PERIPHERY REVOLUTION: THE ENGINE OF THE EU BIOECONOMY IN 2040

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Glossary

Bioeconomy: *"The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and microorganisms – to produce food, materials and energy.[1]"*

Biorefinery: *"is the sustainable processing of biomass into a spectrum of marketable products and energy.[2]"*

Cascading use of biomass: "*the efficient utilization of resources by using residues and recycled materials for material use to extend total biomass availability within a given system.[3]" "Resources should be re-used sequentially in the order of the specific resource quality at each stage.[4]"*

Circular bioeconomy *"is defined as the intersection of bioeconomy and circular economy. It includes the cascading use, recycle, share, reuse and remanufacture of organic waste and bio-based products, materials and resources.[5]"*

Circular economy: *"the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy.[6]"*

Growth pole: "*Growth poles are considered the most dynamic elements of economic growth, the real locomotive of integration on multiple levels: economic, technological, ideological, moral and spiritual development at regional, continental and global levels.[7]*" In our case, they consist of peripheral areas of concentration of biorefineries and related industries, as well as waste management facilities and power plants.

Pre-treatment: *"A stage which is applied to feedstocks in order to make the next stage more effective.[8]"* In our case, their use is seen to relate to "the reduction of water content in biomass, i.e. drying, [that] results in the simultaneous increase in thermal value, preservation potential, ease in storage and transportation, less negative impact on the environment and a more uniform combustion.[9]

[1] European Commission (2017)
[2] de Jong and Jungmeier (2015)
[3] Carus and Dammer (2018)
[4] Olsson et al. (April 2016)
[5] Carus and Dammer (2018)
[6] European Commission (2015)
[7] Dobrescu and Dobre (2014)
[8] Collins Dictionary (1998)
[9] Rupar-Gadd (2006)

Sustainability: Following Khan[10] we distinguish economic, social and environmental sustainability. Economic sustainability pertains growth, profitability, productivity and development. Social sustainability encompasses culture, institutional stability, accessibility and participation, and empowerment. Environmental sustainability relates to ecosystems, biodiversity, pollution and climate change.

[10] Khan (1995)

Introduction

Today's economy is characterized by an inefficient use of both renewable and non-renewable resources. This has negative effects on the environment and human health. According to FAO[11], by 2050 the world's population will reach 9.1 billion, further increasing environmental pressure. Thus, significant changes are needed to achieve a sustainable development (i.e. "*economic growth subject to environmental and sociological constraints"*[12].)

Historically, the EU has contributed significantly to global warming. In fact, the EU-28 has the third highest CO_2 emissions from fossil fuel combustion[13]. Therefore, European Commission has set targets to reduce its greenhouse gas (GHG) emissions by 20% in 2020[14]. Continuing from this, the E.C. has set a framework for 2030, 2040 and 2050, aiming to cut GHG emission by 40%, 60% and 80%, respectively[15]. However, this transition is hampered by lack of a proactive and unitary perspective, which is hindering different social actors, governments and industry in cooperating effectively[16]. Furthermore, the lack of public understanding of the bioeconomy has been recognized as one of the major challenges to be overcome[17]. This requires clear communication between science and society[18].

Our project aims at contributing in this regard by the creation of a vision for the bioeconomy in 2040. We provide a vision that is youthful and innovative while also maintaining feasibility. We focus on sustainability of different kinds: environmental, social, and economic, as outlined in Khan[19]. Economic sustainability relates to growth and productivity. Social sustainability deals with issues like equity, public participation and culture. Environmental sustainability pertains to biodiversity, pollution and climate change. These different sustainability aspects are taken into consideration within the broader context of sustainable development as a concept, and as a goal for our transition.

We propose a comprehensive EU-wide regulatory framework, where the national and regional legislation is tailor-made depending on each country's environmental, economic and social possibilities. This will help overcome the current vagueness and unclarity of EU objectives in the Bioeconomy Strategy and its Action Plan[20]. In this way, we motivate the different actors involved to cooperate with each other in fostering the bioeconomy transition.

[11] FAO (2009)
[12] Zilberman et al. (2013)
[13] Boden et al. (2009)
[14] European Commission (2018)
[15] European Commission (2011a, 2013)
[16] McCormick and Kautto (2013); Twomey and Gaziulusoy (2014)
[17] McCormick and Kautto (2013)
[18] Scarlat et al. (2015)
[19] Khan (1995)
[20] European Commission (2017)

The group process

Three main activities were emphasized during the teamwork: literature reviews, brainstorming and experts interviews.

Throughout the first five weeks of this project, we collected detailed background information to create our vision. For this purpose, we identified four main areas of interest: biomass resources (e.g. agricultural and forestry residues, and dedicated crops such as miscanthus[21]), bioproducts and biomaterials (e.g. pharmaceuticals, plastic, supplements[22]), construction materials (e.g. concrete, cement[23]), and bioenergy & biofuels (e.g. methane, gas, diesel, ethanol[24]). This information was then used in a first brainstorming session, which led to (i) the investigation of the political framework 2040 (e.g. the actions of the government with regards to the bioeconomy[25]), (ii) the technology required for the vision to be implemented (e.g. algae biorefineries and bioreactors[26]), and (iii) the socio-economic and environmental consequences (e.g. rural development, economic prosperity, biodiversity conservation[27]). In this process we regularly shared our findings with each other, and highlighted areas of further interest for later research.

Based on the literature retrieved, one of the main goals of the brainstorming session was stimulating creativity on our own personal visions and allowing for a certain degree of flexibility. We began by highlighting the aforementioned areas of interest. After the first literature review we held another series of brainstorms and discussions to work out the general structure and overview of our vision. At this point, we identified several driving forces of the bioeconomy. After selecting two main driving forces (e.g. government and technology), we defined for each of them either what we thought desirable, but also feasible given the literature. Based on this we framed a rudimentary vision and used this as a starting point for the discussion. Sorting out the implications of this vision was the focus of the last literature review and the expert interviews.

Finally, we conducted four interviews in total with experts from Wageningen University focused on their areas of expertise. These experts were asked to give their opinion on the aspects of our vision that connected closely to their academic background, to evaluate feasibility and possible implications we overlooked. We interviewed Prof. dr. ir. Rene Wijffels about algae and third generation biofuels; Prof. dr. Wim Heijman on regional economics and growth poles; Ir. Greet Overbeek about public participation, and Prof. dr. Johan Sanders on biomass and first and second generation biofuels. Moreover, our project was supervised by Drs. Cor Langeveld as the coach of our group, and by Dr. Emiel Wubben as our academic advisor. These experts' contributions were considered in the development of the final product.

[21] Koops and Trindade (2010)
[22] Carus and Dammer (2018); Schreiber (2017); Scott et al. (2007)
[23] Khatib (2016); Zea Escamilla and Habert (2014)
[24] EurObserv'ER (2017a, 2017b); Mohan et al. (2016)
[25] Devaney et al. (2017)
[26] Bruins and Sanders (2012); Singh et al. (2014)
[27] Domac et al. (2005); Johnson and Altman (2014); Lehtonen and Okkonen (2013); Weterings et al. (2011)

Periphery revolution: the engine of EU bioeconomy in 2040

The growth pole

The development of growth poles is at the center of our vision. These consist of several biorefineries, waste management facilities and a power plant for heat and energy production. The refineries themselves are large-scale facilities dedicated to produce a wide array of products. The large-scale is necessary to ensure internal economies of scale and cheap production. The growth pole attracts other businesses to profit from the infrastructure and from the cooperation with related companies[28].

Growth poles are situated in regions featuring abundant reserves of biomass or arable land to ensure plentiful inputs[29]. Pre-treatment plants first reduce biomass inputs in volume in to lower transportation costs. The choice of location has implications for the region as well, by attracting investments and highly-educated people, creating jobs and infrastructures, and providing farmers a stable demand for their products[30]. In this way, we turn the formerly peripheral rural regions into centres for the new bioeconomy. That is the revolution we propose.

Governments play an important supportive role in the creation of these growth poles. We avoid the mistakes of the past, e.g. that the government does specifically designate one spot within the region as a growth pole[31]. Instead, governments indicate certain areas of potential, in less developed European regions like Poland. Moreover, industries encourage the development of the growth pole and/or stimulate the demand for bio-products[32]. With regards to ownership, the main refinery and associated industries are private-owned. The pre-treatment plants and energy plants are state-owned to *"combine commercial and non-commercial objectives"* (e.g. transparent targets, social objectives)[33].

Biomass inputs

Moving towards a bioeconomy requires an increasing use of already available natural resources, both from land and sea. Thus, the availability and sustainable production of biomass is critical. In this regard, we foster land and water conservation (e.g. cover crops and zero tillage) and high technology applications (e.g. precision agriculture) to ensure the protection of the soil resource as well as fish population. We emphasise the cascading approach to optimize the use of biomass. There are abundant biorefinery technologies nowadays to valorise waste streams and increase resource use efficiency, reducing the need for extra land use for biomass

[28] Heijman and Schipper (2010)
[29] Carus et al. (2015)
[30] Domac et al. (2005); Lehtonen and Okkonen (2013)
[31] Parr (1999)
[32] Carus et al. (2015)
[33] GROW.B1 (2016)

production[34]. Another potential approach is the use of genetically modified organisms in agriculture and forestry, enhancing the more efficient extraction of compounds of interest.

Agricultural and forestry residues are utilized differently depending on which products can be obtained (e.g. sugar beet for the production of biopolymers, and oak - hardwood - for construction materials). Dedicated crops (e.g. *Miscanthus*, *Camelina sativa*, *Crambe abyssinica*) are bred to obtain desired compounds as inputs for production (e.g. of biofuels, bioplastics, etc). Interviews with experts made clear that algae production should be focused on bioproducts and biomaterials due to their higher value and economic viability. However, further technological developments are needed to exploit algae production.

We expect that the exploitation of currently marginal land for biomass production will be profitable in 2040. Thus, increasing demand and prices will stimulate biomass production[35]. This might, however, compete with food production. Governments need to engage in comprehensive spatial planning to manage this conflict and the production of both food and of dedicated biomass crops (e.g. sugar beet).

The role of waste

Central in our vision is the concept of circular bioeconomy. At the end of the production process, the residues from bio-refining will be used as the raw material for other goods (e.g. energy and construction materials) produced in the growth pole.

With regards to waste streams occurring mostly outside the growth pole, we foresee the implementation of a system called 'smart waste station'. This is a waste-gathering facility connected to a web platform that enables businesses to easily access, purchase and re-use valuable waste streams. In addition to this system and the associated platform, governments can contribute by banning non-recyclable materials such as regular plastics, as well as stimulate deposit-refund and cradle-to-cradle systems.

Technology and production processes

The pre-treatment plants - where the biomass is dried - optimise biomass transportation reducing logistic costs, and providing a ready-to-use crude product for the growth pole. Here, both biomass inputs from peripheries and waste from industry and citizens are combined and processed through a cascading approach[36]. Furthermore, knowledge and investments are fundamental aspects that ensure and increase the optimal use of biomass resources.

[34] Mohan et al. (2016)
[35] Slade et al. (2011)
[36] Carus and Dammer (2018); Zilberman et al. (2013)

As part of the cascading approach, the residues that result from the production process of bioproducts and materials will be then used to obtain several by-products. This is part of the implementation of the circular bioeconomy[37]. For example, wood log can be used by different industries at different stages to retrieve a wide array of products (e.g. sawn timber, paper from residues, construction materials, and finally heat and energy[38]). The point of cascading is to first focus on the highest-valued products, as described in the biomass value pyramid[39], and second to use the residues as inputs for lower-value products. The emphasis is on obtaining the more valuable and profitable bioproducts (e.g. biopharmaceuticals and biopolymers) instead on focusing on the production of biofuels. Thus, we envision to increase the exports of such bioproducts and lower the imports of biofuels.

The bioeconomic transition needs to go hand-in-hand with research, funding and knowledge development. Furthermore, it requires collaboration between the government, research institutes and industries that are directly involved. In this collaboration, the government provides the favourable political environment for the development of the growth pole and for stimulating the involvement of the industries. Industries invest in technological development and in the creation of the growth poles, while research institutes focus on providing the tools for breeding crops to obtain specific compounds, optimizing refineries production, and analysing the economic and political implications of the bioeconomy transition.

Citizens and public participation

Public participation can improve societal trust and reduce conflict to smooth the way for the bioeconomy[40]. Moreover, public engagement is essential in the decision-making process, since the bioeconomy directly affects citizens[41] .

The collaboration between governments (supranational and national), industries and research institutes allows the exchange of information and increases its accessibility. In this collaborative process, we propose to organize consultative sessions in which representatives of the society (e.g. civil society movement, trade unions, NGOs) are involved in the decision-making process. These activities are expected to improve citizens' knowledge and awareness, and stimulate their active participation towards the bioeconomy.

The role of the government

We give the EU an important role in coordinating the different actors involved in the bioeconomy transition. This is done through setting strict guidelines and regulations. Our vision

[37] Carus and Dammer (2018)
[38] Mair and Stern (2017)
[39] Lange et al. (2012)
[40] de Bakker et al. (2016); Ribeiro and Millar (2015)
[41] Davies et al. (2017)

is based on the idea that the central government (e.g. European Commission, European Parliament and the Council) provides guidelines in the form of regulations and directives, following a top-down approach. This is meant to standardize targets and rules throughout all Europe. In this regard, research institutes are pivotal in providing the knowledge to set these guidelines and to advise the policy makers in the decision-making process. Current youths favour a more collaborative view of the EU[42]. Hence, we consider this feasible. Moreover, government intervention is also fundamental to ensure sustainability criteria in the bioeconomy (e.g. preserve biodiversity & ecosystems, tackle climate change, and people's enjoyment of nature[43]) through legislation like the Common Agricultural Policy (CAP). Finally, the EU can issue labels and certifications specifically relating to bioeconomic products.

We propose the founding of an European Bioeconomy Agency (EBA), to foster the collaboration and policy making in the 2040 European bioeconomy. The EBA offers a platform to connect stakeholders and contributes to integrating policies across government departments and economic sectors. Furthermore, it takes an independent and holistic position making proposals to integrate policies dealt by different Directorates at the European level.

Besides the EBA, EU plays a role in increasing demand for bioproducts and other renewable alternatives[44]. In this regard, The government has several tools to stimulate the bioeconomy transition. Following Schumpeter[45], we distinguish technology push - access to biomass feedstocks at competitive prices, support of niche products where necessary - and market pull factors - banning non-recyclable products, financial and non-financial incentives (e.g. bonus and reward with bioproducts such as "biobottles"), and facilitating high and stable carbon pricing.

We consider current norms and thresholds with regards to use of renewables, and propose further goals for the future. New concrete goals which we envision for 2040 are:

- 40% energy from renewable sources
- 40% energy efficiency improvement (as compared to 2005)
- 40% of fossil-fuel-based chemicals and materials from renewable sources.

[42] Cresci (2016); Nelsen and Guth (2003)
[43] Network (2017)
[44] Carus et al. (2015)
[45] Schumpeter and Backhaus (2003)

Table I - *Current renewable thresholds 2020 - 2040 - 2050*

	2020 (directive)	2040 (not legally binding)	2050 (not legally binding)
GHG reduction (CO_2-eq)[46]	20% lower than in 2005. (ETS-companies slightly higher).	60% lower than in 2005.	80% lower than in 2005
Energy[47]	* 20% energy from renewable sources * 20% energy efficiency improvement	'GHG-reduction goal is leading principle'	'GHG-reduction goal is leading principle'
Transport[48]	* 10% of transport fuels of every EU country from renewable source * Fuel suppliers are required to reduce the greenhouse gas intensity of the EU fuel mix by 6% in comparison to 2010	"Electricity could partially replace fossil fuels in transport and heating"	*Electricity provides 65% of energy demand by passenger cars and light duty vehicles, as shown in all decarbonisation scenarios *No fossil-fuelled cars in cities *40% use of sustainable low carbon fuels in aviation; at least 40% cut in shipping emissions.

Concluding remarks

Our vision is based on several key principles. Firstly, in a central role, the creation and development of a growth pole will promote rural and economic development, decentralised production, and strong linkages towards industry. Secondly, the circular bioeconomy emphasises the recycle, reuse, and remanufacture of waste to promote and support environmental sustainability. We use available biomass as efficiently as possible through cascading, and produce new biomass using the highest standards in land and water conservation. The main focus in the European bioeconomy is the production of pharmaceuticals, chemicals and advanced bioproducts rather than fuel or energy.

All the stakeholders play key roles in making this vision a reality. Governments by creating a favourable policy framework in which industry invests in the creation of the growth pole promoting economic sustainability, and citizens indirectly collaborate in the decision-making process of the bioeconomy transition ensuring social sustainability. Moreover, research institutes are central actors in promoting innovation and in stimulating new knowledge on bioeconomy. Ultimately, the actions of the stakeholders in shaping the bioeconomic transition are all geared towards ensuring an economy that is environmentally, economically and socially sustainable.

[46] European Commission (2011a)
[47] European Commission (2011b)
[48] European Commission (2011c)

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