Urban Transformations

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# Promoting urban sustainability transitions while revitalising regions: a blueprint for accelerating Leipzig's urban bioeconomy and sustainable urban-rural development

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## Abstract

Depending on local strengths and priorities, the urban bioeconomy offers various solutions for different cities to reduce greenhouse gas emissions, develop recyclable raw material sources, conserve natural resources, close material and energy cycles and preserve biodiversity. This study explored how Leipzig's current policy mix can evolve in order to initiate and implement the transition to a sustainable urban bioeconomy. Through expert interviews, we uncovered potential future fields and necessary measures for Leipzig. The analysis indicates that establishing the bioeconomy cannot be confined to urban areas. The bioeconomy vision for Leipzig encompasses the creation of an urban-rural system that facilitates the formation of regional value-added networks through the utilisation of biological resources, biobased processes and products. Our findings offer interested policy makers actionable recommendations for practical implementation. By identifying which policy areas, actors and levels of governance should be involved in the transition process and which challenges, success and risk factors currently exist for the transformation, we set the stage for co-creating a transition agenda for an urban-rural bioeconomy system.

## Science highlights

- Establishing the bioeconomy cannot be limited to urban areas.
- Revitalizing urban-rural ties via the bioeconomy can drive regional change for sustainable development.
- Cities present opportunities for integrating bioeconomic value chains from surrounding regions.

**Keywords** Bioeconomy, Urban bioeconomy, Urban transformations, Sustainability transitions, Transition management, Policy mix

## Policy and practice recommendations

Initiating a bioeconomy transition in Leipzig needs comprehensive adjustments of the existing policy mix.

Establishing an urban-rural bioeconomy system requires new transformative capacities.
Further evaluation of policy options for actions may increase social acceptance of the transition process.

## Introduction

This year marks the 20th anniversary of the bioeconomy. In 2005, the European Commission introduced for the first time the concept of the knowledge-based bioeconomy. Since then, the bioeconomy has evolved from a research-oriented strategy to a policy model in more than 60 countries (Patermann and Aguilar 2021). Along the way, the concept was taken up at the international level by the Organisation for Economic Co-operation and Development (OECD) in 2009. Driven by advances in the life sciences, the bioeconomy promised to add value to a wide range of products and services, thereby making a significant socio-economic contribution in OECD countries (OECD, 2009). The first Global Bioeconomy Summit in 2015 showed that the conceptualisation of the bioeconomy varies across the world, suggesting the existence of multiple bioeconomies (IACGB, 2015). In 2018, the international bioeconomy community agreed on a unified definition by stating that the "bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy." (IACGB, 2018). This understanding shows that the bioeconomy is not only about replacing fossil fuels with renewable raw materials, but also about developing products and services with improved properties and novel functionalities that can bring social, health and environmental benefits (IACGB, 2020). The political motivation for promoting the development of the bioeconomy in 2015 varied according to a country's resource base, specialisation and level of economic development. However, recent strategies have changed to incorporate a wider range of objectives, including promoting sustainability and the circular economy, addressing climate change (Teitelbaum et al. 2020), and mitigating trade-offs between economic, environmental and social objectives (Dietz et al. 2024). More recently, the bioeconomy has also been associated with the potential to accelerate the transition to a more sustainable economic system. This transformative concept goes beyond conventional notions of economic growth, encompassing not only the emergence of new industries on the supply side, but also significant changes in lifestyles (Losacker et al. 2023).

Paes et al. (2024) explain how the bioeconomy offers also a unique opportunity to address the complex challenges of sustainable urban development. At the local level, the integration of biological principles into urban planning and city life promises to sustainably transform cities, with environmental benefits (e.g. reducing carbon dioxide in urban environments for a better climate and cleaner air), economic benefits (e.g. new revenue streams from recycling bio-waste) and social benefits. For example, urban food production practices have the potential to improve food security and thus increase local self-sufficiency. Moreover, it can lead to educational benefits, such as higher employment rates, and health benefits, including healthier lifestyles through better access to green infrastructure (Paes et al. 2024). The term 'urban bioeconomy' is therefore understood to denote an economic system that integrates bioeconomic components, such as green

infrastructure, urban agriculture and bio-waste utilisation, with a view to improving environmental, economic, social and health outcomes for cities and their surrounding areas (Yang and Yang 2022).

Compared to the overarching concept of the bioeconomy, the urban bioeconomy has received little attention in academic discourse to date. However, we note that the topic has implicitly attracted growing interest in the scientific community. In a literature review, Stöber et al. (2023) concluded that the urban bioeconomy is mainly associated with urban metabolism (Bezama et al. 2021), green innovation areas (Pallagst et al. 2019), urban green infrastructure (Schneider et al. 2020) and urban agriculture (Schneider et al., 2 020 & Winkler et al. 2019), as well as in the context of circular economy, waste management and ecological value creation (Taylor Buck and While, 2021; Ddiba et al. 2022 & Taffuri et al. 2021). It was found that the current scientific literature focuses mainly on ecosystem services and the use of new resources in urban areas (Stöber et al. 2023).

Despite the numerous opportunities presented by the bioeconomy it is not inherently sustainable and carries a number of potential risks, including increased competition for land and biomass use, soil pollution (Yang and Yang 2022), and the possibility of rebound effects, where efforts to increase, sustainability may inadvertently lead to increased resource use (Paes et al. 2024). Furthermore, Eversberg et al. (2023) point out that it is not practical to replace the vast and ever-increasing quantities of fossil resources with bio-based and renewable alternatives. Other researchers have even suggested that a sustainable increase in biomass use may not be possible at all, especially in the Global North, where the majority of countries are already net importers of biomass. An increase in biomass imports has been identified as a significant risk factor, with potential negative impacts such as biodiversity loss and reduced food security, particularly in the Global South (Boyer et al. 2023). These critical perspectives indicate that the impacts of the bioeconomy on economic growth and development must be included in economic assessments and that various trade-offs must be taken into account to ensure the sustainable development of the bioeconomy, including at the urban level (von Braun 2018).

Managing these trade-offs and embedding the urban bioeconomy politically is a highly complex process, as it involves cross-sectoral and multi-level policymaking (Boldt and Thrän 2023). Dietz et al. (2022) highlight the critical issue of identifying the most effective policy strategies for managing the transition to a sustainable bioeconomy. At the same time, the literature analysis by Gottinger et al. (2020) shows that so far only 21% of scientific publications examine regional and local bioeconomy transformations, with only 17% focusing on policy measures and their influence on transformation. These findings highlight the need for further research to enable governing the transition to a sustainable bioeconomy at the local level. This paper addresses this research gap by providing a more in-depth analysis of the urban bioeconomy concept to understand a city's priorities and the means by which a transformation towards an urban bioeconomy can be initiated. We focus on the case of Leipzig as the city was the first municipality in Germany to prioritise the development of a bioeconomy in an urban context.[1] In 2020,

[1] Since then, other German cities have also adopted the urban bioeconomy model. For instance, in April 2024, the city of Stuttgart unveiled the world's first urban strategy for a bioeconomy policy, with the objective of contributing to the city's climate neutrality by 2035 (Schuchardt et al. 2024).

the Leipzig Economic Development Corporation set up a working group on the urban bioeconomy with the aim of identifying sustainable business models for the bioeconomy in Leipzig and the surrounding region. In addition, the initiative sought to facilitate the transition to a sustainable bioeconomy in collaboration with urban and regional stakeholders. With a population of 628,718 in 2023 (city of Leipzig 2024), Leipzig is among the most rapidly growing cities in Germany. The city is located in the Central German Mining Region, which comprises three German federal states (Saxony, Saxony-Anhalt and Thuringia) and a total of seven districts and two district-free cities. In recent years, Leipzig has undergone dynamic development and established itself as one of the most important economic, scientific and cultural centres in the region. A significant number of companies of varying sizes have established themselves in the city (Brödner et al. 2023), while Leipzig also houses a substantial number of research institutions. The specific thematic focus of bioeconomic research is on biotechnology and systems biology, chemistry and economics. Various non-university research institutions, the University of Leipzig and local universities of applied sciences, as well as transfer and innovation funding institutions with a specific focus on the bioeconomy are attractive employers within the local bioeconomic research landscape (Gaffenberger and Brödner, 2022). As a centre of economic activity and knowledge creation, Leipzig thus represents a compelling case study for the study of the urban bioeconomy and offers a unique opportunity to generate bioeconomic innovations through a dynamic interplay between entrepreneurial and academic research and development.

With this study we are striving to understand: What are Leipzig's strengths in the context of the urban bioeconomy and which bioeconomic solutions and topics should be prioritised in the future? Furthermore, we want to explore the measures necessary to implement the identified solutions and to anchor the vision of an urban bioeconomy in Leipzig. Given the origins of the bioeconomy as a policy-driven topic, expert interviews were considered an appropriate methodology to gain a deeper understanding of the local dynamics of bioeconomy development. The interviews were analysed using a qualitative thematic coding approach (Kuckartz 2007) and the computer-assisted qualitative data analysis software (CAQDAS) MAXQDA. Individual questions were also analysed quantitatively using simple frequency counts in Excel.

The study provides insights into the changes in the existing policy mix necessary to initiate and implement the transition to an urban bioeconomy in Leipzig, offering interested policymakers with recommendations for practical implementation. With this study, we aim to build bridges between research on policy mixes in bioeconomy research, political sciences and innovation studies. By combining an exploratory, qualitative methodology with broader conceptualisations of policy mixes and relevant insights on bioeconomy governance we intent to contribute to the new strand of interdisciplinary social science research on policy mixes (Kern et al. 2019). In doing so, we deliver an insightful empirical analysis that can furnish other cities in Germany and Europe for identifying strengths in relation to the urban bioeconomy, determining priorities and instruments for future implementation.

## The power of policy mixes in navigating urban bioeconomy transitions

Transitioning to an economic system based on a sustainable bioeconomy refers to fundamental change in the existing economic system: from a linear fossil-based to a circular bio-based economy. The challenge is to integrate a multitude of new products, markets and technologies, while simultaneously adapting existing infrastructures and changing social norms and behaviours, as well as political and institutional structures (Schiller 2024).

In the field of sustainability transitions, the term 'transition' is used to describe a fundamental change in socio-technical systems. These changes can include technological, material, organisational, institutional, political, economic and socio-cultural aspects. A key feature of transitions is that they involve a wide range of actors and usually extend over a considerable period of time (Markard et al. 2012).

Urban transitions are particularly complex, given that they comprise multiple economic sectors simultaneously and necessitate a multi-level policy perspective (Frantzeskaki et al. 2018). The evidence from the field of urban climate transitions demonstrates that successful climate policy at the local level necessitates urban experimentation and partnerships in vertical governance (between local, regional and national governments) and horizontal governance (between civil society, the private sector and government) (Shtjefni et al. 2024).

Despite the contribution of various initiatives and technological innovations to the rapid development of the bioeconomy in recent years, the transition process is still at an early stage. This is mainly due to the existence of barriers that still hinder the transformation. In this context, Gottinger et al. (2020) identified six main barriers to the transition process: (1) existing or lacking policies and regulations, as well as problems with policy implementation; (2) technology application and product development, as well as the availability of raw materials, supply structures and physical infrastructure; (3) market demand and creation, as well as investment conditions; (4) social acceptance; (5) the creation and application of knowledge and the existence and development of efficient networks, and (6) the willingness and ability of incumbents to accept lock-ins and challenges related to prevailing standards that evolve over time. The analysis revealed the pivotal role of a supportive policy framework in facilitating the transition to a sustainable bioeconomy. This includes robust accompanying measures that account for potential trade-offs (Gottinger et al. 2020). Rogge et al. (2017) emphasise that low-carbon transitions, in particular, require strategic political efforts to overcome existing unsustainable, carbon-rich energy systems. Policy mixes provide a method of understanding this real-world complexity while also promoting deliberate transitions to more sustainable practices (Rogge et al. 2017).

In order to approach the research questions, we draw on different disciplinary perspectives on policy mixes from, i.e. bioeconomy research, political science and innovation studies.

Analysing policy mixes in the context of bioeconomy research is a relatively new field of research. While Marvik and Philp (2020) and Dietz et al. (2023) focus on the policy instrument mix to initiate transition processes, other authors focus on identifying effective policy mixes for a specific aspect of the bioeconomy, such as the forest sector (Ladu et al. 2020) or analysing a policy mix for certain region (Ecuru et al. 2016) or city (Boldt and Thrän 2023).

In contrast, policy mixes in the field of political science tend to consider analysing both the instruments and the objectives they are intended to achieve. The characteristics of policy mixes are also considered, including the consistency of multiple instruments, the coherence of multiple objectives, and the composition of instruments to achieve policy goals (Rogge et al. 2017). Kern and Howlett (2009) found that policy objectives are coherent if they can be achieved simultaneously without significant trade-offs or compromises. Policy instruments, on the other hand, are consistent if they reinforce rather than undermine each other in the pursuit of policy objectives (Howlett and Rayner 2013). The more coherent the policy objectives and the more consistent the policy instruments, the more effective the policy can be (Kern and Howlett 2009).

Also, the interdisciplinary field of innovation research examines the role of policy mixes in promoting innovation from a broader perspective. It emphasizes their dynamic nature, the importance of policy processes and long-term objectives, and the challenges for policy coordination across multiple sectors and levels of government (Rogge et al. 2017). While Quitzow (2015) proposes the concept of a policy strategy as an alternative framework for policy assessment and comparison, Rogge and Reichardt (2016) define policy mixes as a combination of three building blocks (1) *policy elements* that define the strategic direction through policy strategies (policy objectives and principal plans) 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). These broader contributions on policy mixes have recently attracted increased attention in the scientific literature on sustainability transitions, with a growing number of studies examining and analysing their impacts on the transitions of sociotechnical systems and their practical applications. At the same time, the assessment of individual mix components has been steadily developed (e.g. Purkus et al. (2017), Rosenow et al. (2017), Del Río and Cerda (2017), del Río González (2007) and Duan et al. (2017) (Ladu et al. 2020).

We adopt this broader conceptualisation of policy mixes to identify means and mechanisms for initiating and implementing a sustainable urban bioeconomy transition. With a view to our Leipzig case study, we want to explore how the existing policy mix needs to be adapted in order to establish an urban bioeconomy. Previous analysis by Boldt and Thrän (2023) has demonstrated that the current policy mix for a bio-principled city in Leipzig is complex, uncoordinated and lacks in concrete measures. While the bioeconomy has received little or no attention at the state or city level so far, explicit policy strategy documents have been identified at the supranational and national policy levels. The existing and proposed policy instruments currently focus more on public investment and market-based instruments, while information-based and regulatory instruments are less frequently considered. In terms of policy areas contributing to the transition process, the current focus is on promoting innovation and transformative governance. It is noteworthy that the diffusion of innovation through commercialisation measures, the promotion of changes in consumer values and behaviour, and instruments to promote exnovation are not given due consideration (Boldt and Thrän 2023).

This study aims to underscore the pivotal role of policy mixes in facilitating urban bioeconomy transitions, thereby enhancing the empirical understanding of policy mixes. To this end, we aim at comprehensively examining necessary policy instruments, while

also exploring the involvement of goals, policy areas, actors, and governance levels in the transformation process. Furthermore, we intent to identify the prevailing challenges, critical success and risk factors for the transformation and explain policy options for action to be taken. In doing so, we aim to bridge across scientific disciplines and to generate comprehensive actionable knowledge.

## Methods

As outlined in Chap. 2, the analysis of policy mixes constitutes a relatively novel research topic within the domain of bioeconomy research. Consequently, this study adopts an exploratory approach, utilising a qualitative method to gain a deeper insight into the development processes of the bioeconomy in Leipzig, in addition to enhancing comprehension of the measures necessary to implement the identified bioeconomic solutions for the city. To this end, expert interviews were conducted with the assistance of a questionnaire (see Additional file 1). This approach facilitated a more profound understanding of the local focus areas, challenges and obstacles, culminating in the formulation of hypotheses at the end of this study that are relevant for future research.

### Questionnaire

A questionnaire was developed with the objective of ascertaining the necessary adjustments to the prevailing policy mix in Leipzig in order to initiate and implement a transition towards a sustainable urban bioeconomy. This approach is grounded in the broader conceptualisation of policy mixes proposed by Rogge and Reichardt (2016). In doing so, the questionnaire was structured into three sections. The initial section comprised a series of open-ended questions designed to elicit the experts' general attitudes towards the potential of the regional and urban bioeconomy, as well as the level of awareness of local bioeconomy activities. The central section of the questionnaire was divided into two topic areas: In order to ascertain the strengths of Leipzig in the context of the urban bioeconomy and to identify strategic fields of action for *policy strategy*, we were initially interested in the experts' assessment of the implementation potential of various bioeconomic topics and solutions. A total of 15 topics and solutions were provided, representing elements of the vision of a bio-principled city as identified by Boldt and Thrän (2023). The evaluation should be made on a seven-point Likert scale. Furthermore, respondents were invited to propose additional topics and solutions that they considered relevant to the urban bioeconomy in Leipzig in order to identify any regional characteristics that were not encompassed by the aforementioned topics. The experts were permitted to indicate that they held "no opinion" at any point during the survey. These responses were assigned a value of "0". In order to examine *policy processes* necessary to actually implement the identified topics and solutions, the experts were further asked to indicate which policy areas and actors should be involved in policy making and implementation. We focus on policy areas and actors, since their efforts and activities particular determine all phases of the policy cycle, including problem identification, agenda setting, policy formulation, legitimisation and adoption, implementation, evaluation or assessment, policy adjustment, succession and termination (Rogge and Reichardt 2016). The experts were further asked to assess the leverage effect of specific measures (*instrument mix*). As the German Advisory Council on Global Change (WGBU) noted in 2011, the transformative effect on the production and consumer side requires simultaneously applicating

different instruments so that systemic changes can be triggered (WGBU, 2011). In light of the aforementioned considerations and in alignment with the findings of Kahlenborn et al. (2013), the measures have been structured into five domains of action, with a view to elucidating the ways in which policy can facilitate the transition process: promoting (1) innovation, (2) commercialisation, (3) changes in consumer behaviour and values, (4) exnovation, and (5) transformative governance (Kahlenborn et al. 2013).

The final section of the questionnaire was designed to ascertain how the financial flexibility of municipal actors could be enhanced in order to facilitate the transition towards a sustainable bioeconomy in Leipzig. Furthermore, the objective was to identify the current challenges, opportunities and risk factors associated with this transformation. Finally, inspired by Stark et al. (2021), the experts were asked which three factors they considered most important for the development of a sustainable urban bioeconomy in Leipzig.

The questionnaire was subjected to a preliminary examination by three independent parties. The feedback was used to refine the questionnaire's structure and clarity.

#### Sample

The authors conducted an extensive stakeholder mapping and expert analysis. Experts were defined as individuals with competence and expertise in the field of bioeconomy, for example through their professional position, relevant publications or recommendations from third parties. Concurrently, experts were sought who possess knowledge of local and regional backgrounds and contexts in the bioeconomy that are otherwise difficult to access (Wassermann 2015). The relevant experts were identified through the following data sources: the websites leipzig.de, staatsregierung.sachsen.de, bioökonomie.de, dbfz.de/biooekonomieatlas.de, sas-sachsen.de and nachhaltiges-leipzig.de. Additionally, the authors were able to incorporate the contacts they had previously established during the inaugural meeting of Leipzig's urban bioeconomy cluster in 2019. Furthermore, experts were identified through search engine keyword research. Initially, 137 potential experts were identified and registered in a database, representing a broad spectrum of areas. These included different political levels (international, supra-national, national, federal state and city level) and different stakeholder groups relevant for the bioeconomy, such as science, business, civil society, politics, as well as other actors from clusters and associations, foundations, and advisory bodies.

A total of 16 experts were selected from the initial population and contacted in a first round on 25 September 2023. The different levels of knowledge and information about current developments and frameworks for the bioeconomy at different policy levels were considered and categorised in the assessment. Each stakeholder received a personal email invitation to the interview. In selecting the sample, the authors aimed to ensure that the experts were as heterogeneous as possible, so that a relatively manageable sample would cover the widest possible range of expertise, experience, and perspectives on the research topic. In the event of automatic responses or no response to the invitation, stakeholders were contacted again by e-mail or telephone. A total of two follow-ups were carried out. Due to some refusals, the group of experts was extended. The authors employed a combination of theoretical and snowball sampling, which involved an iterative process. This implies that, while the initial interviews were being conducted, the interviewees recommended further interview partners in Leipzig and the surrounding

**Table 1** Identified contacts

| Institution | Contacts |
|---|---|
| Public administration | 34 |
| Civil society | 26 |
| Business | 24 |
| Non-university research | 16 |
| Cluster, networks & associations | 11 |
| Economic development agencies | 11 |
| Politics | 6 |
| University research | 5 |
| Federal state agencies | 5 |
| Consultancy & Think Tanks | 5 |
| International Organisations | 4 |
| Foundations | 3 |
| **Total** | **150** |

*Source* Own calculation

**Table 2** Role of interviewees

| Interviews | Role of Interviewees |
|---|---|
| Interview 1 | Cluster |
| Interview 2 | Network |
| Interview 3 | Informal regional development platform |
| Interview 4 | Architectural office |
| Interview 5 | University research institution/university of applied sciences |
| Interview 6 | Bioenergy company |
| Interview 7 | Non-university research institution |
| Interview 8 | University research institution/university of applied sciences |
| Interview 9 | Circular economy company |
| Interview 10 | Cluster/network |
| Interview 11 | Public limited company |
| Interview 12 | Network |
| Interview 13 | Non-university research institution |
| Interview 14 | Chamber of Industry and Commerce |
| Interview 15 | Association/network |

*Source* Own survey

region who were already active in the field of the urban bioeconomy or provided information on further topics and viewpoints on the bioeconomy in the region. These were taken into account in the further selection of experts. The additional stakeholders identified were added to the existing database and invited for interviews. This resulted in a total of 150 identified contacts (see Table 1).

The recruitment of experts continued until 15 individuals had been identified and contacted, with interviews conducted between 5 October and 8 December 2023.

Table 2 illustrates the diverse range of experts involved in the survey. Despite best efforts, it was not possible to recruit representatives from politics and public administration. In response to many enquiries, feedback was often received indicating that representatives were unable to provide meaningful statements on the topic of the bioeconomy or that there was no responsibility for it within their respective institutions. Furthermore, it was often stated that answering the second part of the questionnaire on policy measures would necessitate the involvement of the relevant management level.

All interviews were conducted digitally using the video communication software Zoom. Following verbal consent, 14 of the 15 interviews were audio and video recorded. For one interview, a memo was written as the interviewee did not wish to have the interview recorded. Interviews generally lasted one hour. On three occasions, individual questions were subsequently answered by e-mail due to lack of time. The authors concluded that the most significant insights had been gathered following the 13th expert interview, due to the increasing repetition of responses. Additionally, it proved challenging to recruit further experts for interviews. It became evident that although the extended group of experts were well-versed in Leipzig, they lacked specialist knowledge of the bioeconomy. The objective of this study is to present a comprehensive overview of the current trends and perspectives, based on the insights of leading experts. To this end, 15 interviews were conducted.

### Data analysis

The 14 recorded interviews and the memory log were automatically transcribed using the Amberscript software. Subsequently, the transcripts were reviewed and corrected manually. All transcripts were fully anonymised for further processing. The expert interviews were analysed using a qualitative thematic coding approach (Kuckartz 2007) with the computer-assisted qualitative data analysis software (CAQDAS) MAXQDA 2022. In doing so, the main categories were developed on the basis of the questionnaire (questions guiding the analysis). All text passages referencing the predefined categories were coded accordingly. This approach also facilitated the identification of text passages in which the context of the categories was only implicitly described. We then analysed the coding material in more detail by identifying inductive subcodes. This process resulted in a deductive-inductive coding system (see Additional file 2). Additionally, individual questions (including questions 1, 2, 4, 5, 6, 8, 10, 12, 13, 14a-e, 16 and 21) were also analysed qualitatively using simple frequency counts in Excel.

During the interview, it was observed that some of the experts occasionally exhibited difficulty in clearly assigning the responses to the given scales. This was attributed to the fact that they found it challenging to decide between one or the other number. As the interviewer did not insist on a clear choice during the interview, this resulted in ambiguous variables (e.g. 2.5) being rounded up during the analysis. In order to maintain the clarity of the results, the introduction of additional variables was avoided. Nevertheless, the authors choose to include these responses in the analysis, particularly because a discernible trend emerged, and because the objective of the survey is less about statistical representativeness than about identifying perceptions, trends, and perspectives.

## Results

### Urban bioeconomy in Leipzig: strengths, priorities and opportunities for regional integration

With regard to the **potential of the urban bioeconomy** for a more sustainable economy in Leipzig the experts highlighted that there are a number of potential avenues for integrating bioeconomic value chains. Consequently, nine out of fifteen experts rated the potential as very high to rather high. In particular, the research landscape in Leipzig was identified as a significant source of innovative potential for the further development of the bioeconomy. Moreover, the local population`s receptivity to change was discerned.

Subsequently, the experts were then requested to indicate which **bioeconomy-related topics and solutions** they would like to see more implemented in Leipzig in the future. The results are summarised in Fig. 1.

To quantify the results, the median (Mdn) of all interview statements was calculated. According to the experts, the urban bioeconomy in Leipzig should initially prioritise the promotion of recycling, nutrient recovery, and the circular use of materials in the city and the surrounding region, the development of cross-company solutions for closing material cycles, the promotion of urban greening and greening technologies and the use of building materials made from renewable raw materials (Mdn = 7). Other topics they would like to see implemented (Mdn = 6) include the use of biomass in the chemical industry; the integration and decentralisation of recreational, production, service, working and residential spaces; the creation and restoration of wetlands, forests and green spaces through the use of organic cultivation techniques and environmental biotechnology; the development of innovative material and design solutions; the expansion of urban agriculture; and the use of biogas for municipal electricity or heat.

Furthermore, the experts proposed additional topics for consideration in Leipzig's urban bioeconomy, including the biobased recycling of textiles, the production of green hydrogen from biogenic sources as part of the energy mix, as well as greater involvement of the food industry. A comprehensive analysis of the expert responses on the implementation potential of individual bioeconomy topics and solutions is presented in Additional file 3.

Nevertheless, six out of fifteen interviewees evaluated the potential of the urban bioeconomy in Leipzig rather low as they found it challenging to delineate the urban bioeconomy. The potential for establishing a bioeconomy was perceived more in the context of the urban-rural relationship. This was due to the fact that the biomass resources in urban areas were considered to be limited, and the biobased value creation takes place outside of Leipzig, in particular with regard to the industrial bioeconomy. Instead, the bioeconomy should be considered in its totality, as it is a matter of overall regional effects, of which Leipzig is merely one component. Figure 2 compares the experts' assessments regarding the potential of the bioeconomy for the Central German mining region and for the city of Leipzig.

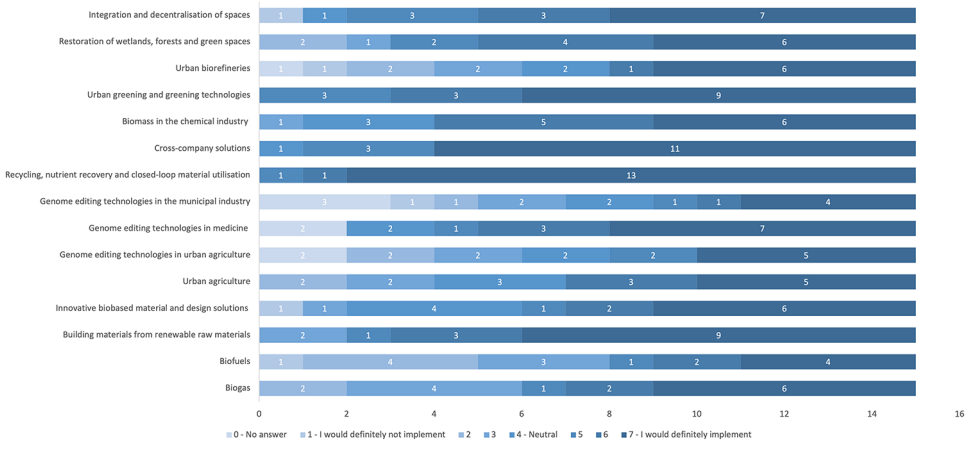


**Fig. 1** Expert evaluation of bioeconomy topics and solutions. *Source*: Own survey

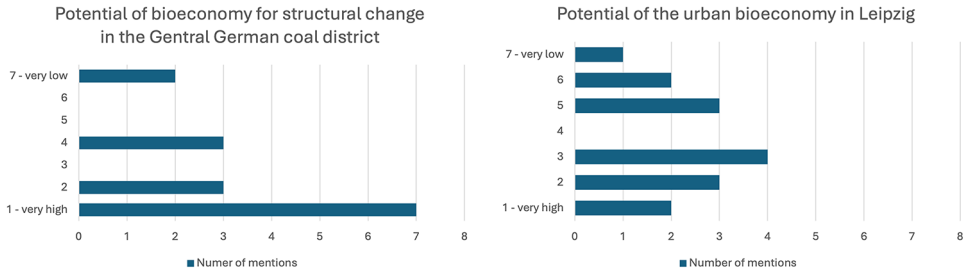


**Fig. 2** Expert assessment of the potential of the bioeconomy in Leipzig and the Central German mining region. *Source*: Own survey

The results demonstrate that 10 out of 15 experts rated the **potential of the bioeconomy for structural change in the Central German mining region and the establishment of sustainable value chains** as being of very high or high order. In doing so, they identified specific characteristics in the Central German mining region that support this assessment. These include various economic sectors that could be made fit for the future, such as the agriculture and forestry sectors, as well as the food and the chemical industries. They also noted the current settlement and investment activities of industrial manufacturing companies[2], as well as the high concentration of scientific expertise. The region has a wealth of expertise in a wide range of disciplines, coupled with a robust resource base, including those derived from agriculture and forestry, industrial by-products, and residual and waste streams. This endowment is perceived as a promising avenue for leveraging the bioeconomy, particularly as a potential feedstock for biomanufacturing. This expert assessment confirms the findings of Brödner et al. (2022) and of Brandt et al. (2021) who stated that the Central German mining area is no longer characterised solely by the lignite industry. Rather, a well-developed and diverse industrial structure has already been established as a result of the structural break in the course of the system change in 1990. This includes the region's knowledge-intensive (highly innovative) economy, whose core actors are currently diversifying their core competences to develop new fields of competence (such as renewable energies, bioeconomy, hydrogen, recycling and recycling management), which also offer direct technological links with high economic potential for the actors in the lignite industry (Brandt, 2021). The bioeconomic topics and solutions that the experts identified as relevant for the region include the use of biogas for electricity or heat production, the utilisation of building materials manufactured from renewable raw materials, the expansion of urban-rural agriculture, the promotion of recycling, nutrient recovery and circular economy in the city and the surrounding region, the utilisation of biomass in the chemical industry, and the establishment of biorefineries to convert organic waste into high-quality raw materials.

Consequently, the experts proposed the establishment of an **urban-rural system for raw materials and products**, in which value chains could be developed collectively in an efficient and value-adding manner. Such an approach could assist to counter alienation from the producing or raw material-providing area. Many experts considered cities to be

[2] A number of bioeconomic flagship projects are currently being funded in the region. For instance, the Finnish UPM Group is currently investing over EUR 1 billion in the construction of the world's first industrial-scale biorefinery in Leuna, with operations scheduled to commence imminently. Furthermore, a facility for the production of bio-based ethyl acetate is under construction in Elsteraue near Zeitz by CropEnergies, with an anticipated commencement date of April 2025. The bioethanol produced at the Südzucker site in Zeitz will be refined into a platform chemical (BioEconomy Cluster e.V., 2024).

a nucleus that could provide the scientific basis for re-establishing urban-rural cooperation. Furthermore, the city could be regarded as a demand engine for bio-based products originating from the surrounding region and thereby fostering regional integration. As a hub of economic activity and knowledge creation, Leipzig offers a unique opportunity to produce bioeconomic innovations through a dynamic interplay between entrepreneurial and academic research and development - with benefits extending beyond the urban area, i.e. the Central German mining region. The Leipzig case study thus supports the theoretical assumptions of Stöber et al. (2023) that the competencies of a city can also drive the bioeconomic transformation of regions. It thus provides an interesting example for other resource-intensive regions, such as coal mining, intensive agriculture and forestry in Germany and Europe, by showing that the revitalisation of urban-rural relations through the bioeconomy has the potential to drive further regional structural change towards sustainable development.

#### Adaption of the existing policy mix in Leipzig

In order to implement the identified bioeconomic topics and solutions the interviews revealed the necessity for adapting the existing policy mix in Leipzig. In light of these findings, it became evident that a combination of major changes is initially required. First and foremost, *organisational and institutional changes* would be needed for developing new business models and reducing bureaucracy. The city of Leipzig represents a unique case, as the political parties and associations represented in the Leipzig City Council are organised into seven distinct factions. This often necessitates a considerable degree of compromise among political parties. Experts 4 and 5, both residents of Leipzig, emphasised their own experience with a system change, namely from the German Democratic Republic (GDR) to the Federal Republic of Germany (FRG) in 1990. The transition brought numerous changes, demonstrating that once the political framework has been defined, the development of technological innovations also progresses, and consumer behaviour also changes.

Secondly, *cultural and behavioural changes* are key drivers for implementation. Expert 6 posited that the will of the population must be altered before political frameworks can be adapted. It is evident that mere regulation and perceived patronising by the government would not be acceptable in a democratic society, as evidenced by the so-called heating debate in 2023 (Krohn 2023)[3].

#### *Policy processes*

All the experts interviewed emphasised that all the *policy areas* listed in Fig. 3 must be involved to a greater or lesser extent in the policy making and policy implementation process in order to shape the urban bioeconomy in Leipzig. It would be difficult to exclude any one policy area as synergies between policy departments are key. This reflects the complexity of implementing the bioeconomy, with the primary challenge being the involvement of numerous stakeholders.

Furthermore, all experts emphasised the necessity of *involving a diverse range of stakeholders* at various policy levels in policy making and policy implementation (see Fig. 4).

[3] In order to enhance Germany's commitment to climate protection, the German government has enacted the Buildings Energy Act (Gebäudeenergiegesetz – GEG). The amendment to the GEG, known as the Heating Act, has been the subject of considerable debate among the German public and politicians, primarily due to concerns that it would impose undue financial burdens on citizens.

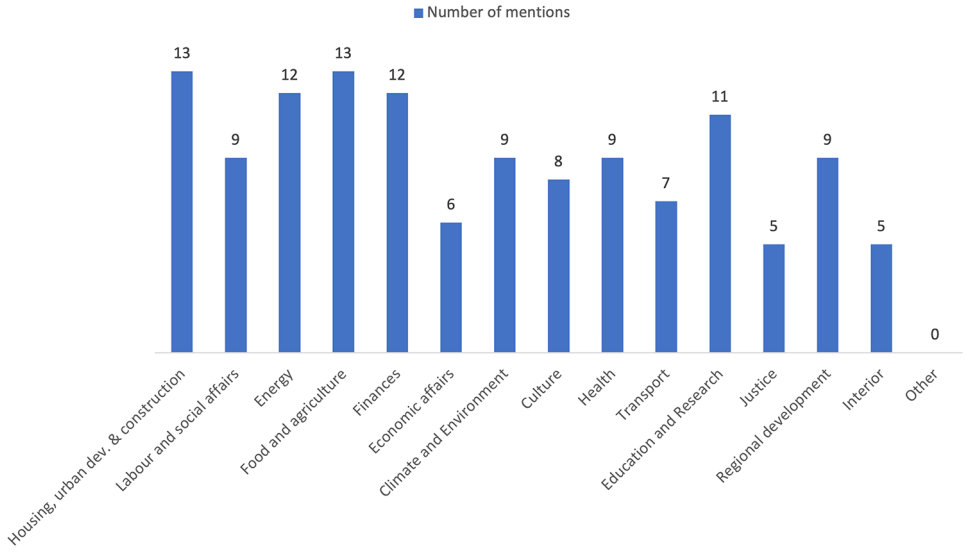


**Fig. 3** Policy areas that need to be involved in an effective policy mix to steer the transition to an urban bioeconomy in Leipzig. *Source*: Own survey

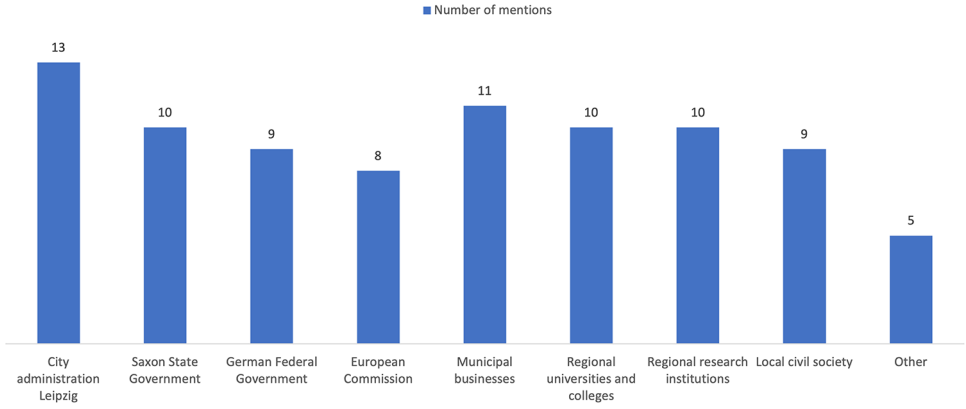


**Fig. 4** Stakeholders to be involved in shaping an urban bioeconomy in Leipzig. *Source* Own survey

Expert 7 underscored the importance of integrating also the educational sector into the development of the urban bioeconomy. This encompasses both primary and secondary educational institutions, as well as post-secondary vocational training and adult education centres.

The impetus for bioeconomy-related change is currently initiated primarily from Brussels, which is then implemented at the federal level. It is, however, imperative to incorporate additional actors at the local and regional levels as local shaping would primarily occur at these levels. The experts emphasised that the driving force behind an urban bioeconomy should be the city of Leipzig in collaboration with the state of Saxony. However, local authorities lack the capacity to implement financial measures effectively. Consequently, the federal government and the European Commission are seen as crucial for coordinating and funding implementation.

Other experts emphasised the necessity for the involvement of a robust actor in the implementation process, such as a regional network or a municipal outsourcing company, in order to facilitate Leipzig's engagement with its surrounding region. Expert 1

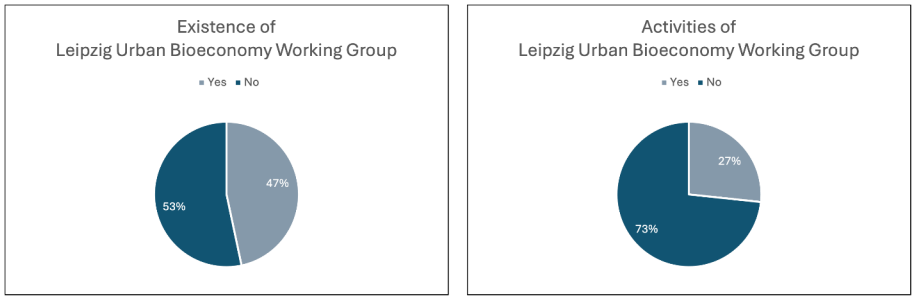


**Fig. 5** Experts' awareness of the existence and activities of Leipzig's urban bioeconomy working group. *Source*: Own survey

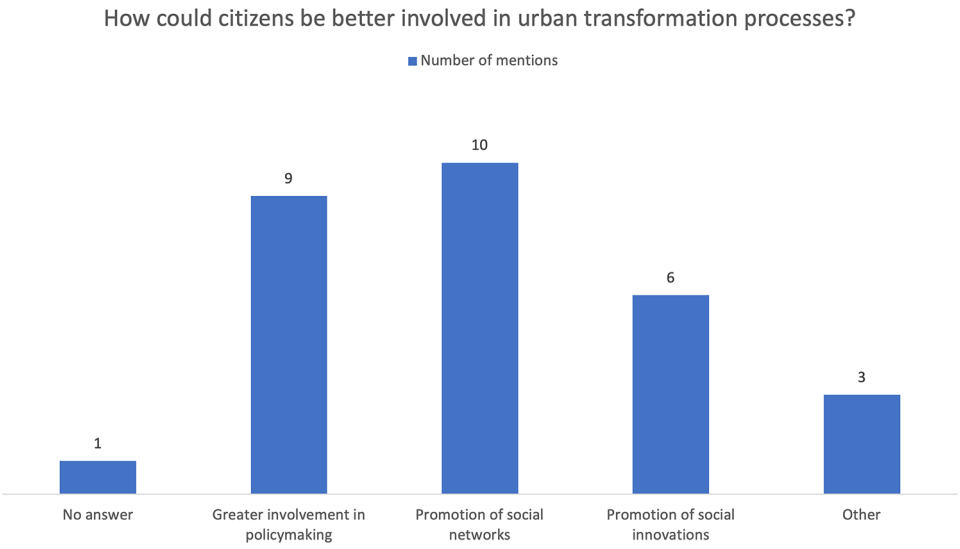


**Fig. 6** Suggestions from experts on how to better involve citizens in the urban bioeconomy transformation. *Source*: Own survey

highlighted that local actors are already engaged in collaborative efforts and are currently members of the Network Energy and Environment e.V. (Netzwerk Energie und Umwelt e.V.). Nevertheless, less than half of the experts surveyed were also familiar with the bioeconomy working group, while only just under a quarter were aware of its activities (Fig. 5).

The feedback from the experts regarding the involvement of stakeholders in policy design and implementation further indicated that there is no single instrument that is more effective than others in involving citizens in the transformation process (see Fig. 6).

### *Policy elements*

In regard to the overarching *policy strategy*, the majority of experts concurred that greater integration of the urban bioeconomy into German bioeconomy policy would have a leverage effect, enabling the transfer of EU-level goals to the national context, embedding a transformative, systemic perspective in national policy and promoting horizontal and vertical coherence. Moreover, the necessity for the formulation of explicit urban and regional bioeconomy strategies was emphasised, given the absence

of a dedicated bioeconomy strategy for Saxony or Leipzig (in contrast to other German federal states or cities).

With a view to an appropriate *instrument mix* that could facilitate the implementation of the prioritised bioeconomic topics and solutions identified in Sect. 4.1, the experts have evaluated the most promising measures that would be important to implement in addition to the existing and already proposed instruments (see Additional file 4, Fig. 1). The assessment resulted in the adaptation of the inventory of multi-level, cross-sector policy instruments proposed by Boldt and Thrän (2023) (see Fig. 7). As illustrated in Fig. 7, a substantial proportion of the prioritised policy instruments reinforces the existing set of instruments in areas where there are existing gaps. This emphasises the necessity for specific interventions in the transformation process to initiate it (e.g. with regard to the commercialisation of innovations). This results in a more comprehensive overall mix of instruments. A comprehensive analysis of the expert responses on the most

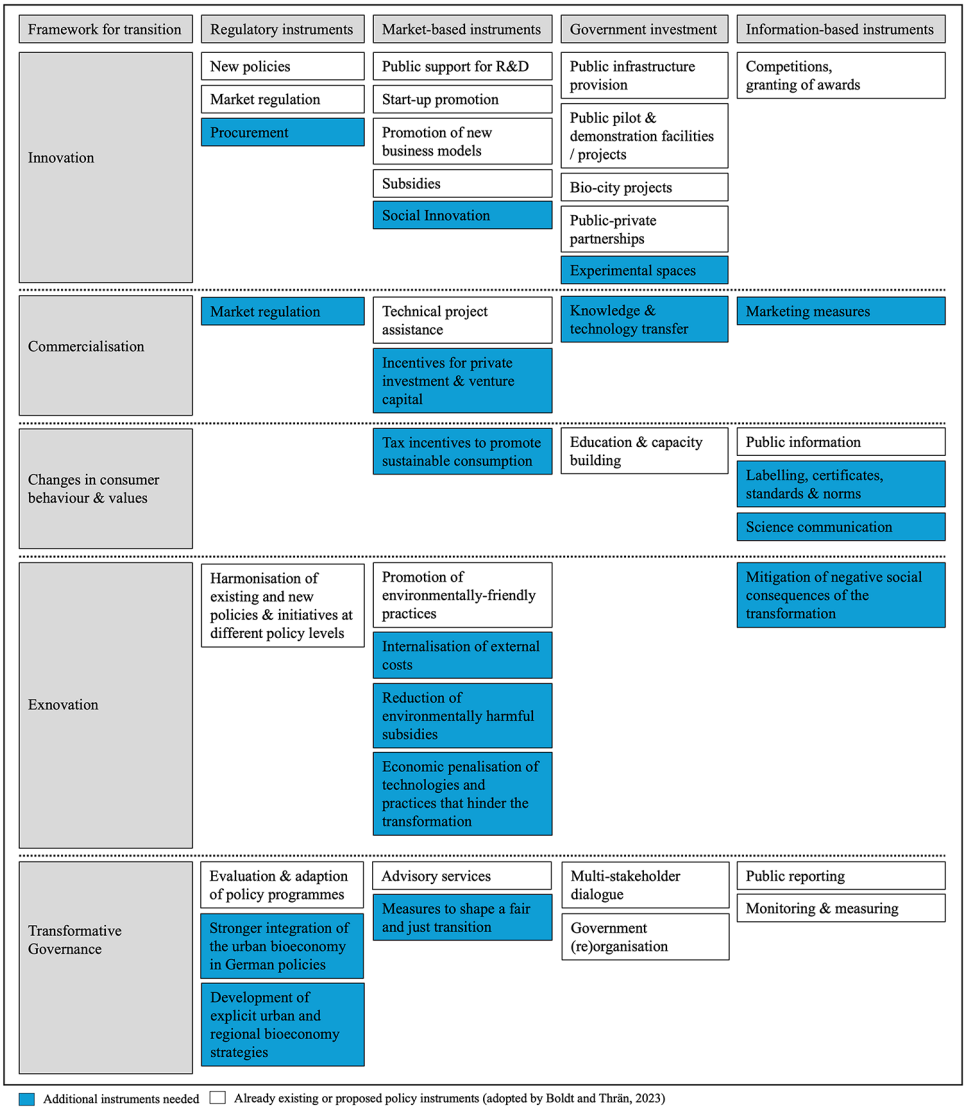


**Fig. 7** Adapted inventory of proposed policy instruments. *Source* Own illustration based on Boldt and Thrän (2023).

promising measures to implement the identified bioeconomic topics and solutions is presented in Additional file 4.

**Current challenges, success and risk factors for a sustainable urban bioeconomy in Leipzig**

One of the most significant current challenges for initiating and implementing the transition towards an urban bioeconomy in Leipzig, is the connection to rural areas and the regional application of bioeconomic innovations. Despite the existence of numerous developments and promising concepts and ideas, there is a gap in application, which is also due to the regional economic structure. While the region is home to a number of large companies, there is a dearth of small and medium-sized enterprises (SMEs) (German "Mittelstand"), which play a pivotal role in the innovation landscape.

Another significant challenge is the attraction of financial resources at local level. In order to improve the financial flexibility of local actors the experts emphasised the necessity of considering a wide range of financing options. This would include banks taking up the issue of sustainable finance, but also increased government funding from higher policy levels, private capital, and crowd funding. They also emphasised the importance of open funding possibilities.

Other challenges for Leipzig include the attraction of manufacturing companies to the region, limited renewable resources, low purchasing power and local entrepreneurial capital, a lack of cooperation between different authorities and the coordination within the city administration and with industry and neighbouring municipalities, a lack of visibility and the difficulty in communicating the concept of the bioeconomy, as well as a lack of political courage to drive the transformation process forward. Furthermore, the existing regulatory framework was also frequently cited as an obstacle to the approval of new products. In this context, the over-bureaucratisation and overly restrictive nature of regulation were identified as significant risk factors for successful transformation, as they impede openness to innovation. Concurrently, the erratic nature of policy frameworks and the unpredictability of changing agendas would render policy direction unreliable for enterprises, thereby increasing business risk and discouraging investment.

Conversely, the experts identified the citizens of Leipzig as a crucial success factor in the success of the transformation to an urban bioeconomy in Leipzig. Other success factors have been identified, including reducing competition for use (e.g. in land use), ensuring multiple and cascading use of raw materials, transparency and monitoring of the transformation, agile public agencies as drivers of the bioeconomy (such as the SPRIND agency[4] already based in Leipzig) (SPRIND, 2024), and the economic viability and visibility of the bioeconomy.

As illustrated in Fig. 8, the availability of biomass is anticipated to be the most pivotal factor influencing the advancement of a sustainable urban bioeconomy in Leipzig. Expert 10 drew attention to the fact that Germany is already a net importer of biomass and is shifting its footprint abroad. It is therefore important that the bioeconomy does not exacerbate this trend. Expert 7 added that this applies not only to biomass, but to resources in general. Other factors that could influence sustainable urban bioeconomy development include stronger political support for a sustainable bioeconomy, the

[4] The Federal Agency for Breakthrough Innovations (SPRIND) is a federal agency in Germany that has as its objective the promotion of disruptive technologies. Following a successful analysis and evaluation process, project subsidiaries can be set up and funded as required, currently with between EUR 4 and EUR 15 million per year.

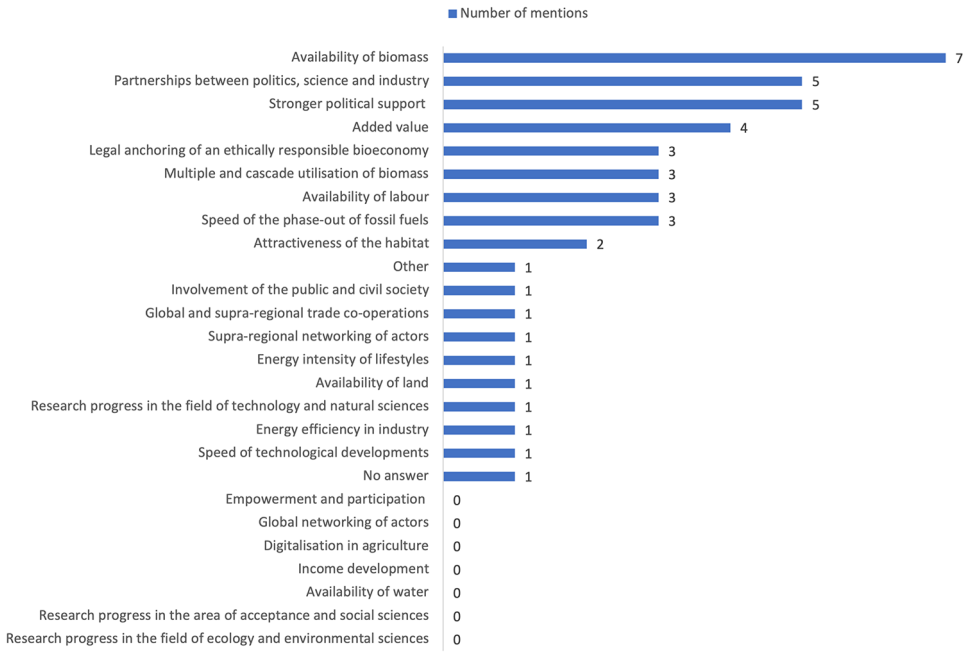


**Fig. 8** Experts' voting on success factors for sustainable urban bioeconomy development. *Source* Own survey

development of partnerships between politics, science and industry, as well as the creation of added value.

## Discussion & conclusion

One of the main findings of this study is that the establishment of a bioeconomy cannot be limited to urban areas. In fact, the bioeconomy vision for Leipzig extends beyond the urban area and encompasses the creation of an urban-rural system that facilitates the formation of regional value-added networks through the utilisation of biological resources, biobased processes and products. From an urban perspective, the establishment of such a bioeconomy system represents a significant opportunity to reinforce local and regional economies across administrative boundaries. In the case of Leipzig, a city situated within the Central German mining region, the multitude of existing bioeconomic initiatives present opportunities for revitalizing the urban-rural relationship. With this result, we provide an insightful contribution to the existing scientific literature on urban bioeconomy transitions, as it illustrates the relevance of the surrounding region for bioeconomic urban development beyond previous assumptions.

The study further demonstrated that the utilisation of renewable resources in urban areas must be conducted in a sustainable manner. In order to establish a sustainable urban bioeconomy, it is therefore of the utmost importance to avoid competing uses and to promote value creation networks within the framework of circular and cascading utilisation. Nevertheless, the plethora of ongoing initiatives in Leipzig illustrate that an urban bioeconomy encompasses not only the substitution of fossil resources with renewable materials, but also the development of products and services with enhanced properties and novel functionalities that can confer social, health and environmental benefits.

Nevertheless, the current policy mix is inadequate and needs to be adapted to achieve substantial advancement towards a sustainable urban bioeconomy in Leipzig. Therefore,

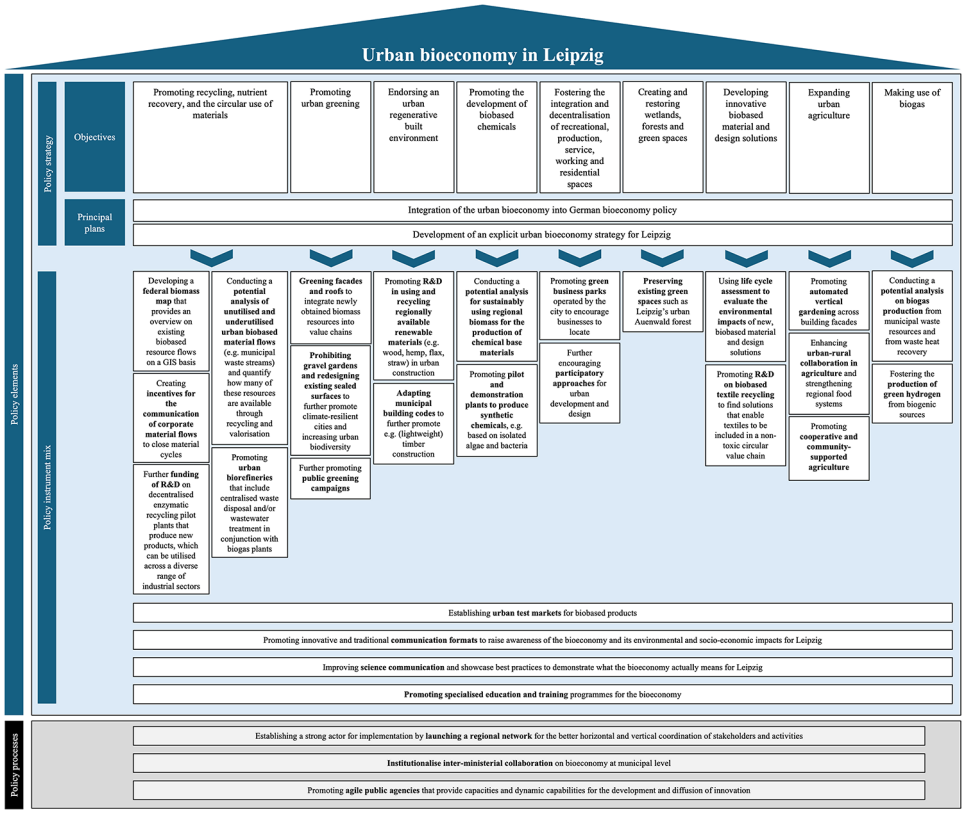


**Fig. 9** Policy options for action to adapt the current policy mix in Leipzig

a transition agenda is required which considers not only promoting innovations, but also organisational, institutional, cultural and behavioural changes as major turning points. In light of the identified strengths of Leipzig in relation to the urban bioeconomy and the evaluated measures for implementing the prioritised bioeconomic topics and solutions, we propose the following policy options for action to adapt the current policy mix in Leipzig (Fig. 9).

We recognise that these options for action, formulated on the basis of the experts' responses, are still very general. We maintain that this is mainly due to the fact that Leipzig is still at an early stage of its transformation. However, these options for action could serve as points of reference for Leipzig in formulating a more concrete transition agenda. Such an agenda should include not only the responsibilities for implementation, but also the time horizons, milestones, necessary financial and human resources and success indicators.

In addition to numerous political and administrative levels, a diverse range of stakeholders from business and industry, science, civil society and the general public must be involved in this transition agenda. However, the results of the expert survey indicate that there is currently a lack of capacities and financial resources for cooperation that includes a wide range of actors, as well as different political domains and levels. It can thus be hypothesised that new forms of effective cooperation must be found to meet this governance challenge. We therefore see a need for further research to improve understanding of how transformative capacities can be built at the urban level.

The adapted inventory of policy instruments, as presented in Chap. 4.2.2, could further form part of a future transition agenda. However, Kern and Howlett (2009) highlight that, due to the intricate nature of political decision-making processes, it is challenging to implement significant alterations to the policy mix, even when new political objectives are established. Achieving consistency, coherence and congruity is a challenging undertaking for management, given the presence of existing interests, ideas and institutional path dependencies, which collectively serve to complicate reform efforts (Kern and Howlett 2009). It is likely unfeasible to attain complete coherence and consistency in practice. Therefore, the objective should be to make incremental progress towards optimal coherence within the constraints of available resources (Rogge and Reichardt 2016). The success of a potential reform process in Leipzig will depend on the extent to which policy objectives and instruments are aligned with existing policies. A comparison to the snapshot of the policy mix presented in Boldt and Thrän (2023)[5] allows us to show that the objectives for the urban bioeconomy in Leipzig identified in this study can be aligned with objectives at higher (supranational and national) policy levels. However, as a report by the European Environment Agency (2022) demonstrates, a policy mix can include a range of objectives, not all of which can be addressed at the same time, and the relative importance of the objectives can change over time or be challenged by different actors, meaning that transitions are not linear processes.

In terms of the policy instrument mix, it is evident that the policy instruments proposed in this study are primarily aimed at reinforcing the existing mix, e.g. with regard to the commercialisation of bioeconomic innovations, and making it more comprehensive. This should particularly help to identify solutions that are suitable for the urban-rural system. However, many of the experts emphasised that the removal of existing regulatory barriers is essential to enable the full implementation of biobased processes (e.g. regarding the use of residual and waste materials). Furthermore, the results demonstrate that some of the measures (e.g. those related to exnovation) would present significant regulatory challenges and that social acceptance is unlikely to be guaranteed. We therefore hypothesise that policy or strategy must be developed in such a way that social acceptance of bioeconomic transformation processes can be guaranteed and see need for further research in this area.

While the assessment method is only able to capture the complexity of policy instruments to a limited extent, it provides valuable insights, including the identification of central points for political intervention. As the policy mix for the urban bioeconomy in Leipzig currently also consists of implicit policies, the consistency and coherence with goals and instruments of other policy areas, such as climate or circular economy, would also have to be examined. We thus see further research potential here to examine the consistency of the elements, the coherence of the processes and the completeness of the policy mix in more detail – also with regard to policy design in the context of multi-level governance.

This study on the transition to an urban bioeconomy in Leipzig makes an empirical contribution to the new strand of interdisciplinary social science research on policy

[5] To demonstrate the extent to which the updated (or proposed) policy mix is consistent and comprehensive, the present study primarily compared the consistency of policy instruments and the coherence of existing and proposed policy objectives with existing strategies that explicitly address the bioeconomy (see Boldt and Thrän 2023). A detailed overview of the policy objectives of the various strategies is presented in Table 1 of Annex 5, while Table 2 of Annex 5 then summarises synergies and incoherences as well as the different prioritisation of these strategies.

mixes by combining an exploratory, qualitative methodology with broader conceptualisations of policy mixes and relevant insights on bioeconomy governance. In doing so, the study also enriches bioeconomy research by applying a broader policy mix perspective and providing insights into the geography of transitions that are also relevant for practitioners. The formulation of policy options that could feed into a future transition agenda provides actionable knowledge to support urban transformations for sustainability and resilience. We conclude, that while a systemic transition to an urban bioeconomy in Leipzig is challenging, it is nevertheless feasible, and that Leipzig has the potential to act as a nucleus for establishing of an urban-rural bioeconomy system and would be able to drive systemic change at the regional level, particularly in the Central German mining area.

A limit to our study is that the limited number of interviews conducted limits the reliability of the research findings. Furthermore, the coding system developed, and the subsequent analysis represent a subjective procedure. As a result, the quantification of the results is not representative by nature, but rather provides an exploratory overview. Additionally, interview effects such as communication and situational factors have been attempted to be minimised, but cannot be completely excluded. Finally, our study provides only a static snapshot analysis of policy mix at a given point in time.

**Abbreviations**

| | |
|---|---|
| CAQDAS | Computer-assisted qualitative data analysis software |
| EC | European Commission |
| EU | European Union |
| EUR | Euro |
| FRG | Federal Republic of Germany |
| GDR | German Democratic Republic |
| GEG | Gebäudeenergiegesetz (Buildings Energy Act) |
| Mdn | Median |
| OECD | Organisation for Economic Co-operation and Development |
| SDG | Sustainable Development Goal |
| SMEs | Small and medium-sized enterprises |
| SPRIND | Federal Agency for Disruptive Innovation |
| WGBU | German Advisory Council on Global Change |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42854-025-00074-w.

Supplementary Material 1: Questionnaire

Supplementary Material 2: Deductive-inductive coding system

Supplementary Material 3: Detailed analysis of the experts' responses to question 8: implementation potential of individual bioeconomy topics and solutions for Leipzig

Supplementary Material 4: Detailed analysis of the experts' responses to questions 14a, 14b, 14c, 14d and 14e

Supplementary Material 5: Comparison of strategic goals

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**Author contributions**

C.B.: Conceptualisation, Methodology, Formal analysis, Investigation, Writing - Original Draft, Visualization, Project administration. D.T.: Supervision, Writing - Review & Editing.

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**Data availability**

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

## Declarations

**Ethics approval and consent to participate**
Not applicable. By participating in the study, all participants consented to the anonymous analysis and publication of the results. No personally identifiable information, including biomedical, clinical and biometric data, was collected.

**Competing interests**
The authors declare no competing interests.

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