International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.1604

(08/2022)

SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Circular and sustainable cities and communities

Development framework for bioeconomy in cities and communities

Recommendation ITU-T L.1604

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ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1604

Development framework for bioeconomy in cities and communities

Summary

Bioeconomy concerns both sustainability and circularity and covers all biological resources. The aim of this Recommendation is to provide cities with a framework for the development of the bioeconomy, especially under the lens of circularity and sustainability.

The main elements examined in this Recommendation are:

- The definition and role of bioeconomy in cities, with a focus on circularity and sustainability.
- The determination of factors and key performance indicators (KPIs) that affect bioeconomy development in cities.
- The definition of a generic implementation framework for bioeconomy in cities.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1604	2022-08-13	5	11.1002/1000/15032

Keywords

Bioeconomy, circularity, city, framework, sustainability.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Introduction

In the last decade, interest in bioeconomy has increased due to the adoption of policies for the emergence of biotechnology for new product and market development and for the utilization of biomass [b-Birch]. The continuous effort of governments to mitigate the post-petroleum economy has led to the definition of several national strategies for bioeconomy. However, the migration to bioeconomy is an expensive and slow process, which engages all industries and social living.

Bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, biobased products, energy and services [b-EC-4].

A definition for bioeconomy given by the European Commission concerns the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, biobased products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge [b-EC-3], b-UNECE].

As such, bioeconomy deals with both sustainability and circularity. Regardless of the fact that cities can become circular bioeconomy hubs and of existing strategic approaches and action planning (e.g., in Europe) limited attention has been given to urban bioeconomy and only some pilot cases can be identified [b-EC-1], [b-EC-2].

Food systems, waste and sewage processing, green terraces, recycling and others are only some of the urban systems that are benefit from bioeconomy and in this respect this Recommendation will be useful for city policy makers and corresponding industries.

On the other hand, urban innovation has emerged due to continuous urbanism and environmental degradation, phenomena that have highlighted the importance for cities' transformation to sustainability, resilience and climate neutrality. Information and communication technologies (ICT) have resulted in recent trends for smart, circular and green cities, which highlight the central role of cities in adopting policies and in initiating actions against challenges such as climate change. The urban metabolism framework, which synthesizes a roadmap for city circularity and depicts the crucial role of bioeconomy for urban innovation (technological, climate, governance and social innovation), can be considered one of these actions.

Recommendation ITU T L.1604

Development framework for bioeconomy in cities and communities

1 Scope

This Recommendation defines a framework for the development of the bioeconomy development, which will help identify the scope, priorities, objectives (i.e., ensuring food and nutrition security; managing natural resources sustainably; reducing dependence on non-renewable energy sources; climate change mitigation; new jobs' creation, etc.) and key performance indicators (KPIs) for its development, especially under the lens for improving sustainability and circularity and achieving Sustainable Development Goal 11 and related targets, and the climate objectives of the Paris Agreement.

The main elements examined in this Recommendation are:

- The definition and role of bioeconomy in cities, with a focus on circularity and sustainability.
- The determination of factors and KPIs that affect bioeconomy development in cities.
- The definition of a generic implementation framework for bioeconomy in cities.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 circular bioeconomy [b-Kardung]: Applying the principles of circular economy in bioeconomy**.**

3.1.2 smart sustainable city [b-ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects.

NOTE – City competitiveness refers to policies, institutions, strategies and processes that determine the city's sustainable productivity.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 bioeconomy: The production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, biobased products and bioenergy.

NOTE 1 – Three main interpretations of the term coexist, one referring to the entropic narrative of the economic process, a second referring to the industrial promises offered by the biotechnology revolution, and a third referring to the biobased carbon economy.

NOTE 2 – Based on [b-EC-3] and [b-Giampetro].

3.2.2 circular economy: An economy closing the loop between different life cycles through design and corporate actions/practices that enable recycling and reuse in order to use raw materials, goods and waste in a more efficient way.

NOTE 1 – The circular economy concept distinguishes between technical and biological cycles, the circular economy is a continuous, positive development cycle. It preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows, while reducing waste streams.

NOTE 2 – Definition adapted from [b-ITU-T L.1022] and [b-ITU-T L.1020].

3.2.3 urban metabolism [b-Lucertini]: The process of supplying material, energy and food to a hypothetical city, as well as the resulting waste products.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

EU European Union

IoT Internet of Things

LCA Life Cycle Analysis

R&I Research and Innovation

SME Small and Medium Enterprise

UM Urban Metabolism

5 Conventions

None.

6 Bioeconomy in the urban ecosystem

6.1 Definition of bioeconomy

There is no commonly adopted definition of bioeconomy; some of the existing ones are summarized as follows in [b-Giampetro]:

1. 2020: The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forest, fish, animals and micro-organisms – to produce food, materials and energy.
2. 2019: The co-existence of three main interpretations of the term: one referring to the *entropic narrative of the economic process*, a second referring to *the industrial promises offered by the biotechnology revolution*, and a third referring to *the biobased carbon economy*.
3. 2009: All industrial and economic sectors and their associated services which produce process or in any way use biological resources (plants, animals, micro-organisms). These sectors include: agriculture and forestry, the food industry, fisheries, aquaculture, parts of the chemical, pharmaceutical, cosmetic, paper and textile industries, as well as the energy industry.

4. 1970: A term intended to highlight the biological origin of the economic process and thus spotlight the problem of humankind's existence with a limited store of accessible resources unevenly located and unequally appropriated.
5. 1954: The combination of the terms 'bio' and 'economy' to indicate: (i) the economic return on investment (typical of the economic narrative) – information relevant for the economic system of control; and (ii) the risk of reducing the long-term productivity of the economic activity (an ecological problem) –information referring to the biophysical processes taking place in the environment.

It could be also considered the combination of what should be done (the circular economy) and how it can be done (bioeconomy) into a single package, labelled "circular bioeconomy" [b-Giampetro]. To stimulate the economic growth of developed economies can be considered a good solution combining a desirable 'what' (circular economy) with a feasible, viable and desirable 'how' (bioeconomy).

Moreover, since the existing definitions of circular economy focus on controlling flows in the "technosphere" (products, components and materials) and do not explain how these flows can be recycled without using ecological processes from the "biosphere" (energy, water, land, biomass, minerals); the role of bioeconomy appears to be promising.

6.2 Bioeconomy in cities

Since bioeconomy has been justified as an emerging trend that is being coined with circular economy, how and why it can be seen in cities must be justified. Thus, the urban metabolism (UM) concept (Figure 1) is utilized, which shows resources that enter the boundaries or interaction space of a city. This space considers flows of materials and energy and economic and social flows embodied in urban-rural interactions [b-Lucertini].

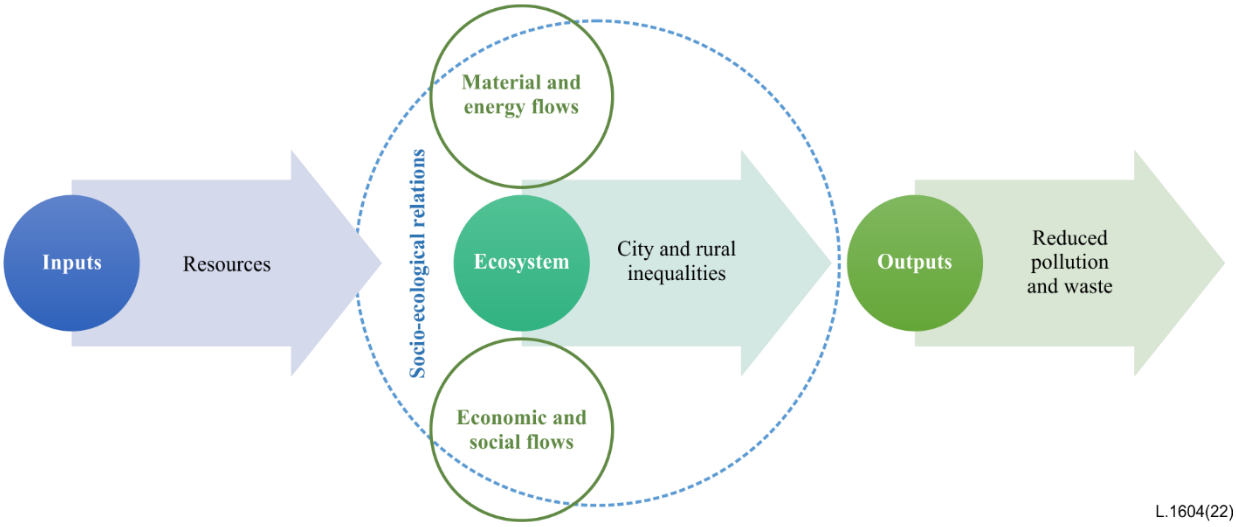

Figure 1 – The urban metabolism concept
(Figure based on [b-Lucertini])

Urban systems are becoming more complex, cities are growing and levels of production, consumption and waste are increasing, which make UM and circular economy very promising concepts. The circular UM framework (Figure 2) is the result of the circular economy concept applied in a UM context (see also [b-Lucertini]). The circular UM framework can help planners and policymakers to rethink urban activities (e.g., transport or food production), within the urban-rural space and through time.

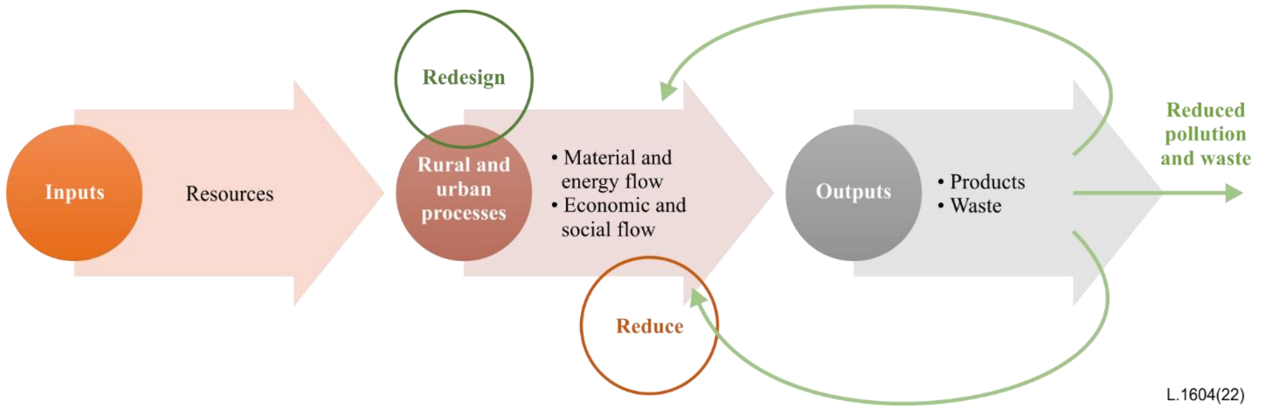

Figure 2 – The circular urban metabolism framework
(Figure based on b-Lucertini])

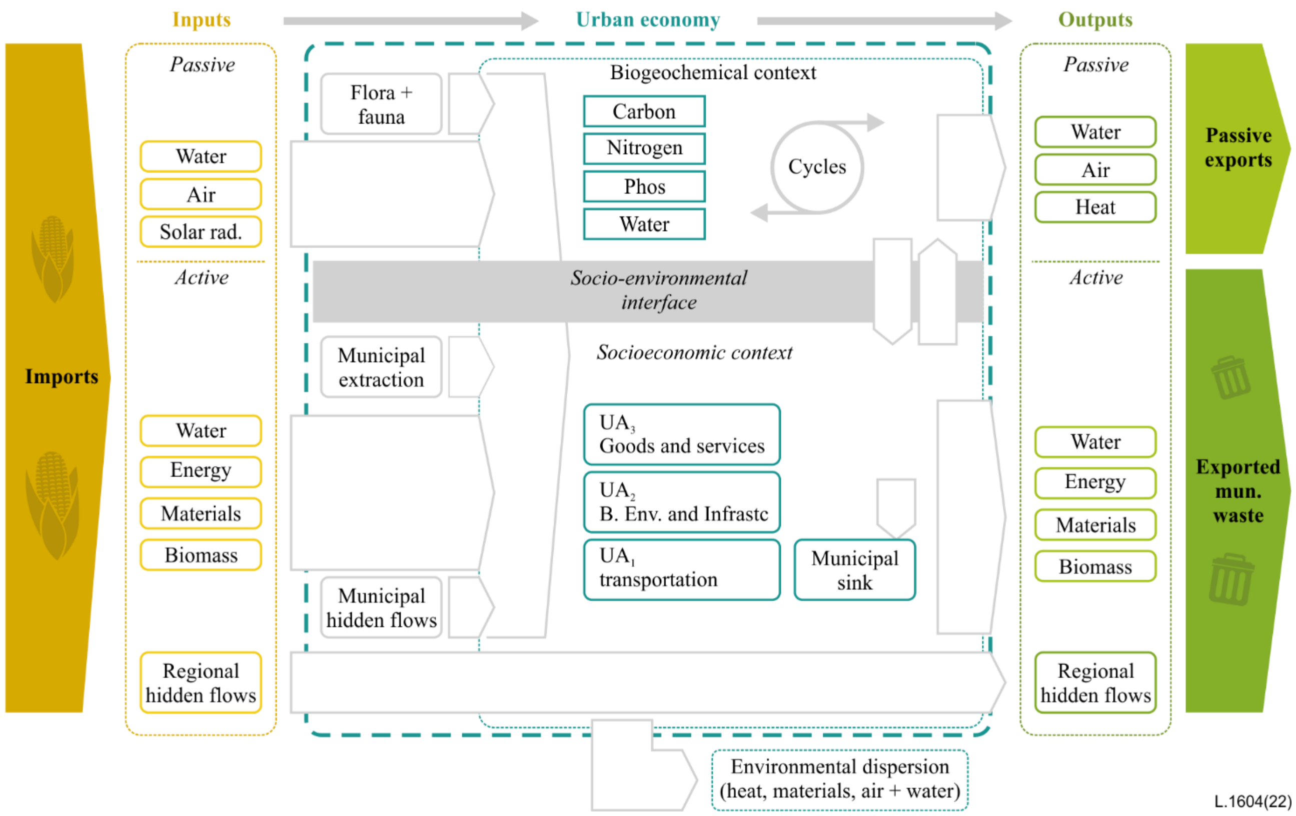

Figure 3 – The urban metabolism (UM) framework
[b-EC-5]

The urban metabolism framework (Figure 3) on the other hand, depicts the flows within urban space and the interrelation of city subsystems and can result to a roadmap for circular performance in cities [b-EC-5].

The UM framework can depict areas where bioeconomy can contribute to urban innovation, such as natural resource management, biochemical framework, energy, waste and climate conditions. All local stakeholders participate in this framework: industries, academia, government and the community, while technological, climate, governance and social innovation are needed to establish migration to the circular bioeconomy in cities.

6.3 A development framework for bioeconomy in cities

This clause introduces a generic development framework for bioeconomy in cities. The framework is analysed in process steps, whose context consists of specific activities. The introduction of each activity in a process step is based on evidence from the literature. The identification of the appropriate framework is not a simple process. Table 1 gives the number of results obtained when searching popular databases of scientific literature with relevant terms.

Table 1 – Searching scientific repositories for bioeconomy framework

	Search term	
Source	**"bioeconomy framework"**	**"bioeconomy framework" AND "city"**
ScienceDirect[a)]	42	10
Google Scholar[b)]	163	49
Web of Science[c)]	8	0

a) https://www.sciencedirect.com/
b) https://scholar.google.com/
c) https://www.webofscience.com/

The collected articles were screened regarding their relevance to the study. Mainardis et al. [b-Mainardis] performed a life cycle analysis (LCA) for seagrass processing and presented a corresponding framework, which concluded on the best alternatives in terms of environmental performances (biogas production as a renewable energy source). The framework recognized the system of seagrass accumulation and processing, with (a) **inputs** (seagrass, raw materials, fuels, water and electricity); (b) **processing plant**; (c) **outputs** (wastewater, digestate, biogas, compost and inorganic fertilizers). The framework enables the calculation of both the direct and the indirect costs of the overall process. The introduced framework for urban bioeconomy is inspired by the UM framework and in this respect it can be considered an iterative and continuous process which consists of implementation steps justified with evidence from the literature (Figure 4, Table 2).

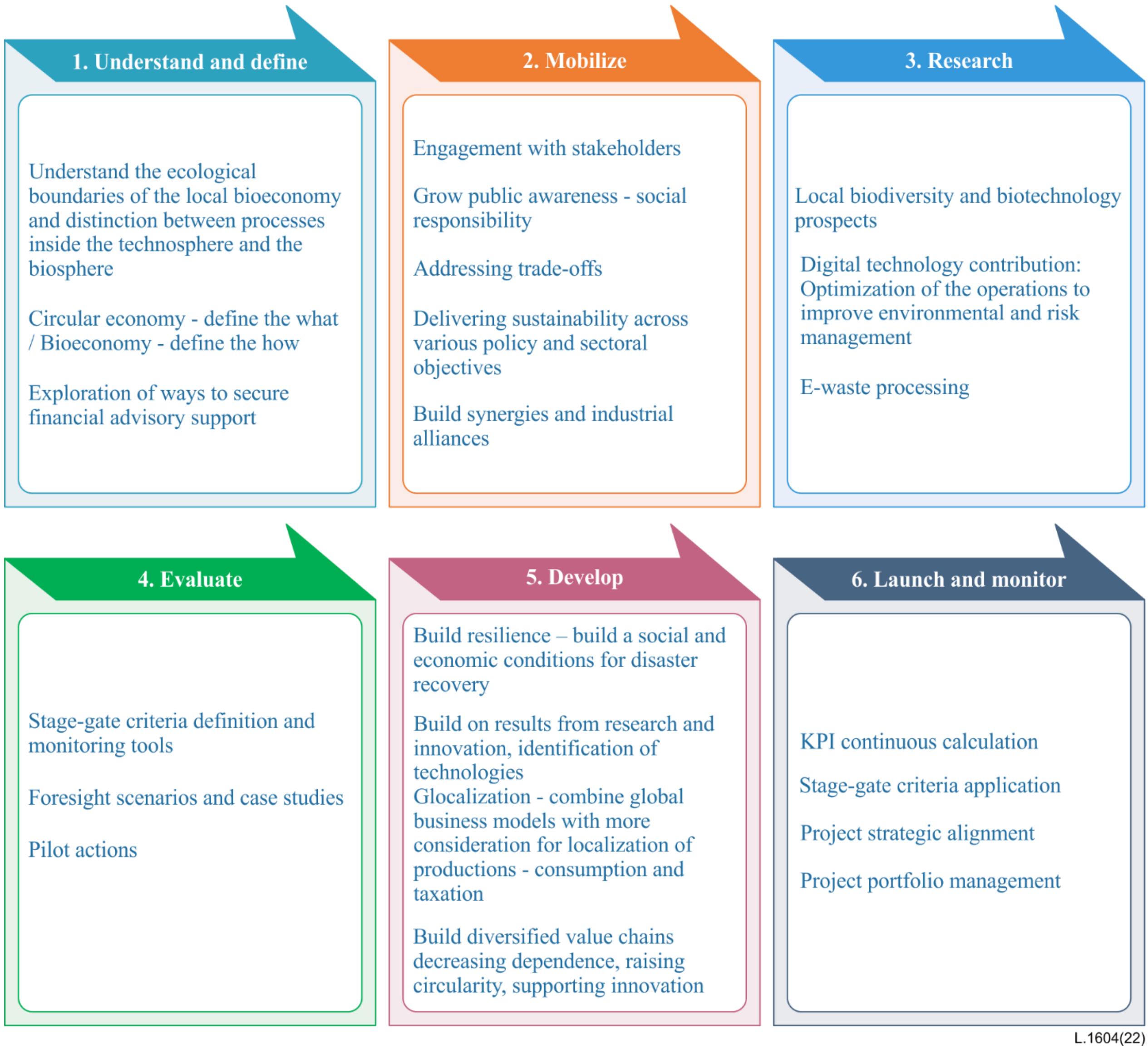

Figure 4 – The proposed framework for the development of the urban bioeconomy

Table 2 – The introduced bioeconomy framework

1 Understand and define	
• *Understand the ecological boundaries of the local bioeconomy and the distinction between processes inside the technosphere and the biosphere*	[b-Giampetro] [b-EC-4] [b-D'Amato] [b-O'Hara] [b-Singh] [b-Fava]
• *Circular economy – define the what / Bioeconomy – define the how*	[b-Giampetro] [b-Singh] [b-Fava] [b-Delzeit]
• *Exploration of ways to secure financial advisory support*	[b-Giampetro] [b-Singh]

Table 2 – The introduced bioeconomy framework

2 Mobilize	
• *Engagement with stakeholders*	[b-Giampetro] [b-EC-4] [b-O'Hara] [b-Fava] [b-Delzeit] [b-Dieken]
• *Grow public awareness – social responsibility*	[b-EC-4] [b-D'Amato] [b-Singh] [b-Fava] [b-Dieken]
• *Addressing trade-offs*	[b-EC-4] [b-Roberta] [b-D'Amato] [b-Singh] [b-Fava] [b-Dieken]
• *Delivering sustainability across various policy and sectoral objectives*	[b-Giampetro] [b-EC-4] [b-D'Amato] [b-Kuckertz] [b-Singh]
• *Build synergies and industrial alliances*	[b-Giampetro] [b-EC-4] [b-Kuckertz] [b-Singh] [b-Fava] [b-Dieken]
3 Research	
• *Local biodiversity and biotechnology prospects*	[b-Giampetro] [b-Singh] [b-Fava] [b-Dieken]
• *Digital technologies' contribution: optimization of the operations to improve environmental and risk management*	[b-Giampetro] [b-Singh]
• *E-waste processing*	[b-Giampetro]
4 Evaluation	
• *Stage-gate criteria definition and monitoring tools*	[b-Giampetro] [b-EC-4] [b-Roberta] [b-D'Amato] [b-Singh] [b-Fava]

Table 2 – The introduced bioeconomy framework

	[b-Dieken] [b-JRC]
• *Foresight scenarios and case studies*	[b-Giampetro] [b-EC-4] [b-D'Amato] [b-Fava] [b-Delzeit] [b-O'Hara]
• *Pilot actions*	[b-EC-4] [b-D'Amato] [b-Fava] [b-Delzeit] [b-O'Hara]
5 Develop	
• *Build resilience - build social and economic conditions for disaster recovery*	[b-EC-6]
• *Build on results from research and innovation, identification of technologies*	[b-Giampetro] [b-EC-4] [b-D'Amato] [b-Kuckertz] [b-Fava]
• *Glocalization – combine global business models with more consideration for localization of productions, consumption and taxation*	[b-EC-6] [b-Giampetro] [b-O'Hara] [b-Fava]
• *Build diversified value chains decreasing dependence, raising circularity, supporting innovation*	[b-EC-6] [b-Giampetro] [b-EC-4] [b-Kuckertz] [b-D'Amato] [b-Kuckertz] [b-Fava]
6 Launch and monitor	
• *KPI continuous calculation*	[b-EC-6] [b-Giampetro] [b-Roberta] [b-EC-6] [b-Giampetro] [b-Roberta]
• *Stage-gate criteria application*	
• *Project strategic alignment*	
• *Project portfolio management*	

The introduced framework is justified as described below.

1 Understand and define

• *Understand the ecological boundaries and distinguish between the technosphere and biosphere*

To achieve sustainability through bioeconomy, we should be able to evaluate environmental benefits and to better understand and measure its effects and impacts on the ecological boundaries of our planet. As a society, we need to better understand the interdependencies between forest, industrial and ocean bioeconomies, so that we can avoid, or at least limit, the potential dangers of unintended consequences of future activities and better sustain the ecosystems on which our world depends. It is necessary to develop the bioeconomy in a way that alleviates pressure on the environment, values and protects biodiversity and enhances the full range of ecosystem service. For example, the economic exploitation of a renewable resource must always respect the external limits imposed by the characteristics of the exploited ecosystem. The need for cooperation at all levels of our society is critical to inform, educate and build a knowledge base for creating sustainable solutions.

It is very important to enhance our knowledge on the resilience and status of specific areas including on their biodiversity, as well as land- and sea-based ecosystems. The status and management of forest ecosystems, in addition to the availability of sustainable biomass, will also yield important insight. It is very doubtful, however, that it will be possible to expand the complete recycling of products and components at zero biophysical cost.

Until now, research focusing on the perception of industry, political and research stakeholders has been dominated by a technology-based and resource-based understanding of the concept, while there is a noticeable lack with respect to the ecological dimension of the bioeconomy in stakeholder perceptions and a concerning lack of public involvement, which challenges the bioeconomy concept's claim to contribute to sustainable development.

- *Circular economy – define the what / Bioeconomy – define the how*

Economic narratives often ignore the distinction between the processes inside the technosphere and the biosphere. While the biosphere is the total biomass of the Earth and its interaction with its systems, the technosphere (or anthroposphere) is the total mass of human-generated systems and materials, including the human population, and its interaction with the Earth's systems. It is vital to understand that while the biosphere can efficiently produce and recycle materials through processes such as photosynthesis and decomposition, the anthroposphere is highly inefficient at sustaining itself. Therefore, circularity defines what we would like to achieve, while bioeconomy defines the 'how' (biophysical properties).

- *Exploration of ways to secure financial advisory support*

Financial support and its appropriate use are always necessary, and they are identified during this framework's step.

2 Mobilize

- *Engagement with stakeholders*

One of the most important steps to achieve bioeconomy is the engagement with stakeholders. Research highlights that the bioeconomy transformation is, inter alia, a process of societal change, with different stakeholders being key for how the bioeconomy is developed and governed. The European Union's (EU) 2018 strategy emphasizes engaging economic stakeholders in the development and commercialization of technologies and products. Overall, the different stakeholders are identified as key drivers of the bioeconomy and its potential contribution to sustainable development. Thus, a detailed research and analysis of the data across stakeholder groups and their perceptions is vital in developing and implementing a bioeconomy.

Until now research articles have covered a range of stakeholders. However, the groups of government and political actors, industry and commerce, and research have been investigated almost twice as often as citizens and consumers, farmers and forest owners, stakeholders from social and environmental initiatives and NGOs. This finding supports the observation that the bioeconomy is mostly discussed by the "golden triangle" of government, universities and industry.

Research on citizens' perceptions is challenged by this group's considerable lack of knowledge of the bioeconomy, which has been identified as a threat to the acceptance of and participation in a bioeconomy transformation. Against this background, the review demonstrates a worrisome lack of engagement with the public.

Thus, any strategy and research aiming to facilitate this transformation will need to consider the views and concerns of stakeholders on different aspects of the bioeconomy. The EU will intensify the mobilization of public and private stakeholders in the research, demonstration and deployment of biobased solutions, to accelerate the development and deployment of sustainable and circular biobased solutions on which the modernization, strengthening and competitiveness of our industrial base depend.

• *Grow public awareness – social responsibility*

There is a consensus that it is of utmost importance for the future development of the bioeconomy not only to broadly engage stakeholders, but to also raise public awareness. Lacking social acceptance, new societal conflicts and the potential for disappointment are considerable barriers for the bioeconomy. Consumer acceptance becomes a challenge with underdeveloped standards and certification procedures and unfamiliarity with biobased products. There is also the necessity to raise consumer awareness, which can be aided by policies promoting reuse, recycling, recovery and circularity of biobased products, as well as regulating their standards through labelling and certification.

The first key objective, after ensuring that new products are compatible with existing processes, standards and distribution channels or infrastructures, is to increase consumer awareness about the quality and availability of biobased products. As mentioned above, there is a lack in citizens' perception research which is challenged by the lack of knowledge on this objective. It is therefore vital to accelerate and enhance engagement with the public.

• *Addressing trade-offs*

Being a part of complex socio-economic and environmental systems, it is difficult to foresee all the direct and indirect impacts of the bioeconomy, and trade-offs are of course expected.

Research is needed on the opportunities but also trade-offs and potential risks of developing the bioeconomy, for ecosystem services and biodiversity. There is a vital need to develop further knowledge on the synergies and trade-offs between various ecosystem services – both for terrestrial and marine ecosystems – and how to reconcile economic activities and social needs with the sustainable management of ecosystems, primary production and biodiversity.

This involves developing knowledge about the risks and opportunities of working with biological resources, sustainability thresholds and the values of biodiversity, including economic, cultural and intrinsic values. There is a need to also analyse enablers and barriers for the deployment of biobased innovations. A better understanding of the status of terrestrial and aquatic ecosystems, biomass demands and supplies and their drivers, their costs and their associated impacts (economic, environmental and social), would help to better understand the synergies and potential trade-offs between the various uses of biomass with regard to climate change mitigation, food security, raw materials and energy security, natural capital conservation, cohesion, trade, environmental services, and so on.

In addition, when asked for the topic of "trade-offs", stakeholders emphasized trade-offs in land use that cause social and environmental conflicts between industrial and developing countries. This is aggravated by the lack of research on developing and emerging countries. On the one hand, this neglects the global trade dimension of biomass and biotechnology, while on the other hand it conceals issues of global justice in the sense of negative ecological and social implications of biomass production and consumption, which might have been outsourced to developing countries. Something like this will undermine the bioeconomy concept's claim to contribute to sustainable development.

Access to third country trade raises concerns related to cropland footprint and emissions from direct and indirect land-use change, as well as to changes in the pressure on natural resources and potential demand/supply conflicts, which in turn will require careful consideration.

Studies reveal a disconnect between the bioeconomy's conceptualization as a transformation pathway towards sustainability on the one hand and stakeholders' perceptions on the other, which primarily revolve around national economic growth generated by biotechnology and biomass utilization (at least as researched up to this point). This highlights the need for closely monitoring the bioeconomy's sustainability impacts and stakeholders' perceptions thereof.

Also, a key challenge in land use for non-food biomass production is competition and trade-offs between food and non-food applications. This can be overcome with the exploitation of marginal land. Although this presents a key opportunity to reduce pressure on agricultural land, there is still scepticism surrounding crop productivity and its environmental benefits. Similarly, overexploitation of land for non-food biomass can lead to deforestation or soil degradation, compromising land quality and food system resiliency given growing threats from climate change.

To explore potential outcomes of bioeconomy strategies assuming different future pathways, scenario analysis is a tool used to inform decision-makers about policy impacts and trade-offs.

- *Delivering sustainability across various policy and sectoral objectives*

To apply bioeconomy requires investments, innovation, strategies and systemic changes that cut across different sectors (agriculture, forestry, fisheries, aquaculture, food, biobased industry). That means enhancing our capacity to translate opportunities from all types of innovation into new products and services on the market and creating new jobs locally.

It is necessary to move beyond research and innovation and have a strategic and systemic approach to the deployment of innovations to fully reap the economic, social and environmental benefits of the bioeconomy. Such an approach should bring together all actors across territories and value chains to map the needs and actions to be taken. It will require addressing the systemic challenges that cut across the different sectors, including synergies and trade-offs, to enable and speed up the deployment of circular economy models.

The more actors of different types involved, the more diverse knowledge is available, which is essential to realize transformative entrepreneurial projects in the bioeconomy.

- *Build synergies and industrial alliances*

Research and teaching lay the foundation for successful technology transfer into the ecosystem. Technology transfer connects academia and business practice. This can only be achieved by creating academic spin-offs to help bridge the gap between academia and business. A further requirement is that current knowledge and research results related to the bioeconomy are supplied to active entrepreneurs, which might be achieved by developing platforms and events that bring entrepreneurs into the university. Ideally, the approach should support the formation of interdisciplinary teams and alliances between bioeconomy start-ups and universities. A logical consequence is that universities must not only support bioeconomy entrepreneurship but also behave entrepreneurially themselves.

To be effective, socio-economic and technological strategies must support the locally routed implementation of the required interdisciplinary innovations. They must also facilitate cooperation and synergy between education providers, researchers, innovators, communicators and consumer representatives, including through the facilitation of informal learning. Finally, to reverse the scattering of resources, there is an urgent need to leverage public and private stakeholders, fill the gaps in regulations and align European, national, regional research and innovation (R&I) investments and policies.

A characteristic feature of the bioeconomy is the many entrepreneurial opportunities not only to change processes and services but also to introduce innovative consumer goods generally characterized by rapid and radical innovation.

Government should support entrepreneurial experimentation with policies stimulating entrepreneurship and diversification of existing firms, advice systems for Small and Medium Enterprises (SMEs), incubators, low-interest company loans, [and] venture capital. Such programmes should not only target entrepreneurs but also aim to educate all actors in biobased industries about the potential of entrepreneurship. This would involve building the necessary entrepreneurial mindset among, for example, potential entrepreneurs, farmers, scientists and resource managers. Such action would be especially important in risk-averse societies and in societies where fear of failure is significant.

The EU has promised, in addition to R&I grants under Horizon 2020, to deploy a targeted financial instrument to de-risk private investments in sustainable solutions. This will build on and reinforce synergies with ongoing and future EU initiatives.

There is a need for a space where regular and strategic international cooperation at multipartner level can take place with a focus on building policy coherence and on exploiting synergies between countries and regions considering existing mechanisms.

3 Research

- *Local biodiversity and biotechnology prospects (skills, production systems, etc.)*

Bioeconomy can be understood as a territorial configuration with very specific local conditions. It should firstly be applied to sectors moving to systems, by effectively interconnecting the main pillars of the bioeconomy through the leveraging of deeply rooted traditional sectors as well as local public and private stakeholders. In addition, there has to be created value from local biodiversity and circularity, respecting natural harvest cycles and efficiently aligning regional, national and EU policies and promoting a cohesive political commitment to the implementation of the bioeconomy.

- *Digital technologies contribution – optimization of the operations to improve environmental and risk management.*

Digital technologies (i.e., the ones that deal with smart environment) can enhance environmental and risk management. Installed environmental stations and IoT-based sensors can collect dynamic information, which after the appropriate analysis can contribute to risk estimation and avoidance.

- *E-waste processing*

E-waste poses numerous threats to the environment, human health, society, data security and privacy. Thus, there is a need to handle e-waste cautiously to minimize harmful effects. Strict policies and legislations should be implemented to ensure the proper and safe handling and disposal of e-waste. It is also imperative to create awareness regarding the various aspects of e-waste, including the various crimes that may put users' lives at serious risk. E-waste forensics may play a significant role in solving these grave and endangering situations.

There is a need to enhance product durability, to be able to recycle, repair and reuse at the equipment and manufacturing levels.

4 Evaluation

- *Stage-gate criteria definition and monitoring tools*

Because of bioeconomy's inherent complexity and the very high level of ambition of the bioeconomy strategy itself, the progress towards a truly sustainable bioeconomy must be closely monitored with reliable data and robust analysis to provide a holistic view of all the dimensions of sustainability and to highlight eventual trade-offs among them.

Further, monitoring is essential to identify areas in need of policy intervention as well as to assess the coherence and the impacts of existing legislation. The Action Plan of the 2018 EU Bioeconomy Strategy [b-EC-4], for instance, includes a specific action for the development of an EU-wide, internationally coherent monitoring system to track economic, social and environmental progress towards a circular and sustainable bioeconomy. It is also important to provide robust indicators whose numbers can be trusted as a reference for bioeconomy-related policy formulation, assessment, and evaluation to:

1) ensure a flexible monitoring system that is conducive to modifications as new data and information become available,
2) coordinate with other monitoring frameworks,
3) identify relevant indicators to gauge the progress and sustainability of the EU Bioeconomy both within and outside the EU,
4) minimize reporting burdens on all data providers,
5) improve data collection exercises to close identified gaps,
6) review the framework periodically to ensure it is fit for purpose,
7) disseminate the information in a user-friendly way, through dashboards and other dynamic visualizations,
8) provide underlying data and assumptions behind the indicators, ensuring reproducibility to the best extent possible.

The most important categories that can be evaluated are the following:

1) biophysical assessments (field observations and experiments, remote sensing, modelling and expert-based considerations),
2) social valuation (surveys, questionnaires, ethnographic methods, focus groups, analysis of secondary statistics and documents, scenario analysis, multicriteria analysis, citizens' juries),
3) monetary valuation (market price, production function, avoided damage / replacement cost, hedonic pricing, travel cost, contingent valuation, choice modelling).

When mapping indicators to normative criteria, it becomes apparent that different types of indicator are required to answer specific questions. There are therefore, necessarily, different levels of indicators, which start from data measurement indexes and rises to system level indicators, increasing the index complexity and interpretation (Figure 5).

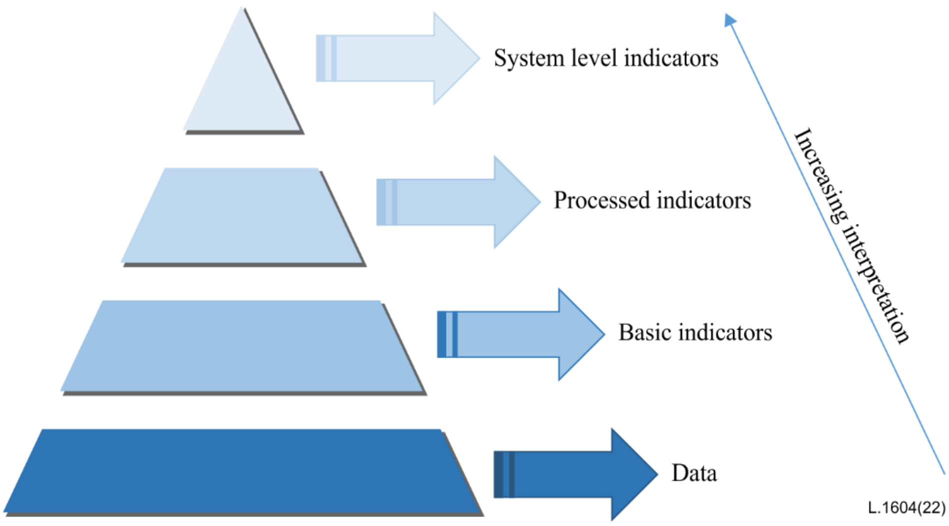

Figure 5 – Different types of levels for index definition

- *Foresight scenarios and case studies*

A scenario analysis is a tool to inform decision-makers about policy impacts and trade-offs and is used to explore potential outcomes of bioeconomy strategies assuming different future pathways. The main challenge for this transformation will be the simultaneous achievement of sustainable use of natural resources, global food security and economic growth. Strategic foresight can be used to identify possible scenarios. It can help develop a forward-looking analysis of how to leverage the power to support strategies for cooperation and partnerships. It also helps identify possible alliances, analyse different ecosystems and assess risks, opportunities and future needs for strategic industries. A foresight cycle can take up to one year to complete and covers: a diagnosis of how past developments have led to the current situation, the likely future evolution based on trends and emerging issues if no action is taken, and alternative future possibilities; collective visions; alternative roadmaps and a timetable for their implementation; the selection of pathways and associated strategies, actions and partnerships; and the definition of adequate monitoring indicators, so that actions can be adapted along the way. The external dimension of foresight cycles includes engaging systematically in strategic discussions with institutions, citizens, civil society and key stakeholders. The internal dimension includes the mainstreaming of strategic foresight into policy- and decision-making, through methods such as impact assessments, alternative scenario planning and testing and information sharing to build collective intelligence.

There is a need for science-informed development of bioeconomy opportunities, in terms of communication and outreach, data and monitoring, and case studies to create a sustainable bioeconomy and information policy.

Case studies are being developed to assess successes and failures to elucidate best practices and lessons learned for bioeconomy projects. These case studies build upon prior analyses and case studies and document the need for trade-offs to succeed in incentivizing change. For example, case studies exploring the growing production and trade in wood pellets produced from forest residuals are being developed and identify how policies and regulations and project-specific sustainability aspects can impact on the effectiveness of individual projects. Case studies are indeed a valuable tool for informing our understanding of ways to better implement bioeconomy solutions.

- *Pilot actions*

For the bioeconomy and therefore sustainability to become reality, pilot actions are required, starting from local and then growing to large scale application of this enormous and important project. The EU action plan for bioeconomy promises to launch pilot actions for the deployment of bio economies in rural, coastal and urban areas. Implemented pilot actions will enhance synergies between existing EU instruments to support local activities, introducing a more explicit focus on the bioeconomy.

This should consist of:

- Approaches in coastal areas and islands.
- Specific interventions to be developed under the Common Agricultural Policy to support inclusive bio economies in rural areas.
- Pilots of carbon farming encouraging Member States to establish a fund to buy carbon credits from farmers and forest owners who implement specific projects that aim at increasing soil and biomass carbon sequestration and/or reducing emissions in the livestock sector or that are related to fertilizer use.
- Developing and testing place-based innovations based on ecological approaches and circularity in primary production and food systems. This will allow adapting innovations to site-specific needs, involving the relevant stakeholders and facilitating their further adoption and deployment.

5 Develop

This framework step concerns the implementation phase for bioeconomy measures. It prioritizes resilience for the urban environment, it builds on innovation, scales down business models to local conditions and installs value chains that deal with circularity. More specifically, this phase consists of the following steps:

- Build resilience – Build a social and economic conditions for disaster recovery.
- Build on results from R&I, identify technologies.
- Glocalization – combine global business models with more consideration for localization of productions – consumption and taxation.
- Build diversified value chains decreasing dependence, raising circularity, supporting innovation.

6 Launch and monitor

This last phase is crucial for the successful implementation of bioeconomy since it deals with its development management. Innovation management methods (i.e., stage-gate models for structured innovation management) and typical methods for project alignment to strategic objectives (e.g., financial models, balanced-scorecards) and for project portfolio management estimate and maximize innovation success and prioritize project implementation. Moreover, KPIs are being monitored continually to ensure failure avoidance with on-time measure application. The following aspects are involved:

- KPI continuous calculation,
- stage-gate criteria application,
- project strategic alignment,
- project portfolio management.

6.4 Factors and KPIs for bioeconomy development in cities

For the purposes of this Recommendation, several works that approach the definition of factors and indexes that affect the development of bioeconomy in cities were analysed. Among the works that were investigated were [b-Kardung]; [b-Karvonen2017]; [b-Food Systems Dashboard] (Table 3).

According to the previously defined bioeconomy development framework, we must also define the indicators by which its performance will be monitored. These indicators must be related to the framework's objectives. The main goals of the bioeconomy in a city are:

- secure food,
- achieve sustainable management of natural resources,
- reduce dependence on non-renewable sources,
- mitigate climate change, and
- maintain the competitiveness of the city by creating new jobs.

Table 3 summarizes the indicators to be monitored for the development of the bioeconomy in a city or community, based on a literature review and the focus group meetings.

Table 3 – KPIs for bioeconomy development progress monitoring

Goals		KPIs	Indicative unit of measurement
Food security	1	Domestic food supply in terms of production – import	Tonnes/annually
	2	Food availability – Total supply of biomass used for food	Tonnes/annually

Table 3 – KPIs for bioeconomy development progress monitoring

Goals	KPIs		Indicative unit of measurement
	3	Access to food – Food purchasing power	% GDP
	4	Daily calorie intake per capita by source (animal/vegetable)	Kcal/capita/day
	5	Government support for research and development in agriculture	EUR/inhabitant
	6	Economic implications of food imports by type of food	EUR annually
Sustainable management of natural resources	7	Environmental quality – Ecological condition of rivers, forests, agricultural areas	Mg of nutrients/L
	8	Structural and functional characteristics of the ecosystem – biodiversity	N/A
	9 9.1 9.2	Resource availability: Livestock density Organic crops in utilized agricultural areas	unit/ha (hectares) %
	10	Sustainable management of the primary production sector	N/A
Reduction of dependence on non-renewable sources	11	Resource efficiency	%
	12	Waste prevention, reuse	kg/capita
	13	Municipal waste recycling rate	%
	14	Household materials consumption	Tonnes
	15	Food waste along the supply chain and by type of food	Tonnes
	16	Biomass production by type of source	Tonnes/source/year
	17	Total biomass per use – consumption for energy or materials	Tonnes
	18	Share of renewable energy in total energy consumption	%
	19	Share of renewable energy sources for transport, heating, electricity	%
	20	Renewable energy production and biogas and biofuel production	%
Mitigation and adaptation to climate change	21	Greenhouse gas (GHG) emissions by sector (agriculture, fisheries, bioenergy, biobased industries)	tCO_2eq (Carbon dioxide equivalence per tonne)
	22	Crop yield	tonne/ha (hectares)
	23	Financial support for biobased sectors	EUR annual/sector
Job creation and maintaining competitiveness	24	Turnover in bioeconomy by sector	EUR annual/sector
	25	Value added products and services per sector	%
	26	Employees in bioeconomy by sector	Total number
	27	Companies in bioeconomy	%
	28	Knowledge on bioeconomics	N/A
	29	Investment in R&I (both form public and the private sectors)	EUR annually
	30	Imports/Exports	Tonnes/annually

To ensure **food security**, apart from the quality that should be ensured, it is necessary to monitor the quantities that can be produced, and the quantities that then need to be imported. This affects the city's economy and, through monitoring it, we can understand the city's needs and adjust production accordingly, so that more is produced and less is imported, if possible. The less that needs to be imported, the more self-sufficient the city is.

The total amount of biomass available for food production is also a very important indicator. The food industry is highly dependent on fossil fuels, a market that is volatile and can have large cost fluctuations, which in turn affects the cost of buying food, creating insecurity. Therefore, by controlling and regulating the production of biomass for this purpose, we can achieve food security, which is the goal.

On the same topic, whether the city has access to food depending on the purchasing power should also be monitored. By food purchasing power refers to a household's financial capacity to purchase food, which is determined by the income available for purchasing food, the price of the food it consumes, and the number of family members [b-Fallo]. To achieve the primary goal, it is necessary to also monitor whether food is accessible to citizens in order to make the necessary arrangements.

It is also useful to monitor the consumption of the inhabitants by food source (animal or plant), which affects the production and import of food, depending on what the city itself can produce. By monitoring this indicator, production can be adjusted according to the needs of the city's inhabitants.

Naturally, it is necessary to monitor whether there is government support for research and development in agriculture, a key sector for the bioeconomy. If there is not enough support, new technologies will not be able to be applied and the bioeconomy and the agricultural sector will not be able to evolve based on the needs of the environment and people.

For a bioeconomy to exist in a city or community, the **sustainable management of its resources** is a prerequisite. It is necessary to know in advance, but also to closely monitor, the quality of the environment, i.e., the ecological status of forests, rivers, seas and agricultural areas of the region, as well as the structural and functional characteristics of the ecosystem. This will assist in understanding the ecosystem and its condition, so that if the environment is suffering, the necessary actions are taken to restore it, or, if it is healthy and fertile, to exploit its expanse. We need to check, for example, if there is fertile land for agricultural use and monitor it closely for any improvements or problems that may arise.

It is also necessary to know the availability of resources in the area. What is the density of livestock in the area? To what extent do the utilized agricultural areas have organic crops? This percentage should ideally increase as the bioeconomy develops. At the same time, the primary production sector should be managed using sustainable practices, which should be monitored to determine the extent to which sustainability is implemented and what adjustments can be made to achieve it.

The next goal to achieve bioeconomy is to **reduce dependence on non-renewable sources**. There are many factors to monitor the progress of this goal, as it is multifaceted: initially, measurements regarding the production and consumption of renewable energy and its share in the total energy consumed must be performed. Ideally, we would like the largest percentage of both production and consumption to be related to renewable energy. If this percentage is very small, then it is difficult to achieve sustainability and reduce dependence on fossil fuels. It is therefore of the utmost importance to control these rates to maintain viability. The share of renewable energy sources used for transport, heating and electricity should also be separately monitored. These are the main needs related to energy consumption and the most important to be regulated if this percentage is not sufficient to achieve sustainability.

Another important factor is waste management. In this area we have to monitor the extent to which waste is reused and what the recycling rate is. Naturally, we would like to have a large percentage of recycling or reuse, to achieve circularity in the bioeconomy. This indicator will demonstrate whether we are achieving circularity in the bioeconomy and, of course, the higher it is, the more we achieve our goal and the less we pollute the environment.

At the same time, we should monitor the household consumption of materials, so that we know what is consumed in the city. This will help us to have a more complete picture of the previous recycling index, but we will also know what the city residents' needs are to regulate them and maybe, if consumption is high, to reduce them with various actions such as informative campaigns aimed at citizens.

It would also be helpful to monitor food waste in the supply chain. Food waste needs to be controlled and disposed of and such waste should be reduced or repurposed. By monitoring this indicator, we will know, ideally, at what stages of the supply chain waste is produced, to either reduce it or use it in biomass production.

Finally, to reduce dependence on non-renewable sources, biomass production is a very basic indicator. We have already established the amount of biomass used in the food sector as an indicator. But now, to achieve our goal, it is necessary to monitor the production of biomass by source type, but also the total production by use-consumption. In a city where we want to produce biomass, we must monitor the sources from which it can be produced and the percentage of biomass produced per source. If, for some reason, a source cannot produce enough biomass then it would be prudent to discover new sources or to prioritize sources that produce the desired result. An additional indicator, as mentioned above, is the total biomass available by use. Monitoring where most of the biomass is consumed, in which sector, is a logical continuation. Is it consumed for energy or for materials production? This way, we will know the city's consumption needs and where we need to focus our attention for support and research.

Adapting to and mitigating climate change is by no means an easy task. It is of the utmost importance to make the necessary measurements so that we know, in every city that follows the path of bioeconomy, what pollution it produces. Therefore, greenhouse gas emissions should be measured, ideally in each sector separately, i.e., what are the emissions from agriculture, fisheries, biobased industries and so on. We cannot protect the environment if we do not know what pollution we produce. Using these measurements, we can monitor whether the methods applied reduce the pollutants introduced in the environment, and if not, then proceed with reforms.

Naturally, here too we need financial support for the biobased and other sectors, so that they may constantly evolve with new technologies that are more environmentally friendly and will contribute to achieving the coveted goals of the bioeconomy. If there is no continuous support, then there will be no continuous development in the bioeconomy.

For the bioeconomy framework to succeed, **new jobs must be created** in relevant sectors and promoted in order to fill vacancies, and of course the competitiveness of each city which is about to change its entire economy must be maintained.

For these reasons, we must monitor the bioeconomy's turnover by sector, so that we know which the strongest sector in the city in question is and which sectors need additional support. Another related indicator is the value added by each sector. We want all sectors to bring added value, so by monitoring which sectors do not bring added value we can put more emphasis on them, more support and reforms so that every sector may produce the prerequisite added value.

It would be useful to monitor how many employees are employed in relevant industries. With this knowledge we can monitor which industries are the most and the least competitive. The industries that we observe have the fewest employees will have room for job creation and will have to become more competitive. Therefore, we will know the shortcomings in each branch. The same goes for companies by sector. Similarly, we need to monitor how many companies there are in each sector in order to find the shortages, eliminate them if possible and know which industry should draw our attention because it does not show sufficient activity.

Another indicator to be monitored is the bioeconomy-relevant knowledge of the city, from that of the ordinary citizen to industry and research and development. The higher the level of knowledge, the greater the development there will be. If knowledge is not sufficient, this should also be monitored so that there can be mobilization, information about the bioeconomy and knowledge transfer. The level of knowledge should be constantly increasing to develop sustainability and bioeconomy.

An additional indicator regarding knowledge is investment in research and development. This indicator will monitor whether there is also investment in the development of the bioeconomy, as the greater the investment in research, the greater the knowledge of new technologies and the greater the step towards achieving sustainability and competitiveness, since innovation leads to competitive advantage.

Finally, to measure competitiveness, we cannot ignore the city's ratio of imports and exports. The more exports and the fewer imports, the more competitive and self-sufficient a city is. Therefore, knowing how much the city imports and exports, we can define and perhaps control its competitiveness.

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Printed in Switzerland
Geneva, 2022