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Bio-Inspired Innovation (MSc)

Bioeconomy in Austria, Germany, Italy and The Netherlands; Green growth or rotten tomatoes?



Literature review (7.5 ETCS)

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I. Executive summary

This literature review presents the development of Bioeconomy strategies with emphasis on bio-based materials in Austria, Germany, Italy and The Netherlands. It will give an overview of the general strategies, main biological resources, applied technologies, bio-based materials and incentives to support the transition for a Bioeconomy. All strategy documents were updated within the last five years and refer to the Bioeconomy strategy of the European Commission (European Commission, 2018).

The aim of the Bioeconomy is to move away from fossil fuels since industry is dependent on this limited, environmentally harming resource. The strategy for achieving this goal uses financial support of industry and research, and the education of the public about the importance of a transition to a bio-based economy. Austria and Germany are using a top-down approach, positioning their government as the director for the transition, whereas Italy and The Netherlands are governing more as a facilitator for the industry (bottom-up approach).

The comparative analysis revealed that the policies and development of the Bioeconomy in these countries are still in the early stages, which is reflected in the limited technologies and products. The strongest Bioeconomy sector, bio-energy, is already in the early market phase; the bio-based materials are limited to conventional products and show a lack of innovation. It is concluded that the Bioeconomy strategies have a strong interest in establishing their industry however, they are missing the goal for sustainable development regarding its social aspects. The sector of bio-based materials is in need of innovative ideas, which is suggested to be achieved by a more bottom-up approach.

II. Layman's summary

Our society has been marked with a picture of polluted landscapes, smoggy cities and changing climate conditions. Initiatives to change these conditions have arisen, and their concepts have gotten more and more attention by governments. One of the approaches is called the Bioeconomy concept. It mainly aims to use biological resources as their building blocks for any kind of products (energy, food, materials) and by this move away from fossil fuels. Several governments are trying to transition to a Bioeconomy by creating new policies and publishing their strategy documents.

The European Commission published their strategy for the Bioeconomy in 2012 and 2018, which covers the goal to establish a market for bio-based products and contribute to sustainable development. Austria, Germany, Italy and The Netherlands updated their Bioeconomy strategy within the last five years inline with the European Commission's strategy. Considering the urgency of the current conditions, it was of interest to get an overview of the current developments in the Bioeconomy in Europe. Therefore, this review looks at the development of the Austrian, German, Italian and Dutch Bioeconomy and its bio-based materials and aims to give insights for their future development.

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1. Introduction

Due to societal challenges such as climate change, scarcity of natural resource and environmental pollution, voices of scientists, policy makers and public rose with the demand for sustainable transformation of the fossil-based economy. The usage of biomass is seen as a potential alternative because of its high availability, renewability and minor environmental pollution (Costanza et al., 2017; Barbier et al., 2014) and is used as the main resource in the concept of Bioeconomy. Bioeconomy is mainly defined as an economy which derives its key components for materials, chemicals, and energy from renewable biological resources and thus move away from the fossil ones to create a sustainable economy (McCormick et al., 2013). It is intended to convert natural biomass into food, feed, energy, and bio-based materials and receives more and more attention in research (see Figure 1).

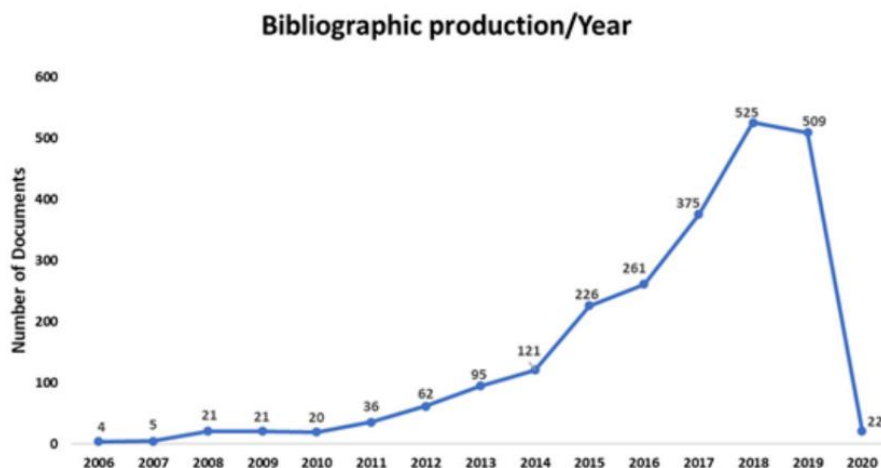


Figure 1: Annual Scientific Production of bioeconomy; state of analysis: spring 2020 (Perea et al. 2020)

For a transition to a Bioeconomy, several countries are developing or have already developed a strategy, which can be found in official governmental policy documents. The European Union launched their first Bioeconomy strategy in 2012 towards a transition to a low-fossil economy and urges its

members states to follow (European Commission, 2012). Until 2019, 50 countries have developed their Bioeconomy strategy, and its number is expected to rise (Sczas et al., 2019).

An overview of the current literature showed that the Bioeconomy focuses on the bio-energy sector (Scarlat et al., 2015). Different technologies and sources for energy conversion have been developed to move away from fossil fuels entirely. However, there has been little research into the implementation and action regarding bio-based materials within the Bioeconomy, which cover everything other than food and energy by biological sources.

Therefore, this report puts the attention on bio-based materials by looking at the resources, technologies and examples of bio-based products. Additionally, it will give an overview of the incentives by the governments to support the industry for the development of bio-based materials and to channel the publics consumption of bio-based materials. The scope of this writing assignment covers a comparative analysis of the most recent Bioeconomy policy documents of Austria, Italy, Germany, and The Netherlands regarding the mentioned topics and will give an overview of the current Bioeconomy developments in Europe.

2. Methodology

This review is an analysis of the Bioeconomy strategies of different EU countries by comparing the strategies on the following topics:

- ❖ overview of the general Bioeconomy strategy
- ❖ overview of the inputs and outputs of the Bioeconomy
- ❖ overview of the incentives regarding the bio-based materials

The underlying questions around each topic are depicted in the Figure 2. Therefore, it was important to take the official governmental policy documents as the source of comparative analysis. Additionally, scientific papers and reviews or summaries of different ministries were also consulted. In order to determine the countries with comparable bioeconomy policies, a set of criteria was set:

- I. Country is a member states of the European Union
- II. The Bioeconomy strategy of the country refer to the European strategy from 2012 and 2018 (European Commission 2012, 2018)
- III. Bioeconomy policy document of the country is updated within the last five years
- IV. Bioeconomy progress of the country is discussed in scientific literature

The application of the criteria leads to the selection of the following countries for the analysis: Austria, Germany, Italy, and The Netherlands.

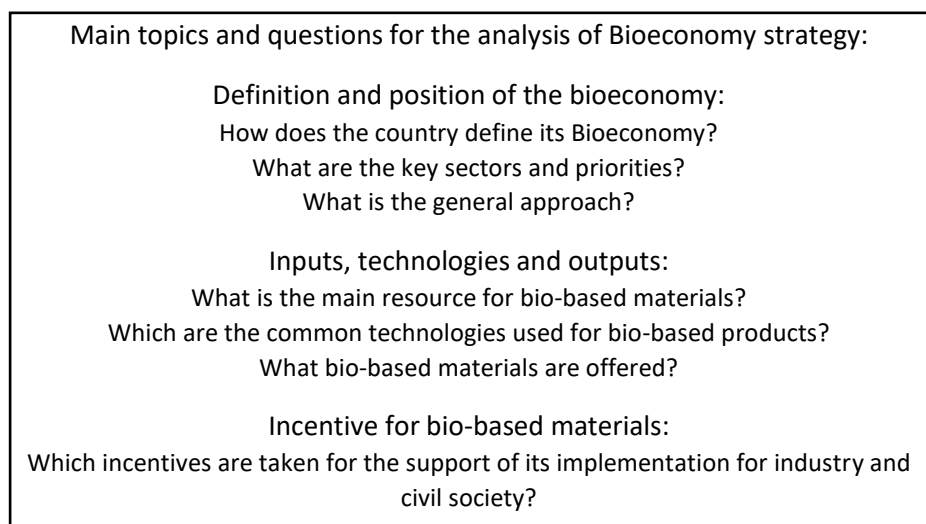


Figure 2: Overview of the analysis questions for the comparison

3. Results

3.1 Overview of Bioeconomy strategies

All four countries refer to the aim and definition of the 2018 Bioeconomy strategy of the European Commission (EC) in their strategy documents. It states to “us[e] renewable biological resources from the land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy” (European Commission, 2018). The EC Bioeconomy strategy mainly aims to increase sustainable deployment and contribute to the 2030 Agenda for Sustainable Development and Paris agreement. Additionally, it sets the target to at least 32% renewables for 2030; however, it is not defined what kind of renewable bioproducts and leaves it open to the industry. The following three key points are set out in the agenda:

1. Strengthen and scale-up bio-based sectors
2. Rapidly deploy local Bioeconomies across the whole of Europe
3. Understand the ecological boundaries of the Bioeconomy

Building upon the EC strategy, the countries formulated their specific policies, whose key points are presented in table 1. It covers the name of the *main policy document* and the additional references needed to analyse the country's Bioeconomy. Next to this is also the *official actor*, which is acting and presenting the strategy and the general *approach* of the strategy. The approaches are defined by either being top-down or bottom-up. With a top-down approach takes the government director position with a clear focus. In contrast, with the bottom-up approach takes the government as a facilitator to achieve the desired success. Lastly, the *key policy objectives* and *carbon targets* are shown, covering the main ambitions and targeted reduction of carbon emissions, respectively.

The main pillars of each Bioeconomy strategy are to decarbonise their economy as far as possible and develop technologies and innovation with the prospect of job creation, which aligns with the ambitions of the European Commission. In order to achieve these goals, Austria and Germany take the top-down approach, and Italy and The Netherlands the bottom-up approach. The Italian and Dutch governments take a stakeholder-driven approach, open for radical innovations. Germany and Austria, however, are focusing on job creation and improving innovation and research to become technological leaders. By following this approach, they keep the already existing industries intact and enforce laws and legislations to follow their goal (more in section 3.3). The main objective for Germany and Austria is similar since both are invested in research and innovation to enhance their Bioeconomy. The Netherlands is aiming to enact a climate policy and energy agreement whilst using as little biomass as possible. Italy is the only country setting a specific goal in the form of income increase by 15%; however, it does not define how much each bioeconomic sector shall contribute to that goal.

Table 1: Overview of the Bioeconomy strategies

Country	Main strategy document	Central actor	Approach	Policy objective	Carbon targets	Additional references
Austria	Austria's bioeconomy strategy (2019)	Ministry for tourism and sustainability, ministry for innovation and Technology, ministry for education and science	Top-down	Becoming European technology leader	carbon-neutral by 2040	Flagship projects of the Bioeconomy in Austria (2021) Stern et al., 2018
Germany	National Bioeconomy Strategy (2020)	The Federal Government (BMEL - food and agriculture) and BMBF (education and research)	Top-down	Job creation by funding in research and innovation	Carbon-neutral by 2045	National policy strategy on Bioeconomy (2014) Bioeconomy2030 (2011) Imbert et al., 2021
Italy	Bioeconomy in Italy (II) (2019)	Ministry for economy, education, agriculture, tourism, environment, Italian regions committee, Technology clusters for green energy	Bottom-up	Increase Bioeconomy turnover by 15% from 2017 to 2030	64% reduction by 2050*	Implementation action plan (2020-2025) for the Italian Bioeconomy strategy BIT II (2021) Fava et al., 2021 Imbert et al., 2018
The Netherlands	The position of the bioeconomy in the Netherlands (2018)	Ministry of economic affairs and climate policy	Bottom-up	Meeting energy and climate agreement	Carbon-neutral by 2050	Biomass in the balance A sustainability framework for high-value use of bio-based (2020) Bosman et al. 2016)

* No reference to the Bioeconomy Strategy

Regarding the goal of carbon reduction, three out of four countries connected their Bioeconomy plan with carbon neutrality within the next three decades. It is hoped to achieve this through investments and bio-energy improvements. However, Italy is the only country not mentioning any carbon neutrality plans in their Bioeconomy strategy. This is despite an updated post-covid energy and climate policy document showing that Italy aims to reduce carbon emissions by 64% by 2050 (Lombardini, 2021). Overall, Italy focuses less on the energy sector than the other three countries. This is also reflected in the Italian energy sector's low income and employment rate compared to their other Bioeconomy sectors.

3.2 Inputs, technologies, and output in the Bioeconomy

The Bioeconomy is based on biomass conversion to bio-based products. The European Commission defined bio-based products as “wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised”, which are mostly industrially processed, for example, with the help of enzymes (European Commission 2018). Most countries distinguish in their bio-based products between bio-based nutrition, energy and materials.

This section describes the input, applied technologies and bio-based materials output of each Bioeconomy, which is presented in table 2. The overview of the *main input* indicates the biological resource which contributes to the highest turnover for the Bioeconomy. Next to this are the leading *biomass processing technologies* listed, which are used to convert biomass for any bio-based products but food. These technologies are distinguished between biological and thermo-chemical conversion. Biological conversion refers to processes that make use of enzymes or bacteria to support a reaction. Thermo-chemical conversion is the exposure to temperatures and/or oxidation of biomass. Lastly, *bio-based materials* of each country are given.

Table 2: Main input, technologies and bio-based materials of the Bioeconomies

<i>Country</i>	<i>Main input</i>	<i>Biomass processing technologies</i>	<i>Bio-based materials</i>
<i>Austria</i>	Agriculture	<ul style="list-style-type: none"> • Biological conversion: composting and fermentation with help of bacteria and enzymes • Thermochemical conversion: pyrolysis, combustion 	<ul style="list-style-type: none"> • Paper and pulp • Fibres Chemicals Wood Biopolymers
<i>Germany</i>	Agriculture	<ul style="list-style-type: none"> • Biological: aerobic and anaerobic digestion Thermochemical: - 	<ul style="list-style-type: none"> • Biopolymers
<i>Italy</i>	Agriculture	<ul style="list-style-type: none"> • Biological: - • Thermochemical: - 	<ul style="list-style-type: none"> • Paper • Textiles and wearing apparel • Wood products • Pharmaceutic • Chemicals

<i>The Netherlands</i>	-	<ul style="list-style-type: none"> • Biological: anaerobic/ aerobic fermentation and composting with help of bacteria and enzymes • Thermochemical: combustion, gasification, pyrolysis, torrefaction 	<ul style="list-style-type: none"> • Biopolymers • Chemicals • Paper • Wood • Textiles • Minerals
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Since the Bioeconomy is based on the usage of biological resources, it is presumed to make use of natural land, which is done by all countries in the form of agriculture. Agriculture is one of the biggest Bioeconomy drivers in Austria, Germany and Italy but, there was no clear indication by The Netherlands. Since the Netherlands is the fifth most densely populated country in Europe (worldatlas.com, 2020), it can be presumed that there is proportionally not as much area for agriculture as in the other countries. In contrast, Italy gets by far its primary income for their Bioeconomy by agri-food.

Next to the agriculture are two other Bioeconomy sources to mention, which occur in all policy documents: microalgae and waste streams. All four countries mention microalgae as a promising resource and trying to improve technology around it since it can be used for nutrition and energy purposes (Rösch et al., 2019). Germany and Italy are already showing some success by being one of the frontrunners in algae production in Europe besides Spain (Araujo et al., 2021). This new biological resource is a global trend and is generating international competition (Veira de Mendonca et al., 2021). Next to this are waste streams which are a reliable resource. However, the overview of all countries shows that waste streams are still an underdeveloped resource. In most cases, it will be used for energy purposes, which uses a significant amount of energy and creates emissions of greenhouses gases (GHG). The management of waste streams could also be tackled from a different perspective by setting the goal to reduce the waste stream in general. This point was already taken by several researchers in 2019, explaining that reducing food waste could eradicate the world hunger problem (Hamm et al., 2019).

The Netherlands and Austria made their technology public, presenting a similar range of technologies in the thermochemical sphere. Thermochemical technologies are mainly used for energy purposes creating a 'green energy alternative'. However, the conversion of biomass to biofuels also leads to GHG emissions depending on feedstock and the production process. Researchers discuss the effectiveness compared to fossil fuels since these technologies shift the problem of earth pollution but do not solve it (www.epa.gov.com, 2017). There is a distinct lack of technological development in the biobased materials sector compared to the energy sector. It can be questioned how the countries want to achieve a carbon neutrality within the next 2-3 decades with this pace of development given the level of system change required. In general, it can be concluded that current technologies need to develop further to more significantly reduce earth pollution and a greater emphasis needs to be put on developing non-energy based innovations.

The range of bio-based materials is similar between Austria, Italy and the Netherlands. Germany did not provide information about their bio-based materials. A comparison between the bioplastic progress between Italy and Germany revealed clear evidence for the production of biopolymer (Imbert et al., 2017). With this example, it can be assumed that Germany offers other bio-based materials, most probably similar to the other countries as well. Examining the range of bio-based materials being developed, it is noticeable that these products are mostly ‘traditional’ materials such as paper wood or textiles, which are already in production in the last century, showing a lack of radical innovation. There is also innovation for biochemicals and bioplastics but this also represents a desire to ‘green’ pre-existing materials rather than generate new materials.

3.3 Incentives to support bio-based materials

Each government formulated incentives in their strategy program to enhance the Bioeconomy development. These incentives are distinguished here by addressing the industry and others that address the public behaviour, which is depicted in the table 3. The *industry* is seen as an essential lever to change the economic system and thus needs support. The incentives addressing the *public* are needed to systematically change consumerism and support the economic transition. Table 3 presents both types of incentives, which are used in all four countries.

Table 3: Industrial and public aimed incentives by all four countries.

Incentives for the industry	Incentives for the public
<ul style="list-style-type: none"> • Fundings for innovation • Fundings for research and development • Investment in artificial intelligence to optimize material application and minimize accumulation of residue during product development 	<ul style="list-style-type: none"> • Ecolabels to inform the customer about the products safety • Funding of public sector to be a positive example • Education and consulting programs about the opportunities of bioeconomy

As shown in the previous section, the technologies do not differ that much between the countries and, as a result, limit the way of biomass conversion into biobased materials. However for biobased materials to significantly impact the markets of these countries, a greater variety of products is needed. As the biobased industry is mainly supported by funding into innovation, research and development from the government they are heavily reliant on meeting specific government criteria for funding packages. Fundings in biorefineries development receive most of the Bioeconomy funding, as in the case of Italy, which offers up to 10-times more funding for biorefinery development than all other projects. As most biorefinery products enter the bioenergy industry, government funding packages incentives more innovation in the energy sector than the materials sector.

One of the alternative policies to enhance bio-based materials is AI and digitalisations which is

mentioned as one of the pillars in their strategy. It is expected to be used as a tool for efficient modelling of products and data processing. The modelling is aimed to minimise material waste and increase product stability for a more sustainable product. The AI can be seen as a facilitating tool to achieve bio-based products' criteria. In conclusion, these incentives show that the industry is still at the beginning of a transformative change by preparing their technologies and developing tools to follow their criteria for future products.

Next to the industrial incentives are the societal ones, which try to change the citizens' habits. In order to trigger a change, each government is offering educational and consulting programs. Bioeconomy master programs as such have been offered in Italy since 2018 (www.masterbiocirce.com, 2018), and training for professionals are designed to inform participants about the Bioeconomy. A study in 2018 showed, however, that most of the public is still in need of more clarification regarding the job opportunities in the Bioeconomy (Stern et al., 2018). Most citizens feared job loss in regard to the bioeconomy, which shows that the educational programs have not reached society yet. Several researchers have claimed the policy document require more citizen inclusion to make their strategy more approachable for the citizens and their needs and fears (Mustalahti et al., 2018). Italy is the only country that left its policy draft for open consultation for a month before releasing it. It is unclear how much input the government received and put into action in that short time frame, however it is the first step in more citizens included in policymaking.

Lastly, Austria's strategy shows a noticeable incentive towards its society by adopting its legalisation to support its Bioeconomy. With their top-down approach, they used their government as a director and released in 2020 a ban for plastic bags in Austria (www.bmk.gv.at, 2020). This active intervention for the Bioeconomy is also reflected in the greater goal of reforming the European Guidelines on State Aid for Environmental Protection and Energy to put more attention for the other sectors. The Austrian government recognises the minor focus on bio-based products compared to the bio-energy sectors and therefore aims to change this imbalance by changing the European framework.

4. Discussion

This literature review aims to provide an overview of the most recent Bioeconomy developments in European countries and investigate their handling of the bio-based material sector. The choice of the European countries was limited to Austria, Germany, Italy and The Netherlands since only these countries showed policy documents published within the last five years. This criterion was set to have an overview of the most recent developments EU-wide. However, it is not representative of the European developments since it only represents 4 out of 27 countries. Additionally, it can be suggested that the selected countries are also more climate-aware than the other European member states since they keep their strategy up-to-date suggesting it may be even less representative.

Furthermore, this overview mainly investigated official governmental policy documents, of which some were only in their native language. This brought two implications, firstly, it can be assumed that some resources were not found due to boolean searches being performed in English and German. As a result, there may be other, undiscovered documents pertaining to the European bioeconomy. Secondly, Translations of official documents into English were done via online translator, which can be inaccurate. As a result some countries policies may be misquoted.

Lastly, the time frame of this work is limited the outreach to governments as well as to professionals or advisors of the governments reducing access to more official data.

The analysis in sections 3.2 and 3.3 shows that the development stage of the Bioeconomy in Austria, Germany, Italy and The Netherlands is still in the beginning phase. Most of the investments are still used for research, innovation, or technology improvements. Also, society still needs to be educated about the coming transition. This assertion is supported by Londo 2021 in "the innovation curve and policymaking", which suggested the current state of the Bioeconomy is still in the research and development phase and starting to enter the market (Londo, 2021). The earlier mentioned investments in research and innovation are expected for the first two phases, invention and innovation. However, the development and usage of eco-labels and biorefineries standards show that some criteria of bio-based products are getting protected with which the Bioeconomy enters the niche and early market phase of innovation.

The most developed bio-based sector, which entered the market within the last decade, is the bio-energy sector. The bio-based sector, however, is at a different level of development. As mentioned in results 3.2, the bio-based products offered by the countries are still conventional, which are already established in the market. However, these show very little variety and a lack of radical, innovative materials. It can be assumed that the industry and stakeholders already existing structure need an impulse, facilities and freedom. These conditions are usually given by a bottom-up approach, which could be applied to this specific sector to enhance its change in the market. Since the bio-based materials are closer to the public's eye, innovative products could

eventually shape their experience and consumerism to benefit the Bioeconomy; therefore, a change in the conventional materials is needed.

Lastly, it is to question how much the Bioeconomy strategies are trying to contribute to sustainable development. All four members refer to the European Bioeconomy Strategy, which takes a clear stand of contributing to the 2030 Agenda for sustainable development. The 2030 agenda covers environmental, economic and social aspects and a call for global collaboration. However, the analysis of the strategies here shows that the countries have the intention to establish their positions in a new market with the condition of low and eventually no carbon emissions; the approach does not cover a holistic approach to generate a global, socio-economic and environmentally sustainable market. Backhouse's research groups and European stakeholders have observed this gap as well and concluded that current Bioeconomy strategies focus mainly on the following SDGs 7,9, 11, 12 and 13 (affordable and clean energy, industry, innovation and infrastructure, sustainable cities and communities, responsible consumption and production, climate action, respectively) and leave the aspects of social inequality completely out (Backhouse et al., 2021; Zeug et al., 2021). Both parties complain about the business-as-usual approach in the Bioeconomy of European countries, referred as "Green capitalism", and call for an inclusion of socially sustainable actions to achieve a systematic transition.

In conclusion, the Bioeconomy in Austria, Germany, Italy and The Netherlands is in its early stages of development and policymaking. Especially, the bio-based sector needs more attention in order to rise and enter the market with convincing innovations.

Additionally, the Bioeconomy strategies are in need to be adjusted for holistic, sustainable development. The Bioeconomy started with the intention of moving away from fossil fuels but is getting more and more used in movements for sustainable development. By already observing the dynamic development of the Bioeconomy concept and its applied strategies, it will be interesting to observe where this approach will lead the twenty-first-century society and its planet eventually.

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