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From bio-based products to bio-based industries development in an emerging BioEconomy

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Abstract

In the last years the increasing demand for food security, conservation of energy, water and raw materials created the necessity for more and more renewable resources to be integrated into economy. In this way, the bioeconomy (which comprises the production, transformation and usage of bio-based materials and products) become the center theme of the majority of economic strategies and programs. This paper reviews the emerging markets of bio-based products in the current environment created by bioeconomy strategies, R&D investments and public policies. Our purpose was to assess the key driving forces which affect and reshape the agriculture sector patterns, the perception on biotechnologies role and bio-based industry markets. Our approach remains in general terms due to the fact that bioeconomy is yet difficult to define or measure. However, we focus on the relations with the evolution of agriculture, food supply, bio-based industries and emerging markets to emphasize the real dimension of bioeconomy today and future perspectives.

Keywords:bioeconomy, bio-based products, biomass, emerging markets

1. Introduction

The transition from a fossil-based economy towards a bio-based economy is the main issue of our present. How we change a society which relies on oil and gas to support cooling, heating, transportation etc.? The main idea was to shift towards a greener economy based on biomass, solar energy and resource efficient industries. In this context has risen the concept of "bioeconomy" like a part of the whole green economy.

The emergence of this concept is due to the many challenges faced by our economy today, like: the increasing demand (for food, water, energy, etc.), the degradation of ecosystems (which multiple effects on climate changes and the usage of resources), the limitation of non-renewable resources (like fossils) etc. On this background we observed in the last years the political and economic orientations towards the use of bio-based renewable resources, the recycling of waste in production systems, the integration of bio-resources into biological processes (through biotechnology) to obtain bio-based products etc., in many cases without a real assessment on the future changes. The foreseen impact of these changes varies from replacing (partially or even totally) fossil fuel with bio-based substitutes (for energy, material, clothing, plastic, and chemical applications and non-market service) (EUROPEAN COMMISSION[1]) to the concerning issue of food security (VON BRAUN[2]).

When we refer to bioeconomy we mainly think to agriculture and food production, but it relates also with material, pharmaceutical, industrial etc. sectors. Actually we may say that "Bioeconomy means "biologisation" of the economy" (EICKHOUT[3]) and we have to see it like a cluster of conventional and innovative activities which cuts across sectors and penetrate the whole economy.

There are many issues related with bioeconomy emergence: the increase of biomass led to the increase of demand for biomass generation and refinement in industry; the increasing waste led to the support of innovative initiative related for example with the integration of animal production in the value chains of other industries; "the emerging GHG mitigation markets are increasing the incentives for biomass stocks (rather than food production) for sequestration and re-carbonizing the biosphere" (VON BRAUN[2]); the increase in biofuels markets influenced the demand for biomass, but also the prices of land, water etc. markets; there is an increasing demand for new biomass types, new recycling systems etc. which will increase the R&D investments necessities etc.

However, there are many advantages that can be point out to maintain the orientation towards a bio-based economy": ensuring the "ecological sustainability, economic viability and societal well-being"; reducing the fossil resources dependency; reducing the greenhouse gas emissions (GHG); ensuring the efficient use of resources etc. (VON BRAUN[2]). The main impact however is economic, the support of bioeconomy having the potential to develop the agriculture, the rural manufacturing, the chemical industry, the innovative SMEs etc. In European Commission opinion, "direct research funding associated to the Bio-economy Strategy under Horizon 2020 could generate about 130 000 jobs and € 45 billion in value added in bio-economy sectors by 2025" (EUROPEAN COMMISSION[1]).

2. Materials and Methods

This paper aimed to create an overview of the European bioeconomy in terms of a policy and implications. We followed to emphasize the conceptual delimitation of bioeconomy and the current and potential impact on agriculture, food production and bio-based industries. We point out the main definitions of the bioeconomy and we investigated the relations between bioeconomy, innovation and the bio-based production. The methodology behind this paper is based on a review of recent literature, including projects, conferences and reports. Ouranalyze is not meant to be exhaustive but is concentrated on important documents related with European bioeconomy.

3. Results and Conclusions

Bioeconomy "encompasses all industrial and economic activities that make use of renewable biological resources for the provision of products and services by applying innovative biological and technological knowledge and processes" (according with the concept of Knowledge based bioeconomy used by EU CommisionerPotocnik in 2005)(GERMAN BIOECONOMY COUNCIL [4]). The "Cologne Paper" defines bioeconomy "as mainly based on biological instead of fossil resources, with biomass as primary feedstock and biorefineries as important production facilities"(GERMAN EU COUNCIL PRESIDENCY[5]).

In 2009, OECD define bioeconomy as a "set of economic activities relating to the invention, development, production and use of biological products and processes" and further states that "the bioeconomy involves three elements: the use of advanced knowledge of genes and cell processes to design and develop new processes and products; the use of renewable

biomass and efficient bioprocesses to stimulate sustainable production; and the integration of biotechnology knowledge and applications across a range of sectors" (OCED[6]).

According with the European Commission (2012), "the bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Its sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge" (EUROPEAN COMMISSION[1]). In Bioeconomy Council vision (2013), "bioeconomy is the knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system" (GERMAN BIOECONOMY COUNCIL [4]).

Starting from these definitions we may conclude that bioeconomy offers a "sustainable alternative for the production of energy, chemicals, materials and transportation fuels from biorenewable feedstocks (JENKINS[7]).

Political approach

The development of bioeconomy assume changes at societal, technological and economical level based on strong and clear political strategies. Related with bioeconomy we point out:

- "Innovating for Sustainable Growth: A Bio-economy for Europe" of the European Commission which focus on "ensuring food security, managing natural resources sustainably, reducing dependence on non-renewable resources, mitigating and adapting to climate change, creating jobs and maintaining European competitiveness" (EUROPEAN COMMISSION[1]). The measures are concentrated on increasing the investments in research, innovation and skills, on the reinforcement of policies and stakeholder engagement and on the enhancement of markets and competitiveness in bioeconomy.

- "The bioeconomy to 2030: designing a policy agenda" of OECD which focus on "biotechnology applications in primary production, health, and industry"(OCED[6]).

However, the political measures need to cover many areas like agriculture, research and innovation, energy, environment, climate change, industry etc. to really sustain bioeconomy development. From the documents related with bioeconomy we point out: the "Europe 2020 Strategy" which follows to increase the share of renewables in final energy consumption to 20% (solar, wind, biomass sources) and to increase energy efficiency; the "Directive on renewable energy" which estimate the in 2020 "almost 9.0% of the renewable energy in transport will come from biomass"; the "Biomass Action Plan" which propose key activities for "boosting the bioenergy market and encourage Member States to establish national Biomass Action Plans" etc.

Bioeconomy sectors and measurement challenges

In present is still difficult to analyze the bioeconomy due to the lack of data regarding the newly created subsectors, to the continuously changes in technologies and the boost of biotechnological innovations.

In 2012, the European Commission established a "bioeconomy observatory" which collect the information from emerging markets, regarding sector components, technology innovations, research, industry and processing elements (EUROPEAN COMMISSION [1]). "Bio-based products can include a diverse cross-section of items like enzymes; bio-based

end-use products (e.g., glass cleaners); commodity, fine, and specialty chemicals; intermediates and polymers; food additives; fuels; flavors and fragrances; pharmaceuticals; and bio-based energy. These products are woven into the economy in complex ways, making it difficult to compute the impact on the … economy" (USDA[8]).

At European level the measurement of bioeconomy is also very difficult due to the fact that the specific indicators are classified under the three key pillars of EU policy (Biomass Energy Europe, 2011): economic indicators (regional development policy), social indicators (social inclusion policy) and environmental indicators (sustainability & resource efficiency policy). However, at EU level exists a real concern in the assessment of the bioeconomy characteristics, in establishment of measurable criteria and in providing of empirical indicators for measuring drivers of bioeconomy.

Bioeconomy and biotechnological innovations

Along with bioeconomy development was identified the need for boosting the research and innovation sector. Basically "policy needs the input from science, an input which can only take place if science is targeted at the right needs and communicated efficiently" (ALBERTS[9]).

The R&D policies identified several needs related with bioeconomy which should materialize in new technologies, bio-based products, types of biomass, production techniques etc. Essentially the topics focus on the chain from the production of biomass (in agriculture and forestry) to the use of waste in energy sectors and other industrial areas (chemical, textile, paper, pharmaceutical etc.).

The 7th Framework Programme (2007-2013) had one of his thematic areas ("Food, Agriculture and Fisheries, and Biotechnology") aimed the construction of a European Knowledge Based Bio-Economy (KBBE) (EUROPEAN COMMISSION[10]). The financed projected focused on biomass, bioproducts, biorefineries processes etc. The new program Horizon 2014-2020 has a budget of 35 billion euro designated for Societal Challenges, including "Food security, sustainable agriculture, marine and maritime research, and the bio-economy" (4.7 billion euro), "Smart, green and integrated transport" and "Climate action, resource efficiency and raw materials". Also, under theme "Industrial Leadership" will be supported the innovative projects, including in area of biotechnology and nano-technology.

The technological innovations can contribute to resource efficiency especially in a high-value bio-based economy.

Biotechnology towards bio-based products and bio-based industries

The concept of the bioeconomy started from "the life sciences and biotechnology spheres, which has then been extended to incorporate other ideas such as the biorefinery concept". In OECD vision, the biotechnology offers solutions for many health and resource challenges, but an advanced bioeconomy and biotechnology can lead to changes in the global economy (OCED[6]). Also EuropaBio specify that "the application of biotechnology for sustainable processing and production of chemicals, materials and fuels from biomass creates an opportunity to reduce significantly our dependence on coal, oil and gas" (EUROPABIO[11]).

In present biotechnology plays an important role in the production of bio-based products in different branches (EUROPABIO[12]):

- white biotechnology: "uses enzymes and micro-organisms to make bio-based products in sectors such as chemicals, food and feed, detergents, paper and pulp, textiles and bioenergy (such as biofuels or biogas)";

- red biotechnology: “refers to a medicinal or diagnostic product or a vaccine that consists of, or has been produced in, living organisms and may be manufactured via recombinant technology”;

- green biotechnology and blue biotechnology works with agricultural, marine or aquatic resources.

According toEuropean Commission, bio-based products are “products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised” which have the potential to resolve the current energy and environmental crises.

The current biotechnologies and the innovative initiatives can contribute to the usage of different types of biomass to make bio-based products competitive with fossils-based products. Also, regarding the bio-based industries the most important issue is the public-private partnerships (PPP) like The Bio-based Industries Consortium (formed by a mix of sectors, including agriculture, agro-food, technology providers) and the Bio-based Industries Initiatives which can promote the locally production of bio-based products (such as food, feed, chemicals etc.) and sustain the EU competitiveness on international bioeconomy markets. The European Commission established in 2014 the “Bio-Based Industries Joint Undertaking” like official legal body responsible with the boosting of PPP to support the European bioeconomy development.

Bioeconomy development, agriculture and food security

Bioeconomy is re-defining the way in which we understand the role of agriculture and sustainability of food production. The emerging bioeconomy through the increasing demand of biomass in sectors like bio-energy, biofuels, bio-based plastics and chemicals, etc. can lead to landscarcity, competition with food supply, biodiversity loss etc. In present, the main sources of biomass are trees, grasses, energy crops, agricultural residues, animal wastes etc. and through different biotechnological processing (fermentation, combustion, chemical conversion etc.) conduct to varies bio-based products like fiber boards, paper, adhesives, plastics, solvents, etc. However, plants are the major source of renewable biomass for bioproducts, having a remarkable chemical diversity and adding value to agricultural commodities.

Due to the development of bioeconomy, there is an increasing demand for biomass and also an increasing demand for arable land with energy crops which could lead to the reduction of forest and grass lands. In other words, an agricultural land mainly used for the production of food for people and feed for animals, by transition towards a bioeconomy, will be specialized in crops for biofuels and other applications for energy market.

The increase of biofuels shares in the global use of several crops influence the price levels and leads to price volatility, because there is very little elasticity in the agricultural market. Also, the food supply may be affected in the future by different factors, like: the changes in population demographics which will increase the global consume; the increase in the meat consume which will lead to a bigger demand for feed (SER[13]); the droughts and floods phenomenon due to climate change which will affect the supply of food crops etc.

Biomass production is dependent of the availability of land and a high demand can lead to biodiversity loss and large scale land acquisitions. According with World Bank, in 2000-2010 were acquired in developing countries over 71 million hectares of farmland, from which almost 80% was designated to agriculture, but it is estimated “that over three quarters of that land will be used for the production of crops for biofuels”. Even if the data are not entirely correct, we may affirm the demand for biofuels is the key driver for many land

acquisitions. In the future, we may be confronted with a large-scale displacement of land as biofuels demand focuses on higher value lands and this will put a pressure on land at the expense of biodiversity with a direct impact on the livelihoods of people.

The bioeconomy during 2004-2012 periods was based on a production of biomass that reached at EU level over 1.0 billion dry matter, a production of biomass from forestry over 400 million m3, a production of biomass from fishery over 6 million tons live weight and a waste biomass production over 40 million tons (Table 1).

Table 1. Biomass supply in the EU-27 per category of the biomass (2004-2012)

		2004	2005	2006	2007	2008	2009	2010	2011	2012
***Used resi*dues**	1 mill T Dry Matter	181.91	162.71	153.71	154.37	179.55	172.94	160.43	161.52	162.26
Unused residues	1 mill T Dry Matter	380.32	341.26	318.08	304.20	362.98	349.90	333.49	357.18	332.49
Harvested production	1 mill T Dry Matter	592.99	555.01	526.80	532.66	583.34	577.75	554.25	588.60	571.13
Agricultural – total	1 mill T Dry Matter	1,155.22	1,058.99	998.60	991.22	1,125.87	1,100.60	1,048.18	1,107.30	1,065.88
Wood	Mill cubic meters	416.80	447.50	422.27	462.51	419.60	388.31	427.61	433.66	423.36
Wood pulp	Mill tons	40.14	39.10	41.61	41.46	39.96	34.73	36.91	37.43	45.04
Fishery	Mill tons live weight	…	…	…	…	6.26	6.18	6.33	6.14	…
Waste	Mill tons	79.48	…	…	…	46.61	…	40.41	…	42.21

Note: *Bioeconomy Observatory*(EUROPEAN COMISSION[14])

In 2013, the majority of the estimates agricultural biomass (1.833.3 thou dry matter) is composed by cereals (harvested production and residues) (Table 2). Over half of crop biomass comes from Germany, France and Spain. At EU level average agricultural biomass per hectare is about 6 tons of dry matter (including fodder crops) (EUROPEAN COMISSION[14]).

Table 2. Agricultural Biomass supply in the EU-28 per category of the biomass in 2013 (1000 tons dry matter)

	Harvested production	Residues Used	Domestic Extraction Used	Residues non-used	Total
Agricultural crops	620,579	144,150	764,729	303,835	1,833,293
Fodder crops	39.8	0.0	32.3	0.0	27.0
Total cereals incl. rice	43.7	89.1	52.3	71.4	55.4
Fruits and Vegetables	5.0	1.5	4.4	6.5	4.7
Sugar crops	4.2	4.8	4.3	2.3	4.0
Starchy Roots	1.8	0.8	1.6	3.4	1.9
Total Oilseeds	4.8	3.8	4.6	16.2	6.5
Protein crops	0.4	0.0	0.4	0.2	0.3
Other crops	0.1	0.0	0.1	0.0	0.1
Fiber Crops	0.1	0.0	0.1	0.0	0.1

Note: *DataM – Biomass estimates* (BIOBS[15])

For the future there are many projections regarding the biomass consumption. According to Beurskens the final energy consumption from biomass in electricity, heating &

cooling and transport will increase with almost 65% until 2020 (BEURSKENS& al. [16]). "Even with this rapid growth, the required biomass for bioproducts will remain lower than the amount of biomass required to replace fossil fuels in the transport or energy sectors" (EICKHOUT [3]).However, we have to consider that in the future will intervene many factors which will affect the decision to use biomass for energy, fuel, and biomaterials such as the production costs, the capital cost of process equipment and facilities, the alternative energy and materials markets, etc.

In conclusion, at European level we observed a real political implication in diverting support to bioeconomy sectors, from agricultural innovation to energy systems, and also a real preoccupation for the integration in strategic documents of regulation regarding biotechnological knowledge, biological resources use and potential of biomass usage. Actually we may affirm that the bioeconomy development is related with the evolution of agriculture (especially the role of biomass) and of R&D sector. We observed a political orientation towards measuring bioeconomy dimension, identifying emerging sectors and in rising awareness regarding the latent value of biological resources, but also public-private initiatives designed to strengthen the synergies between sectors. Our review reaffirmed that biotechnology is an essential component of the bioeconomy and that biomass remains the basis feedstock along with bio-based products obtain through biotechnological processes. Also our research provides some insights regarding the future importance of bioeconomy, especially regarding the opportunities and challenges rising from biomass usage and food supply.

References

1. EUROPEAN COMMISSION, Communication (COM (2012) 60 final). Innovating for Sustainable Growth: A Bioeconomy for Europe (2012).
2. J. VON BRAUN. The role of Science and research for development policy and the millennium development goals" Humboldt Foundation, Berlin (2008).
3. B. EICKHOUT, A strategy for a bio-based economy, *Green New Deal Series*, volume 9 (2012).
4. GERMAN BIOECONOMY COUNCIL, Bioeconomy Policy Synopsis and Analysis of Strategies in the G7 Government (2013).
5. GERMAN EU COUNCIL PRESIDENCY, "Cologne Paper" at the biotechnology conference "En Route to the Knowledge-Based Bio-Economy" (2007).
6. OCED, The Bioeconomy to 2030: designing a policy agenda - International Futures Programme (2009).
7. T. JENKINS. Toward a biobased economy: examples from the UK.*Biofuels, Bioproducts and Biorefining*, 2: 133(2008).
8. USDA, Biobased Economy Indicators. A report to the US Congress (2011).
9. B. ALBERTS. Policy-making needs science. *Science*, 330: 1287 (2010).
10. EUROPEAN COMMISSION, Work Programme 2012, Theme 2 - Food, Agriculture and Fisheries, and Biotechnology, C (2011) 5068 of 19 July 2011.
11. EUROPABIO (European Association for Bioindustries), Building a Bio-based Economy for Europe in 2020; European Association for Bioindustries: Brussels, Belgium, 2011.
12. EUROPABIO (European Association for Bioindustries), What is Biotechnology?, at http://www.europabio.org/what-biotechnology.
13. SER.Meerchemietussengroen en groei. De kansenendilemma"s van een bio-based economy, *Den Haag, SER*, ADVIES 10/05: 87 (2010).
14. EUROPEAN COMISSION, DataM – Biomass estimates (v3): a new database to quantify biomass availability in the European Union (2015).
15. BIOBS. Bioeconomy Observatory, at https://biobs.jrc.ec.europa.eu/.
16. L.W.M. BEURSKENS, M. HEKKENBERG, P. VETHMAN, Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States, ECN and EEA (2011).