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Public Governance across Borders

The Bioeconomy and the Achievement of the Sustainable Development Goals (SDGs)

To what extent can the Bioeconomy Strategies of Germany and Queensland help to achieve the SDGs, particularly considering SDGs 2, 7, and 12?

Abstract: The Bioeconomy is seen as a promising concept to realize the Sustainable Development Goals (SDGs). However, to help achieve the goals, bioeconomy strategies must incorporate specific features that ensure their effectiveness. Therefore, This study assessed two bioeconomy strategies, namely Germany's and Queensland's, and analyzed to what extent their strategies can promote the achievement of the SDGs. The analysis focused on SDGs 2,7, and 12 since economic development can affect these goals. A qualitative content analysis was conducted to assess the strategies, which found that both strategies can promote responsible consumption and production (SDG 12). Germany's strategy can additionally achieve improved food security (SDG 2). However, it cannot ensure greater access to modern energy (SDG 7). This is opposed to Queensland's bioeconomy strategy, which can promote SDG 7 but does not incorporate significant measures that would allow the promotion of SDG 2. The study further identifies pivotal features that must be incorporated into bioeconomy strategies to achieve SDGs 2,7 and 12. These include available biorefineries, sufficient access to biomass, adequate governance mechanisms, as well as specific SDG-related features.

Keywords: bioeconomy, sustainable development goals, bioeconomy assessment, bioeconomy strategies, biofuture, germany, queensland

List of Abbreviations

BMBF - The Federal German Ministry of Education and Research

BMEL - The Federal German Ministry of Food and Agriculture

DSDILGP - Queensland Department of State Development, Infrastructure, Local Government and Planning

FAO - Food and Agriculture Organization of the United Nations

GHG Emissions - Greenhouse Gas Emissions

IACGB - International Advisory Council on Global Bioeconomy

IMAG - Interministerial Working Group on the Bioeconomy

SDGs - Sustainable Development Goals

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1. Introduction

In the 21st century, the world faces many severe challenges. Providing sufficient food for a growing world population, mitigating the threats posed by global warming, and combating the global pandemic are just some of the wicked problems humanity is confronted with today. Policymakers and scientists are eager to find solutions to solve these problems and stop further disruption. Earlier solution proposals were based on fostering economic growth as it was believed that economic growth is the one solution for promoting development and fighting problems like poverty. However, focusing on economic growth caused fundamental harm to the environment (Turner, 2008). Maintaining this approach to foster development would be impossible without overexploiting natural resources and causing irreversible damage to the ecosystem and its functioning. Industrial processes fueled by fossil raw materials cannot meet demands for goods and services in the future if their availability is depleted (Ekardt, 2019). In recent years, scientists and policymakers have acknowledged that promoting economic growth and the consumption of endless resources has its limits and is not effective or sustainable in tackling emerging problems. Therefore, the UN introduced a different approach to address global problems and sustainably promote development: *The Sustainable Development Goals (SDGs),* also known as the Agenda 2030 (Figure 1). It is a comprehensive normative framework that acknowledges the interdependence of global problems by underlining that they cannot be targeted individually. It contains "17 Goals to tackle the world's most pressing social, economic, and environmental challenges in the lead-up to 2030" (WBCSD, n.d.). Even though the framework is holistic and defines guidelines for its implementation, the agenda is not legally binding and relies on governments to set up regulations and policies to diffuse the targets. Since the establishment of the SDGs in 2015, many different programs have been introduced that aim to promote the achievement of the goals. The bioeconomy is one concept seen as promising to realize some of the targets because it can reduce GHG emissions, diversify sources for renewable energy and provide a more reliable and efficient food supply. This, in turn, can help to mitigate climate change, provide more affordable access to modern energy, and combat malnutrition or hunger. The bioeconomy is a relatively new economic model that is defined as an approach "[...] whose aim is to create, develop, and revitalize economic systems based on a sustainable use of renewable biological resources" (Aguilar et al., 2019, p. 1). The idea is to replace using unsustainable resources like fossils for energy generation and producing goods with renewable

biological raw materials for industrial purposes, making it more eco-friendly. Over the last decades, more researchers started investigating the concept, and it became a renowned approach that can influence sustainable development positively. It was found that the bioeconomy can be linked to several of the goals defined by the Agenda 2030 (Heimann, 2019; Székács, 2017; El-Chichakli et al., 2016; Allen et al., 2020; Issa et al., 2019; Vera et al., 2022; Zeug et al., 2019). To date, the bioeconomy is a well-known concept among researchers and policymakers, and almost 60 countries and many regional actors developed bioeconomy strategies to transition their economies. Nevertheless, the design and the extent to which the bioeconomy can promote the SDGs varies significantly and is not guaranteed by implementing a strategy per se. It is strongly affected by the understanding and approach that underpins the implementation of bio-based economic systems. Besides that, the governance landscape and the present natural and infrastructural conditions determine whether the bioeconomy has the potential to solve global challenges (CIRCE, 2019). To date, most studies focus on exploring the relationship between the bioeconomy and sustainability. Only a few scholars explored links between the concept in general and the SDGs. However, little is said about specific bioeconomy strategies and their potential to effect achieving the Agenda 2030. Still, it is essential to identify which features and mechanisms in those strategies might affect their success and what lessons can be learned from those strategies to take them as guidance for developing improved approaches (Calicioglu & Bogdanski, 2021).

Therefore, this study contributes to scientific knowledge by investigating the question: **To what extent can the bioeconomy strategies of Germany and Queensland help to achieve the SDGs? The study particularly investigates SDG 2 (Zero Hunger), 7 (Affordable and Clean Energy), and 12 (Responsible Consumption and Production).**

To complement this research question the following subquestion will be explored: **What features in the bioeconomy strategies determine their potential to help achieve the selected SDGs?**

Answering these questions is essential to promote solutions for problems like climate change, hunger, and environmental degradation to ensure the survival of future generations. If

transitioning to a bio-based economy can supposedly realize the achievement of the SDGs and therefore mitigate some of the current and future problems, it is essential to evaluate what makes a strategy successful. Finding out which criteria increase the potential of a bioeconomy strategy to achieve the goals can bring valuable insights for policymakers that aim to develop approaches to achieve more responsible consumption, increased access to renewable energy, promote food security and realize the sustainability agenda. For that reason, this study establishes an assessment framework containing pivotal factors to evaluate the effectiveness of bioeconomy strategies. Based on that framework, the two strategies of Germany and Queensland are strategically analyzed to outline to what extent they fulfill the criteria and can potentially advance the achievement of the selected SDGs. The assessment and evaluation of the strategies can have practical implications for future research and legislators that want to explore methods to promote the targets.

The paper is structured as follows: First, a thorough literature review presents the state of knowledge on the discourse and identifies the research gap this contribution fills. Based on that, the theoretical framework defines the bioeconomy and the SDGs as relevant concepts for the analysis. Further, the assessment framework is established, and relevant criteria are identified to guide the strategies' systematic analysis. The following section presents the research design, data collection, and analysis methods. The central part comprises the qualitative content analysis of the strategy documents of Germany and Queensland, which provides the necessary information to answer the research question and conclude the study. The paper finishes by providing suggestions and practical implications for future research and policymakers.

2. Literature Review

This section reviews the literature published on the bioeconomy and its relation to sustainable development and introduces the state of the art on this discourse. Providing an overview of the subject's background is essential to situate this study into the context of the literature and determine the research gap.

The available literature on the bioeconomy and its link to sustainability is extensive. Researchers have investigated their relationship over the last two decades and made valuable findings. Initially, opinions on the relationship differed significantly and were, to some point, contradictory. Some scholars claimed that the bioeconomy itself is not inherently sustainable

because the use of biogenic material can lead to an "economization of nature" and immoderate exploitation of resources (Gawel et al., 2019; Pfau et al., 2014; Bennich & Belyazid, 2017; Székács, 2017). It has been criticized that the bioeconomy is being used for greenwashing and primarily focuses on economic growth under the claim of being "bio". Therefore, it is considered more of a "smokescreen" (Thrän & Moesenfechtel, 2022, p. 6) or an "empty or arbitrary phrase" (Gawel et al., 2019, p. 4). However, a study of 87 articles that link the bioeconomy to sustainability by Pfau et al. (2014) showed that the overall perception of the direction of the relationship between the concepts is positive if certain preconditions are met. Nowadays, most scholars recognize the positive impact of the bioeconomy on sustainable development, and it is underlined that it has not only the potential to foster economic growth but also provide beneficial social effects and reduces impacts on the environment (Liobikiene et al., 2019; Thrän, & Moesenfechtel, 2022). With the introduction of the SDGs (Figure 1), the discourse on a sustainable bioeconomy broadened and centered around the opportunities and challenges it has for achieving the Agenda 2030 (Heimann, 2019; Maksymiv et al., 2021; Issa et al., 2019; Ronzon, & Sanjuán, 2020). The Global Bioecnomy Summit identified the bioeconomy "[...] as a transformative strategy for advancing SDGs" (IACGB, 2018, p. 2). Scholars have identified that goals 2, 6, 7, 9, 12, 13, 14, and 15 can be linked to the bioeconomy, but some of them have closer relation and more potential to be realized by it (Allen et al., 2020; El-Chichakli et al., 2016; Zeug et al., 2019; BIC, 2018; Teitelbaum et al., 2020). Nevertheless, achieving the SDGs through bioeconomic approaches has many challenges and is not guaranteed inherently. Many goals' targets interrelate, and some are incompatible, making it hard to reconcile their achievement under one strategy (Maksymiv et al., 2021). A policy that helps achieve one goal might cause trade-offs for the realization of others. The literature stresses that an effective bioeconomy strategy needs to consider these risks and implement measures to mitigate them (Dietz et al., 2018). Since the bio-based economy became more prominent as an approach that advances sustainable development and many nations began their transition, it is essential to investigate what features are crucial for policies and strategies effectively promoting the SDGs. The thorough evaluation of bioeconomy strategies and their potential to achieve specific goals is not explored by other scholars to date. Yet, it is crucial for policymakers and stakeholders that aim to realize these objectives through their strategies to know what features determine the

success and which strategies might serve as guiding examples. Therefore, this study fills a research gap and contributes to scientific knowledge.

3. Theoretical Framework

The last sections introduced the background of the problem investigated in this study. To better understand the components that are part of this research, the following section defines the concepts more thoroughly, especially the bioeconomy and the SDGs with their respective targets. To conclude, the assessment framework that guides the analysis and helps determine to what extent Queensland's or Germany's strategy can contribute to achieving SDG 2,7, and 12 is presented.

3.1 The Bioeconomy

The bioeconomy is an economical approach that uses renewable biological resources to power industrial processes. Even though the concept has been discussed extensively, it lacks a unified definition since most actors adapt the understanding to their unique agendas. The International Advisory Council on Global Bioeconomy (IACGB) defines the bioeconomy as "the production, utilization, and conservation of biological resources, [...] to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy" (Teitelbaum et al., 2020, p. 9). Because it relies on biomass as feedstock and not uses endless resources like fossils, the bioeconomy can decouple economic growth from CO_2 emissions and reduce the overall consumption of resources. Biogenic raw materials emit fewer greenhouse gases when converted into feedstock or used for energy production, making them more sustainable than conventional economic models (Dietz et al., 2023; Lanzerath et al., 2022). Biomass is the primary material used for industrial purposes in bioeconomy systems and is referred to as "[...] every renewable resource that is widely available and could be acquired at minimal cost" (Sillanpää & Ncibi, 2017, p. 56). Most biomass is generated from biological organisms of agriculture, forestry, or marine life, like wood, food crops, or animal waste, which is converted into valuable feedstock to produce energy, chemicals, or other products. Besides the biomass extracted directly from organisms, many resources are generated from byproducts or residues from these industries or municipal waste (Michael & Dammer, 2018). Using residues and recycling waste creates a circular and cascading

use of materials, which increases the valorization of resources and reduces their overall consumption of them. These circular economic methods keep resource consumption within the planetary limits, protect biodiversity, and are less of a burden for ecosystems (Birner, 2018). The bioeconomy is also referred to as a *bio-based economy*, *bioindustry*, or in Queensland's document as *biofuture.* These terms can be used interchangeably and refer to the same aspects of the bioeconomy defined in this section.

3.2 Sustainability and the SDGs

Discourse on the bioeconomy is commonly linked to sustainability and the SDGs. Sustainable development, defined by the UN World Commission on Environment and Development, means "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (UN Brundtland Commission, 1987, p.20). The omnipresent notion of sustainability concerns three pillars: the environmental, economic, and social aspects. Only if all dimensions are considered and balanced in approaches can sustainability be guaranteed (Ekardt, 2019). The UN goes even further in its understanding of what entails promoting sustainable development with its introduction of the SDGs in 2015. This set of 17 goals with 169 targets aims to conquer the most urgent problems and needs of the 21st century (Figure 1). It is a normative framework that should guide governments, stakeholders, and civil society to transform their actions to end problems like poverty, malnutrition, climate change, and warfare (UN Department of Economic and Social Affairs, n.d.). Effective implementation of the targets is challenging since many goals intersect and influence each other, which can cause synergies and trade-offs in realizing the agenda.

The following section introduces the goals selected for the analysis more profoundly. Analyzing all goals and the potential of bioeconomy strategies to achieve them would exceed the scope of this study. These goals have been selected because it is even more urgent to achieve their targets in times of ever-growing world population, the COVID-19 pandemic, and dwindling endless resources. Besides that, these goals are affected by to changes in economic development and other studies found that their achievement could be supported by the bioeconomy, making their investigation reasonable (Teitelbaum et al., 2020). For a detailed illustration of the goals and their targets, see Appendix A.

Figure 1. UN Sustainable Development Goals. (GLEC, 2023).

3.2.1 SDG 2 - Zero Hunger

Over 800 million people worldwide suffered from hunger in 2021. With problems like global warming or the Ukraine war, providing enough food to meet the demands of a growing world population becomes more challenging. Therefore, conquering malnutrition and hunger is one of the most important goals of the Agenda 2030 (UN Department of Economic and Social Affairs, n.d.). The goal aims to increase access to nutritious food **(Target 2.1)** and to end malnutrition **(Target 2.2).** To realize these targets, the productivity of agriculture should be enhanced, and small-scale food producers be supported **(Target 2.3)**, under the condition that biodiversity and ecosystem services are protected **(Target 2.5).** Additionally, sustainable and resilient food production practices should be developed and implemented **(Target 2.4)** by investing in infrastructure, research, and technology **(Target 2.6)**. The bioeconomy can potentially promote these targets because new agricultural and industrial production is being implemented under most strategies, and biomass can be generated locally and from smallholder farmers (Pfau et al., 2014). To what extent these targets are considered in the strategies of Germany or Queensland will be part of the analysis of Section 5.2. Other targets that adhere to SDG 2 are not respected in the analysis.

3.2.2 SDG 7 - Affordable and Clean Energy

Goal 7 aims to ensure access to affordable, reliable, and modern energy **(Target 7.1).** To realize this target, renewable energy generation should be increased and diversified **(Target 7.2),** and the efficiency of existing sources should be improved **(Target 7.3)**. These targets should be facilitated by developing innovative technologies and investing in research advancements and cooperation **(Target 7.4)**. Developing technologies and infrastructure should increase access to renewable energy for developing countries **(Target 7.5).** Because biomass can be converted into energy, biofuels, or gas, and since biomass resources are abundantly available and can be extracted in rural areas, renewable energy supply can be more efficient, reliable, and affordable in a bioeconomic system, which promotes the achievement of SDG 7 (Sillanpää & Ncibi, 2017).

3.2.3 SDG 12 - Responsible Consumption and Production

Promoting responsible production and consumption is a goal that is particularly linked to the bioeconomy. Realizing Goal 12 requires sustainable management of natural resources **(Target 12.2)** and the responsible management of waste **(Target 12.4)**. Waste production, especially food waste, should be reduced **(Target 12.2 & 12.5)**. To achieve these targets, awareness about the need for sustainable lifestyles should be increased **(Target 12.8),** and companies should be encouraged to implement sustainable production **(Target 12.6),** for example, by supporting sustainable public procurement practices **(Target 12.7)**. Since the bioeconomy does not rely on endless and unsustainable raw materials for production and promotes the circular use of resources, it is suitable to promote important aspects of the goal (Möller et al., 2020; Issa et al., 2019).

3.2.4. Trade-offs between the Goals

As shown, a bio-based economy can promote the achievement of the SDGs. Yet, achieving these goals is challenging because some of the objectives can be incompatible, which can cause trade-offs in their implementation or even adversely impact their achievement. This needs to be acknowledged by bioeconomy strategies that aim to realize the goals. Challenges can occur in implementing goals 2 and 7, known as the "food vs. fuel debate". In the bioeconomy, biomass is converted to generate renewable energy; therefore, arable land is dedicated to growing energy crops. This creates competition for land and biomass because the same crops are used to ensure a

sufficient food supply. This competition can lead to inflating food prices and monoculture. More productive agriculture is needed to meet the demands of biomass, which often results in the use of gene-edited plants that can cause biodiversity loss and damage ecosystem services (Vera et al., 2022; Moyer, 2019).

Additionally, the increased demand for biogenic raw materials can lead to overexploitation of resources, increased water usage, or deforestation to provide arable land for biomass production. This is in contrast to achieving goal 12 and a responsible management of natural resources (Székács, 2017). Bioeconomy strategies that aim to promote sustainable development need to consider these risks.

For that reason, the analysis of Germany's and Queensland's approaches illustrates what and if measures are taken to prevent trade-offs.

3.3 The Assessment Framework

The following chapter introduces the assessment framework that guides the analysis of Germany's and Queensland's bioeconomy strategy. Therefore, criteria are outlined that are considered pivotal for a strategy to promote food security, clean energy, and responsible consumption of resources. These criteria are operationalized into codes suitable for analyzing those approaches to outline relevant data for evaluation. One can distinguish between general criteria and specific SDGs-related criteria that determine whether a bioeconomy strategy has the potential to help realize SDGs 2,7 and 12. Table 1 illustrates the assessment framework and the codes broadly; for a detailed description of the coding scheme, see Appendix C.

The general features cover external conditions and circumstances required to transition to a bio-based economy that can promote sustainable development. These include:

1. **The strategy's objective to achieve SDGs 2,7 and 12.**
2. **The availability of infrastructure that can convert biomass into materials usable by bioeconomic industries (Biorefineries).**
3. **Suitable natural conditions to provide sufficient biomass.**
4. **Governance mechanisms that enable effective implementation of the strategy.**

The potential of a bioeconomy strategy to realize sustainable development is significantly higher if it defines the objective to foster the respected SDGs or, more specifically, food security, clean energy, and responsible consumption and production. Therefore the first assessment criterion will analyze the strategy's vision and intentions and assesses how it aligns with the goals.

Furthermore, a suitable infrastructure is required to guarantee the functioning of a bioeconomic system. The availability of biorefineries that turn biomass into valuable products and feedstock is considered "the engine propelling bioeconomy and its sustainability dimension (Sillanpää & Ncibi, 2017). Thus, the availability or construction of biorefineries is a necessary precondition for a bioeconomy and, therefore, another assessment criterion.

As biomass and byproducts of industry are the primary material for all production processes, sufficient availability of those resources is essential for an effective economy to provide energy and food. Thus the bioeconomy strategies will be assessed to what extent they consider and promote the natural conditions required to provide sufficient biomass (Birner, 2018).

As pointed out in previous sections, an effective implementation of a bioeconomy strategy is challenging and, therefore, highly dependent on a governance landscape that supports the transformation path. A successful strategy must provide concrete measures and governance instruments to enforce the strategy. Dietz et al. (2018) differentiated between enabling and regulatory governance instruments driving the transition. "[P]olitical support measures such as the creation of favorable legal frameworks [...] intended to make it more attractive for companies to invest in the bioeconomy "(Dietz et al., 2018, p. 5). These measures can include subsidies, tax benefits, cooperation mechanisms, or the funding of bioeconomy-related programs that enhance the recognition of bioeconomy services and increase the competitiveness of its products. Constraining policy instruments can include regulations, mandates, laws, or other equivalent measures enacted by the government. It is considered pivotal that these measures and strategies are monitored and assessed to guarantee adequate regulation.

The analysis will assess to what extent Germany's and Queensland's action plans incorporate these criteria in their strategies, enhancing their potential to promote the selected SDGs.

It is essential to not only evaluate general features and conditions that must be met to guarantee an effective strategy but also to assess criteria related to the individual SDGs to analyze which attributes in the strategy contribute to their achievement specifically. Scholars found that the SDG targets and indicators are tangible measures to assess the bioeconomy regarding their

relation (Calicioglu & Bogdanski, 2021; Gomez San Juan et al., 2019). Therefore, the targets of SDGs 2,7 and 12 are operationalized into adequate criteria for evaluating the bioeconomy strategies.

The assessment of SDG 2 is operationalized into three criteria that determine whether the respected strategies can promote combating hunger. The code, **Promotion of Food Security,** evaluates targets 2.1, 2.2, and 2.4 and measures whether agricultural practices are explored that enhance the productivity, resilience, and nutritional value of crops to increase the supply of food, which helps to achieve the targets. **Employment and Support of Local Farmers** represent target 2.3 and analyze whether bioeconomy processes are used to support rural agriculture, enhance employment rates, and support small-scale farming. Target 2.5 is measured as the **Protection of Biodiversity** to assess how the strategy respects planetary limits and protects ecosystems functioning. **Research and Technology for Food Security** (Target 2.6) evaluates if investment is directed to research for developing the necessary facilities to implement the objectives.

To achieve the goal of increased access and affordability of clean energy, the bioeconomy needs to incorporate features that help to reduce the dependency on fossil fuels and replace them with modern energy sources. The criteria **Transitioning to Bioenergy** indicates if a "favorable enabling policy environment for bioenergy [...]" (International Energy Agency, 2017, p. 64) is created that facilitates the conversion of biomass into suitable materials that can be used for transportation, electricity, or heat. Exploring alternative sources of energy by converting biogenic materials or waste into energy can increase the access and availability of clean energy, which helps to achieve targets 7.1, 7.2, and 7.3 (CIRCE, 2019). To facilitate the diffusion of bioenergy, research is needed to develop appropriate technologies that can diffuse bioenergy and improve its efficiency. Therefore, the **Research and Technology for Bioenergy** criterion assess the achievement of targets 7.3 and 7.4.

The realization of SDG 12 requires more responsible consumption and production practices. To evaluate to what extent the strategies incorporate features that can help achieve this goal, the assessment evaluates if **Sustainable Resources Management** is promoted. This criterion reviews if mechanisms guarantee sustainable use of natural resources and waste (Target 12.2 and 12.4). This is essential because the bioeconomy depends on biogenic raw materials to power their industries; therefore, the analysis examines features that provide sustainable exploitation of

these resources within planetary limits or by waste recycling. This criterion is complemented by evaluating a **Circular Economy**, which represents targets 12.3, 12.4, and 12.5. The assessment determines if waste and materials are reused and valorized for other purposes and how bioeconomic processes aim to reduce waste production. To guarantee SDG 12, civil society and private companies need to be aware of the advantages of a bioeconomy and the need to practice more responsible consumption of resources. The criterion **Awareness Spreading** assesses how the targets 12.6, 12.7, and 12.8 are promoted.

These evidence-based indicators that compile the assessment framework are illustrated in Table 1. This comprehensive framework guides the analysis of the strategy documents of Germany and Queensland to conclude whether they can help to promote SDGs 2,7 and 12.

Table 1. The Assessment Framework with Codes

Category	Assessment Criteria (Codes)
Strategy Objective	Objective to Promote SDG 2,7 and 12
Infrastructural and Natural Conditions	Availability of Biorefineries Reflection of Availability and Sources for Biomass
Regulatory Governance	Governance Mechanisms Monitoring and Evaluation
SDG 2 related Features	Promotion of Food Security (Target 2.1; 2.2; 2.4) Employment and Support of Local Farmers (Target 2.3) Protection of Biodiversity (Target 2.5) Research and Technology for Food Security (Target 2.6)
SDG 7 related Features	Transition to Bioenergy (Target 7.1; 7.2; 7.3) Research and Technology for Bioenergy (Target 7.3 & 7.4)
SDG 12 related Features	Sustainable Resource Management (Target 12.2 & 12.4) Circular Economy (Target 12.3; 12.4; 12.5) Awareness Spreading (Target 12.6; 12.7; 12.8)

3.4 Concluding Remarks

This chapter defined the most relevant concepts and presented the assessment framework that. The criteria selected for the evaluation are based on factors considered pivotal for a bioeconomy strategy to achieve food security, clean energy production, and more responsible consumption of natural resources. The following section presents the cases of analysis and the methodology.

4. Methodology

This chapter aims to illustrate the employed research methods used to conduct the study, which is essential to evaluate the reliability and validity of the results. The section presents the motivation behind the case selection and demonstrates why the chosen cases are relevant to the research topic. Furthermore, the research design, data collection, and analysis method will be elaborated to show how they are suited to answer the research question.

4.1 Case Selection

The study assesses the potential of Germany's and Queensland's bioeconomy strategy to help achieve SDGs 2,7 and 12. The cases were selected because they have similar preconditions that influence the opportunity to transition to a bio-based economy. Both cases have a strong economy, large agriculture sector, and developed infrastructure system and are considered industrial states (Staffas et al., 2013). Besides, their governments state the objective to promote sustainable development with their legislation. They have introduced policies to mitigate climate change and to foster the achievement of the Agenda 2030; therefore, it is interesting to examine to what extent they use their respective bioeconomy strategies to realize the SDGs (Department of Environment and Science, 2022; The Federal Government, 2022). Besides that, it is reasonable to analyze the nation-state of Germany and the federal state of Queensland because both have bioeconomy-related strategies in place, resemble each other's stage of industrial development and have a more comparable area size than, for example, comparing Australia as a nation-state. Additionally, the cases are significant when looking at the timeline of the bioeconomy development. Germany was one of the first countries to introduce a national bioeconomy strategy, and Queensland only recently engaged in research and policy implementation. Even though Germany could develop a holistic strategy over the years, Queensland had the opportunity to base its strategy on substantial scientific knowledge of what

makes a strategy effective. The selection was further motivated by their strategies' focus on related targets. Both cases aim to promote innovation in energy, health, and nutrition and support biotechnological research (Dieckhoff et al., 2015a; Dieckhoff et al., 2015b). These sectors are specifically linked to SDGs 2, 7, and 12. Therefore it is reasonable to analyze to what extent the strategies qualify to promote the achievement of these goals and realize their potential.

4.2 Method of Data Collection

To investigate to what extent the bioeconomy strategies of Germany and Queensland can lead to achieving sustainable development, this study relies on secondary data. Google Scholar and the online libraries of the University of Twente and University Münster were used as databases to select relevant sources. Besides, the Sustainability Journal and the EFB Bioeconomy Journal provided access to many insightful scientific papers (Sustainability, n.d.; EFB, n.d.). Keywords were used to browse the databases for suitable material. These were, amongst others: the bioeconomy, bioeconomy and the SDGs, biotechnologies, circular bioeconomy, national bioeconomy strategies, and assessment of bioeconomy policies. The selected literature was thoroughly reviewed, and relevant information was extracted. The primary data sources for the analysis are the official policy documents on the German *National Bioeconomy Strategy* and the *Queensland Biofutures 10-year Roadmap and Action Plan* (Queensland Government, 2016; BMBF & BMEL, 2020). Based on these documents, a qualitative content analysis was conducted, and the relevant data was extracted. Besides that, the *Global Bioeconomy Policy Report (IV)* from the IACGB and the document on the *Bioeconomy Policy (Part II)* from the German Bioeconomy Council provided valuable data for the discussion (Dieckhoff et al., 2015a; Dieckhoff et al., 2015b).

4.3 Method of Data Analysis

A qualitative content analysis was conducted to examine the policy document on bioeconomy strategies. Qualitative research seeks in-depth knowledge and understanding of a subject by analyzing non-numerical data. Analyzing documents according to their content allows for identifying key patterns, concepts, and themes within the text; it facilitates the interpretation of large text data sets and helps to situate the documents in a context. Phillipp Mayring developed the qualitative content analysis method as a rule-bound process to review text data

systematically. The assessment framework will guide the systematic analysis to code the documents and extract relevant information for the discussion (Mayring, 2014). The data obtained from the review is interpreted to answer the research question properly. This guided analysis aims to highlight aspects of the bioeconomy strategies that show whether the criteria of the assessment framework are fulfilled and to determine to what extent the strategy can promote the achievement of SDGs 2,7 and 12. The software ATLAS.ti was used to support the coding process and analyze the policy documents (Appendix D).

The study proceeds by presenting the findings of the document analysis and discusses the most relevant findings on the bioeconomy strategies and their potential to achieve the selected SDGs. The findings are interpreted to answer the research questions and to give an outlook for future research and the practical implications of the results.

5. Data Analysis

The following chapter presents the empirical analysis of the bioeconomy strategies of Germany and Queensland to answer the research question of to what extent Germany's and Queensland's bioeconomy strategies can promote the achievement of SDGs 2,7 and 12. Therefore, the relevant information is outlined to determine whether the strategies sufficiently fulfill the framework's criteria. Based on interpreting the text data, the research question will be answered. The chapter introduces the necessary background information on the two strategies and then moves to their document analysis.

5.1 The Bioeconomy Strategies of Germany and Queensland

The German *National Bioeconomy Strategy* was enacted in 2020 by the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food and Agriculture (BMEL). The document contains 68 pages and presents an elaborate approach for the transformation to a bio-based economy with specific objectives and guidelines for implementation (BMBF & BMEL, 2020). The document is based on the national research strategy *BioEconomy 2030*, which was published in 2011, and the *National Policy Strategy on Bioeconomy* enacted in 2014. These two documents defined research areas and political measures that need advancement to lay the ground to transition to a bioeconomy (BMBF, 2011; BMEL, 2014). The German strategy is

known to be very holistic and one of the first national strategies that was introduced globally. Compared to that, the Queensland policy document is less extensive and contains 20 pages. The *10-Year Roadmap and Action Plan for Queensland's Biofuture* was published in 2016 and updated in June 2022 by the Department of State Development, Manufacturing, Infrastructure, and Planning (DSDMIP). The strategy may not be as advanced as Germany's, but it defines a clear vision and opportunities for transforming into a bio-based economy. Queensland was one of the first regions in Australia to dedicate research and investment toward a biofuture to explore its potential to achieve development (DSDILGP, 2016; DSDILGP, 2022).

5.2 Document Analysis and Discussion

The following section systematically analysis the bioeconomy strategy of Germany and Queensland to determine whether the documents provide evidence that indicates that the strategies are capable of promoting the achievement of SDGs 2,7 and 12.

5.2.1 Assessment of the General Criteria

The first part of the analysis focuses on the general features identified as essential for a bioeconomy to promote sustainable development effectively. These include the assessment of the objectives of the strategies, the availability of biorefineries and sufficient resources to meet the demands of bioeconomy industries, and the regulatory governance mechanisms that enable effective implementation.

Strategy Objectives

The analysis reveals that the two respective strategies aim at different objectives with their intention to implement a bio-based economy. Germany expressed the purpose of supporting sustainable development and the achievement of the Agenda 2030. It is very explicit about which goals should be realized and illustrates explicitly to achieve SDGs 2,7 and 12 as an objective. The objective to realize the SDGs 2 and 12 is additionally mentioned in the following excerpt:

> *"This strategy was revised in 2018, with a stronger emphasis placed on sustainability and viability, the definition of new priorities, and the reaffirmation of the five goals of the original strategy, namely to secure the supply of food, manage natural resources sustainably, reduce dependence on unsustainable raw materials, combat and adapt to*

climate change, increase competitiveness, and secure and create jobs" (BMBF & BMEL, 2020, p. 17).

One can assess that the strategy's objectives are very holistic and ambitious and clearly target promoting the SDGs. The aim to guarantee food security and to manage resources more sustainably is repeatedly underlined. Yet, achieving SDG 7 is not expressed more elaborately. It is only mentioned by the intention to align the national bioeconomy with the Agenda 2030. One can assess that the strategy fulfills the criteria of the assessment framework as it explicitly refers to achieving the SDGs in their approach.

Queensland expresses a different direction with its action plan and does not explicitly mentions the SDGs or the intent to realize the goals. However, the government underlines the intention "to see a strong and sustainable industrial biotechnology and bioproducts sector become a reality" (DSDILGP, 2016, p.1). One can evaluate that the main objective and interest behind the transitioning of the economy is promoting economic growth and increasing employment opportunities which are underlined in their vision statement:

> *"Our vision is a $1 billion sustainable and export-oriented industrial biotechnology and bioproducts sector attracting significant international investment, and creating regional, high-value and knowledge-intensive jobs" (DSDILGP, 2016, p.3).*

This supports the assumption that their primary objective does not explicitly align with the SDGs' achievement. Yet, the vision to establish a large bioeconomy sector and promote the attached industries might reveal evidence that the SDG 2,7 and 12 targets can be achieved regardless. Simply assessing the intentions behind their strategy does not provide evidence for the assumption that it has the potential to support the targets. Whether the strategy still incorporates features that would promote their achievement is part of the following evaluation.

Infrastructural Features

The availability of adequate infrastructure is an essential criterion to evaluate whether the bioeconomy has the potential to drive the achievement of the goals. A strategy that aims to increase the responsible consumption of natural resources needs to consider the requirements for specific facilities that enable the utilization and conversion of biological raw materials into feedstock. Therefore, biorefineries are considered "[a] fundamental unit that will enable the

bioeconomy implementation [...]" (Golberg et al., 2019, p. 175). They are essential for the sustainable conversion and processing of biomass into biochemicals, bioproducts, and feedstock for energy production. Hence, biorefineries' construction and availability are crucial criteria to assess whether the strategies can provide clean energy and responsible industrial processes.

The German document highlights the lack of facilities for local biomass conversion, which results in higher CO_2 emissions because resources must be transported to the closest processing facilities. Interestingly, the document is very shallow in its references to biorefineries. It does not point to biorefineries as facilities that would enable biomass conversion and are not very reflective of their need for an effective bioeconomy. It states:

> *"One focus shall be on the local processing of biogenic raw materials to higher-quality materials suitable for subsequent processing stages" (BMBF & BMEL, 2020, p.44).*

This can be interpreted as the intention to support the construction of bioeconomy facilities that converts biomass into feedstock, but this does not inevitably mean biorefineries. The document does not further elaborate on the intention or specific construction plans. Evaluating the national bioeconomy strategy does not indicate sufficient evidence that biorefineries are acknowledged. Therefore, the criterion is not satisfied, and the potential to achieve their sustainable development objectives is hindered.

Compared to that, Queensland's Strategy emphasizes the availability of three biorefinery plants and underlines their value for the state to promote their bio-sectors, especially for transportation:

> *"Queensland has an emerging industrial biotechnology and bioproducts sector, largely characterised by three biorefinery plants located in the state. These plants are capable of producing more than 160 million litres of ethanol and biodiesel for domestic transport using conventional production technologies" (DSDILGP, 2016, p. 5).*

Besides the existing infrastructure, Queensland promotes research and pilot projects to advance the productivity of their biorefineries and explores how they can be utilized to strengthen their bioindustries and increase the output of products and materials. Their strategy aims to reach a higher capacity of their biorefineries and get a "reputation as a developer of advanced biofuels and novel biorefining technologies" (DSDILGP, 2016, p.12). This is evidence that Queensland already has much potential to convert raw materials and residues into bioenergy or bioproducts, which promotes the achievement of SDG 7 and the targets of SDG 12.

Biorefineries convert biomass into bioproducts and feedstock for energy generation. Hence it is crucial for a strategy that aims to reduce the dependency on fossil raw materials to be reflective of the availability of sufficient sources of biomass and consider ways for its acquisition to satisfy the need for industrial processes (CIRCLE, 2019).

Queensland's roadmap identifies many sources for biomass in its strategy. It underlines the abundant access to productive feedstock due to its sub-tropical climate, efficient infrastructure, and access to arable land. Sugarcane, algae, sweet sorghum, and agave, but also the byproducts and waste of their industry, like cotton residues or urban waste, are considered valuable feedstock for the bioindustry. It states that:

> *"Queensland's highly-productive agricultural industry annually produces large quantities of potential non-food feedstocks required for the bioproducts sector"* *(DSDILGP, 2016, p. 6).*

This expert shows that the strategy reflects on the sources for biomass and is confident that enough biomass is accessible to power the bioindustry. One can assess that the strategy fulfills the precondition to produce enough biomass to implement a bioeconomy and potentially promote sustainable development effectively.

The National Bioeocnomy Strategy of Germany also reflects the high demand for biomass to enable bio-based production. It states that:

> *"It is essential that we understand biomass flows and cycles, and that we can estimate them using suitable methods"* *(BMBF & BMEL, 2020, p. 32).*

Biomass is mainly extracted from the forest industry, but Germany's productive agriculture also contributes significantly to biomass generation. Residues and raw materials from these industries are mostly extracted in rural areas, yet generating those sufficient resources is threatened by the increasing occurrence of extreme weather caused by climate change. The productivity of agriculture and forestry to produce enough biomass depends on their capability to adapt to these circumstances. Therefore the strategy suggests using research and innovative technologies to explore resilient agricultural practices. It is repeatedly emphasized that biomass must be extracted sustainably and should not exceed planetary limits or risk overexploiting accessible resources (BMBF & BMEL, 2020, p.30). For that reason, degradable and marginal land should

be used to enhance the areas dedicated to biomass extraction. Additionally, biomass from biological raw materials should be "[...] supplemented by biogenic residues and waste materials" (BMBF & BMEL, 2020, p.41). Generally, the strategy reflects the sources that provide feedstock for the bioindustry and aims to assess possible alternatives that add to biomass production to meet the rising demands in the future. Although it is not as explicit on which plants provide biomass as Queensland, it states the diverse access to resources, which is why it fulfills the criterion for suitable natural preconditions of the assessment framework.

Governance Mechanisms

As underlined in section 3.3, effective implementation of the bioeconomy is highly dependent on the governance framework that underpins the transition. Governance mechanisms like subsidies, constraining measures, regulations, and positive incentives must create a "favorable legal framework" (Dietz et al., 2018, p.5). Besides that, these policies must be monitored and evaluated to guarantee their applicability. Considering these measures enhances the effectiveness of a bioeconomy strategy which is why the assessment evaluation to what extent mechanisms are incorporated in the investigated approaches.

Germany's approach indicates the adoption of several governance measures that should guarantee the effective implementation of their strategy and therefore enhance the potential to achieve the targets of the SDGs. This is underlined by the following statement:

> *"Policy makers shape the implementation of the bioeconomy by means of regulatory and support measures, and through communication and cooperation. The individual fields of action are designed to support the sustainable development of the bioeconomy in Germany" (BMBF & BMEL, 2020, p.39).*

Many of those measures address research and development because providing the necessary knowledge for implementation is considered pivotal. Therefore, the document has an extensive research and funding strategy which underlines that "instruments that support the validation of research results for a transfer to practical application are provided" (BMBF & BMEL, 2020, p.31). Bridging the gap between research and industry and supporting networks between these sectors is crucial for effectively transforming scientific knowledge into suitable instruments. It has a concrete program for developing innovative agricultural practices and crops that are more resilient and productive. Besides that, the government subsidizes the agriculture industry and

wants to promote more employment opportunities in this sector by enhancing the land dedicated to producing biomass (BMBF & BMEL, 2020, p.41). It also implements mechanisms to reduce the pressure on land by exploring alternative land capacity, innovating agricultural practices, and improving supply chains. The development of these instruments leaves room for investment and employment, a positive incentive for strengthening the bioeconomy market. The strategy further regulates the responsible use of resources as it states that the bioeconomy must adhere to the law of the Circular Economy Act, which promotes the responsible management of waste. This concrete state regulation shows the strategy's potential to promote the respected SDG. To increase the development of sustainable products and strengthen the bioeconomy industry, the strategy additionally provides incentives for companies and a specific program for start-ups and small and medium-sized enterprises to support their development of bio-based products (BMBF & BMEL, 2020, p.32). To increase the competitiveness of these products, the government supports policies to "to minimise the high investment risk associated with launching bio-based products and processes [...]" (BMBF & BMEL, 2020, p. 32). Another mechanism introduced in the strategy is "selecting and publicising good examples of sustainable uses of bio-based raw materials as beacons help to raise public awareness of these issues and create additional incentives for the use of renewable raw materials" (BMBF & BMEL, 2020, p. 44). The regulation of the use of clean energy is only implicitly referred to and does not promote any concrete policies or measures. However, it is occasionally underlined that the use of fossil fuels should be reduced and the replacement of renewable biological materials be promoted, implying that renewable energy sources are facilitated under the strategy. However, this is not directly indicated by any specific means.

These are just some examples of policy measures taken to promote food security and increased responsible consumption; the strategy is even more exhaustive. To coordinate these policy measures and ensure coherence among them, the German government established the *Interministerial Working Group on the Bioeconomy (IMAG).* Together with the *Bioeconomy Council,* these bodies should assess the strategy's effectiveness, monitor its implementation and give advice for improvements. Assessing the regulatory and enabling governance instruments considered by the German strategy, one can conclude that this criteria is sufficiently fulfilled. The strategy provides many examples of positive incentives to promote the bio-based market. The government resorts to more political support measures than using constraining or regulatory

mechanisms to promote the implementation of the strategy; however, both instruments are considered. With the establishment of the two advisory bodies, one can state that their monitoring and evaluation mechanisms are extensive, which fulfills the assessment criteria.

Even though Queensland engaged later in developing a bioeconomy strategy, it provides a comprehensive framework of regulatory measures that guarantee its implementation. One of those regulatory measures is the *Queensland Biofuel Mandate*, enacted in 2017:

> *"The ethanol mandate requires that 3% of regular unleaded petrol sales must be ethanol, while the biobased diesel mandate requires that 0.5% of all diesel fuel sold be biobased" (DSDILGP, 2016, p. 11).*

This concrete directive replaces fossil-based fuels in the transport sector and encourages the use of sustainable alternatives. Besides that, Queensland supports the *Australian Biomass for Bioenergy Assessment* program to identify land and resources that can be used as feedstock to increase the supply of clean energy. In addition, the document states that future actions should "[i]nvestigate policy and market development opportunities to encourage re-use of waste currently going to landfill "(DSDILGP, 2016, p.13), which shows the government's ambition to take actions that help achieve the targets of SDG 12. Additionally, it directs close operations with the Australian government to support the taxation of unsustainable fuels and the implementation of "fuel quality standards" to positively incentivize the consumption of clean energy in the transport sector (DSDILGP, 2016, p.13). Generally, the strategy has different programs in place to fund research, innovation, and development of their bioindustry. The *Advance Queensland* program, for example, has a 180 million AUS Dollar budget to realize research ideas and produce "commercial outcomes" (DSDILGP, 2016, p.11). Most of the policy measures taken under the strategy aim to attract international investment and a reputation for their bioindustry. However, it lacks regulatory or enabling means that help promote the agricultural sector to secure a sufficient food supply.

Examining Queensland's action plan of 2016 shows that no monitoring or evaluation strategy is initiated and there is no independent body that recommends on policy implementation. Nevertheless, the updated document from June 2022 states to:

"Maintain a Biofutures Industry Advisory Group to provide specialist, local leadership and guidance that will help overcome the challenges and create opportunities for the industry to grow" (DSDILGP, 2022, p.5).

It further indicates providing an evidence-based assessment to support the industry and improve the implementation process. To conclude the evaluation of the policy mechanisms provided by the action plan, one can assess that they have adequate measures in place to achieve the targets of SDG 7 and 12. However, no concrete regulations have the potential to support the achievement of SDG 2. Besides that, a more comprehensive monitoring strategy is needed to guarantee the effective implementation of their approach and to achieve a more sustainable economy.

5.2.2 Assessment of the SDG-related Criteria

Now that the general features were analyzed that indicate whether the necessary preconditions for an effective strategy are considered, the analysis turns to evaluate to what extent the strategies take measures that are directly linked to the realization of the targets of goals 2,7 and 12.

Analysis of SDG 2

The food supply for a growing world population becomes even more challenging in times of climate change. Germany made it one of its priorities to conquer the challenge and end malnutrition and hunger by transitioning to a bio-based economy. The strategy shows great potential to enhance food availability, provide more nutritious crops, and guarantee more resistant production chains to increase access to food. It aims to dedicate research towards developing improved agricultural practices and explore opportunities for "yield optimisation, optimal use of nutrients, resistance to and tolerance of flooding, heat, drought and plant diseases and pests [...]" (BMBF & BMEL, 2020, p.27). The document repeatedly underlines that making crops resistant to natural conditions is essential to guarantee a sustainable food supply. The development of improved agricultural practices should be backed up by science, and the development of innovative technologies should be funded under the strategy. These efforts significantly improve the potential to achieve targets 2.1, 2.4, and 2.6 of the Agenda 2030 because increased resilience and productivity will enhance access to secure and nutritious food sources. To combat hunger, the strategy stresses exploring organisms like fungi, insects, and

algae and promoting research on their capacity to provide food. Besides that, the competition for crops between the energy sectors and the food industry risks the potential to reduce hunger. However, this trade-off is mitigated as shown in the excerpt:

> *"Where there are competing uses [for crops], food security is always the priority"* (BMBF & BMEL, 2020, p.15).

Besides that, the potential to achieve targets 2.1 and 2.2 is additionally supported by the productivity and nutritional value of agricultural plantations, which biotechnologies and scientific innovations should increase. Besides that, the strategy emphasizes promoting a "low-meat diet" (BMBF & BMEL, 2020, p.39), which is proven to support food security because less land and crops are used as livestock feed (Parlasca & Qaim, 2022). However, providing more productive agriculture has the potential to endanger biodiversity and the functioning of ecosystems. Thus, the UN Agenda requires "maintain the genetic diversity of food production" (Target 2.5) and underlines the importance of ensuring environmentally friendly and sustainable agricultural processes. The increasing demand for biogenic raw materials to power the bioindustry can endanger biodiversity losses and increase deforestation or environmental degradation since the pressure on land and farming to produce enough biomass is high. The German strategy combats these risks by exploring options to restore degraded and marginal land unused, to relieve the pressure on agriculture. It states that:

> *"It is of central importance in this context that biodiversity conservation and the preservation of soil and water quality be recognised as prerequisites for the maintenance of ecosystem services"* (BMBF & BMEL, 2020, p.29).

This underlines that target 2.5 of the goals are protected and realized under the German strategy. To increase the income of small-scale food producers (Target 2.4) and strengthen the development of rural infrastructure and agriculture in rural areas (Target 2.6), the German strategy promotes the processing and production of biomass locally and in rural areas, which can help increase local farmers' employment and income and support the development of "structurally weak regions" (BMBF & BMEL, 2020, p.19). This evidence underpins the assessment that the German strategy has the potential to enhance food security and help to achieve the targets of SDG 2.

Assessing Queensland's potential to achieve food security and the SDG targets shows that it is less promising and does not focus on changing agricultural processes or providing more secure food supply chains in its strategy. The only target that might be supported is the priority to enhance regional employment in the agriculture sector through a higher production of biomass used for the bioeconomy. Queensland has the vision to "[...] create thousands of jobs and a new high-value, knowledge-intensive industry in Queensland, particularly in rural areas and regional centers" (DSDILGP, 2016, p.2). This could imply that investment is directed to support local agriculture and extract biomass from those regions, which in turn could at least support target 2.3. Yet, this vision lacks specialization, and one can not assess that Queenlsnad's biofuture roadmap has the potential to help achieve food security.

Analysis of SDG 7

Opposed to that, Queensland's document shows much dedication to increasing the availability of modern energy and providing more sustainable alternatives to fossil-based sources. Queensland emphasizes its potential to produce a significant amount of biofuels, a low-carbon alternative that can be used in the transport sector or as feedstock for heat and electricity. Besides the three existing biorefineries, Queensland attracted another biorefinery project, the *Oceania Biofuels'*. The construction of the new biorefinery in Gladstone started in 2023 and should produce sustainable aviation fuels and biodiesels to base Australia's transport sector on green alternatives. Additionally, as indicated in the updated strategy, the company Mercurius started a project on a pilot biorefinery that uses a new process and innovative technologies to convert biomass into bioethanol. The research project is now "ready for take-off" (DSDILGP, 2022, p.6). Furthermore, in cooperation with the Mackay Transit Coaches, Queensland's government started a 12-month trial to fuel all buses with bioethanol, under the biofuture strategy. Projects like these "demonstrate Queensland is a leading destination for clean energy investment" (DSDILGP, 2016, p.6). These programs presented by Queensland's biofuture strategy show that the strategy and its concrete measures have much potential to increase the access and overall availability of modern energy, which helps to achieve SDG targets 7.1 and 7.2. Besides that, the strategy strongly emphasizes investment in research to improve the efficiency of their biorefineries. Therefore, James Cook University and the Queensland University of Technology develop biotechnologies

to guarantee the applicability of bioenergy sources. Additionally, the updated document states that:

> *"[T]hrough the Queensland Hydrogen Industry Strategy, Australians will benefit from increasing supplies of reliable, affordable and renewable energy" (DSDILGP, 2022, p. 4).*

The promotion of research and the support of regional programs enable higher production of bioenergy, which makes it more affordable and increases the supply of modern energy for the public and transport sectors. These efforts, underlined by the strategy, support the achievement of target 7.4 and enable effective transformation to a more sustainable and modern future for energy. Additionally, the document emphasizes its advantageous position as a "gateway to the Asia-Pacific," which allows for close collaboration and significant export opportunities for bioenergy to neighboring countries (DSDILGP, 2022, p. 8). This is very promising in upgrading the energy supply to developing countries, which supports target 7.5 because it aims to expand energy services to those nations.

Based on analysis of the document, one can conclude that the strategy considers many measures and actively promotes the production of modern energy with their biofuture strategy and therefore has much potential to achieve the targets of SDG 7.

Germany's policy document indicates the aim to promote the achievement of SDG 7 as one of its objectives. However, the strategy is less explicit on how to achieve this goal. It is underlined that research should be conducted for "[...] conceiving new ways to produce biogenic raw materials for material and energy purposes" (BMBF & BMEL, 2020, p.29). The funding programs indicated by the strategy should support the development of technologies that support this process which would promote the target 7.4. Still, promoting the transition to modern energy is less of a priority within the strategy than other objectives. This is emphasized by how the strategy reacts to the trade-off between SDG 2 and 7 to solve the "food vs. fuel debate". It states to prioritize the food supply, which means that crops that can also be used as feedstock for energy should be dedicated to the food industry (BMBF & BMEL, 2020, p. 15). This impedes increasing access to modern energy to achieve targets 7.1 and 7.2. Even though the strategy does not indicate any concrete measures that would imply the achievement of SDG 7, the document emphasizes:

"renewable raw materials can be used to underpin the energy supply in some regions, for example, in remote rural areas" (BMBF & BMEL, 2020, p.19).

This shows that Germany generally acknowledges the ability of the bioeconomy to increase access to renewable energy. Yet, this potential is not exhausted because it lacks concrete measures that enable this vision. The analysis showed that Germany's bioeconomy strategy does not sufficiently facilitate the availability and access to modern energy within its strategy, and only SDG target 7.4 has the potential to be sufficiently achieved.

Analysis of SDG 12

Under the right circumstances, the bioeconomy can be an approach to achieve SDG 12 because less unsustainable resources are exploited, and the valorization of waste and residues can generally reduce resource exploitation.

Analysing Germany's document to this end shows that the strategy emphasizes the implementation of a biobased economy that should "[r]ecognise and harness the potential of the bioeconomy within ecological boundaries" (BMBF & BMEL, 2020, p.16). To comply with this objective, one of the guidelines for implementation is that waste, residues, and by-products are used to promote a circular economy because these materials are suitable for recycling and cascading utilization. The valorization of biomass is mandatory within Germany's bioeconomy, which makes the strategy capable of 12.2. The following statement provides evidence for this assumption:

"The principles of the German Circular Economy Act (Kreislaufwirtschaftsgesetz) governing the conservation of natural resources and the environmentally compatible management of waste must also be adhered to" (BMBF & BMEL, 2020, p.42).

The circular use of resources not only reduces the production of waste but also decreases the need for raw materials supporting the sustainable management of natural resources and promoting targets 12.2 and 12.5 (BMBF & BMEL, 2020, p. 15). To further ensure more sustainable management resources existing supply chains should be optimized and new ones established that are more efficient, which decreases the loss of valuable materials and fosters targets 12.2 and 12.5 (BMBF & BMEL, 2020, p.42). As indicated in the analysis of SDG 2, the strategy emphasizes optimizing agriculture processes to adapt plantations to the changing climate conditions. This would substantially reduce harvest spoiling, which promotes target 12.3 (BMBF

& BMEL, 2020, p. 17). Additionally, the government wants to establish platforms for exchanging knowledge and discussing the bioeconomy. The strategy implies measures to raise awareness of the advantages of bioproducts. The following measure should realize this aim:

> *"Product labels and, where applicable, certification labels create transparency and strengthen trust in bio-based products"* (BMBF & BMEL, 2020, p.44).

Besides that, it indicates investing at least 300 billion € a year into public procurement projects that develop bio-based and sustainable products, which would encourage companies and private actors to engage in the bioeconomy sector (BMBF & BMEL, 2020, p.44). These measures make the strategy suitable to help achieve targets 12.6, 12.7, and 12.8.

Examining Queensland's roadmap, one can assess that their strategy approaches to reduce the dependency on fossil fuels and promote responsible consumption of resources. The strategy identifies that many by-products from their local industries can be used as feedstock to produce biofuels, bioproducts, and chemicals for the bioeconomy. Biorefineries and the development of new technologies that convert these resources into bioproducts "[...] will allow for greater resource efficiency by creating more value from given feedstock with less environmental impact" (DSDILGP, 2016, p.7). Additionally, the action plan initiated a *Waste to Biofuture* program that promotes the conversion of waste into valuable materials. Supported by this program, Kilcoy Global Foods, one of the biggest beef producers in the country, turned to using waste as feedstock to generate renewable energy for all its facilities. Furthermore, Queensland supports initiatives similar to this to foster its transition to a low-carbon, resource-efficient, and sustainable economy (DSDILGP, 2022, p.7). These measures promoted under their action plan reduce the overall consumption of natural resources (Target 12.2) and promote the valorization and reduction of waste (Target 12.4 and 12.5). Even though the circularity for economic practices is not explicitly addressed, the strategy makes efforts to promote the reuse and recycling of materials as shown by the intent to "[u]ndertake a review of wastes in Queensland that may be suitable for diversion from disposal to higher-order and more sustainable uses" (DSDILGP, 2016, p.13). Besides that, reducing food waste can be promoted as the strategy wants to take action to improve agricultural supply chains and identify gaps in their supply systems (DSDILGP, 2016, p.15). This is particularly effective in reducing waste because less agricultural yields are dissipated due to inefficient distribution of crops. This proves that the strategy can

achieve targets 12.3 and 12.5 of the Agenda 2030. The strategy proposes to "[d]evelop a marketing and communication campaign to raise awareness and promote opportunities for the sector" (DSDILGP, 2016, p.12), which would help to promote an understanding of sustainable lifestyle and the advantages of a bio-based economy. Additionally, the strategy states to:

> "Investigate a Queensland Government bioproduct procurement policy to increase local consumption and improve the market for new investors (DSDILGP, 2016, p.13).

If these measures are implemented as the strategy indicates, they can support realizing the SDG targets 12.6, 12.7, and 12.8.

Table 2. Analysis Results

Assessment Category	Code	Germany	Queensland
Strategy Objective	Objective to Promote SDG 2,7 and 12	✓	✗
Infrastructural and Natural Conditions	Availability of Biorefineries	(✗)	✓
	Availability and Sources for Biomass Availability	✓	✓
Regulatory Governance	Governance Mechanisms	(✓)	(✓)
	Monitoring and Evaluation	✓	(✗)
SDG 2-related Features	Promotion of Food Security (Target 2.1; 2.2; 2.4)	✓	✗
	Employment and Support of Local Farmers (Target 2.3)	✓	(✗)
	Protection of Biodiversity (Target 2.5)	✓	✗
	Research and Technology for Food Security (Target 2.6)	✓	✗
SDG 7-related Features	Transition to Bioenergy (Target 7.1; 7.2; 7.3)	(✗)	✓
	Research and Technology for Bioenergy (Target 7.3 & 7.4)	(✓)	✓
SDG 12-related Features	Sustainable Resource Management (Target 12.2 & 12.4)	✓	✓
	Circular Economy (Target 12.3; 12.4; 12.5)	✓	✓
	Awareness Spreading (Target 12.6;12.7;12.8)	✓	✓

Explanation: ✓- fully satisfied; (✓) - satisfied with minor limitations; (✗) - not completely satisfied; ✗ - not satisfied

5.3 Analysis Results and Concluding Remarks

To conclude this chapter, the key insights from the analysis and evaluation of the strategy documents will be summarized. The assessment revealed that strategies have the potential to achieve SDGs 2,7 and 12 to some point. While both strategies met the requirements for achieving SDG 12 because they incorporate extensive measures to promote sustainable consumption and more resource-efficient production chains, the strategies differ significantly in their capability to promote food security or the supply of clean energy. This can be explained by their differences in infrastructural conditions and intentions behind their strategy. Germany places achieving food security as one of the main priorities of their strategy and therefore aligns their actions to this goal. Research, investment, and governance mechanisms are mainly directed toward increasing the opportunities for improved agriculture, which results in the strategy's ability to promote SDG 2. These efforts are missing in Queensland's strategy, making its approach unsuitable to combat hunger. However, the analysis showed that Queensland is dedicated to increasing access to renewable energy, and the mechanisms incorporated in its biofuture strategy facilitate the realization of this intention and makes the roadmap suitable to achieve SDG 7. Germany's document does not expose sufficient evidence it can promote achieving SDG 7; this can be repatriated to the fact that it fails to address the need for adequate infrastructure that allows renewable energy production under their bioeconomy. What is noticeable is that even though Germany has an intense background in bioeconomy research and development, its strategy is not significantly more capable of achieving all three goals and still lacks some clarification on how to promote access to affordable and reliable clean energy. Although Queensland's action plan misses the intention to contribute to the Agenda 2030, it has much potential to promote at least SDG 12 and 7 through its strategy.

6. Conclusion

This last chapter concludes the paper by answering the research question and providing an outlook on how the findings give practical implications for other scholars and policymakers.

It has been underlined that in crises like the global pandemic, the Ukraine war, and global warming, achieving long-term goals like ending hunger or guaranteeing reliable access to clean energy becomes more challenging. However, it proves that solutions must be resilient to those external shocks to be effective and stable. The bioeconomy can be a first step towards

guaranteeing responsible management of resources to provide greater food supplies and reliable modern energy for a growing world population. To assess which strategies and what features make a bioeconomy affective in this regards, this study explored the question: To what extent can the bioeconomy strategies of Germany and Queensland promote the achievement of the SDGs, particularly considering SDGs 2,7 and 12? The analysis examined which features in those strategies determine their success. Germany's strategy has great potential to achieve SDG 12 and 2. This is guaranteed by its extensive governance mechanisms that regulate the use of resources within planetary boundaries and its mandates that adapt the bioeconomy to circular resource use. Besides that, promoting more efficient agricultural practices with the help of research and technological innovations assures the achievement of SDG 2. An essential feature in the strategy that influences its success is the establishment of extensive monitoring and evaluation processes, which helps to tailor the strategy to achieve the SDGs. However, due to the lacking focus on biorefineries and infrastructure to generate clean energy, it can not be stated that Germany's bioeconomy can promote SDG 7.

Queensland's biofuture action plan is also capable of achieving the targets of SDG 12. The strategy's success is determined by its focus on providing adequate infrastructure to convert waste and industrial by-products into valuable materials. Their biorefineries and numerous state programs, like the *Waste to Biofuture* project, guarantee waste recycling and reduce natural resource consumption. Besides that, the analysis showed that the roadmap could help achieve greater availability of modern energy and realize SDG 7. This is affected by the feature in the strategy that supports research and investment into technologies to help diffuse and produce biofuels that can be used as energy in the transport sector. Although Queensland's strategy can promote greater access to modern energy and improved resource consumption, the action plan can not achieve enhanced food security. This is due to the missing features that enhance agriculture productivity.

It can be said that bioeconomy strategies need to consider holistic measures to guarantee their effectiveness in promoting the Agenda 2030. It was found that the availability of adequate infrastructure and natural conditions significantly impact the strategies' success. Besides that, governance mechanisms that regulate the implementation are a necessity. An independent body must monitor and assess policies and regulations to advise on improvements and effective implementation. To achieve SDG 2, more productive agriculture must be guaranteed, and

trade-offs between energy and food supply must be managed. To increase the generation of renewable energy, access to a sufficient amount of renewable biomass must be guaranteed, and suitable facilities that can convert those resources into energy and fuel must be available. To achieve SDG 12, bioeconomy strategies must consider recycling industrial by-products and waste to reduce the dependency on natural resources in their bioeconomy. Additionally, society and industry must become aware of the need for sustainable lifestyles by encouraging more responsible consumption of materials. If these features are incorporated and effectively implemented in bioeconomy strategies, they can promote food security, renewable energy production, and sustainable consumption of resources more effectively.

6.1 Limitations and Practical Implications

Since more governments develop bioeconomy strategies to contribute to sustainable development, more research is needed on what determines the effectiveness of those strategies to achieve the SDGs. This study provided the first steps in this research direction and found some valuable insights that can be used for future studies. Nevertheless, the study faces some limitations due to the applied research design and the scope of the research question. Since the study's findings are based on the evaluation and interpretation of text data, the conclusions can be influenced by researcher biases and subjectivity. This has consequences for the reliability of the results as other scholars might interpret findings differently. However, this risk is significantly mitigated using the assessment framework to guide the text analysis. The operationalization of critical aspects to evaluate bioeconomy strategies into measurable criteria ensures enhanced objectivity and validity of the data analysis. In addition, the generalizability of the findings is limited since only a selected number of cases and SDGs were analyzed. However, this provides opportunities for other scholars to add to this investigation by analyzing different strategies or other goals and analyzing what influences their success more comprehensively. The assessment framework developed in this study can be used for that purpose and might be supplemented by additional criteria or tailored to the analysis of other SDGs. The insights from this paper can have practical implications for policymakers developing bioeconomy strategies. Understanding what weaknesses and strengths other strategies have that affect the achievement of SDGs 2,7, and 12 might help develop more successful approaches because they can learn from examples and copy best practices. Policymakers that want to establish a bioeconomy

strategy that aims to promote sustainable development can use the assessment framework of this study as guidance for evaluating their approach. Besides, the FAO's guide with aspirational principles and criteria for a sustainable bioeconomy can instruct the development (FAO, 2021).

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Appendices

Appendix A: SDGs 2, 7 and 12 and their respective Targets

SDG	Target	Description of the Target
Goal 2	**Zero Hunger**	
	Target 2.1	UNIVERSAL ACCESS TO SAFE AND NUTRITIOUS FOOD
	Target 2.2	END ALL FORMS OF MALNUTRITION
	Target 2.3	DOUBLE THE PRODUCTIVITY AND INCOMES OF SMALL-SCALE FOOD PRODUCERS
	Target 2.4	SUSTAINABLE FOOD PRODUCTION AND RESILIENT AGRICULTURAL PRACTICES
	Target 2.5	MAINTAIN THE GENETIC DIVERSITY IN FOOD PRODUCTION
	Target 2.6	INVEST IN RURAL INFRASTRUCTURE, AGRICULTURAL RESEARCH, TECHNOLOGY AND GENE BANKS
	Target 2.7	PREVENT AGRICULTURAL TRADE RESTRICTIONS, MARKET DISTORTIONS, AND EXPORT SUBSIDIES
	Target 2.8	ENSURE STABLE FOOD COMMODITY MARKETS AND TIMELY ACCESS TO INFORMATION
Goals 7	**Affordable and Clean Energy**	
	Target 7.1	UNIVERSAL ACCESS TO MODERN ENERGY
	Target 7.2	INCREASE GLOBAL PERCENTAGE OF RENEWABLE ENERGY
	Target 7.3	DOUBLE THE IMPROVEMENT IN ENERGY EFFICIENCY
	Target 7.4	PROMOTE ACCESS TO RESEARCH, TECHNOLOGY AND INVESTMENTS IN CLEAN ENERGY
	Target 7.5	EXPAND AND UPGRADE ENERGY SERVICES FOR DEVELOPING COUNTRIES
Goal 12	**Responsible Consumption and Production**	
	Target 12.1	IMPLEMENT THE 10-YEAR SUSTAINABLE CONSUMPTION AND PRODUCTION FRAMEWORK
	Target 12.2	SUSTAINABLE MANAGEMENT AND USE OF NATURAL RESOURCES
	Target 12.3	HALVE GLOBAL PER CAPITA FOOD WASTE
	Target 12.4	RESPONSIBLE MANAGEMENT OF CHEMICALS AND WASTE
	Target 12.5	SUBSTANTIALLY REDUCE WASTE GENERATION
	Target 12.6	ENCOURAGE COMPANIES TO ADOPT SUSTAINABLE PRACTICES AND SUSTAINABILITY REPORTING

Target 12.7:	PROMOTE SUSTAINABLE PUBLIC PROCUREMENT PRACTICES
Target 12.8	PROMOTE UNIVERSAL UNDERSTANDING OF SUSTAINABLE LIFESTYLES
Target 12.9	SUPPORT DEVELOPING COUNTRIES' SCIENTIFIC AND TECHNOLOGICAL CAPACITY FOR SUSTAINABLE CONSUMPTION AND PRODUCTION
Target 12. A	DEVELOP AND IMPLEMENT TOOLS TO MONITOR SUSTAINABLE TOURISM
Target 12. B	REMOVE MARKET DISTORTIONS THAT ENCOURAGE WASTEFUL CONSUMPTION

Source: Globalgoals.org. (2023)

Appendix B: Data Collection

BMBF. (2011). *National Research Strategy BioEconomy 2030 : Our Route towards a biobased economy*. Federal Ministry of Education and Research. Retrieved July 12, 2023, from https://www.pflanzenforschung.de/application/files/4415/7355/9025/German_bioeconomy_Strategy_2030.pdf

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and-action-plan-june-2022.pdf

Appendix C: Assessment Framework with the Coding Scheme

Assessment Category	Code	Description	Examples
Strategy Objectives	Objective to Promote SDG 2,7 and 12	The strategy mentions the SDGs or the objective to promote food security, promote clean energy and responsible consumption and production	"[...] secure the supply of food, manage natural resources sustainably, reduce dependence on unsustainable raw materials, combat and adapt to climate change, increase competitiveness, and secure and create jobs." (BMBF & BMEL, 2020, p. 17)
Infrastructural and Natural Conditions	Biorefineries	The availability of biorefineries is evaluated and their construction is considered	"Queensland has an emerging industrial biotechnology and bioproducts sector, largely characterized by three biorefinery plants located in the state" (DSDILGP, 2016, p. 5).
	Availability and Sources of Biomass	Sources for biomass are evaluated and sufficient supply is guaranteed	"The ability to competitively produce some of the world's most energy-dense and productive feedstock such as sugarcane, eucalypts and algae. Additional feedstock includes red and sweet sorghum, native grasses, crop stubble, cassava, agave, and pongamia" (DSDILGP, 2016, p.8).
Regulatory Governance	Governance Mechanisms	Governance mechanisms are exhausted to promote the efficient implementation of the objectives	"Policy makers shape the implementation of the bioeconomy by means of regulatory and support measures, and through communication and cooperation." (BMBF & BMEL, 2020, p.39)
	Monitoring and Evaluation	Monitoring and evaluation mechanism are implemented for improving and assessing the strategy	"To this end, the German Federal Government initiated a comprehensive monitoring programme for the bioeconomy in 2016" (BMBF & BMEL, 2020, p.54).
SDG 2-related Features	Promotion of Food Security (Target 2.1; 2.2; 2.4)	Improved agricultural practices are considered like using gene-edited plants, increasing land dedicated to crop plantation, or increasing reliance and nutritional value of crops	"This can pave the way for the maintenance of innovative and sustainable agricultural and forest systems that are re-source-efficient, competitive and resilient in the face of changing climate and environmental conditions, while continuing to provide the necessary supply of biogenic resources" (BMBF & BMEL, 2020, p.29)

	Employment and Support of Local Farmers (Target 2.3)	Biomass is produced and extracted from rural areas to support small-scale farmers and enhance local employment	"Supporting regional forms of product marketing adapted to local conditions can also generate regional added value "(BMBF & BMEL, 2020, p.44).
	Protection of biodiversity (Target 2.5)	The risk of biodiversity loss caused by biomass exploitation is regulated and recognized	Breeding can also contribute to a diversification in agricultural crop production by provid- ing a wide range of species and varieties, and fostering re-silient and ecological farming systems. This can in turn have a positive effect on agricultural biodiversity" (BMBF & BMEL, 2020, p.39)
	Research and Technology for Food Security (Target 2.6)	Innovative technologies are developed based on scientific knowledge which enhances food supply	"The Federal Government will support the technological development of existing production pro- cesses and the testing of innovative processes" (BMBF & BMEL, 2020, p.42)
SDG 7-related Features	Transition to Bioenergy (Target 7.1; 7.2; 7.3)	A supportive policy environment for renewable energy by promoting biomass use and reduction of fossil fuel-energy	"Transitioning our bus network to more sustainable, low and zero emission fuel sources will help us meet our emissions reduction targets and demonstrate Queensland is a leading destination for clean energy investment" (DSDILGP, 2016, p.6).
	Research and Technology for Bioenergy (Target 7.3 & 7.4)	Innovative technologies are developed to guarantee the diffusion of clean energy based on scientific insights	"Jointly fund a Research Chair for Advanced Biofuels with a Queensland university to enhance Queensland's research capacity and reputation as a developer of advanced biofuels and novel biorefining technologies" (DSDILGP, 2016, p.12).
SDG 12-related Features	Sustainable Resource Management (Target 12.2 & 12.4)	Exploitation of natural resources and waste is regulated by efficiently using those materials and guaranteeing effective supply chains	"Germany's Federal Government supports corresponding product and process developments through its funding programs as a means to contribute to a more sustainable, efficient and climate-neutral use of resources." (BMBF & BMEL, 2020, p.15)
	Circular Economy (Target 12.3; 12.4; 12.5)	Reusing, recycling, and composting of by-products and waste is considered	"Investigate policy and market development opportunities to encourage re-use of waste currently going to landfill"(DSDILGP, 2016, p.13)
	Awareness spreading (Target 12.6; 12.7; 12.8)	Mechanisms to raise awareness and nudge the employment of bioeconomy practices are considered	"Other important components that support the market establishment of bio-based products are information and the raising of consumer awareness of the specific advantages and disadvantages of these products" (BMBF & BMEL, 2020, p.44).

Appendix D: ATLAS.ti Coding Quantities

Codes	Number of Citations		
	Total	**Germany**	**Queensland**
Strategy Objective	**12**		
Strategy Objective to achieve SDGs 2,7 and 12		7	5
Infrastructural and Natural Conditions	**36**		
Biorefineries		2	11
Availability and Sources of Biomass		17	6
Regulatory Governance	**52**		
Governance Mechanisms		22	17
Monitoring and Evaluation		11	2
SDG 2 related Criteria	**53**		
Promotion of Food Security		15	2
Employment and Local Farming		7	4
Biodiversity Protection		12	0
Research and Technology for Food Security		17	2
SDG 7 related Criteria	**47**		
Transitioning to Bioenergy		9	16
Research and Technology for Bioenergy		11	13
SDG 12 related Criteria	**47**		
Sustainable Resource Management		14	9
Circular Economy		11	7
Awareness Spreading		9	6

Note: The number of codes can not be interpreted as meaningful insights for the analysis because the two documents differ in their length. Therefore, one document might indicate a higher number of codes but the citation might not be as complex or significant for the analysis.