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Governance of the Bioeconomy: A Global Comparative Study of National Bioeconomy Strategies

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Abstract: More than forty states worldwide currently pursue explicit political strategies to expand and promote their bioeconomies. This paper assesses these strategies in the context of the global Sustainable Development Goals (SDGs). Our theoretical framework differentiates between four pathways of bioeconomic developments. The extent to which bioeconomic developments along these pathways lead to increased sustainability depends on the creation of effective governance mechanisms. We distinguish between enabling governance and constraining governance as the two fundamental political challenges in setting up an effective governance framework for a sustainable bioeconomy. Further, we lay out a taxonomy of political support measures (enabling governance) and regulatory tools (constraining governance) that states can use to confront these two political challenges. Guided by this theoretical framework, we conduct a qualitative content analysis of 41 national bioeconomy strategies to provide systematic answers to the question of how well designed the individual national bioeconomy strategies are to ensure the rise of a sustainable bioeconomy.

Keywords: bioeconomy; governance; development policy; innovation; technology; bio-based

1. Introduction

The bioeconomy is based on the idea of applying biological principles and processes in all sectors of the economy and to increasingly replace fossil-based raw materials in the economy with bio-based resources and principles. An innovative and sustainable use of bio-based resources in different sectors of the economy (i.e., a bio-based transformation) provides opportunities for achieving a number of different Sustainable Development Goals (SDGs), which have been designed to improve social, economic, and ecological living conditions. Particularly, this applies to sustainable solutions to current climate change risks [1]. However, recent studies emphasize the dependence of a sustainable bioeconomy on technical, economic, and social prerequisites that the bioeconomy itself cannot create [2]. Experts, therefore, increasingly demand the development of a comprehensive governance framework for the bioeconomy to ensure the emergence of sustainable bio-based transformations [3,4].

Previous research on this topic is mostly organized around case studies, which focus on the governance of selected segments of the bioeconomy in individual countries or in small samples of countries [5,6]. The detailed contribution by Pannicke et al. [7] on the governance of the German wood industry may serve as an example. However, a broader perspective that provides a comparative global overview about national bioeconomy politics is still missing.

Overall, we found 41 states worldwide that currently pursue explicit political strategies to expand and promote their bioeconomies. In this paper, we provide a systematic overview of 41 of these national bioeconomy strategies in existence at the time of this research. What types of bioeconomies are individual states striving for? Why does the development of a sustainable bioeconomy require an effective governance framework? Which political means are available to states to promote transformations towards sustainable bioeconomies, and how do individual states design their national bioeconomy strategies in order to meet this demand for a sustainable governance framework? In the following sections, we will address these research questions. In doing so, we aim to not only develop an overview of national bioeconomy policies, but also to develop an information tool that enables national and international policy makers to learn from other countries' bioeconomic strategies.

Our considerations rest on a comprehensive understanding of the bioeconomy. We distinguish between four bio-based transformation paths: (1) substitution of fossil fuels with bio-based raw materials; (2) productivity increase in bio-based primary sectors; (3) increasing efficiency in biomass utilization; and (4) value creation and addition through the application of biological principles and processes separate from large-scale biomass production.

Whether or not the bioeconomic development along these four pathways will have a positive impact on the achievement of SDGs is uncertain. One key challenge is that bio-based transformations may involve high conversion costs [8]. Path dependencies and economic incentive systems that stem from the fossil fuel era and pre-biotechnological production processes might hamper investments in a progressive bioeconomy. The question of how politics can support the rise of the bioeconomy through appropriate political means (enabling governance), therefore, presents the first key challenge for the development of a sustainable bioeconomy. In principle, states have a wide range of different mechanisms at their disposal to promote their bioeconomies. These mechanisms may include a bio-based research and development strategy, enhancing the competitiveness of bio-based products through subsidies, or implementing awareness-raising campaigns to increase societal participation in bio-based transformation including more responsible and sustainable consumption.

However, technical progress rarely offers only positive opportunities, but usually also leads to new risks. This is also the case for the bioeconomy. Scholars interested in studying the bioeconomy point to goal conflicts between SDGs that can result from bio-based transformations. Today, the discussion about conflicting goals goes far beyond the original "food versus fuel" debate in the field of bioenergy development and includes issues such as global equity concerns, water scarcity, land degradation and land use change. The identification and effective political management of conflicting goals, therefore, represents the second major challenge for the development of a sustainable governance framework for the bioeconomy. To address this, a number of different public and private governance tools exist that states can use to minimize tradeoffs and promote synergies in bio-based transformation processes (constraining governance).

However, how do individual states really react to these two fundamental governance challenges, and which means do they concretely employ to make their bioeconomies sustainable? Our results suggest the following: today a great number of states have set the goal of developing and expanding their bioeconomies. Further, states are willing to provide comprehensive political support to their bioeconomies to achieve this goal. Currently, states are highly active in addressing the first abovementioned governance challenge (enabling governance). On the other hand, our results show that the political management of conflicting goals has not yet reached the same level of attention. Only a minority of national bioeconomy strategies even mention the potentially negative consequences of bio-based transformations for sustainable development, and those states that are pursuing a more sustainable strategy mostly opt for soft political approaches to manage these conflicts. Overall, states address the second fundamental challenge of developing a sustainable bioeconomy (constraining governance) to a considerably lesser degree than the first challenge (enabling governance).

The paper consists of two sections: the first section lays out the conceptual foundations for our empirical study. We begin with a brief note on the concept of governance. Subsequently, we characterize the four different transformation paths along which bio-based transformations are likely to proceed. We then discuss the two key governance challenges for a sustainable bio-based transformation and present a set of key governance mechanisms that governments can use to support the development of a sustainable bioeconomy. Based on this theoretical framework, the second section presents our empirical analysis of a total of 41 national bioeconomy strategies. Here, we show which bio-based transformation path (or which combination of transformation paths) the states follow strategically, which of the governance mechanisms specified in the first section the states apply to promote their bioeconomies, which goal conflicts they identify, and how they attempt to regulate them. Finally, we summarize the results of the study and present perspectives for further research.

2. Concepts

2.1. A Short Note on the Concept of Governance

Governance can be understood as the process by which societies adapt their rules to new challenges [9]. Governance has a substantial dimension (what are the rules?), a procedural dimension (how are the rules developed?) and, finally, a structural dimension (the procedural rules and institutions that determine rule-making, how the rules are implemented and enforced, and how conflicts over rules are resolved). Societal adaptation of rules to new challenges can be spontaneous and informal at the level of social relationships and networks. However, modern societies also delegate governance functions to specialized institutions, which set and enforce the rules in formally organized procedures. Such institutions first and foremost include the state at local, regional, and national level, but may also include inter- and supranational organizations, as well as private standard setters, which together build an interacting and overlapping governance system of plural authorities. In this sense, the UN Commission has defined the term governance as “[. . .] the sum of the many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. It includes formal institutions and regimes empowered to enforce compliance, as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interest...” (p. 1) [10].

2.2. The Concept of Four Bio-Based Transformation Paths

The course and effects of bioeconomic transformation processes depend, among other aspects, on the development level, resources and political system of a given state (see Figure 1).

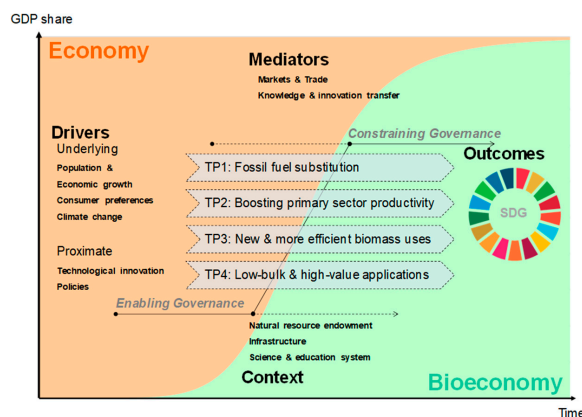


Figure 1. Conceptual diagram of transformative pathways in the bioeconomy (developed by the authors).

Transformation processes can be triggered by the interaction of driving forces, such as population growth and technological innovation, or by political or social action. Depending on the country context and its interaction with other economies, for example in the form of trade and knowledge transfer, bioeconomic transformation can proceed along one or more of the four paths depicted in Figure 1 with different possible effects.

Transformation Path 1 (TP1): In the past, this rather intensely researched TP has often been triggered by temporarily increased oil prices, subsidies, and environmental policies. For example, biofuel policies in the EU and US have led to increased demand for bioenergy, with direct and indirect effects on land use worldwide depending on land availability and the effectiveness of environmental and economic governance systems [11–13].

Transformation Path 2 (TP2): If technological innovation increases productivity in agriculture, forestry, or even fishing, it can release transformative forces that open up new production methods or locations. In the past, and globally, according to the so-called Borlaug hypothesis, this has repeatedly led to an easing in food markets despite increasing population growth [14]. However, regional and local boosts in agricultural productivity have also been shown to increase demand for land in ecological sensitive biomes, leading to losses in globally valued ecosystem services [11,15].

Transformation Path 3 (TP3): Innovation in downstream sectors often aims to increase the efficiency of biomass use and waste stream recycling. Such innovation can be associated with “rebound effects”, i.e., increased demand due to improved provision. In the long term, however, the impact depends on supply dynamics, consumer behavior and the regulatory environment [16,17].

Transformation Path 4 (TP4): Biological principles and processes can be used largely independently of biomass streams’ industrial applications, such as in the case of enzymatic synthesis and “biomimicry”. Many countries with bioeconomic ambitions have high expectations for this knowledge and technology-intensive TP (see Section 2). Corresponding transformative processes result, *inter alia*, from providing cheaper and more environmentally friendly production methods or completely new products.

The above-mentioned transformation pathways can be driven by both production (supply) and consumption (demand) dynamics. We focus primarily on supply side dynamics in this paper. However, it is noteworthy that promoting sustainable consumption through regulations and incentive systems is one among many of the governance challenges of the sustainable bioeconomy.

3. Governing the Bioeconomy: Theoretical Framework

3.1. Governance to Promote Sustainable Bioeconomic Dynamics

The four paths of bio-based transformation presented in the last section offer opportunities as well as risks for a sustainable transformation of our existing economic and social systems. As shown above, one of the major opportunities of a comprehensive bio-based transformation is the possibility of promoting sustainable growth across economic sectors. However, a sustainable bio-based transformation cannot be taken for granted.

Current literature on bioeconomy repeatedly emphasizes the great potential of the bioeconomy for sustainable developments towards SDG achievement, but simultaneously points out that the realization of these potentials is facing considerable hurdles. Some researchers argue that the path dependence of economic and political development is the root cause of the problem [18]. This means that previous decisions in politics, economics, and society—taken before the bio-based transformation paradigm emerged—have shaped the economic system in a way that today hampers the development of a bio-based economy even though it may bring about significant sustainability gains.

First, problems of path dependencies may arise from a lack of adaptation of existing institutional frameworks to the specific needs of the bioeconomy. Indeed, the political and legal institutions (such as intellectual property rights, consumer protection, environmental rights), which govern our current economic systems, have developed over long periods, during which the technological possibilities of the current bioeconomy were unknown. Given this, the chances are high that existing institutions are poorly aligned to the institutional demands of a rapidly developing and innovative bioeconomy. Institutional path dependencies might thus lead to a situation in which the bioeconomy faces high regulatory and transaction costs, which, in turn, may prevent the transformative dynamics of the bioeconomy from unfolding.

Further, problems of path dependency occur at the level of industrial organization and production. Many existing value chains are specialized in an efficient use of fossil-based resources and pre-biotechnological production processes. The same applies to existing infrastructure (transport systems), on which these economic activities are based. Naturally, this leads to lock-in effects [19,20]. Even if bio-based transformations promise long-term sustainability gains for both individual companies and society as a whole, companies currently avoid incurring the costs of changing their organizational structures and methods of production towards bio-based processes, since under the given conditions such changes would still compromise their competitiveness. To conclude, it seems that current economic systems that have been shaped through the utilization of fossil-based resources and pre-bioeconomy production techniques are not yet able to provide the necessary incentives to leverage comprehensive bio-based transformations.

Both points have in common that they conceptualize path dependency problems as problems of economic incentives that ill-inform individual economic decisions. From these rational choice-based approaches, a structural approach can be distinguished. From a sociological perspective, both our identity and knowledge about the world is defined by culture, social norms, and ideology and, ultimately, these social structures also determine our economic conduct [21].

Obviously, normative and cognitive structures that incrementally manifest in a given society are even harder to change than economic incentives. At the level of social structures, path-dependency problems limiting bioeconomic dynamics may, therefore, be even stronger than at the level of economic institutions, organizations and production techniques. Misinformation, including limited knowledge, about the properties of bio-based products or a conceptual reduction of the bioeconomy to risk technologies can undermine consumer confidence (a phenomenon well known from the debate around genetically modified organisms). The bioeconomy has an influence on almost all areas of social life. It changes what we eat, how we live, how we move, how we dress, and much more. Consumption patterns in all these areas are deeply rooted in the cultural habits of societies and, therefore, extremely difficult to change [8].

In conclusion, it can be said that not only the economic institutions, organizations, and production techniques that evolved in the era of fossil resource utilization but also the societal structures that developed during this period may hamper the emergence of a dynamic bioeconomy. Against this background, it is not surprising that scholars interested in bioeconomy research currently regard the creation of an appropriate governance framework that is capable of overcoming the various path-dependency problems as one of the most pressing political challenges in the development of a sustainable bioeconomy.

However, which specific governance mechanisms can governments use to address this challenge? One governance tool, often discussed in this context, presents the implementation of a comprehensive research and development strategy to promote investments in technological innovations whose costs and risks private actors are not willing to incur under the given conditions. [5] Further, political support measures can aim at increasing the competitiveness of bio-based products through subsidies, thereby creating markets for the bio-economy that do not independently develop in the economy [22]. Industrial location policies may have similar effects [23]. Political support measures such as the creation of favorable legal frameworks, state-supported training of the labor force or

the promotion of industry clusters are all intended to make it more attractive for companies to invest in the bioeconomy. This form of political support for the bioeconomy also includes measures for strategic international research collaborations and foreign direct investment. Finally, states can promote bio-based transformation at a societal level through deliberate political campaigns to increase the legitimacy and acceptance of the bioeconomy [8].

Table 1 provides an overview of such governance mechanisms that states can use to promote bio-based transformative processes. In the following empirical section of this paper, this serves as a typology for the policy instruments that states actually intend to use to promote their respective bioeconomies.

Table 1. Overview of the means for enabling governance.

(I)	Promoting research and development for a bio-based transformation
	<ul style="list-style-type: none"> - Funding of research projects - Establishment of specific research facilities - Promotion of research networks and strategic partnerships - Promotion of knowledge and technology transfer (science-praxis-nexus)
(II)	Improving the competitiveness of the bioeconomy through subsidies
	<ul style="list-style-type: none"> - Quotas for the bioeconomy - Promotion of bio-based public procurement - Promotion of sustainable consumption behavior - Tax benefits - Specific credit programs
(III)	Industrial location policies for bio-based industries
	<ul style="list-style-type: none"> - Promotion of industry clusters in the field of bioeconomy - Promotion of knowledge and technology transfer between research and industry - Promotion of labor education in the field - Creation of appropriate intellectual property rights - Promotion of foreign direct investment (FDI) in the field
(IV)	Political support for bio-based social change
	<ul style="list-style-type: none"> - Promote public dialogues to increase understanding of the functioning of the bioeconomy - Promote public dialogues on technological risks in the field of bio-economics

3.2. Governance of Risks and Goal Conflicts

The creation of a favorable political framework within which the bioeconomy can thrive presents one major governance challenge. However, political support measures alone will not suffice to ensure the development of a sustainable bioeconomy. The problem is that, as much as the bioeconomy can contribute to the achievement of a range of different SDGs, it can also undermine the achievement of SDGs [24,25]. An effective political regulation of these conflicting objectives presents the second major challenge for a sustainable governance of the bioeconomy.

The concept of bioeconomy rests on the idea of applying biological principles and processes in all sectors of the economy and to increasingly replace fossil-based raw materials in the economy with biogenic resources. However, the question whether or not bioeconomic transformations will either lead to more sustainability or produce new sustainability risks remains debated. The following table (Table 2) provides an overview of some common aspects of this debate.

Table 2. Possible opportunities and risks of bioeconomic transformation.

Sustainability Dimension (SDG)	Opportunities	Risks
Food security (SDG 2)	Increase via higher yields and new production methods	Reduction due to food price increases
Poverty/inequality (SDG 1, 10)	Reduce via transfer of technology and leapfrogging	Increase via exclusion from technical progress
Natural resources (SDG 7, 14, 15)	Conserve by improving production methods	Degrade/loss through inefficient production and overuse
Health (SDG 3)	Improve through new and refined forms of therapy	Risk/damage through improper use of risky technologies
Climate Change (SDG 13)	Mitigate through emissions reductions	Exacerbate through direct and indirect land use change

Sources: [26–28].

Both the above-mentioned optimistic and critical views on the impact of bioeconomic transformation on SDGs achievements (Table 2) depend strongly on assumptions about how and in which contexts new bio-based technologies and principles will be used. We illustrate this point in the following examples.

Example 1: The EU promotes biofuels with the aim of reducing emissions (SDG 13). This can lead to a global loss of tropical forests through direct and indirect land use change, but also to the spread of environmentally hazardous and health-threatening production methods (which conflicts with SDGs 3, 14, 15). Both technological innovation (e.g., improving production of biomass at marginal sites with higher yields) and governance mechanisms (e.g., implementing existing legislation to prevent illegal deforestation or misuse of agrochemicals or incentive systems for sustainable production) can help alleviate this conflict.

Example 2: Developed countries promote bio-based applications in chemical or pharmaceutical sectors (SDG 3). Due to restrictive patent rights and often lengthy and costly licensing procedures, the associated benefits accrue only to the affluent segment of the world's population. This might create a conflict with SDG 10. This conflict could be mitigated by innovation transfer, more efficient administrative structures and a more inclusive patent system.

These two examples show how narratives of the bioeconomy that highlight the potentially associated risks often assume that regulations constraining the bioeconomy are ineffective, or that existing technologies and processes that might be able to increase the efficiency of the bioeconomy remain inaccessible. On the other hand, perspectives that highlight the opportunities inherent in bioeconomic developments assume that efficient biotechnologies will evolve and diffuse and that appropriate governance frameworks can be set up to regulate the remaining potentially negative effects of the bioeconomy.

The political support measures that enable the evolution and diffusion of efficient biotechnologies have been discussed above (enabling governance). In the following, we focus on the question of what states can do to constrain economic activities related to the bioeconomy where necessary (constraining governance). Looking into this issue of regulating the bioeconomy, it strikes us that various governments and non-government actors have already developed a variety of rules to govern bioeconomic activities in different areas of the bioeconomy. For example, multi-stakeholder initiatives such as the Global Bioenergy Partnership or the United Nations Voluntary Guidelines on the Responsible Governance of Tenure, Land, Fisheries, and Forests in the Context of National Food Security both aim to ensure the priority of the right to food in the bioeconomy to prevent land grabbing. Other examples include the International Draft Standard DIN EN ISO 14046: 2015-11, which sets out guidelines for determining the water footprint of products based on a life cycle assessment, or the United Nations Convention on Biological Diversity, which aims to connect the bioeconomy to conservation initiatives.

Given this relatively well-developed normative basis, the central challenges in developing an effective regulatory framework for the bioeconomy clearly emerge in the later stages of the governance cycle, i.e., in the implementation and enforcement of the existing rules [29]. The adoption of regulations into state legislation is one possibility, but it presupposes the existence of functioning state enforcement mechanisms, which do not exist in many emerging and developing countries. In addition, state regulations operate only within the territory of a state, but they have no reach to regulate cross-border economic processes, and they have less influence again on global economic dynamics, both of which are becoming increasingly important in the global bioeconomy. An expansion of international law might provide a solution, but is itself subject to major compliance problems due to the absence of an authority beyond the individual states that could enforce compliance with international law [30]. Of course, states can refrain from a pure legal enforcement logic and create positive incentives to regulate a global bioeconomy (e.g., payment for ecosystem services [31]), and support softer instruments, such as private standards and certification systems along global value chains [32].

Ultimately, an effective form of regulation for the bioeconomy can only be created through the use of a combination of different public and private mechanisms. We summarize the individual regulatory approaches that states may support to achieve this goal in Table 3 below.

Table 3. Overview of regulatory mechanisms.

(I)	State regulation of the bioeconomy
(II)	Governmental development of positive incentives (e.g., payments for environmental services)
(III)	Government support for private standards and certifications
(IV)	International cooperation (through international organizations and regimes)

4. Methods

We conducted a qualitative document analysis [33] of national bioeconomy strategy documents using ATLAS.TI software. We provide an overview of the countries and documents analyzed in Appendix A at the end of this article. The tables above (Tables 1–3, and Figure 1) served as a codebook guiding the systematic coding of the strategy documents. We have used Table 1 as providing the themes to analyze the enabling governance means for achieving national development goals as well as contributing to addressing selected global sustainability goals contained in Table 2. Table 3 serves as a heuristic conceptual overview of possible regulatory mechanisms grouped into four (I–IV) dimensions. The methods used draw mainly upon techniques of qualitative content analysis [34]. The analytic procedure entailed selecting and appraising passages contained within the policy documents with regard to the themes of the codebook and connecting them to other lines, quotations about political means chosen to address a certain issue. This, for example, is related to the finding of anticipated negative impacts of implementing the bioeconomy policy on land and water resources and the governance means chosen to address them. Such document analysis yielded data in the form of excerpts, quotations, or entire passages chosen according to the major themes and categories from the codebook [35].

5. Results and Discussion

Having laid out our preferred indicators to distinguish and classify national strategies, in this section we now discuss our findings from the empirical analysis of national bioeconomy strategies. Specifically, our empirical analysis of 41 different national bioeconomy strategies aims to contribute to answering the following three questions:

1. Type of bioeconomy: Which of the four bio-based transformation pathways or combinations of transformation paths are individual countries pursuing in their strategies?
2. Enabling governance: Which means of governance do countries employ in their political strategies to overcome problems of path dependencies in the development of a sustainable bioeconomy?

3. Constraining governance: Which goal conflicts in the development of a sustainable bioeconomy have the individual countries identified in their strategies, and which political means have the individual strategies used to regulate these goal conflicts and reduce resulting risks?

5.1. Types of Bioeconomy

Practically all countries with explicit bioeconomy strategies aim to foster transformation processes along at least two of the pathways outlined in Figure 2. In countries that explicitly envision only two transformation pathways, particular emphasis is often placed on the efficient provision of biomass for TP1, both domestically and for trading partners, as in the case of Brazil.

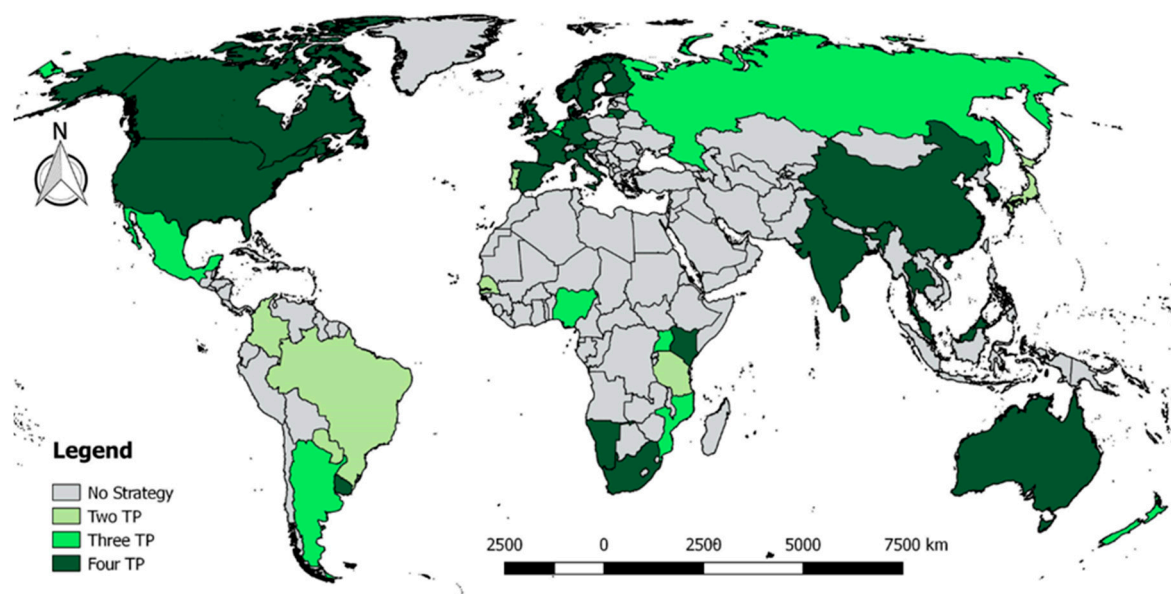


Figure 2. Transformative pathways by country.

By contrast, the majority of industrial nations, as well as some emerging economies, envisage or currently implement more diversified strategies along all four TPs. In the majority of cases, the selection of and focus on individual TPs in the examined strategies reflects three aspects: the respective resource availability of the countries (e.g., availability or scarcity of agricultural area); historically developed pioneering roles in special technology and research areas (e.g., biotechnology); or country-specific development deficits to be overcome. For example, the German bioeconomy strategy specifically focuses on applications in the field of recycling waste streams and the more efficient or cascading use of biomass (TP2). In turn, China's bioeconomy strategy relies strongly on bio-based substitution of fuels and materials (TP1).

5.2. Strategies to Enable the Bioeconomy

How do the individual states intend to promote their bioeconomies politically, and what concrete political means do they use to do so? In this context, Figure 3 below shows the intentions of the individual states to provide political support to their bioeconomies. In Table 2 of our conceptual framework, we distinguished between four political support measures that states can draw upon in promoting their bioeconomies. Our analysis of these national strategies is based on those categories, and reveals that the individual states are indeed intensively using all these means to strategically promote the development of their bioeconomies.

It becomes clear that almost all states with an explicit bioeconomy strategy rely on at least three of the political support measures identified, and the majority of states even deploy all four measures mentioned above. In other words, they pursue a targeted research and development strategy for bio-based transformation and want to improve the competitiveness of their bioeconomy through subsidies. In addition, many countries pursue active industry location policies aimed at improving the overall conditions for bio-based industries, and plan to improve the acceptance of the bioeconomy through education and other capacity-building and awareness-raising campaigns. Thus far, we can state that many countries with bioeconomic ambitions declare comprehensive bioeconomies as a strategic political goal (see Figure 2) and are prepared to intensively promote this development politically (see Figure 3). Overall, this suggests that the bio-based transformation may gain momentum in the coming years.

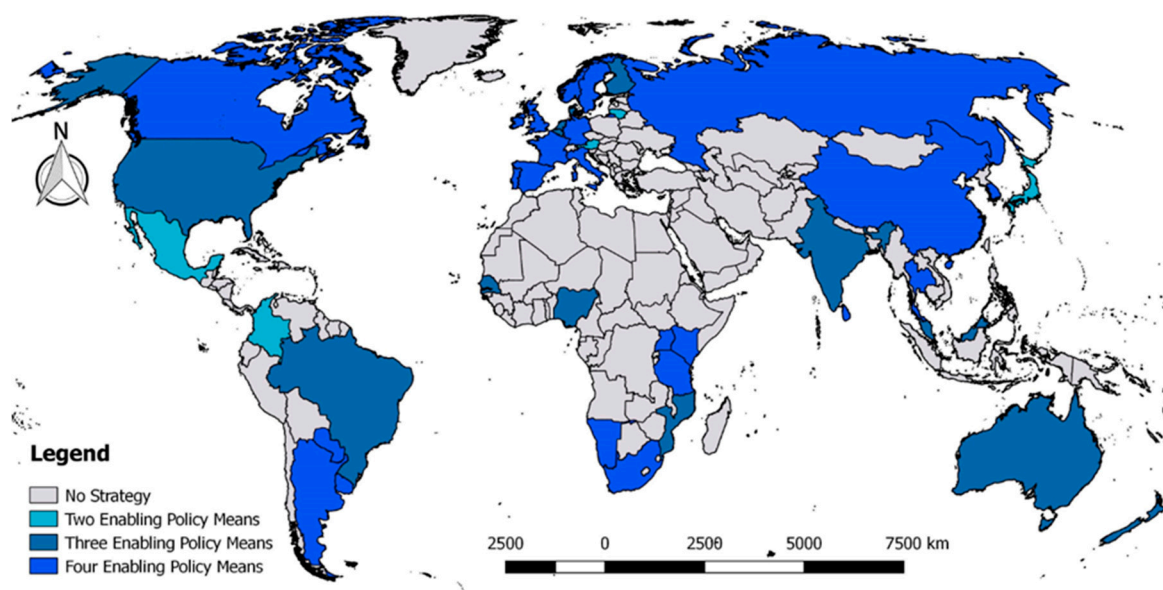


Figure 3. Enabling policy means in national bioeconomy strategies.

5.3. How Do States Regulate Their Bioeconomies?

The complex task of creating expedient regulatory measures for managing conflicting interests throughout the development of a bioeconomy is the second governance challenge. Figure 4 shows the extent to which national bioeconomy strategies give political answers to the risks and potentially related goal conflicts mentioned in Table 2 above.

Most national strategies pay little or no attention to risks and goal conflicts (26 out of 41 states). This includes countries with potentially large bioeconomies, such as the USA, Russia, Brazil, and Argentina. In contrast, China and a few African states explicitly recognize the need to manage risks as a crucial political challenge in shaping a sustainable bioeconomy. Overall, European states show the highest political sensitivity to potential risks and goal conflicts.

Table 4 compares the identification of conflicting goals in national strategies. It shows that states are particularly concerned with negative impacts of the bioeconomy on land and water resources, as well as on global food security. This reflects the discourses about the sustainability risks associated with the first generation of biofuels. Other negative effects potentially associated with the bioeconomy, such as inequality and poverty, climate, or health risks, have only played a minor role in national strategies so far.

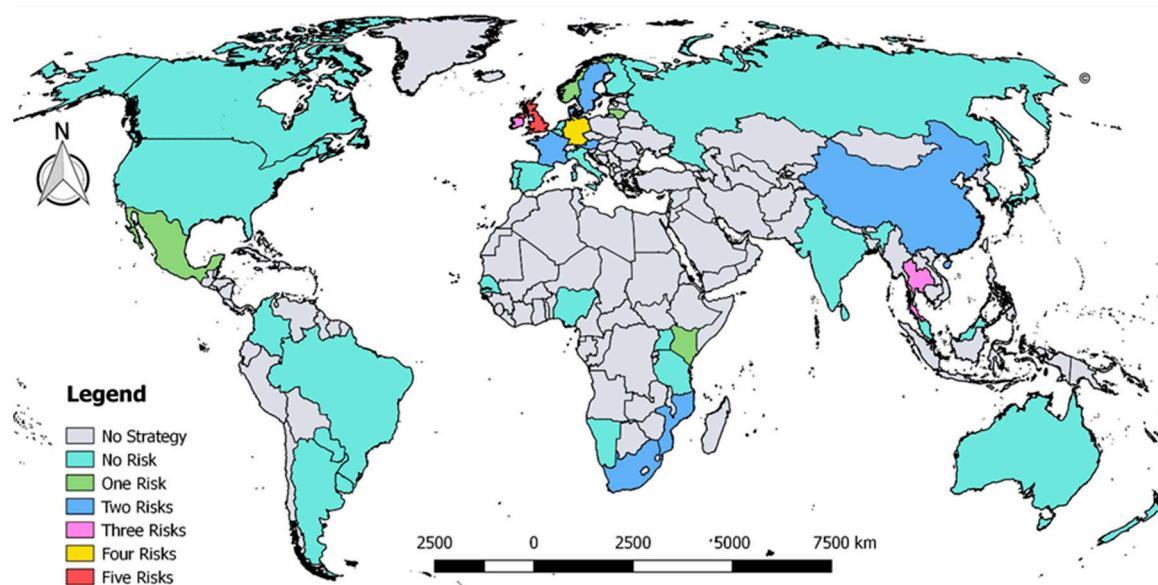


Figure 4. Anticipated risks in national strategy documents of 41 countries.

Table 4. Overview of conflicting goals and associated risks identified in national bioeconomy strategies.

Country	Nutrition	Poverty/Inequality	Nat. Res. (Air)	Nat. Res. (Forests)	Nat. Res. (Land)	Nat. Res. (Water)	Health	Climate
Austria	●					●		
Denmark	●					●		
France	●			●		●		
Germany	●	●		●		●		●
Ireland	●					●	●	
Kenya				●		●		
Lithuania						●		
Mexico				●		●		
Mozambique	●					●		
Norway						●		
South Africa	●		●			●		
Sweden	●					●		
Thailand	●			●		●		●
United Kingdom	●	●	●	●		●	●	●
China	●					●		
Total	12	2	2	6	15	7	2	3

Our content analysis also shows (see Table 5) that states rely heavily on soft regulatory means, such as self-regulation of global value chains through private standards and certification regimes, to manage bioeconomy-related risks. In addition, most states advocating more comprehensive regulation to avoid conflicting goals (as in the case of Germany) aim to intensify international cooperation in this field. Despite this, the need to react to bioeconomic conflicts of interest by means of concrete legislative amendments was not a central focus of the national bioeconomy strategies examined. Our analysis also does not reveal a broad willingness of countries with bioeconomy strategies to safeguard the protection of natural resources through the development of positive incentives, such as the widely discussed instrument of payments for ecosystem services [34].

Table 5. Overview of regulatory mechanisms by country.

Country	State Regulation	Creation of Positive Incentives by Governments	Private Standards and Certifications	International Cooperation	Total
Austria			●		1
Denmark			●		1
European Union			●		1
France	●	●	●	●	4
Germany	●	●	●	●	4
Ireland	●	●	●	●	4
Kenya			●		1
Lithuania	●		●	●	3
Mexico					
Mozambique			●	●	2
Norway			●		1
South Africa	●	●		●	3
Sweden			●	●	2
Thailand			●	●	2
United Kingdom	●	●	●	●	4
China	●	●	●	●	4
Total	8	6	14	10	

5.4. Regional Developments

The last sections have provided a global overview of national bioeconomy strategies. In the following, we complement this view by a short regional assessment. In doing so, it becomes clear from the various figures and maps presented above, that European states have developed the most advanced sustainable bioeconomy strategies, notably the UK and Germany. These results reflect the role of the European Union as an active partner in promoting bioeconomic transformations. It strikes us that most Eastern European Countries are, so far, absent from these developments. Despite the fact that compared to other regions European countries have developed the most advanced bioeconomy strategies, in Europe a substantial governance gap still exists between promoting and regulating the bioeconomy.

The Western Hemisphere presents a further world region in which most individual states are currently advancing comprehensive bioeconomy strategies. Different from the European bioeconomy strategies, which have at least partly integrated some measures to regulate the bioeconomy, regulatory aspects that deal with potential sustainability risks associated with the rise of the bioeconomy are almost completely absent in the strategies drafted by countries located in the Western Hemisphere. The gap between promoting and regulating the bioeconomy is, therefore, even greater here than in Europe. Overall, our results make clear that both North and South American countries are currently undertaking significant efforts to enhance their bioeconomic sectors.

Again, a different picture emerges in Asia and Australia. In this region, we find many states—especially major states such as China, India, Russia, and Australia—that have adopted advanced bioeconomy strategies. However, we also find a significant number of states without explicit bioeconomy strategies. Different from the states located in the Western Hemisphere, among the Asian states at least two states (China and Thailand) pay some attention to the sustainability risks associated with a rise of the bioeconomy.

In Africa, we find the smallest share of countries with bioeconomy strategies. Nevertheless, the countries located in the southern parts of Africa show with their strategies that they see very large potential in the bioeconomy to foster their economic developments in a sustainable way. Among these countries, South Africa and Mozambique stand out in having developed the most advanced bioeconomy strategies. They also include some regulatory aspects. Overall, there is still very large potential for African states to develop more explicit bioeconomy strategies.

6. Concluding Remarks

Summarizing the results of our analysis, it is evident that many countries seek to develop and expand their bioeconomies. In order to achieve this, states are willing to support their bioeconomies through comprehensive political means. It is also clear that countries around the world have embraced the first major governance challenge of enabling bio-based transformation. However, the second challenge of deploying political means to address the potential risks and goal conflicts of bio-based transformation does not appear to be wholeheartedly addressed. Only a minority of states even mentioned the potentially negative implications of bio-based transformation for sustainable development. Those states pursuing comprehensive strategies rely largely on soft political means of risk mitigation and conflict management.

The notion of governance includes the process of how societies adapt their rules to new challenges [9]. In this article, we explored the question of how nation-states globally aim to adapt their rule systems to the governance challenges associated with an emerging bioeconomy. This raises further questions: why are the respective national strategies different? How effectively do individual states implement their strategies? What are the real impacts on SDG achievement that follow when states implement their bioeconomy strategies? In conclusion, it can be said that national governments widely regard the development of a modern bioeconomy as a central strategy to promote their economies and to ensure sustainable development worldwide. However, to achieve these goals, national bioeconomies need an effective and globally coordinated governance framework. Future research should contribute to identifying key ingredients of such a framework and support their effective implementation, for example by documenting implementation processes and outcomes in all relevant sustainability dimensions.

A prerequisite for creating effective governance arrangements is the development of comprehensive approaches for measuring and assessing the bioeconomy [36]. Inadequate monitoring and a lack of impact assessment could otherwise lead to over- or under-regulation of the bioeconomy. The risks associated with the business-as-usual scenario of a fossil-fuel-based future global economy must be confronted with the bioeconomy-specific risks in order to comprehensively assess risks and conflicting goals [35]. This exceeds the scope of this chapter, but we strongly emphasize the need to investigate these issues in future research.

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Appendix A

Table A1. Overview of national bioeconomy strategies.

Country	Title	Author
Austria	FTI-strategy for a bio-based industry in Austria	Federal Ministry for Traffic, Innovations and Technology
	Bioeconomy—Position Paper	Austrian Association for Agriculture, Life and Environmental Sciences with BIOS Science Austria
Belgium	Bioeconomy in Flanders—The vision and strategy of the Government of Flanders for a sustainable and competitive bioeconomy in 2030	Flemish government
France	The new face of industry in France	Ministry for Economic Regeneration
	Les usages non alimentaires de la biomasse	Interministerial
	A Bioeconomy Strategy for France—Goals, Issues and Forward Vision	French Republic
Germany	National Policy Strategy on Bioeconomy	Federal Ministry of Food and Agriculture
	Bioeconomy—Baden Württemberg's path towards a sustainable future	Federal state of Baden-Württemberg, with Federal Association BIOPRO
	National research strategy bioeconomy 2030	Federal Ministry of Education and Research
Ireland	Harnessing Our Ocean Wealth	Ministry for Agriculture, Food and the Marine
	Delivering our Green Potential—Government Policy Statement on Growth and Employment in the Green Economy	Government of Ireland
	Towards 2030—Teagasc's Role in Transforming Ireland's Agri-Food Sector and the Wider Bioeconomy	Teagasc—The Agriculture and Food Development Authority (Intersectoral)
Italy	BIT—Bioeconomy in Italy: A Unique Opportunity to Reconnect the Economy, Society and the Environment	Government of Italy
Lithuania	National Renewable Energy Action Plan	Lithuanian Government
Netherlands	Green Deals Overview	Ministry of Economic Affairs
	2012 Bioenergy Status Document	Ministry of Economic Affairs
Portugal	Estratégia Nacional para o Mar (2013–2020)	Government of Portugal

Table A1. Cont.

Country	Title	Author
Russia	State Coordination Program for the Development of Biotechnology in the Russian Federation until 2020 “BIO 2020” (Summary)	Government of the Russian Federation
Spain	The Spanish Bioeconomy Strategy—2030 Horizon	Ministry of Economy and Competitiveness
Denmark	Growth Plan for Water, Bio and Environmental Solutions	The Danish Government
	The Copenhagen Declaration for a Bioeconomy in Action March 2012	The Danish Council for Strategic Research
Finland	The Finnish Bioeconomy Strategy	Interministerial document
Norway	Research Programme on Sustainable Innovation in Food and Bio-based Industries	The Research Council of Norway
	National strategy for biotechnology	Ministry of Education and Research
	Marine Bioprospecting—a source of new and sustainable wealth growth	Interministerial document
	Familiar resources—undreamt of possibilities—The Government’s Bioeconomy Strategy (English Summary)	Interministerial document
Sweden	Swedish Research and Innovation Strategy for a Bio-based Economy	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (commissioned by the Swedish Government)
Great Britain	A UK Strategy for Agricultural Technologies	Interministerial document
	UK Bioenergy Strategy	Interministerial document
	UK Cross-Government Food Research and Innovation Strategy	Interministerial document
Kenya	A National Biotechnology Development Policy	Republic of Kenya
	Strategy for developing the Bio-Diesel Industry in Kenya (2008–2012)	Ministry of Energy (Renewable Energy Dept.)
Mozambique	Politica e Estrategia de Biocombustiveis	Council of Ministers
Namibia	National Programme on Research, Science, Technology and Innovation	National Commission on Research, Science and Technology (government)
Nigeria	Official Gazette of the Nigerian Bio-fuel Policy and Incentives	Federal Republic of Nigeria

Table A1. Cont.

Country	Title	Author
Senegal	Lettre de Politique de Développement du Secteur de L'Énergie	Interministerial document
	Biofuels in Senegal—The Jathropha program	Enda Energy, Environment, Development Programme (NGO) (sourced from Ministry of Agriculture)
South Africa	The Bio-Economy Strategy	Department of Science and Technology
	A National Biotechnology Strategy for South Africa	Unspecified
	Public Perceptions of Biotechnology in South Africa	HSRC, Human Sciences Research Council (TIA, Technology Innovation Agency)
Tanzania	National Biotechnology Policy	Ministry of Communication, Science and Technology
Uganda	Biomass Energy Strategy (BEST) Uganda	Ministry of Energy and Mineral Development (support UNDP)
	National Biotechnology and Biosafety Policy	Ministry of Finance, Planning and Economic Development
	The Renewable Energy Policy For Uganda	Ministry of Energy and Mineral Development
Canada	Growing Forward 2 In Newfoundland and Labrador	Government of Newfoundland and Labrador
	British Columbia Bio-Economy	Minister of Jobs, Tourism and Innovation
Mexico	Estrategia Intersecretarial de los Bioenergéticos	Interministerial document
USA	Farm Bill	Congressional Research Service
	Strategic Plan for a Thriving And Sustainable Bioeconomy	Bioenergy Technologies Office—U.S. Department of Energy
	National Bioeconomy Blueprint	The White House
Argentina	Biología argentina al año 2030: Llave estratégica para un modelo de desarrollo tecno-productivo	Ministry of Science, Technology and Productive Innovation
Brazil	Plano Decenal de Expansão de Energia 2023	Ministry of Mines and Energy
	Política de Proteção de Desenvolvimento da Tecnologia	Brazilian Government
Colombia	Política para el Desarrollo Commercial de la Biotecnología a partir del Uso Sostenible de la Biodiversidad	Council for Economic and Social Policy (Interministerial)
Paraguay	Política y Programa Nacional de Biotecnología Agroprecuaria y Forestal del Parauay	Agriculture Ministry
Uruguay	Plan Sectorial de Biotecnología 2011–2020	Interministerial document

Table A1. Cont.

Country	Title	Author
China	12th Five-year Plan (2011–2015) on Agricultural Science and Technology Development	Ministry of Agriculture
	National Modern Agriculture Development Plan	Ministry of Agriculture
	13th Five-Year Plan for Environmental Protection	State Council of the People's Republic of China
	13th Five-Year Plan For economic and social development of the People's Republic of China (2016–2020)	Central Committee of the Communist Party of China
	13th Five-Year Plan for the Environmental Health Work of National Environmental Protection	Ministry of Environmental Protection
	The National Medium- and Long-Term Program for Science and Technology Development (2006–2020)	National Development and Reform Commission
	13th Five-Year Plan for Energy Saving and Emission Reduction	General Office of the State Council
	13th Five-Year Plan for Bioindustry Development.	State Council of the People's Republic of China
	Policies to Promote Quick Development of Biological Industry. 2009	State Council of the People's Republic of China
	13th Five-year Plan for National Strategic Emerging Industries	State Council of the People's Republic of China
13th Five Year Plan of Renewable Energy Development	State Council of the People's Republic of China	
India	National Biotechnology Development Strategy 2015–2020	Ministry of Science & Technology
	The Bioenergy Roadmap (2012)	Ministry of Science & Technology
Japan	The 3rd Fundamental Plan for Establishing a Sound Material-Cycle Society 2013	Ministry of the Environment
Malaysia	National Biomass Strategy 2020: New wealth creation for Malaysia's biomass industry Version 2.0	National Innovation Agency of Malaysia
	Bioeconomy Transformation Programme	Ministry of Science, Technology and Innovation (Commissioner)
	Biotechnology for Wealth Creation and Social Wellbeing	Ministry of Science, Technology and Innovation
South Korea	Biotechnology in Korea (2013)	Ministry of Science, ICT and Future Planning (Commissioner)
	Status of Biotechnology in Korea	Biotech Policy Research Center
	Vision 2015: Korea's Long-term Plan for S&T Development	Ministry of Science and Technology
	Biovision 2016—For Building a Healthy Life and a Prosperous Bioeconomy	Ministry of Science and Technology

Table A1. Cont.

Country	Title	Author
Sri Lanka	National Biotechnology Policy	Ministry of Science and Technology
Thailand	Thailand's National Biotechnology Policy Framework (2012–2021)	Ministry of Science and Technology
	Alternative Energies Development Plan 2012–2021	Ministry of Energy
	National Roadmap for the Development of Bioplastics Industry (2008–2012)	Ministry of Science and Technology
Australia	National Collaborative Research Infrastructure Strategy	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
	Opportunities for Primary Industries in the Bioenergy Sector—National Research, Development and Extension Strategy	Rural Industries Research and Development Corporation (Semi-Government agency)
	2011 Strategic Roadmap for Australian Research Infrastructure	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
New Zealand	2014 Sector Investment Plan—Biological Industries Research Fund	Ministry of Business, Innovation and Employment
	The Business Growth Agenda	Ministry of Business, Innovation and Employment

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