycling systems   | <p>"Cities are fully integrated into the region and suburban areas are part of sustainable urban supply systems for food, feedstock and energy instead of being designed as purely dormitory towns." (Cuhls et al. 2015, p. 46)</p>   | <p>Do policy strategies encourage the development of integrated urban supply systems for food, feedstock and energy?<br/>Are policy strategies promoting the self-sufficient production of urban energy, food and goods?</p>  | Urban food systems                               | Urban farming   | 10                               |

**Table 2** (continued)

| Vision elements  | Definition of vision elements  | Questions guiding the analysis  | Deductive codes   | Inductive subcodes                  | References in documents |
|--|--|---|---|-------------------------------------|-------------------------|
| Reduction of wastes and losses   | <p>"Municipal waste covers household waste and waste similar in nature and composition to household waste." (European Commission Eurostat 2017)</p> <p>"Food loss is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers." (FAO 2019)</p> <p>"Food waste refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers." (FAO 2019)</p> | Do policy strategies promote the development of strategies to prevent urban food wastes and losses?   | Prevention of food wastes and losses  |                                     | 0                       |
| Integration and decentralization of spaces for recreation, production, services, work and living                             | <p>"(...) work, shopping and leisure spaces are integrated into urban residential areas." (Cuhls et al. 2015, p. 45)</p> <p>Industrial production is green (clean air, silent, green logistics, etc.) and co-exists with residential living." (Cuhls et al. 2015, p. 46)</p>   | <p>To what extent do policy strategies support the multifunctional spatial use and polycentric design of cities?</p> <p>Are policy strategies fostering green urban industrial production?</p>                        | <p>Polycentric spatial design of cities</p> <p>Multifunctional spatial use</p> <p>Green urban industrial production</p> |                                     | 1<br>1<br>0             |
| Innovate sustainable building designs and construction techniques referring to biological principles and renewable resources | <p>"Design solutions and functional materials that make use of energy depots, natural lightening, wastewater systems and strategic planting to achieve energy and water autonomy." (Cuhls et al. 2015, p. 46)</p>  | Are policy strategies promoting the use of innovative biobased and residual materials, such as wood and biobased composites, to foster the construction of buildings with low ecological footprints and flexible use? | Biobased & residual materials   | Wood construction<br>New composites | 2<br>1                  |

### ***Definition of vision elements***

Inspired by the methodological approach of Miedzinski et al. (2018), we formulated initial definitions for each vision element (see Table 2, column 2). These definitions draw on official definitions of international and supra-national organisations, national government agencies, advisory councils and research institutions.

### ***Definition of lead questions guiding the analysis***

Similar to Miedzinski et al.'s (2018) approach, we defined lead questions (see Table 2, column 3), drawn from the definition of vision elements. The objective of developing lead questions was to apply the vision elements and their overarching definitions to the context of our analysis, while at the same time specifying and sharpening the scope of the analysis. In other words, in the context of urban planning activities, our questions focus on whether and if existing policy documents are promoting the elements expressed in each definition.

### **Identification of policy mix**

#### ***Identification of building blocks of the extended policy mix concept***

We applied the extended policy mix concept for sustainability transitions proposed by Rogge and Reichardt (2016) to identify the building blocks of the current policy mix for a bio-principled city in Leipzig. While the focus of the analysis is on identifying the policy elements and processes, the characteristics will be elaborated in a later research phase.

#### ***Identification of policy elements***

With the help of secondary research, we identified existing *policy strategies*, which were classified as relevant for analysing the current policy framework for a bio-principled city in Leipzig. The focus was on documents which a) address the bioeconomy explicitly, b) affect all relevant government levels of the existing policy framework of the city of Leipzig (city, state, national, supra-national and international), c) were in force in 2020, and d) provide long-term, strategical visions for policymaking (2025 and beyond). Our research revealed that policy documents differ in whether they address measures to promote vision elements of a bio-principled city, which is why we concentrated only on policy strategies that explicitly address such measures. In a next step, we extended the desk research to principal plans and programmes as well as other records such as evaluations, reviews, and progress reports that explicitly address the vision elements of a bio-principled city.

The resulting dataset provided the basis for a qualitative content analysis aiming at elaborating the extent to which the vision elements of a bio-principled city are currently promoted through proposed and implemented *policy instruments*. This includes regulatory, market-based and information-based instruments as well as targeted government support programs, which refer to the overarching existing policy strategies.

We analysed the policy instruments with the help of a qualitative thematic coding approach (Kuckartz 2007) using the Computer-Assisted Qualitative Data Analysis Software (CAQDAS) MAXQDA. In doing so, we developed an initial list of evaluation categories. Each category corresponded to a deductive code, which in turn was defined by the respective guiding question previously established in the operationalisation process

in "Operationalisation of existing visions" subsection (see Table 2, column 4). In the next step, we carefully read and analysed the identified dataset. We then coded all text passages with a reference to the predefined categories accordingly. This approach also helped to identify text passages in which the context of the categories was only implicitly described (Kuckartz 2007). Subsequently, we analysed in more detail the coding material by identifying inductive subcodes (see Table 2, column 5). This process resulted in a deductive-inductive coding system, providing information about which vision elements of a bio-principled city are currently addressed in policy documents and by which policy instruments they are promoted.

Based on the findings of Kahlenborn et al. (2013), we structured the policy instruments found within the dataset into five fields of action in order to elaborate where politics and other societal actors can contribute to the transition process: 1) *innovation* (e.g. intellectual property (IP) and market regulations, support for research and development (R&D), start-up and new business model promotion, infrastructure provision, public-private-partnerships, competitions), 2) *commercialisation* (e.g. subsidies for market entry and development, knowledge and technology transfer, marketing efforts), 3) *support of changes in values and behaviour of all social actors* (e.g. through procurement policies, price setting, education and capacity building, public information), 4) *exnovation* (phasing out unsustainable products, services and economic practices, e.g. through fiscal disincentives and user charges, promotion of environmentally sound practices, review and harmonisation of existing policies), and 5) *transformative governance* (setting the framework to stimulate the overall societal transformation process, e.g. through government reorganisation, advisory services, multi-stakeholder dialogues, monitoring and measuring activities) (Kahlenborn et al. 2013).

In addition to the category-oriented analysis, we carried out a first quantification of the results. However, the coding system and the subsequent analysis represent a subjective procedure, which is why the quantification of the results is not representative by nature, but rather provides a subjective overview of which vision elements and policy instruments are currently most frequently promoted.

#### ***Identification of policy processes – actors involved in policymaking and implementation***

The identification of policy processes included analysing actors responsible for policymaking and policy implementation was conducted via desk research. We analysed which actors were responsible for initiating and implementing the respective policy documents and their related measures. We further examined the dataset to determine which other actors were highlighted as relevant for implementation.

## **Results**

### **Current policy framework for a bio-principled city in Leipzig**

Our desk research resulted in a dataset of 17 documents, including 11 policy strategies, four plans and programmes and two other records from 2018 to 2020 that explicitly address the bioeconomy and core vision elements of a bio-principled city at different policy levels. Figure 2 provides an initial overview on the current policy framework for a bio-principled city in Leipzig, including major policy documents addressing the bioeconomy and a bio-principled city explicitly and implicitly found on official government websites.

The overview however does not claim to be comprehensive. For the case study presented in this paper, our research showed that the bioeconomy has, so far, tended to be explicitly addressed at supra-national and national policy levels, but has received little or no focus at the state or city level. The bioeconomy, and more specifically, core vision elements of a bio-principled city are however increasingly addressed implicitly at all political levels.

Limiting the research to documents that were in force in 2020 and explicitly addressing the vision elements of a bio-principled city meant that we found few, if any, plans or programmes that resulted directly from the relatively newly published strategy documents – let alone evaluations and assessments of their implementation. Moreover, even if vision elements of a bio-principled city were addressed in the strategy papers, they were often not explicitly followed up in the respective action plans and programmes. When searching relevant project databases (e.g. the Community Research and Development Information Service (CORDIS) of the European Commission), it was apparent that only a few projects with a bio-principled city reference are explicitly funded, while many other relevant projects are implicitly funded.

### Inventory of policy instruments

The analysis resulted in an inventory of proposed and existing multi-level, cross-sector policy instruments. Table 3 assigns different policy instruments to the respective fields of action, which were identified by Kahlenborn et al. (2013) (see the Identification of policy elements section).

As the results in the [Current policy framework for a bio-principled city in Leipzig](#) section demonstrate, it was generally difficult to find programmes and plans resulting from identified policy strategy that explicitly address the core vision elements of a bio-principled city, let alone evaluations and assessments showing which measures had been already implemented. The analysis therefore relies predominately on proposed policy instruments from the strategy papers, which are often loosely defined and not supplemented with budgetary allocations. In addition, the presented inventory on different policy instruments provides only a snapshot of current policymaking and we cannot exclude that other instruments were implemented in the aftermath of the publication of this paper.

The coding of the dataset reveals that the focus of the policy instruments promoted is currently more on government investment (32 references) and market-based

(See figure on next page.)

**Fig. 2** Overview on the current policy framework for a bio-principled city in Leipzig

(City of Leipzig 2014, 2016, 2017, 2018a, 2018b, 2019; European Commission 2018a, 2018b, 2018c, 2018d, 2019a, 2019b, 2020a, 2020b, 2020c; Federal Ministry for Economic Affairs and Energy (BMWi) 2019a, 2019b; Federal Ministry for Food and Agriculture (BMEL) 2013, 2019a, 2019b; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2011; Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU) 2012; Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) 2016a, 2016b, 2018; Federal Ministry of Education and Research (BMBF) 2018, 2020; Federal Ministry of Education and Research (BMBF), Federal Ministry for Food and Agriculture (BMEL) 2020; Federal Ministry of Transport, Building and Urban Development 2013; Federal Ministry of Transport, Building and Urban Development (BMVBS) 2007; General Secretariat of the Council 2017; German Advisory Council on Global Change (WGBU) 2011; German Federal Government 2018; Informal Council of EU Ministers on Urban Matters 2016, 2020; Leitinitiative Zukunftsstadt 2016; Saxon State Ministry of Economic Affairs, Labour and Transport 2019, 2020; STADT-LAND-PLUS 2018; State Ministry for the Environment and Agriculture 2009, 2013, 2018; United Nations 2015, 2017)



|  | Explicitly                                   |   | Implicitly                                   |   |
|--|--|---|--|---|
|  | With measures related to bio-principled city | Without measures related to bio-principled city | With measures related to bio-principled city | Without measures related to bio-principled city |
| <b>International</b>   |  |   |  |   |
| New Urban Agenda (2017)  |  |   |  | X   |
| Transforming our world: the 2030 Agenda for Sustainable Development (2015)   |  |   |  | X   |
| <b>Supra-national (EU)</b>   |  |   |  |   |
| New Leipzig Charter - The transformative power of cities for the common good (2020)  |  |   | X  |   |
| EU Biodiversity Strategy for 2030 (2020)   | X  |   |  |   |
| Programme for the Environment and Climate Action (LIFE programme) – multiannual work programme for 2018-2020                                       | X  |   |  |   |
| Farm to Fork Strategy (2020)   | X  |   |  |   |
| Horizon 2020 Work Programme 2018-2020  | X  |   |  |   |
| The European Green Deal (2019)   | X  |   |  |   |
| Proposed Mission: 100 Climate-neutral Cities by 2030... by and for the Citizens (2020)   | X  |   |  |   |
| A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment: updated bioeconomy strategy (2018) | X  |   |  |   |
| Action Plan  | X  |   |  |   |
| Horizon 2020 Work Programme 2018-2020  | X  |   |  |   |
| A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (2018)             | X  |   |  |   |
| A sustainable European future: The EU response to the 2030 Agenda for Sustainable Development (2017)   |  |   |  | X   |
| Establishing the Urban Agenda for the EU: Pact of Amsterdam (2016)   |  |   | X  |   |
| <b>National (Germany)</b>  |  |   |  |   |
| National Bioeconomy Strategy (2020)  | X  |   |  |   |
| Research for Sustainability: A strategy of the Federal Ministry of Education and Research (2020)   | X  |   |  |   |
| Funding initiative "Städte-Land-Plus"  | X  |   |  |   |
| Flagship initiative "Zukunftstadt"   | X  |   |  |   |
| National Industrial Strategy 2030: Strategic guidelines for a German and European industrial policy (2019)   |  | X   |  |   |
| Germany's Energy Efficiency Strategy 2050 (2019)   |  |   | X  |   |
| National Strategy for Food Waste Reduction (2019)  |  |   | X  |   |
| German Sustainable Development Strategy: Update 2018 (2018)  |  | X   |  |   |
| Research and innovation that benefit the people: The High-Tech Strategy 2025 (2019)  | X  |   |  |   |
| Mitigating climate change. Creating value. Utilising resources efficiently. Charter for Wood 2.0 (2019)  |  |   | X  |   |
| The Mobility and Fuels Strategy of the German Government (MFS): New pathways for energy (2013)   |  |   | X  |   |
| White Paper: Green Spaces in the City (2018)   |  |   | X  |   |
| Climate Action Plan 2050: Principles and goals of the German government's climate policy (2016)  |  |   | X  |   |
| Shaping Ecological Transformations: Integrated Environmental Programme 2030 (2016)   |  |   | X  |   |
| National Urban Development Policy: Memorandum "URBAN ENERGIES – Urban Challenges" (2012)   |  |   | X  |   |
| Towards a national Urban Development Policy in Germany: Memorandum (2007)  |  |   | X  |   |
| Future Strategy for Horticulture (2013)  |  |   | X  |   |
| National Strategy on Biological Diversity (2011)   |  |   | X  |   |
| <b>State (Saxony)</b>  |  |   |  |   |
| Innovation Strategy for the Free State of Saxony (Update) (2020)   |  | X   |  |   |
| Mobility for Saxony: State Transportation Plan 2030 (2019)   |  |   | X  |   |
| Sustainable Development Strategy for the Free State of Saxony (2018)   |  |   | X  |   |
| Forest Strategy 2050 for the Free State of Saxony (2013)   |  |   | X  |   |
| Strategy for the Adaptation of Saxon Agriculture to Climate Change (2009)  |  |   |  | X   |
| <b>City (Leipzig)</b>  |  |   |  |   |
| Road tree concept Leipzig 2030 (2019)  |  |   | X  |   |
| Mobility Strategy 2030 (2018)  |  |   | X  |   |
| Integrated Urban Development Concept for Leipzig 2030 (INSEK) (2018)   |  |   | X  |   |
| Open Space Strategy of the City of Leipzig (2017)  |  |   | X  |   |
| Climate change: Adaptation strategies for Leipzig (2016)   |  |   | X  |   |
| Energy and Climate Protection Program of the City of Leipzig 2014 - 2020 (2014)  |  |   | X  |   |

Fig. 2 (See legend on previous page.)

**Table 3** Policy instrument mix currently found supporting Leipzig’s transition towards a bio-principled city

| Framework for Transition                          | Regulatory Instruments  | Market-based Instruments   | Government Investment   | Information-based Instruments                  |
|---|---|--|---|--|
| <b>Innovation</b>                                 | - New policies<br>- Market regulation: e.g., new legislations, prohibitions           | - Public support for R&D<br>- Start-up promotion & promotion of new business models<br>- Subsidies | - Public infrastructure provision<br>- Public pilot & demonstration facilities / projects<br>- Bio-city projects<br>- Public-private partnerships | - Competitions, granting of awards             |
| <b>Commercialization</b>                          |   | - Technical projects assistance  |   |  |
| <b>Changes in Consumer Values &amp; Behaviour</b> |   |  | - Education & capacity building   | - Public information<br>- Labelling            |
| <b>Exnovation</b>                                 | - Harmonisation of existing and new policies & initiatives at different policy levels | - Promotion of environmentally sound practices   |   |  |
| <b>Transformative Governance</b>                  | - Evaluation and adaption of policy programmes  | - Advisory services  | - Multi-stakeholder dialogue<br>- Government (re) organisation  | - Public reporting<br>- Monitoring & measuring |

instruments (32 references), while information-based instruments (11 references) and regulatory instruments (10 references) are less frequently considered.

Regarding the fields of action contributing to the transition process, an emphasis is currently put on promoting innovations (51 references) and transformative governance (24 references). Interestingly, the diffusion of innovations through commercialisation measures (2 references), the promotion of changes in consumer values and behaviour (5 references), and instruments promoting exnovation (3 references) are almost not considered at all. In the next section, we further examine in more detail the individual policy instruments found within the qualitative data analysis.

**Government investment**

The dataset reveals that government investment currently looks to strengthen transformative governance (see Table 3), e.g., through promoting multi-stakeholder dialogue in the form of stakeholder and community alliances in cities, dedicated cities platforms, and multi-level policy working groups to promote exchange of knowledge, experiences and good practices, and to trigger innovation and change. Government re-organisation appears to be another used measure to promote transformative governance, e.g., through the establishment of new public facilities to coordinate funding.

Government investment further focuses on fostering innovation. This is done in particular by providing public infrastructure, such as green infrastructure and the integration of nature-based solutions into urban planning.

Innovation is also promoted through public pilot and demonstration projects, e.g., showcase cities, innovation hubs and urban test fields (“Reallabore”). Currently only at the European level, “bio-city” projects are explicitly funded. The urban bioeconomy pilots promoted within the HOOP project (“Hub of Circular Cities Boosting Platform to Foster Investments for the Valorisation of Urban Biowaste and Wastewater”) aim at turning organic waste and wastewater into valuable resources to produce bio-based products. The European Commission provides around EUR 8 million for a group of eight lighthouse cities and city clusters to build experience and develop investments to valorise municipal waste and urban wastewater sludge into sustainable biobased products (European Commission 2022).

Promoting changes in consumer values and behaviour appears not to be a relevant focus of government investment. However, the focus is on education and capacity building measures. Instruments promoting commercialisation and exnovation, e.g., by stimulating knowledge transfer and cushioning negative social consequences of subsidy reduction are currently not considered.

#### ***Market-based instruments***

Regarding market-based instruments it appears that instruments fostering innovation are promoted over other fields of action for transition (see Table 3). Public support for R&D centres on promoting new research and innovation projects and programmes, encouraging technology development, and supporting pilots and urban living labs. At the national level, for example, the German Government is funding the flagship initiative future city (“Zukunftsstadt”) through the Innovation Platform Future City, which drives exchange on research for sustainable urban development in Germany.

The promotion of start-ups and new business models also seems relevant for policy makers. The European Commission, for example, aims at stimulating entrepreneurship in the bioeconomy in European regions and cities through supporting entrepreneurship skills training via a potential “Bioeconomy Innovation Bootcamp” for researchers. At the national level, new businesses are particularly promoted through the funding initiative “KMU-innovativ” to turn more research results into competitive business ideas and to provide start-up capital or minimize excessive start-up risks. Subsidies e.g., from the EU Structural and Investment Funds operational programmes and the EU Recovery Fund are used to help in financing dedicated climate and environmental action.

Market-based instruments promoting commercialisation and transformative governance are only infrequently mentioned in the policy documents analysed and are limited to technical assistance for project implementation and advisory services provided to municipal authorities, such as the European Investment Bank (EIB) Advisory Hub services and its Urban investment Advisory Platform (Urbis)). This applies also to policy instruments focusing on exnovation, which centre on environmentally sound practices, i.e., voluntary credits to decrease the carbon footprint of private industrial actors in urban areas.

### ***Information-based instruments***

In contrast to government investment and market-based instruments, information-based instruments are rather weakly described and not widely considered in the dataset (see Table 3). Support for transformative governance relies mostly on public reporting measures (e.g., providing websites for presenting relevant data and information on the implementation of strategies) and monitoring activities to measure progress towards goals, ensuring accountability and giving credibility to results. Innovation is particularly fostered through competitions and awards at supra-national and national policy level, e.g., the competition future city (“Zukunftsstadt”) for implementing sustainable visions in practice, or the “Holzbau-Plus” competition, which honours sustainable buildings with a holistic choice of materials, such as wood in combination with other renewable raw materials in construction, insulation and finishing.

Less considered and rarely mentioned are policy instruments promoting changes in consumer values and behaviours, which focus predominately on providing public information and developing labels.

### ***Regulatory instruments***

Regulatory instruments are also only rarely considered in the dataset and centre on promoting innovation through new policies, e.g. for sustainable planning and design, local food production and urban agriculture and market regulations (i.e. implementing new waste legislations at EU policy level and prohibiting pesticides in sensitive areas such as urban green areas) (see Table 3).

Transformative governance is thought to be strengthened through the evaluation and adaptation of policy programmes, while exnovation measures concentrate on harmonising existing and new policies and initiatives at different policy levels.

## **Overview on policy processes**

### ***Policymaking***

As the analysis of the current policy framework for a bio-principled city in Leipzig shows, mainly supra-national and national actors are explicitly involved in bioeconomy policymaking. On the supra-national level, it is particularly the European Commission that drives policymaking in this field, more specifically the Directorate General Research and Innovation and its Unit B.2 – Bioeconomy & Food Systems (former Unit F – Bioeconomy). However, the updated bioeconomy strategy of 2018 emphasizes that the strategy process was preceded by a review process with support from independent external experts and a consultation process involving various stakeholders from science, industry and civil society.

In Germany, it is primarily the Federal Ministry for Education and Research (BMBF) and the Federal Ministry for Food and Agriculture (BMEL) that lead bioeconomy policy under the umbrella of the German Federal Government. The policy strategies often formulate inter-departmental goals, priorities and milestones. In addition, they highlight participatory policy approaches, as for example in the case of the national bioeconomy strategy. The strategy is based on recommendations from an advisory council, evaluation

and progress reports of previous strategies, as well as various conferences, workshops, and consultations with stakeholders from business, academia, government, and society. In both cases, participatory processes were encouraged to consider opinions and perspectives from different stakeholders, which allows these actors to exert influence in policymaking.

At the federal state and municipal policy levels, the case study does not yet reveal any actors explicitly involved in bioeconomy policymaking.

### ***Policy implementation***

With regard to policy implementation, the European Commission often relies on its member states, as well as the cooperation with other EU institutions, such as the European Council, the European Parliament, the European Innovation Council and the European Investment Bank. With the bioeconomy strategy of 2018, the European Commission further pursues the goal of setting up an EU bioeconomy policy support facility as well as a European Bioeconomy Forum for Member States in order to support the implementation of national bioeconomy strategies. In addition, the European Commission specifically invites larger European cities to shape policy directly, for example when it comes to developing urban greening plans. The European Covenant of Mayors is often mentioned as a key actor in this context, providing a cooperation platform that allows local authorities to learn from each other.

German policy strategies often emphasize that strategy implementation takes place in constant dialog with stakeholders from business, science and society (e.g., within the Research for Sustainability (FONA) Forum). In addition, the importance of inter-departmental cooperation is repeatedly emphasized, for which various bodies are established, such as inter-ministerial working groups or state secretary rounds (such as for the implementation of the High-Tech Strategy), which help to define, steer and shape political agendas. In addition, advisory councils are often appointed for strategy implementation and their further development. These committees consist of representatives from science, business and civil society with the aim to provide impetus for implementation. In the case of the National Bioeconomy Strategy 2020, a dedicated advisory council was even appointed to prepare an implementation plan for the strategy.

### **Implications for the vision of a bio-principled city**

The analysis of the data set shows that several vision elements of a bio-principled city are already addressed in policy documents at different policy levels and are thus part of the political reality.

Vision elements that focus on broader sustainability and sustainable urban development issues tend to be addressed more often in policy strategies and its principle plans and programmes. For example, measures that aim to make cities *CO<sub>2</sub> neutral* seem to be the most relevant, being referenced 24 times. However, these measures are kept very general and only one out of the 24 measures was identified that specifically addresses bio-based innovations and solutions. In that case greening urban spaces was highlighted to reduce urban emissions. *Greening cities* seems generally to be of high policy relevance with 19 references. The focus here is on establishing green urban areas and

spaces, rehabilitating urban brownfields, promoting tree planting, installing green roofs and walls and supporting urban gardening. With 17 references, another topic of high relevance in policy documents relates to *locally coordinated production*, focusing on promoting urban food systems in general and urban farming activities in particular. *Closing urban energy and material cycles* through the recycling of residuals, bio-waste and discards and promoting nutrient recovery also appears to be of high policy relevance with 10 references.

Vision elements considered less frequently include *resource efficient* (3 references), *social inclusive* (3 references) and the *integration and decentralization of spaces for recreation, production, services, work and living* (2 references). More specific bioeconomy-related vision elements, such as the *integration of biological principles into urban planning and city life*, and *innovative sustainable building designs and construction techniques referring to biological principles and renewable resources* were only rarely addressed and focused mostly on the use of wood and new composites in construction. Vision elements relating to *energy efficient, reduction of wastes and losses, high level of quality of life, liveable*, and *renewable resources/cropping techniques and biotechnology* were not addressed at all.

### **Discussion & conclusion**

The results of the study show that the current policy mix for a bio-principled city in Leipzig is complex, uncoordinated and lacks in definitive actions. In order to answer our research question on what policy approaches currently exist to accelerate and implement such an urban transformation, we highlight that at the time of investigation, particularly the supra-national and national policy levels dominate in providing an overall policy framework with strategies, goals and instruments to pursue the transition to a sustainable bioeconomy. In doing so, they also touch on various vision elements of a bio-principled city. However, our case study has shown that the federal state and local policy levels would need to be even more explicitly involved in shaping bioeconomy policy in order to promote the transformation to a bio-principled city in Leipzig. This assumption builds on the findings of Loorbach and Shiroyama (2016), who emphasize that solutions for urban transformations would need to include bottom-up initiatives and innovations that interact with and can be connected to different policy levels and governance structures. Furthermore, Geels et al. (2019) state that innovation and learning often occur at regional and local levels, which can provide space for experimentation. This makes these policy levels crucial for sustainability transitions as they can best understand local needs, capabilities, knowledge, and capacities (Geels et al. 2019). From our point of view, explicit, inter-departmental policy strategies on this topic would need to be initiated at the federal state and city levels. Moreover, increased vertical policy coordination appears to be of great importance for the transition to a bio-principled city in Leipzig. Although these findings are certainly not unique to the city of Leipzig and may also be relevant for other cities in Germany and Europe, it must be kept in mind that the transformation towards a bio-principled city requires certain prerequisites. These include linkages to a city's economic structure, the consideration of organisational capacities, capital available and accessible, political interest as well as the support of citizens and civil society for

corresponding policies and practices. In addition, it remains to be clarified whether the chances of adopting the concept are greater in mega cities or more likely to be realised in smaller cities (Yang and Yang 2022). Considering these findings, the question remains as to whether we need to rethink the concept of the bio-principled city. The implementation of the concept in its breadth and depth does not seem realistic in a timely manner.

One challenge that arises, especially in the German context, is the dependence of local governments on higher policy levels. German cities are integrated into the European multi-level governance system and are thus also bound by instructions from several policy levels of action. For example, they must not only implement federal and state laws, but also directives and laws of the European Union (EU). At the same time, they are dependent on financial resources from the EU and the German Federal Government to implement these legal requirements (Reiners 2019). In Germany, moreover, large parts of local financial resources are earmarked for mandatory tasks such as construction supervision, registration system, traffic control and supervision, passport system etc.. For voluntary tasks such as green areas and parks, public transport, cultural programme, leisure activities etc. only left-over financial resources are foreseen (Saaro and Friedel 2014). We thus conclude that German local governments' leeway in contributing to transitioning to a bio-principled city is relatively limited. In this regard, we identify the following unanswered question well suited for future research: How can funding for implementation be ensured at local policy levels?

Policy implementation, inter-departmental cooperation and coordination are consistently emphasized in the analysed policy strategies. With its cross-sectoral orientation, the bioeconomy penetrates the economy as a whole and thus affects all policy fields. This equally applies to the vision of a bio-principled city and poses a particular challenge for horizontal policy coordination, which is currently ensured by inter-ministerial working groups and state secretary rounds. However, it should be further interested as to whether these types of policy coordination adequately enable the implementation of cross-cutting policies and accelerate the transition to a bio-principled city, or whether new organizational structures and processes are needed to overcome issues such as departmental silos.

Policy implementation is accompanied by another phenomenon that came to light during the study: the establishment of (independent) advisory bodies composed of members from business, academia and civil society, which are supposed to accompany the implementation and further development of policy strategies or even (as in the case of the National Bioeconomy Strategy 2020) to develop concrete proposals for the implementation of the strategy papers. The question arises as to whether involving more actors contributes to an increasingly uncoordinated policy implementation process and thus makes the transition to a bio-principled city even more complex, while also shifting the responsibility of policy implementation to new actors.

With regard to our research question to what extent the urban bioeconomy and the idea of a bio-principled city are considered in current policymaking, the results of the study confirm our initial assumption that the bio-principled city currently reflects more of a programmatic idea than a real political agenda. The vision of a *sustainable city* is still the primary focus of the political discourse, often linked to the idea of a smart or

climate-neutral city. The term “bio-principled city” is not explicitly addressed in policy documents, while currently terms such as “bio-city”, “urban bioeconomy” or even “circular cities” are much more frequent. However, it became clear that these terms were particularly used with regard to the recycling and valorisation of urban wastes and residual materials.

Our research framework enabled us to present the existing policy mix for a bio-principled city in Leipzig, including its strategic components and the associated policy processes. At this point, we wish to highlight that the methodology chosen to analyse the policy instrument mix also has its limitations, largely due to the subjective nature of the qualitative document analysis. Against this backdrop, we emphasize that the current policy instrument mix so far consists of rather loose and poorly targeted measures. However, as the German Advisory Council on Global Change (WGBU) noted in 2011 (Fig. 2), the transformative effect on the production and consumer side requires simultaneously applying different instruments so that systemic changes can be triggered.

Our analysis thus offers interested policy makers and scientists an example of how an incidental and thus patchy policy mix can look like in practice. By highlighting its strengths and corresponding limitations, we provide a starting point for deliberate interventions to further promote the vision of a bio-principled city.

We conclude that Leipzig’s current extended policy mix, while not necessarily preventing a transition to a bio-principled city, does not explicitly promote it either. We see further potential for investigating how the current policy mix can be improved and how Leipzig’s transition towards a bio-principled city can be advanced. Future policymaking could benefit from a further assessment of the existing policy mix by examining its impact and evaluating in how far it would need to be adapted (e.g. through additional measures) to achieve the target vision of a bio-principled city and to set the transformation process in motion. In addition, it would be relevant for decision-makers to understand how complex and comprehensive such an adjustment of the policy mix would need to be, which policy fields would have to be included and how the cities’ scope of action could be increased compared to other governance levels.

In this context, it seems to us more realistic and more effective in terms of pragmatic policymaking to first analyse where the potential for a sustainable bioeconomy in Leipzig – or any other city – lies and which strengths the city has regarding the vision of a bio-principled city. Drawing on the local strengths and priorities, targeted policies should first be identified for a more narrowed vision before further exploring the full breadth and depth of implementing the vision of a bio-principled city.

#### Abbreviations

|                 |  |
|-----------------|--|
| BMBF            | Federal Ministry for Education and Research            |
| BMEL            | Federal Ministry for Food and Agriculture              |
| CAQDAS          | Computer-Assisted Qualitative Data Analysis Software   |
| CORDIS          | Community Research and Development Information Service |
| CO <sub>2</sub> | Carbon dioxide   |
| EIB             | European Investment Bank                               |
| EIU             | Economist Intelligence Unit                            |
| EU              | European Union   |
| EUR             | Euro   |
| FONA            | Research for Sustainability                            |
| GDP             | Gross Domestic Product                                 |
| HOOP            | Hub of Circular Cities Boosting Platform               |
| ICT             | Information and Communication Technologies             |



|             |  |
|-------------|--|
| IP          | Intellectual Property  |
| MFS         | Mobility and Fuels Strategy of the German Government                                       |
| NPC         | National Platform City   |
| R&D         | Research and Development   |
| SDG         | Sustainable Development Goal   |
| Trans. gov. | Transformative Governance  |
| FAO         | Food and Agriculture Organization of the United Nations                                    |
| UM          | Ministry of the Environment, Climate Protection and the Energy Sector in Baden-Württemberg |
| UNFCCC      | United Nations Framework Convention on Climate Change                                      |
| Urbis       | Urban investment Advisory Platform   |
| WGBU        | German Advisory Council on Global Change   |

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### Authors' contributions

Christin Boldt: Conceptualisation, Methodology, Formal analysis, Investigation, Writing - Original Draft, Revision, Visualization, Project administration. Daniela Thrän: Supervision, Writing - Review & Editing. The author(s) read and approved the final manuscript.

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### Availability of data and materials

The dataset generated during and/or analysed during the study are available from the corresponding author on reasonable request.

### Declarations

#### Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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