A Systematic Approach for Assessing and Managing the Urban Bioeconomy

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Abstract As urbanization processes happen all over the world, an increasing attention is being given to the management of the resources that feed these urban areas. When addressed from a systems perspective, the connection between resources, production and manufacture sectors and society can be clarified, especially when viewed from a life cycle perspective. The goal of this chapter is therefore to provide an analysis of the state of the art resources management tools that take a life cycle management approach, with a particular focus on bio-based resources and the latest experiences in the bioeconomy sector. This analysis is the basis for discussing the necessary steps and needs for establishing an "urban bioeconomy metabolism", whose definition can help to managing the material streams within the city limits in connection to the bio-based resources of the city's surroundings.

Introduction

Urbanization processes are taking place at unprecedented speed and intensity. The majority of humankind is currently living in urban areas, a development that is predicted to continue, with more than two thirds of the global population expected to live in cities by 2050 (UN, 2015). The implications of this will be enormous. The consumption of land for the development of urban areas, as well as for satisfying the needs of their societies for food, energy and raw materials (e.g. for construction) is ever expanding and is having irreversible impacts on the biosphere (Seto et al, 2012). Cities are using 60% of the residential fresh water resources and produce 75% of the global carbon emissions (Grimm et al., 2008). Furthermore, 90% of the global economic power (GDP) and 65% of the global energy consumption are concentrated in urban areas (Solecki et al, 2013). As a result, the ecological footprint of a city can be as much as 200 times greater than the area of a city itself (Wigginton et al, 2016). It is clear that urbanization is one of the main drivers of global environmental change.

However, the rise of cities and the underlying urbanization processes is also offering great potential for change. On the one hand, cities with their physical, organizational, institutional and demographic compactness (Evans, 2011) have the chance to help reducing ecological footprints through minimizing land consumption and sprawl, supporting short travel distances, allowing efficient use of water, energy and waste. On the other hand, they are places where innovations are catalyzed because people of diverse backgrounds and experiences can come together, bringing in capacities and skills to produce ideas for a sustainable development. Cities can thus play a key role in dealing with the challenges of global environmental change (Rosenzweig et al, 2015), as they are economic fulcrums and places where innovations can be put into practice (Sassen, 2012).

In order to prioritize the work on addressing these challenges, the European Network "Eurocities", an organization that "brings together around 140 of Europe's largest cities and over 45 partner cities, that between them govern 130 million citizens across 39 countries" (www.eurocities.eu) published its "Strategic Framework 2014-2020 - Towards an Urban Agenda for the EU". In this framework, they identify the five focus areas that "to a large extent align with the EU's strategic priorities and provide a strong strategic operational framework for EUROCITIES" (Eurocities, 2016). These are: (i) Cities as drivers of quality jobs and sustainable growth, (ii) Inclusive, diverse and creative cities; (iii) Green, free-flowing and healthy cities; (iv) Smarter cities; and (v) Urban innovation and governance in cities.

The parallels of these strategic focus areas and the goals of the bioeconomy are remarkable. Bioeconomy is defined as "the production and utilization of biological resources (including knowledge) to provide products, processes and services in all sectors of trade and industry within the framework of a sustainable economy" (Siebert et al 2018). According to the German Bioeconomy Council (Bioökonomierat 2018) "the future bioeconomy will satisfy primary human needs; it will be technology-driven and take the environment into account." The relevance of a regional and city-oriented perspective is also highlighted by a global expert survey carried out by the German Bioeconomy Council (Bioökonomierat, 2018). This is due to the many processes within cities in which bioeconomy plays a relevant role, f or example, in the production of sustainable building materials, food production close to the city, and for implementing sound infrastructures for the appropriate cascading systems for waste, residual materials and nutrients.

During December 2017, within the framework of the SYMOBIO project (Systemic Monitoring and Modelling of the Bioeconomy, www.symobio.de), the Department of Bioenergy at the UFZ, Leipzig, carried out a series of workshops. The aim of these workshops was to analyze what representatives of: civil society, the scientific community and the industrial sector in Germany expect towards bioeconomy. To frame the discussion, these workshops focused on the 17 proposed UN sustainable development goals (SDGs) and their relevance for a sustainable transition towards a biobased economy. One of the main results was the ranking of the most relevant SDGs according to the German bioeconomy stakeholders (Thrän et al, 2018; Zeug et al 2019).

The result was a ranking of the SDGs from high relevance to low relevance as follows: (1) SDG 7: Affordable and clean energy, (2) SDG 8: Decent work and economic growth, (3) SDG 9: Industry, Innovation and Infrastructure, (4) SDG 2: Zero hunger, (5) SDG 17: Partnerships for the Goals, (6) SDG 13: Climate action, and (7) SDG 15: Life on land. This resulting list shows the priorities of the various stakeholders.

In addition, it is important to highlight the relevance of the regional perspective, in particular of cities, on the successful implementation of the bioeconomy strategy. In this regard, cities (or city districts in case of larger urban areas) can be considered as the smallest representative entity where an integrative approach, for assessing the potential effects of implementing the bioeconomy, can be carried out. The relevance of this urban-centered perspective is also taken-up by city representative themselves. Many political initiatives are meanwhile pushed forward by cities themselves, particularly in the field of climate change. Also with regard to a more urban-based bioeconomy, there are first steps taken and the first initiatives aiming at linking the global relevance of cities with the ideas promoted by the bioeconomy are starting to be established. In May 2018 the workshop “The road to Urban Bio-economy: Barriers and Solutions to Closing the Loops of Bio-Resources” was organized in Brussels to discuss the challenges faced by cities to promote bio-resources along the entire value chain. However, there is a drawback in the concept taken as a basis for discussion, as the EU discusses the urban bioeconomy concept by focusing it merely on the utilization of the residual bio-based streams (Accorigi, 2018): the definition of an urban bioeconomy in its current form entails too narrow an understanding of the urban bioeconomy concept. In fact, there is a high need to develop a sound and more comprehensive concept of urban bioeconomy.

The urban bioeconomy concept can be used to identify and understand the transformation processes of bio-based resources on an urban level, as well as to understand the mechanisms underlying the interactions between different actors found at the city level in the bioeconomy field and for unraveling the full potential of a city-focused bioeconomy concept. Moreover, by linking the identified urban activities to the actual bio-based material streams that are processed within city limits, the urban bioeconomy model would help in the local monitoring and management of the available bio-based resources.

However, what is “urban bioeconomy,” how can it be thoroughly defined? What are key characteristics of an urban bioeconomy concept? This chapter is a first attempt to draw a connection on the lessons learned in the bioeconomy field and the needs for defining an urban bioeconomy concept that can be actually used by local and regional authorities to optimize the management of bio-based resources within the city limits.

Managing the bioeconomy: lessons learned and challenges ahead

The increasing demand of biomass resources for food, feed, industrial and energy applications is putting a huge pressure on the management of these resources. Moreover, as the definition of sustainability has changed from the three-dimension perspective to a more holistic approach, recently defined by the Sustainabiliy Develoment Goals (SDGs), the complexity behind a sustainable management of the available resources has also increased. As a consequence, management systems and tools have become major attention, as they are capable of incorporating and assessing different factors to provide support to decision makers. For this reason, this chapter intends to provide an analysis of the current state of the art of management systems for resources management, taking into consideration the urban bioeconomy concept as introduced in the previous section. This chapter focuses therefore mainly on the tools that have been developed to address the management of bio-based resources (especially in the industrial sectors), and identifies the needs that should be addressed in the short- to mid-term to understand and manage the sustainability issues involved in an urban bioeconomy.

Management tools in a systems perspective

Bioeconomy has been traditionally connected to the industrial sector, and particularly to the development of novel technological approaches that deal with the utilization of biomass resources. The multitude of technology breakthroughs and innovations in the field over the last years have forced companies and industrial sectors to constantly restructure the ways they work, organize and manage. And it is envisaged that this connection within different sectors will even increase in the short to medium term, as there are several advantages for the establishment of integrated value chains and networks (Bezama et al 2019, Hildebrandt et al 2019, Hildebrandt et al 2020).

However, this will require a series of new management tools, in order to cope with the necessities of the different industrial sectors. Currently, a variety of management tools are available. They vary from tools for technology and project management, knowledge management tools, environmental management tools to business process management tools or costumer relation management tools.

Schawel and Billing (2018) describe in their book “Top 100 Management Tools“ the increasing demands on duties and responsibilities of a manager challenging within the competing market and the multiplicity of tasks and topics to coordinate. Including the definition of strategies, pilot projects, develop concepts and methods as well as increasing the efficiency of the company or motivate the stuff and guide them target-oriented. To achieve these goals and comply the described tasks exist a variety of management tools. They group these different management tools in three categories: strategical management, controlling and timing and communication.

These groups simultaneously represent the steps in a continuous management process. Listed are tools from ABC-analysis, investment management as a strategical management tool, to Sales-Funnel-Analysis as problem analysis tool or the Osborne method as a creativity technique.

In 2007 Rigby asserted an explosion of management tools in the former two decades seeing it as a need to successfully guide an increasingly competitive market. He defines the multifaceted management tool compilation as a help to handle complex decisions, especially business decisions, in a global world. By means of those a company can improve their performance as well as their profits. Therefore it is necessary to encompass the weaknesses and strengths of each tool for a proper appliance. Rigby identified the 25 most popular tools, defined them with an explanation of how the tools are being used.

Rigby and Bilodeau (2017) assessed recent trends in management tools related to usage and satisfaction. They again listed the 25 most popular tools, within Strategic Planning is topping the list as the most popular tool globally. As a trend they identified digital technology as a dominant factor across all industries and regions. Therefore "Digital Transformation" is a tool helping to challenge these shifts evident in increasing popularity and satisfaction compared to the last survey.

Wrisberg and de Haes (2012) compile assessment tools for the environmental dimension of sustainable development to support business decisions. Based on a systemic perspective, subdividing systems as function-oriented and region-oriented or agreement-oriented, they describe the weaknesses, strengths and possible combinations of the most commonly tools as Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), Material Flow Accounting (MFA), Life Cycle Assessment (LCA), Environmental Risk Assessment (ERA), physical and environmental Input Output Analysis (env IOA) or Multi-Criteria Analysis (MCA) within a systems perspective.

Industrial sectors as agriculture, construction, fisheries, forestry and manufacturing use management tools. Qorri et al. (2018) outlined various methods applications in regard to sustainability performance of supply chains in different sectors. The results showed an increasing application of Multi-Criteria Analysis. The most common tools are Life Cycle Assessment, Analytical Hierarchy Process, Fuzzy set approach, Balance scorecard and Data Envelopment analysis.

Lager (2016) reviewed methods and tools within the process industries such as chemicals, food and beverage, mining and metals, mineral and materials, pharmaceuticals, pulp and paper, steel, and utilities. He considers current applications like technology road-mapping, R&D strategy development, and portfolio balancing and future perspectives including raw-material supply, production process and products. He goes in especially for the collaboration between process companies and technology/equipment suppliers. There is outlined a need for closer linkage between innovation management and operations management to come after in industry and academia.

Thinking in a systems perspective requires a change in thinking from a linear understanding to circular. The basic concept of this is seeing biological processes as interlinkage systems. As a result companies have shifted to the product-service-system (PSS) business model. Mourtzis et al (2018) established a holistic approach for PSS evaluation. The aim is to capture all its lifecycle phases in a value-added chain including aspects from providers and costumers perspective. Therefore also a software tool was evolved and applied in a case study of the mold making industry. Also Vezolli et al. (2015) appreciate the (sustainable) product-service-system as a strategic management design or tool applicable to various industrial sectors to combine customer satisfaction and economic wealth respecting environmental impacts.

As a tool for a systemic approach in the cluster management Ucler (2017) developed the intelligent Cluster Assignment Tool concept to enhance innovation applicable to different sectors in developing economies. The approach delivered a strategic framework for cluster management.

Also Tamayo-Orbegozo et al. (2017) developed a strategic model which offers a more regional application within the context of eco-innovation after identifying a lack of analysis of the dynamics of eco-innovation including different agents and sectors. Therefore they extracted from the setting of a multiple-case study an integrating model, holistic and dynamic, which is transferable relating to sustainable and innovative solutions in a specific regional context.

Latest developments in management tools, and application examples in the bioeconomy field

The review of Karvonen et al. (2017) carve out the most relevant impact assessment methods within the bioeconomy, especially the forest bioeconomy. It is worth mentioning that these tools address mainly industrial actors, not addressing governance issues; this is relevant to mention at this point to avoid any misunderstandings and to realize that the focus thus far has been to provide management tools for the individual enterprises. Karvonen et al (2017) compiled the five most common tools in a table including weaknesses and strengths of each method as well as their application in combination with other tools as an amplification. The cost-benefit analysis (CBA) as an economic oriented tool, which is based on monetary units, thus evaluating monetary values is its strength, is combined with for example input-output able to monetize also the non-monetary values and vice versa. Its weakness is to be presumed in ethical and democratic observations regarding values as subjective cases.

The Input-output (IO) methods as an economic or environmental applied method can be expanded with LCA databases or MFA calculations. Economic tables and statistics for environmental IO are commonly available and well documented. But this directly leads to an extensive data output, which is troublesome to analyse and utilise subsequently.

Life cycle analysis (LCA) methods, listed as third sustainability assessment tool, can be applied environment-oriented (ELCA), as well as social-oriented (SLCA) or

economic-oriented (LCC) and various combinations with other methods are possible.
The Material flow analysis (MFA) with its orientation in environment sector can uncover inefficient material usage and production phases in a simpler way compared to LCA methods, but may induce a limited view.
As the fifth tool registered the Multi-criteria analysis (MCA) can provide any desired orientation and offers a complete assessment and balancing between alternatives with the limitation of excluding known unsustainable alternatives preliminarily (Karvonen et al., 2017).

Consistently mentioned there is a lack of assessing the social impacts regarding bioeconomy. Therefore, Mattila et al. (2018) evaluated the social sustainability of bioeconomy value chains. The goal of the paper compared to previous applications in social sustainability methods was to compare the setting, more precisely the impacts of Finnish wood products, in local and global approaches with the aim of developing possibilities of an integrative approach. Therefor a multi-region input-output model was used. The outcome of the study were health and safety and gender inequality as the main social issues within a life cycle perspective. These impacts are mainly presented outside the forest industry sector and not within the Finnish boundaries. They developed options to interconnect the output of local stakeholders, who concentrate primarily on the local issues as working conditions, and the global impact output of this study in terms of a framework combining the global and local considerations (Mattila et al., 2018).

Falcone & Imbert (2018) critizise the neglect of social impacts within the life cycle approach in the analysis of bio-based economy, as well. In their paper they identified the main social impact categories to include them eventually in the social life cycle assessment scheme for bio-based products. This leads to a better informed consumer and an expanding market of bio-based products.

As a need in the latest developments of bioeconomy for assessing social effects a new conceptual framework for a context-specific sLCA, especially to assess wood-based products in a regional perspective, was evolved by Siebert et al. (2018). It facilitates to uncover social hotspots and social opportunities and the location in the wood-based production system of a regional bioeconomy.

The need for a systematic approach for the urban bioeconomy

Bezama (2016) analyzed that from a systems perspective, the implementation of the bioeconomy strategy entails a series of challenges, from which the following two can be identified as important for the sustainable development of cities: Firstly, that there is a lack of synergic work between the different participants in the "innovation chains" of the bioeconomy. Participants of these innovation chains are not only the ones involved in the technology development process but also the market and society players (including public services) that produce the demand for bio-based products. In order to overcome this challenge, it is necessary to identify the different actors along the innovations chains of the bioeconomy and, most importantly, to understand the interactions between these actors, as well as their perspective on the potential and current barriers towards a more urban-centered bioeconomy. In this regard, there is a need to incorporate a more dynamic analysis that takes into account the different scales (local, regional, national, global) and dimensions (social, economic, environmental) directly and indirectly affected by the implementation of these new processes and products (Bezama, 2018).

An important aspect to consider with the implementation of the bioeconomy, is that the impacts of such implementation will most dramatically be observed on a regional and local level. In the particular case of cities, the impacts of the bioeconomy are complemented by the effects of further transition processes, such as the circular economy and a series of societal changes (e.g. environmental awareness, industrialization, economic changes) as well as the global process of urbanization itself, which is closely linked to the consumption of land, increase in traffic and high air pollution, and is considered a major challenge for a sustainable development (EEA, 2015). It is therefore important to link the identified interactions among actors with the actual material streams of available bio-based resources that shape the bioeconomy system (i.e. all inputs and outputs to and from the cities, as well as the internal bio-based material streams that characterize the processes that take place within the city limits).

In this regard, over the last years, the “urban metabolism” concept, first conceived by Wolman (1965), has been considered as an interesting method for supporting the development of sustainable cities and communities (Chrysoulakisa et al 2013; Conke & Ferreira, 2015).

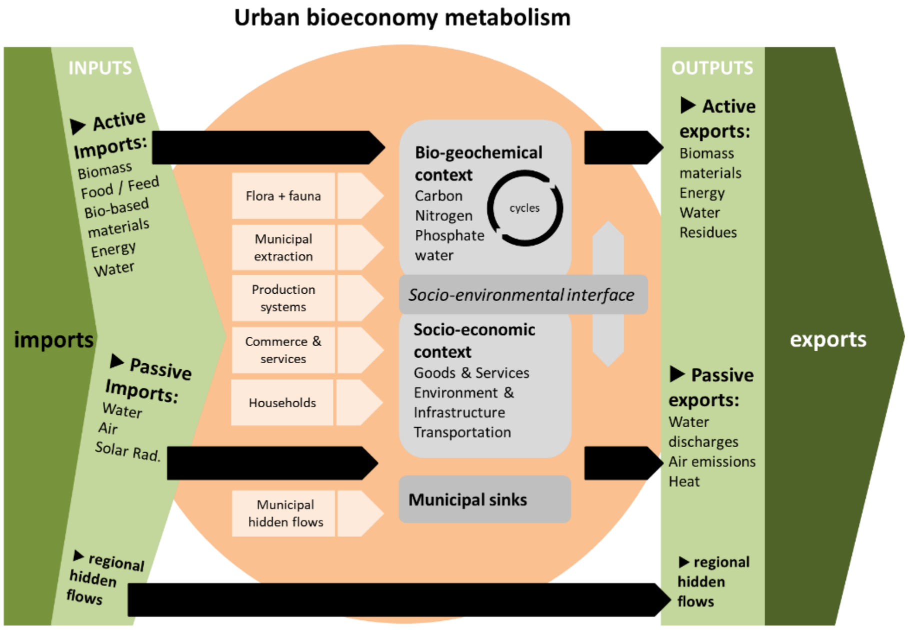

Figure 1. General conceptual description of the flows associated to the urban bioeconomy metabolism concept (adapted from Musango et al (2017))

As described by Kennedy et al (2007, 2011), “urban metabolism” may be defined as “the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste.” The concept of “urban metabolism” was based by providing an analogy of the urban context to the metabolism of organisms. As explained by Decker et al (2000), “cities transform raw materials, fuel, and water into the built environment, human biomass and waste,” thus the analogy to the metabolism observed in natural organisms (see Figure 1 for a simplified version considering the urban bioeconomy metabolism).

The urban metabolism concept is based on an analysis of material and energy flows, thereby tracing the input, storage, transformation, and output processes (Zhang, 2013; Hendriks et al., 2000). In general, material flow analysis starts by classifying the different material flows, followed by an accounting of all the identified flows. Particularly interesting is the use of a life cycle perspective for monitoring the flow of materials throughout their entire life cycle within the urban system (Zhang, 2013).

The urban metabolism concept and its applications to resources management

The urban metabolism concepts is not new. Already in the 1970s there were several pioneering studies utilizing material flow analysis concepts to evaluate and characterize the material flows within the city limits. In the 1990s there were also several studies on UM. It is since the 2000s when the majority of existing studies can be recorded (Anderberg, 2012). In 2001, a standardised MFA for national analysis was issued by Eurostat and used in many studies. About a decade later, scientists have pointed out that MFA at regional and local level still remains very limited (Niza et al., 2009). It is in 2004 when the "Practical Handbook of Material Flow Analysis Authors" by P. H. Brunner and H. Rechberger is published. The book is an introduction to MFA and contains 14 case studies describing the method, in addition to the characteristics and history of MFA (Zeschmar-Lahl, 2004).

In 2006 Hammer et al. published an MFA based on the three regions around Hamburg (HH), Vienna (W) and Leipzig (LE). The analysis is preceded by a list of selected structural features of the regions under investigation, such as the change in settlement and transport areas over the period under investigation. The indicator DMC (domestic material consumption) is used to calculate the material consumption of the respective population within a defined period of investigation (1992-2001: HH, LE; 1995-2003: W). It is calculated on the basis of raw material extraction plus imports minus exports. The evaluations show that even individual changes in material flows can have a major impact on the indicators and the material intensity of a region. For example, the declining quantity of building materials in the region around and in Vienna or a decline in lignite mining in Leipzig during the respective period under review. The analysis also shows gaps: e.g. that an MFA does not cover the conversion of material into energy and interregional electricity exports. This is the case for Leipzig, which is why per capita material consumption also differs significantly from that of the metropolitan regions of Hamburg and Vienna. The comparison also shows that technological developments - i.e. the changed use of certain resources - can significantly increase material efficiency (or reduce the material intensity of an economy) (Hammer et al, 2006). In the context of MFA, Hammer et al. point to the effectiveness of integrating MFA and structural analysis (e.g. ecological footprint) to assess the sustainability of a regional development more comprehensively (Hammer et al., 2006).

More recently, Niza et al (2009) carried out a UM analysis of Lisbon's material flows in 2009 with the aim of methodological improvements. For this purpose, material categories were formed: on the input side biomass, energy sources, metals, non-metallic minerals; on the output side emissions, waste. The result of their investigation was, for example, that 80% of urban material consumption comes from non-renewable sources. One reason for this is the single-story construction of new buildings and the simultaneous lack of renovation of old buildings in Lisbon since the 1990s. The percentage figure also included the switch from public transport to individual car traffic and inner-city transport of transit goods. It is also worth mentioning the inclusion of the life span of products (quick consumption materials 0-1 year, 2-10 years, 11-30 years, over 30 years). This categorization allows for an examination of material storage in cities (city mining) and future waste or the potential utilization of secondary raw materials.

Following the same line of work, Wallsten (2015) combined the quantitative MFA approach with the qualitative social science approach of infrastructure studies in a study to look at a locally specific research topic from a socio-technical perspective. The study focused on the "hibernating stock", i.e. unused pipes and cables underneath the streets of the Swedish city of Norrköpping. By means of a quantitative survey Wallsten determined the amount of steel, copper and aluminum which could potentially be salvaged and thus serve as an alternative material reserve (5000t) as well as its and local distribution. By means of interviews with road construction personnel and other stakeholders, a series of statements could be made about the origin and procedure of the unused materials. The study makes clear a "disconnect and leave behind" logic and leads to three categories for left behind infrastructures (Wallsten, 2015). It is methodologically remarkable that the research object of the "hibernating stock" and the local confinement function as a "boundary object" and thus allow the work with approaches from different disciplines even "without consensus", but with common "modus operandi" (Wallsten, 2015). Wallsten concludes with the policy recommendation to integrate metal recovery into continuous renovation or urban planning processes (Wallsten, 2015).

Finally, Bahers et al. (2019) analyzed the material flows of two medium-sized cities in Western France (Rennes, 400,00 p.e.; Le Mans, 200,000 p.e.) by means of MFA. In their research, the scientists focused on spatial indicators and waste flows. The analysis captured imports and exports at city, local (department), regional and national & international level. In this way, two categories were formed: "local goods" (biomass, building materials, secondary raw materials) and "highly globalized goods" (industrial goods, fuels, metals). In a further step, the waste exports of the two cities are analyzed and compared. The researchers note that externalization practices in this respect are noting that even the recycling of waste takes place primarily at national or even global level. With regard to the urban material stock, this work shows that medium-sized cities are gradually replenishing their material stocks due to the urban sprawl rather than, for example, the metropolis of Paris, where buildings are being renovated. The study shows that the UM of a medium-sized city differs significantly from that of a large city, since the former is located as an intermediate link between rural and metropolitan areas. Moreover, medium-sized cities are characterized by a very strong connection with their rural surroundings (Bahers et al., 2019).

In summary UM does provide a systematic tool to characterize the material flows associated to the resources management of cities. The adaptation of this methodology to the bioeconomy field could be a useful way of providing a robust evaluation of the biomass resources management within the city limits. For this, however, the following aspects should be taken into consideration:

- UM studies focus mainly on large cities. Only a few studies are devoted to regional metabolisms (Bahers et al., 2019).
- UM studies are bound by administrative boundaries (Bahers et al., 2019).
- Limited data availability (e.g. at the local and urban level) prevents exhaustive system descriptions and adds some uncertainty to the results (Bahers et al., 2019; Hammer et al., 2006; Niza et al., 2009; Shahrokni et al, 2015).
- Limited data availability leads to the prioritized consideration of selected material flows with a good data basis (Anderberg, 2012; Niza et al., 2009).

Needs for implementing a urban bioeconomy metabolism

The role of governance and of social aspects

MFA is a method that reduces the complexity of reality to a simplified and reliable form (Brunner & Rechberger, 2003), based on input and output flows. However, this is not enough to understand the relationships between urban and environmental quality and the patterns and lifestyles behind metabolic flows. For this purpose, additional methods are needed to find a balance between studying urban complexity and generating ideas for real politics and urban planning (Broto et al., 2012). According to Björn Wallsten, the usefulness of pure MFAs for political decision-making processes, especially at higher levels, can be seen in concrete examples, e.g. for decisions on recycling projects. Nevertheless, in order to successfully implement recycling targets locally, basic knowledge about the potentially available quantities is required, as well as information about when, where and by whom recycling can take place. Wallsten criticises MFAs at this point: They should overcome their reductionist orientation, as they risk removing the material quantities under consideration from their social and local embedding. There would be a risk that purely mathematical standards would lose relevance for the social sciences (Wallsten, 2015).
In addition, according to Stefan Anderberg, the recording of material flows would make it possible to obtain an overview, but would not allow any statement about the usefulness of those flows for society. UM studies are dominated by a quantifying analysis of material flows, only a few intensively pursue the connections to social aspects. In addition to a more flexible analysis compared to levels and details ("[a] more systematic multilevel analysis"), a closer connection to decisions and institutional structures is needed (Anderberg, 2012). Despite growing awareness and an increase in sustainable objectives, there are still only a few effective initiatives that would shift urban development in a sustainable direction. The growing number of UM-analyses at the urban level and studies from sustainable urban research is contrasted by a relatively small role of these in the urban planning context. It is rare that UM studies or their perspectives are fully integrated into local policy strategies

or planning processes. Nevertheless, UM studies have often contributed to sustainability reports or indicators (Anderberg, 2012). Anderberg pleads for the inclusion of further criteria in UM analyses: climate, age of a city and its development history (Anderberg, 2012). A critical aspect of the social science approach is the focus on groups of actors and the classification of their relevance. Especially in infrastructure issues, workers who work directly on the materials are relevant sources of information and in this sense more valid sources of information than, for example, "system providers" and yet less often the subject of studies (Wallsten, 2015). In this sense, Bristow & Mohareb (2019) stress the importance of Urban Political Ecology (UPE), as it goes beyond the quantitative coverage of an MFA and analyses drivers and impacts in greater depth.

Finally, urban dynamics can also cause negative environmental impacts within the spatial environment of cities, such as urban sprawl in the regional hinterland (Bleher, 2017). The examination of global and inner-city distributional inequalities shows that a meaningful UM model includes not only material analyses but also studies of socio-economic and political contexts. Such an approach thus combines physical flows, which are visible and in the best case quantifiable, with less visible structural contexts that significantly shape those flows. Further theoretical development is needed to determine how such expanded knowledge can be implemented in practice (Broto et al., 2012).

The urban bioeconomy metabolism as a toolbox for the management of biomass resources

A series of scholars and practitioners have identified the model of a natural ecosystem as the most suitable way for developing sustainable cities. In fact, the major uses of the urban metabolism models can be summarized as twofold. First, to be used as basis for sustainable urban design, and secondly, to be used as basis for policy analysis (Zhang, 2013). Thus far, however, there have been no advances in exploring the definition of an urban metabolism in a bioeconomy context.

Considering the above, the main research question to be addressed is: How can we define a "bioeconomy concept in an urban context," based on the metabolism concept, such that we can understand and analyze the transformation processes related to the bioeconomy within the urban system, and link them to the material streams that characterize the available bio-based resources so that we can propose measures to design more sustainable urban concepts?

In order to address this question, we propose that the establishment of the urban bioeconomy metabolism should not only mean the definition of a concept that could help understand the potential impacts of biomass streams. Albeit being an important issue, the major goal of the urban bioeconomy metabolism should aim at managing the resources within the scope limits of the urban areas and their interaction with the peripheral rural areas, thus providing a means for a systematic regional resources management.

Scientific experiences of the urban metabolism context show that integrated approaches that mix quantitative methods, such as Material Flow Analysis (MFA), with policy or infrastructure, sociotechnical analysis or methods of social science; allow more comprehensive studies of the "urban complexity" or even the "urban disorder" (Broto et al 2012; Wallsten, 2015; Bleher, 2017). Solely quantitative approaches such as MFA and footprints are not able to obtain efficient city policy or city planning (Broto et al 2012).

Integrated approaches reflect on resource flows as much as on history, policy and socioeconomic conditions of urban contexts. They include considerations on resilience/resistance (for example in case of hazards) and on flexibility and multifunctionality of urban structures (Anderberg, 2012; Bristow & Mohareb, 2019). Structures of (civil) self-organization, power relations and decision processes allow more detailed perspectives on urban resource flows and access to them (Broto et al 2012; Bristow & Mohareb, 2019).

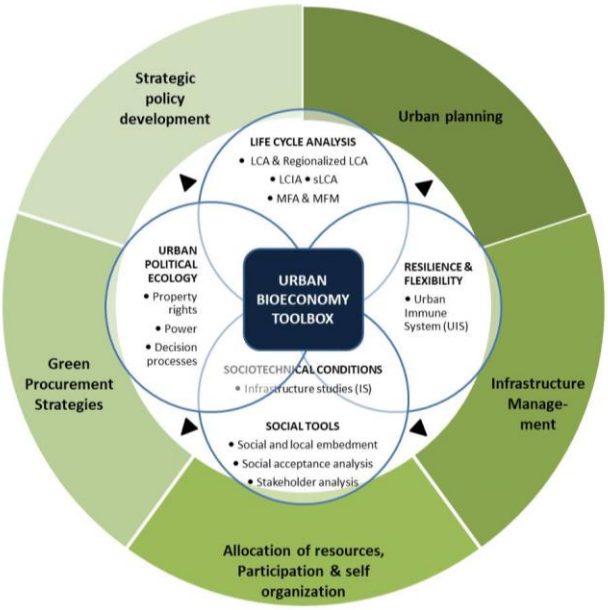

Figure 2. The proposed toolbox for addressing the management of the urban bioeconomy metabolism

By expanding the urban metabolism concept towards a more integrated and interdisciplinary analysis of urban areas it will be possible to make those theoretical approaches closer to the reality of urban planning and policy making. As presented in Figure 2, a Urban Bioeconomy ToolBox contains multiple analysis components and connects to several goals on the policy side.

The concept of the bioeconomy seeks for transformation towards more sustainable economic practices. Transformations depend on structural changes on institutional, societal, legal and technological level. Transition-based governance strategies include necessarily several layers in their analytical preparation (Ludwig 2019).

In this sense, for managing the urban bioeconomy it is needed to count with an integrated planning and assessment of the resources management within and beyond the city limits, for which the implementation of an adequate and dynamic governance framework is required. This is sustained not only by a strategic policy development, but also by a sustainable green procurement program that takes advantage of the regional capacities and strengths (i.e. local resources, human capacities, market needs, and industrial infrastructures, among others).

On the other hand, by connecting the urban planning, infrastructure management and allocation of resources from a bioeconomy perspective, cities could identify and manage the resources in terms of their own defined goals, based on the definition of the local and regional sustainability development plans. A regional life cycle management approach could then help in bringing the necessary information for decision makers and involved stakeholder groups and individuals to generate a more robust and mutually agreed resources management plan.

Outlook

Depending on how cities are built, heated and cooled, on the efficiency of their infrastructures and the consumption and transport habits of their inhabitants, this influences the amount of greenhouse gas emissions, the impact on land use, water and mineral resources in the global framework (Anderberg, 2012).

Sustainable urban planning would not only include more efficient, integrated and flexible water, sanitation, waste, heating and energy infrastructure, but would also aim at resilience to changes in population, economy, climate and water balance. This results in urban systems that are multifunctional, as they fulfil several values and functions simultaneously (Anderberg, 2012).

The approach of urban metabolism offers the possibility for expansion and integration with other approaches. An integrated consideration of dynamic energy and material flows, which includes land use changes or soil degradation and urban sprawl effects in its analyses, is missing in some cases (Bleher, 2017). In addition, it should be integrated with regionalized life cycle methods and tools for helping the management of locally available resources, such as the RELCA and RESPONSA models (O'Keeffe et al., 2016, Siebert at al, 2018a, Siebert et al. 2018b)

The introduction of the urban bioeconomy metabolism as a toolbox for identifying the main issues of the biomass flows within the city limits, providing also the resources for providing the necessary information to build a sound decision basis for local and regional stakeholders.

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