A Definition of Bioeconomy through the Bibliometric Networks of the Scientific Literature

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The purposes of this paper are to present the different bioeconomy strategies within European Union (the national member states' published bioeconomy strategies are presented), the United States, and China, to construct bibliometric networks of the global scientific literature in order to shape a "visual" definition of bioeconomy, to locate in which aspects of economic activity intervenes (with which terms) and to draw conclusions regarding the primary causes of its appearance, its present form and its future perspectives. Our pursuit is not just to present a "static" bioeconomy, but using the means of bibliometric analysis, to reach more critical conclusions.

Key words: bioeconomy, circular bioeconomy, VOSviewer, SocNetV.

Introduction

Any system that is dependent on the inflow of raw materials is bound to eventually collapse. The cause for this pessimistic finding lies with the 2nd Thermodynamic Law and the rise of system entropy; the increased consumption triggers unequally increased demand. Furthermore, in a resource-finite geosphere the combination of the aforementioned natural law with human imprudence and greed seems catastrophic. By the year 2050 world population will probably have transcended 9 billion (United Nations [UN] Department of Economic and Social Affairs [DESA], 2010) while the legitimate aspirations of developing countries to catch up with the living standards of the developed ones mean the need for natural resources likely will have doubled (Bringezu et al., 2017). Therefore, an alternative paradigm concerning both the production and the consumption spheres ensuring sustainability becomes a necessity.

During recent years, a rising interest driven by the challenges facing humanity, on the matter of bioeconomy is observed in the global scientific literature. Figure 1 presents the number of references of the term "bioeconomy" on the Web of Science[1] (WoS) website during the last decade (2008-2018).

This phenomenon is deeply related to the growing criticism, over recent years, of the inefficiencies and deadlocks of the linear, fossil-based model whose composition and operational mode has been described as "take-make-dispose."

This paper sets as its goal to construct a comprehensive "visual" definition of bioeconomy, through the bibliometric networks of global scientific literature, in order to come to a conclusion for the roots of bioeconomy, its present and future. The different orientations of the European Union, the United States, and China on the matter of bioeconomy strategic documents will be analyzed and related to the bibliometric search and shaping of the term. We have chosen bibliometric network analysis in order to shape a holistic definition of bioeconomy which will include its different aspects.

In the WoS, only 0.5% (5/1036 results) of the bioeconomy related literature (query: bioeconomy "AND" bibliometric analysis) contains the term "bibliometric" thus, our purpose is not add a different perspective to an insignificant number of studies, but rather to convert a static term (that "traditional" bibliometric techniques give) into a constantly evolving one through time. We will use the conventional quantitative tools of bibliometric analysis as well as social network analysis in order to convert quantitative observations to qualitative conclusions.

The structure of the paper is composed of six sections. The next section analyzes the tools and methodology followed; the second part introduces the concept of bioeconomy; the third part presents the EU, US, and Chinese bioeconomy strategies; the fourth part analyzes the bibliometric network of bioeconomy; the fifth part shapes the definition of circular economy, and the sixth part completes the paper with concluding comments.

Methodology

In this section, we describe the methodology below on how to define bioeconomy from the scientific literature through the process and tools of bibliometric analysis.

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1. *https://www.webofknowledge.com/*
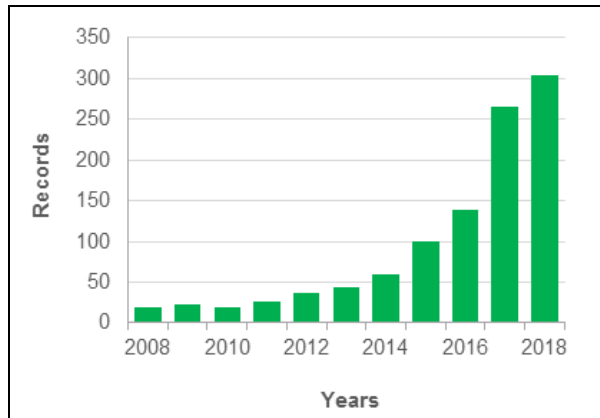
Figure 1. Publications mentioning the term "bioeconomy" (2008-2018) in chronological order.

What is Bibliometric Analysis?

Bibliometric analysis is defined as the process of identifying national and international networks as well as mapping the development of new trans-disciplinary fields of science and technology through statistical indicators from the scientific literature on the productivity of individuals, groups, institutions, and countries.

"Originally, work was limited to collecting data on numbers of scientific articles and publications, classified by authors and/or by institutions, fields of science, country, etc., in order to construct simple productivity indicators for academic research. Subsequently, more sophisticated and multidimensional techniques based on citations in articles, and more recently also in patents, were developed. The resulting citation indexes and co-citation analyses are used both to obtain more sensitive measures of research quality and to trace the development of fields of science and of networks.

Bibliometric analysis uses data on numbers and authors of scientific publications and on articles and the citations therein (and in patents) to measure the "output" of individuals/research teams, institutions, and countries, to identify national and international networks, and to map the development of new (multi-disciplinary) fields of science and technology." (Organisation for Economic Co-operation and Development [OECD])[2]

Bibliometric Network

A bibliometric network is defined as the visual representation, by means of nodes and links, of complex meanings with multi-level influences that allows us to transform the quantitative bibliometric information into qualitative conclusions. There are five main types of analysis that are used to determine the relatedness of the network's terms (van Eck & Waltman, 2009).

- Co-authorship analysis: The relatedness of items is determined based on their number of co-authored documents.
- Co-occurrence analysis: The relatedness of items is determined based on the number of documents in which they occur together.
- Citation analysis: The relatedness of items is determined based on the times they cite each other.
- Bibliographic coupling analysis: The relatedness of items is determined based on the number of references they share.
- Co-citation analysis: The relatedness of items is determined based on the number of times they are cited together.

Centrality Indices

There is a variety of statistical indices that have been proposed to estimate the importance of each node in a network (Koschützki et al., 2005). We have selected the four most commonly used (SocNetV Manual):[3]

- Degree Centrality (DC): The DC measure quantifies how many ties a node has to other nodes in the network.
- Eigenvector Centrality (EC): Is defined as the ith element of the leading eigenvector of the adjacency matrix. The leading eigenvector is the eigenvector corresponding to the largest positive eigenvalue. Eigenvector centrality, proposed by Bonacich (1987), is an extension of the simpler degree centrality because it gives each actor a score proportional to the scores of its neighbors.
- Betweenness Centrality (BC): For each node u, BC is the ratio of all geodesics between pairs of nodes which run through u. It reflects how often that node lies on the geodesics between the other nodes of the

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2. *From the OECD Glossary of Statistical Terms: https:// stats.oecd.org/glossary/detail.asp?ID=198*

3. *https://socnetv.org/docs/index.html*

network. The BC score of each actor can be interpreted as a measure of potential control as it quantifies just how much that actor acts as an intermediary to others. An actor which lies between many others is assumed to have a higher likelihood of being able to control information flow in the network.

• Closeness Centrality (CC): The CC index focuses on how close each node is to all other nodes in the network. Nodes with high Closeness Centrality are those who can reach many other nodes in few steps. The idea is that a node is more central if it can quickly interact with more of the others.

Network Tools

To construct the network and calculate its centrality indices we used two programs, namely VOSviewer (Van Eck & Waltman, 2009) and SocNetV (Kalamaras, 2014), whose selection was based on the four criteria below:

1. Tested: have been validated in similar, methodological, studies.
2. Reliable: to be commonly accepted in their operation.
3. User friendly: no seminar or specialized knowledge is needed.
4. Open software: anyone can access them for gratis.

Software programs that fulfill the above conditions contribute to the following:

• Accessibility: anyone can access both work data and its tools.
• Repeatability: the results can be reproduced.
• Valuation: Factors 1 and 2 related, contribute to the validity of the conclusions.

VOSviewer is a software tool for the creation, visualization and reproduction of bibliometric networks. It uses the Van Eck and Waltman (2009) visualization of similarities (VOS) technique, combining the mapping with the clustering method, which are spatially independent, thus exceeding the two-dimensional constraint of the first cartographic approach (Waltman, Van Eck, & Noyons, 2010). The VOS technique is structurally convergent to the well-known multidimensional scaling technique (Borg & Groenen, 2003), but more focused on graphic data representation. VOSviewer is a distance-based network program which means that the distance
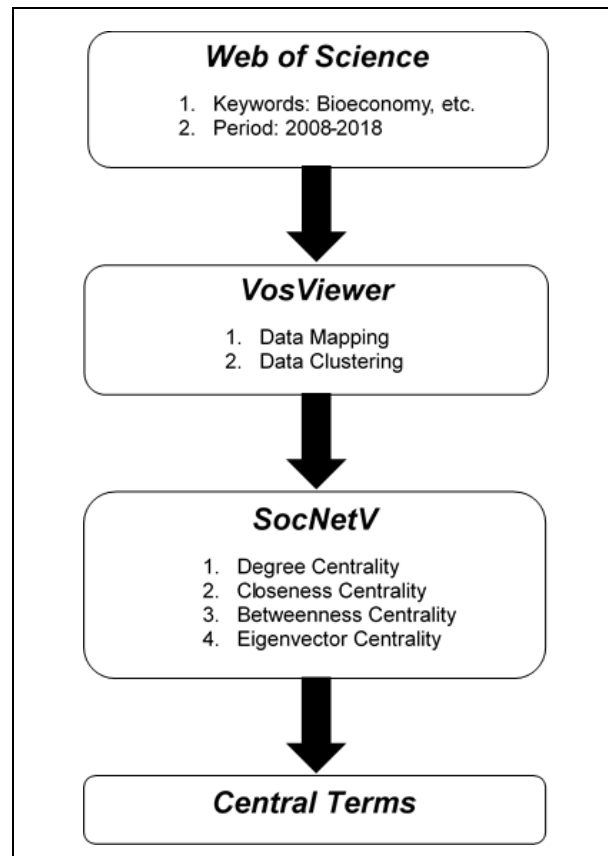

Figure 2. Schematic representation of the methodology.

between two nodes in the visualization approximately indicates relatedness.

SocNetV elaborates various file formats (GraphViz, GraphML, Adjacency, Pajek, UCINET, etc.) to construct networks as well as to quantify the inherent characteristics of the network (density, diameter, and distances), and more complex statistical indicators (DC, CC, BC, EC, graph, clustering coefficient, etc.).

The steps described are summarized in Figure 2.

Bioeconomy Concept

Although human societies set out as absolutely dependent on nature, as centuries went by the contribution of technology and the generalized use of artificial materials in conjunction with the increase of the population resulted in the exploitation of the biosphere to such a degree that its basic operations are being affected by human activities, especially in the wake of the industrial revolution. Since then, in many cases, humans have approached or even transcended the endurance and feedback thresholds of the environment, both on a periph-

eral/regional and a universal level, so that geologists have named the era we are currently living in the Anthropocene era. The main cause is the depletion of non-renewable resources and the irreversible impact on life cycles (atmosphere, water, minerals). These phenomena gave rise to the theory of environmental science and its connection to action, initially through the movement of concerned scientists and, afterwards, in the society and the political system. The effort is focused on the increase of the productivity and the effectiveness of the production process and the substitution of mineral and non-renewable resources by renewable ones. It is about reverting to bio-centrality and, as such, the transition to bioeconomy gains significant footing towards the end of the 20th century and is now a strategic element on a transnational, national, and regional level.

Institutionally, bioeconomy is defined, according to the European Commission, as the sum of the sectors of economy which use renewable biological resources from the land and the sea—such as crops, forests, fish, animals, and microorganisms—for the production of food, materials, and energy (European Commission, 2012), while according to the OECD "a bioeconomy can be thought of as a world where biotechnology contributes to a significant share of economic output. The emerging bioeconomy is likely to involve three elements: the use of advanced knowledge of genes and complex cell processes to develop new processes and products, the use of renewable biomass and efficient bioprocesses to support sustainable production, and the integration of biotechnology knowledge and applications across sectors."

But does the increased involvement of the biological element or the commercialization of biotechnological innovative products suggest that sustainability and viability for both the economic system and environment are ensured? The negative answer to this rhetorical question constitutes an opportunity for a new dialogue. This assertion, though it may initially seem nonessential and commonplace, suggests a new qualitative criterion for the characterization of bioeconomy. The issue that arises is not merely the biggest possible penetration of renewable resources and energy sources into the production process, but the sustainable manner of use and processing, based on the non-distinction of objective and method. According to that, the raw material can in no way be viewed as evidence of productive sustainability, as that would be causing a distortion of the meaning, which would in turn convert the whole issue of the reorientation of production into a technical form disconnected from any essential interaction between the econ-

omy and other fields. More specifically, the idea that the conversion of today's linear conventional production into a renewably-sourced system without any forethought regarding matters that indirectly affect the system, such as population growth, natural renewal rate, and various consumer and market behaviors (i.e., Jevons paradox, boomerang effect), is self-deception. Furthermore, as Székács (2017) points out, the idea of constant biotechnology-based economic growth is limited by two main factors. First, the initial expansion of bio-products and bio-based chemicals will eventually need to be lessened as bioeconomy solutions gradually replace fossil fuels-based technologies and, second, the renewal rate of bio-resources would constitute an external limiting factor.

Biofuels constitute a typical example, as their production would, according to scientists and stakeholders, contribute to coping with the greenhouse effect, inciting governments to promote biomass production from dedicated crops cultivated on arable land. This, however, has been strongly contested; when indirect and induced land use change effects are taken into consideration, environmental impacts of biofuel use are rather negligible or even negative except in few specific cases (Székács, 2017). In 2015, new rules came into force which amend the current legislation on biofuels up to the Sustainability Directive (2009/28/EC of The European Parliament and of The Council of 23 April 2009) on the promotion of the use of energy from renewable sources, which promotes the introduction of accompanying measures to encourage an increased rate of productivity on land already used for crops, the use of degraded land, and the adoption of sustainability requirements. To this end, the European Commission considered the inclusion of a factor for indirect land-use changes in the calculation of greenhouse gas emissions. At the same time, the need to allocate additional incentives to sustainable biofuels which minimize the impacts of land-use change and improve biofuel sustainability with respect to indirect land-use change is pointed out. On the other hand, the paradox of the increased consumption of fossil fuels was observed because of the decrease of their prices, which was brought on by the accumulation of the total reserves of fuels resulting from high biofuel production. Furthermore, Grafton, Kompas, and Van Long (2012) showed that with zero extraction costs, linear marginal costs for biofuels, and a linear demand for energy, a subsidy has no effect on the path of fossil fuel extraction; the supply of biofuels only generates its own additional energy demand. Thus, a more basic differentiation of bioeconomy from previous forms of economic organiza-

tion is its assertion of changing the univocal validation of biological raw materials both in production processes and in social proceedings.

Bioeconomy Key Players

We present in this section the bioeconomy strategic goals of the European Union, the United States, and China as an overview of the different approaches to bioeconomy.

European Union

As expressed in the 2012 strategic document, EU goals on bioeconomy are (a) ensuring food security, (b) managing limited and depleting natural resources sustainably, (c) reducing dependence on non-renewable resources, (d) mitigating and adapting to climate change, and (e) creating jobs and maintaining European competitiveness (EC, 2012). These goals constitute the general guidelines of Bioeconomy Strategy in the European Union, whereas member states are allowed to construct their own bioeconomy plan adapted to their special needs and features; various specific features and particular conditions are reflected to the strategic documents announced in cases revealing different approaches and action plan implementation rationales.

In order to illustrate this statement, we have gathered the published European National Bioeconomy Strategies (Figure 3), according to the EC/Bioeconomy Knowledge Center, and grouped them according to their common orientation (definition of bioeconomy, goals) based on the Bugge, Hansen, and Klitkou (2016) classification of the bioeconomy into three main directions: bio-technology vision, bio-resource vision, and bio-ecology vision.[4]

Table 1 shows the classification of the national strategies of the EU member states according to the Bugge et al. (2016) visions. The classification was held according to the meaning that each country gives bioeconomy and its goals. For example, France, which has been classified as holding bio-ecology vision, defines bioeconomy as "the one encompasses the whole range of activities
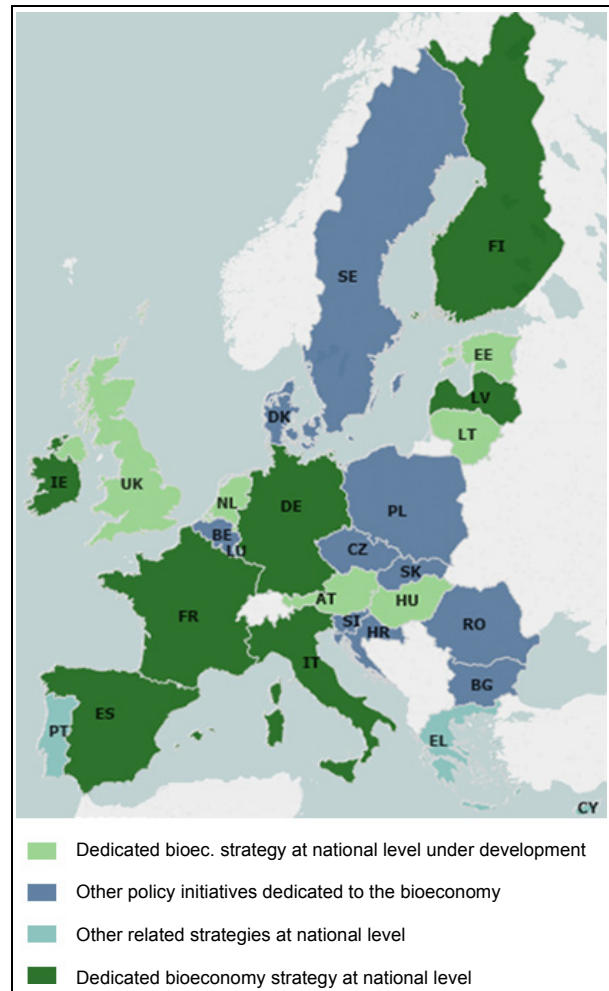
Figure 3. Progress on bioeconomy strategy development in EU member states.
Source: EC, Bioeconomy Knowledge Centre.

linked to bioresource production, use, and processing. The purpose of bioresources is to provide a sustainable response to the need of food and to part of society's requirements for materials and energy, as well as providing society with ecosystem services. Bio-based products are defined as products deriving entirely or partially from bioresources." While the Latvian strategy states, "bioeconomy covers those parts of economy where renewable bio-resources (plants, animals, microorganisms, etc.) are used in the production of food, feed, industrial products, and energy in a sustainable and well-considered way." Furthermore, France sets as goals of bioeconomy: (a) to guarantee food security and sustainable living standards for current and future generations by conserving natural resources and the ecosystemic functions of habitats, (b) to be efficient,

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4. biotechnology vision: *focuses on the rapid utilization and commercialization of biotechnology research in various sectors of the economy.*
    bio-resource vision: *emphasizes sustainable utilization of biological raw materials.*
    biecology vision: *promotes maintenance or improvement of biodiversity and ecosystem services, as well as the avoidance of monocultures and soil degradation.*

Table 1. Classification of published European and national bioeconomy strategies.

	Bio-technology vision	Bio-resource vision	Bio-ecology vision
2011		Germany-National Research Strategy Bioeconomy 2030	2011
2012			2012
2013		National Policy Strategy on Bioeconomy	2013
2014	Finnish Bioeconomy Strategy		2014
2015			2015
2016	Spain - Spanish Strategy on Bioeconomy - Bioeconomy Action Plan		2016
2017	Latvian Bioeconomy Strategy 2030	France - National Bioeconomy Strategy Action Plan Italy- National Strategy for Bioeconomy	2017
2018		Ireland - National Policy Statement on the Bioeconomy	2018

resilient, circular, and productive over the long term, (c) to focus on the general public and to be rooted in local regions, contributing to the development of economic value and jobs, and (d) to offer innovative solutions that are effective, affordable, and capable of addressing the diversity of human needs. By comparison, Latvia's bioeconomy goals are: (a) advancement and retention of employment in the bioeconomy sectors for 128 thousand people, (b) increasing the value added of bioeconomy products to at least EUR 3.8 billion in 2030, and (c) increasing the value of bioeconomy production exports to at least EUR 9 billion in 2030.

What we see is that for France bioeconomy strategy is oriented to eco-friendly, sustainable, and socio-centered schemes, while Latvia's approach stresses its economic aspects and prospects.

Thus, France and Latvia constitute examples of how the shape of bioeconomy can vary even among European member states and why a classification of European visions is needed. The classification does not insinuate an absolute separation of the different approaches; for example, bio-ecology vision strategies naturally include techno-economic aspects, but rather gives the "spirit," the dominant mentality of each national strategy.

United States

According to the Biomass R&D Board (USDA, 2016), bioeconomy is defined as "the global industrial transition of the sustainably utilizing renewable aquatic and terrestrial biomass resource in energy, intermediate, and final products for economic, environmental, social, and national security benefits." while the *National Bioeconomy Blueprint* (The White House, 2012) sets five strategic goals: (a) support R&D investments that will provide the foundation for the future bioeconomy, (b) facilitate the transition of bio-inventions from research

lab to market, including an increased focus on translational and regulatory sciences, (c) develop and reform regulations to reduce barriers, increase the speed and predictability of regulatory processes, and reduce costs while protecting human and environmental health, (d) update training programs and align academic institution incentives with student training for national workforce needs, and (e) identify and support opportunities for the development of public-private partnerships and precompetitive collaborations where competitors pool resources, knowledge, and expertise to learn from successes and failures.

Thus, for the US plan bioeconomy is related to economic growth while social and environmental benefits are considered as derivatives of the correlation of R&D with the market and the commercialization of biotechnological innovations.

China

In view of its critical status in the context of the so-called fourth industrial revolution, bioeconomy has been identified as a strategically new, pillar industry for China's economy. Its importance as well as the exclusive supportive tools have been confirmed in a series of official documents, including "*The Thirteenth Five-Year plan for National Economic and Social Development of the People's Republic of China*," "*The Thirteenth Five-Year National Plan for the Development of Strategic Emerging Industries*" and "*The Thirteenth Five-Year National Plan for the Development of Bioenergy Industry*." In those documents, the market mechanism for resource allocation has been given full respect. In the meanwhile, the government will play a guiding role, providing all-round support for the development of biology industry with favored public financial, tax, financial services, and talents policies.

Table 2. Alternative wording in the terms searched for the "bioeconomy" concept.

Term	SQL Query	Number of articles	Number of articles after deleting duplicates
BIOECONOMY	TS=Bioeconomy AND PY=2008-2018	600	
BIO-ECONOMY	TS=Bio-economy AND PY=2008-2018	171	
BIO ECONOMY	TS=Bio economy AND PY=2008-2018	889	
BIO-BASED ECONOMY	TS=Bio-based economy AND PY=2008-2018	260	
BIO BASED ECONOMY	TS=Bio based economy AND PY=2008-2018	506	
TOTAL		2,426	1,369

Accordingly, priority has been given to seven fields of bioeconomy in the following five years per a National Development and Reform Commission press release: (1) biomedicine. More focus will be put on the understanding and holding the revolution of drugs R&D pushed by precise medical mode. (2) biomedical engineering. Following the new trends of intelligence, network, and standardization, new types of medical devices should be vigorously developed and new means of modern diagnosis and treatment will be provided. (3) biological agriculture. In the fields including biological seed industry, biological pesticide, biological veterinary medicine, biological feed, biological fertilizer, and other new products development and application, a major breakthrough is expected to significantly enhance the competitiveness of biological agriculture. (4) biological manufacturing. The large-scale production and application of bio-based materials, bio-based chemicals, and new fermentation products will be promoted, as well as the demonstration and application of green bio-technology in chemical, pharmaceutical, textile, and food industries. (5) bioenergy industry. The bioenergy development model will be innovatively developed along with the expansion of the application of bioenergy and the enhancement of the industrial development of bioenergy. (6) bio-environmental technologies. In this branch, several bio-environmental technologies should be paid attention to: bio-microbial agents and biological agents with high efficiency, bio-chemical technologies and equipment with high efficiency but low consumption, as well as an integration system of bio-physicochemical optimization for bioremediation of environmental pollutants and the utilization of waste resources. (7) biological services. Consistent with the improvement of R&D efficiency and resource utilization of biology industry, biological service industry will be vigorously developed. Particularly, along with further specialization of biology industry, the needs for high-quality specialized services will emerge.

Data Collection

We attempted to achieve the maximum possible gathering of related scientific literature regarding the bioeconomy. For this reason we opted to focus our research on the core collection of the WoS website since it fulfills three main criteria:

- extensive coverage of the database,
- extensive availability of features for searching, sorting, and exporting bibliographic data as well as for computing performance indicators on them, and
- open access of the database (not subscription-based).

We chose to use five different wordings of the term "bioeconomy," as presented below, limiting our search to the decade 2008-2018.

We downloaded the results (Tab-delimited format / Full Record and Cited References) and, via the MS Excel program, we traced and eliminated the duplicates which resulted a final number of 1,369 documents (Table 2). Afterwards, by filtering the "author keywords" column we traced and removed the overlapping terms (i.e., bio-economy = bioeconomy).

Countries Network

The different approaches of and relations between national strategies are also imprinted on the network of scientific literature. Co-authorship analysis (the relatedness of item is determined based on the number of co-authored documents) of the VOSviewer program indicates that the different national orientations are also translated into increased scientific collaboration-interaction between familiar-strategic countries.

In Figure 4, each color of the network represents a cluster of related items but, as we have already mentioned, the relation of the items (nodes) in VosViewer program is also determined by the distance from each node to the others. We can, thus, distinguish two forms of relations; the color-based relation and the distance-based relation. So, the true question that arises is, which
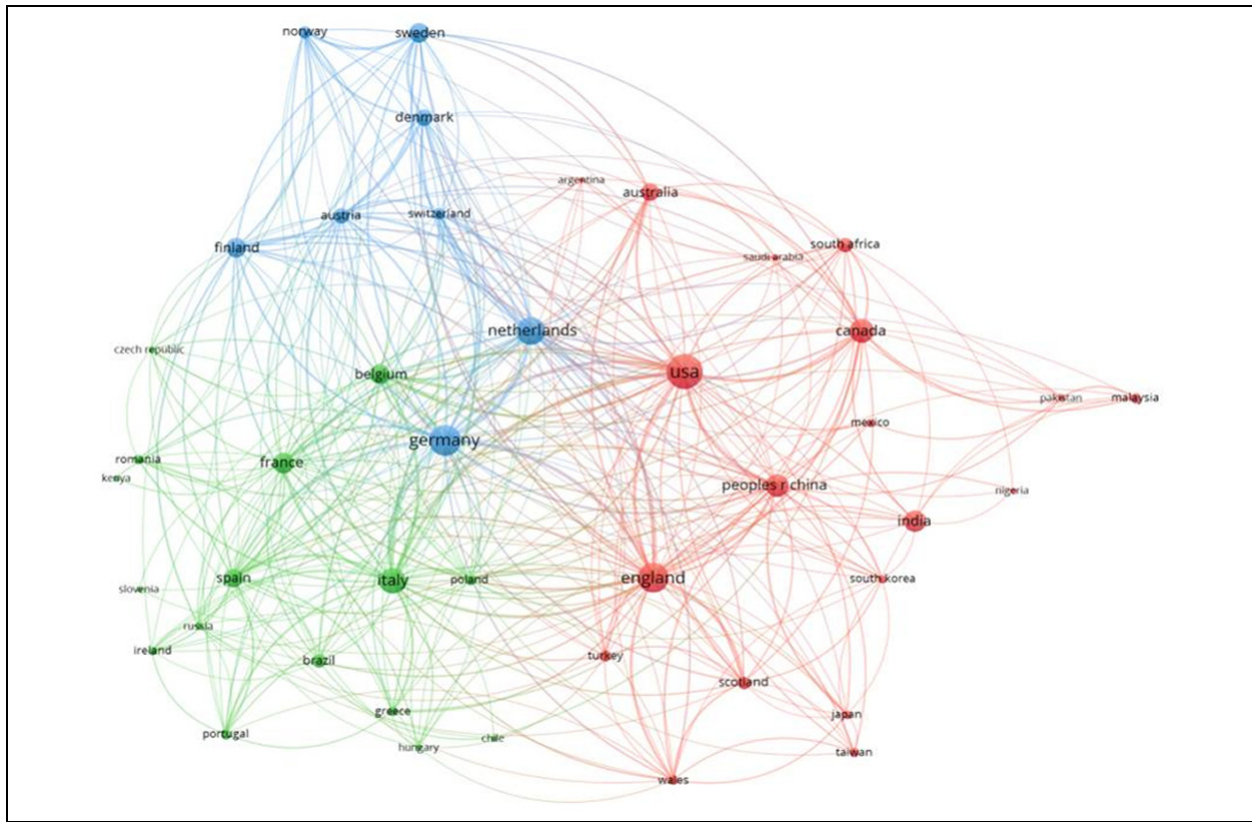
Figure 4. Co-authorship analysis/countries.

is the most reliable form of relatedness; for example, is France closer to Portugal (same cluster) or to Germany (smaller geodesic distance)? The answer lies in the "type" of relation we are looking for.

Each cluster represents a group of intensively related items whose relation is strong enough to form a separate entity; that entity, in order to exist as such, is obliged to create "relations" with other, similarly formed, separate entities. The interesting part in our case is that the interaction of entities (clusters) is achieved through the most important "nodes"-terms of each entity. This means that the most central countries in bioeconomy scientific literature are crucial in both ways. At first, they are the poles around whom smaller nodes are gathered to form a group of related terms, and at the same time it is they who allow the global scientific interaction between different clusters; they are the "bridge-nodes" of the network. In our example, Portugal, in its separate cluster, can interact with non-directly connected nodes through the interaction of the most central nodes of its cluster and at the same time exist as a separate entity.

In our network, we can trace the three directions defined by Bugge et al (2016); the red cluster represents the bio-technology vision oriented countries, the green cluster the bio-ecology oriented, while the blue cluster represents the bio-resource vision countries. As we see, the bio-resource oriented countries are located most central in our network, between the two clusters, which could be explained by the fact that this vision contains elements from both the bio-technology and the bio-ecology visions.

Furthermore, if we interpret the countries network in Figure 5 based on the Levidow, Birch, and Papaioannou (2012) different visions of bioeconomy we will reach some interesting remarks. According to them, we can trace two bioeconomy narratives, i.e., life science vision and agroecology, which originate from different economic and socio-technical imaginaries.[5] Life science vision respresents the economic imaginary of bioeconomy which supports that "it will enhance productivity

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5. *The social imaginary is "the creative and symbolic dimension of the social world, the dimension through which human beings create their ways of living together and their ways of representing their collective life" (Thompson, 1982).*
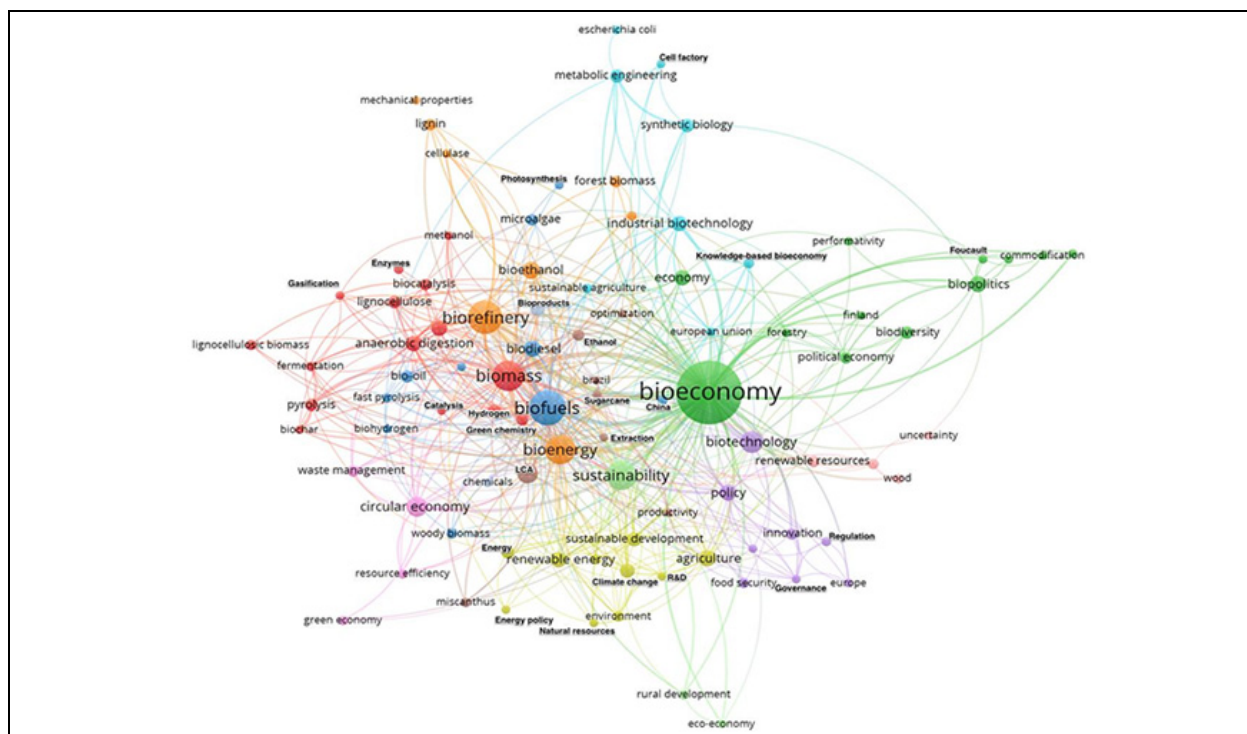
Figure 5. Bioeconomy network, author keywords.

through global value chains" (Levidow et al., 2012). Thus it is related to the neo-liberal idea that the social benefits are derivatives of economic growth, so any social aspects of bioeconomy will be shown, perforce, only after the reinforcement of bioeconomic competitiveness. Agroecology vision comes from the socio-technical imaginary, according to which technological orientation and innovations directly reflect societal purposes and pursuits, and supports "shorter food supply chains as a means for farmers to gain more from the value they add" (Levidow et al., 2012).

The authors content the life science vision is the dominant narrative of bioeconomy, which is also supported by the countries network, regarding that bio-technology and bio-resource visions correspond to "life science" vision and bio-ecology to "agroecology," in which bio-resource and bio-technology visions cover the most extensive part of the network, including the world's biggest economies (blue + red clusters).

Author Keywords Network

To construct the bioeconomy scientific literature network we used co-occurrence type of analysis, using the full counting method and author keywords as the unit of analysis. We have limited our results to a minimum of

five occurrences, which gave us 92 terms, plotted as network nodes. This means that our network, shown in Figure 6, contains the keywords that authors have used to summarize their papers related to each other according to the number of times they occur together, while each term is used at least five times in the data. Each reference counts the same weight.

Through the network analysis and the calculation of centrality indices, we can easily locate the most central elements composing bioeconomy, such as biofuels, biomass, bioenergy, biorefinery, sustainability, biotechnology, etc., and construct a "visual" definition of the term.

As we have mentioned before, the purpose of our paper is not a simple repetition of the findings of previous researchers on bioeconomy, but, having in mind that bioeconomy came up as a necessity of the environmentally harmful conventional fossil-based model, to reach to a conclusion regarding the primary causes that led to the creation of its scheme, its present form, and its future possibilities.

To achieve this, we will rely on three parameters, clustering, kernel-term width, and overlay visualization, to further interpret the network. At first, we determine two different clustering levels, general and specific, to categorize the terms. The two parameters that determine the size of each cluster are resolution and minimum
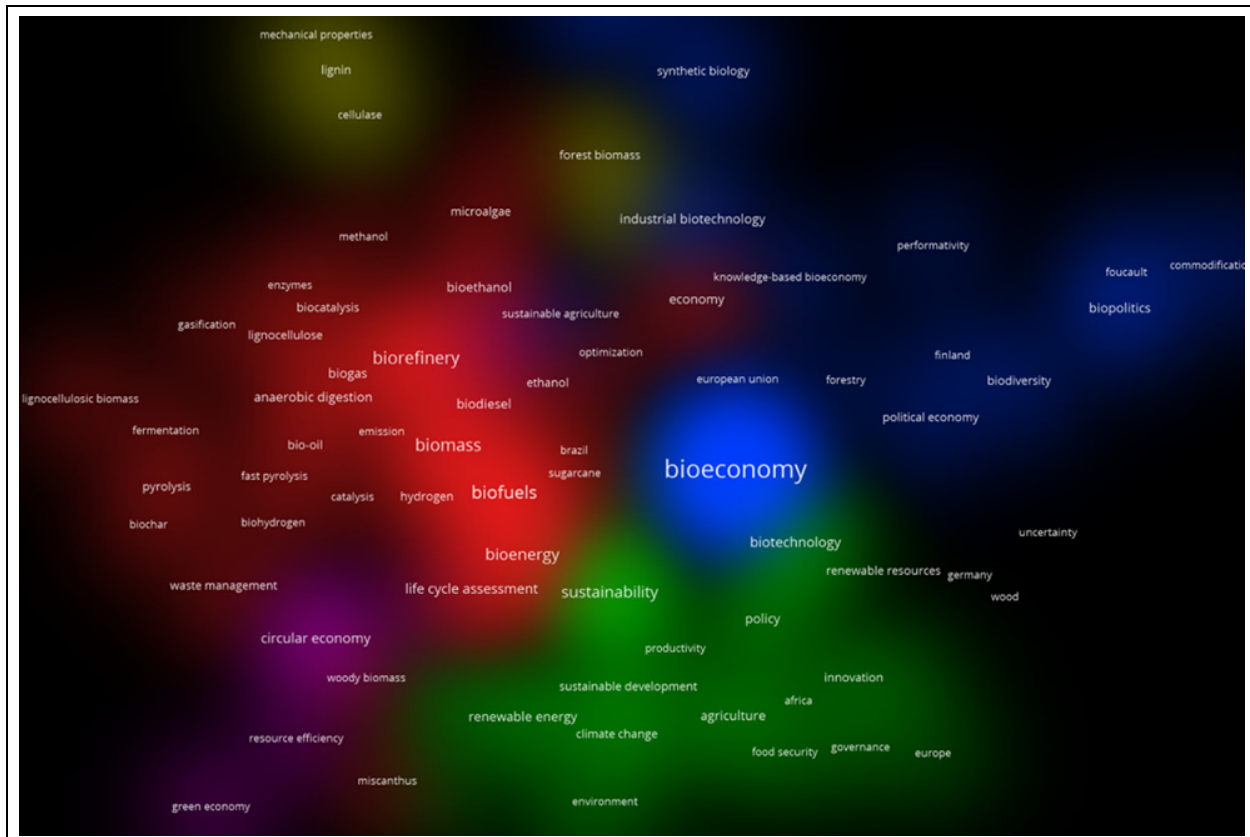
Figure 6. General clustering network.

cluster size. The lower the value of the resolution, the more generally the terms are grouped; low value of the resolution parameter means fewer and wider clusters. Similarly, the minimum cluster size defines the lower threshold of terms that a cluster must include; i.e., a minimum cluster size of 4 means that no cluster contains fewer than 4 terms. For our analysis, we have chosen resolution = 0.6 and minimum cluster size = 4 for the general clustering level and resolution = 1.4 and minimum cluster size = 3 for the specific clustering level. The general level contains six clusters (four main, two secondary) while the specific level contains 12 smaller clusters. The separation and names of the clusters have been selected by the authors by taking into account which organizational level of bioeconomy these clusters influence.

Cluster Density

General Clustering. VOSviewer by default also assigns the nodes in a network to clusters. A cluster is a set of closely related nodes (Figure 7). Each node in a network is assigned to exactly one cluster. The number of clus-

ters is determined by a resolution parameter. The higher the value of this parameter, the larger the number of clusters. In the visualization of a bibliometric network, VOSviewer uses colors to indicate the cluster to which a node has been assigned. The clustering technique used by VOSviewer is discussed by Waltman et al. (2010). The technique requires an algorithm for solving an optimization problem. For this purpose, VOSviewer uses the smart local moving algorithm introduced by Waltman and Van Eck (2013).

From the general clustering, we can distinguish four main clusters in Figure 6 and the terms they include, corresponding to the levels on which the bioeconomy is organized, as the authors defined: red = energy Demand, green = land demand, blue = governance, purple = interaction with other schemes. Table 3 contains the most central terms that characterize the cluster.

Specific Clustering. The Clusters 1-12 correspond to the second, more detailed, clustering. Table 4 classifies the detailed clusters to more general fields we defined above.
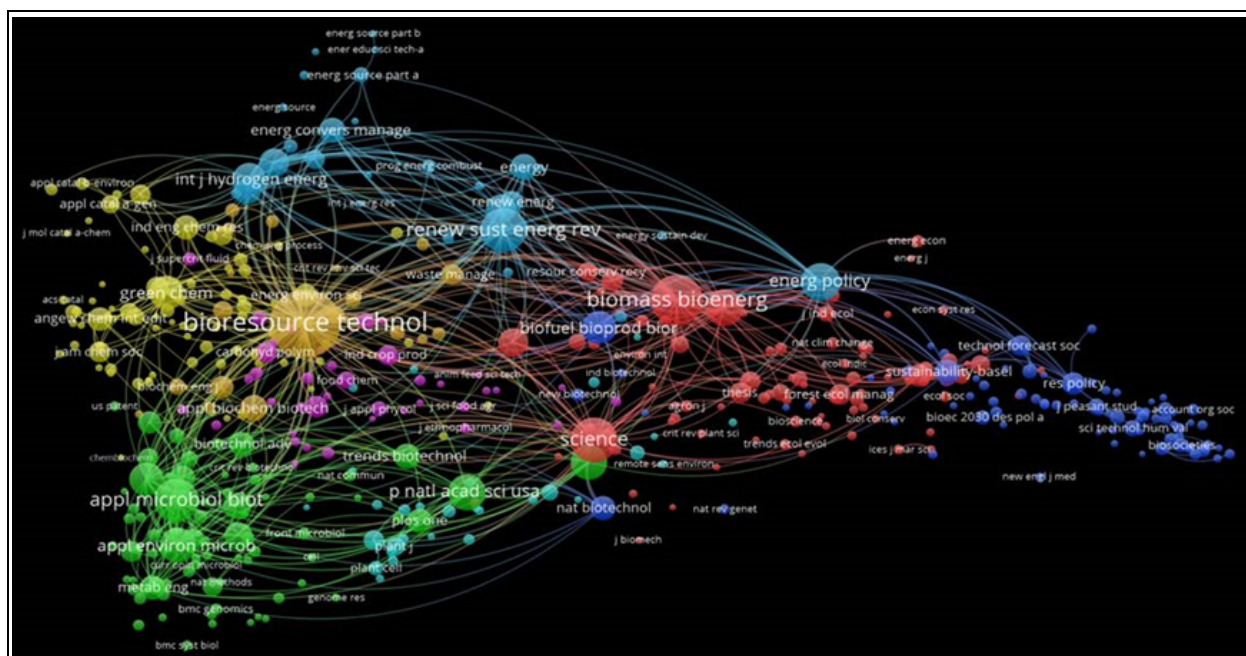
Figure 7. Most important nodes for specific clustering (Degree-Eigenvector Centrality).

Table 3. Main clusters, names attributed, and selected pivot elements.

Energy demand	Land demand	Governance	Interaction with other schemes
Biorefinery	Sustainability	Bioeconomy	Circular economy
Biomass	Biotechnology	Industrial biotechnology	Green economy
Biofuels	Agriculture	Biopolitics	
Bioenergy	Policy	Metabolic engineering	

- **Cluster 1:** biodiversity, bioeconomy, biopolitics, commodification, Finland, Foucault, neoliberalism, performativity, political economy, stem cells.
- **Cluster 2:** biochar, biomass, bioproducts, biorefinery, chemicals, fermentation, gasification, lignocellulose, lignocellulosic biomass, methanol, pyrolysis.
- **Cluster 3:** agriculture, climate change, energy, energy policy, environment, land use, natural

Table 4. Specific clusters related to main clusters.

	Cluster 2
	Cluster 7
Energy demand	Cluster 4
	Cluster 8
	Cluster 9
	Cluster 3
Land demand	Cluster 5
	Cluster 12
	Cluster 1
Governance	Cluster 6
	Cluster 11
Interaction with other schemes	Cluster 10

resources, renewable energy, research & development, sustainable development.
- **Cluster 4:** bio-oil, biodiesel, biofuels, biohydrogen, China, emission, fast pyrolysis, microalgae, photosynthesis, woody biomass.

Figure 8. Co-citation / cited sources/ fractional counting/ network visualization.

- **Cluster 5:** Africa, biotechnology, Europe, food security, governance, innovation, policy, regulation.
- **Cluster 6:** cell factory, Escherichia coli, European Union, industrial biotechnology, knowledge-based bioeconomy, metabolic engineering, sustainable agriculture, synthetic biology.
- **Cluster 7:** bioenergy, bioethanol, celloase, economy, forest biomass, lignin, market, mechanical properties.
- **Cluster 8:** Brazil, ethanol, extraction, life cycle assessment, miscanthus, optimization, productivity, sugarcane.
- **Cluster 9:** anaerobic digestion, biocatalysis, biogas, catalysis, enzymes, green chemistry, hydrogen.
- **Cluster 10:** circular economy, green economy, resource efficiency, waste management.
- **Cluster 11:** Germany, renewable resources, uncertainty, wood.
- **Cluster 12:** eco-economy, rural development, sustainability.

What we notice, at first glance, is that according to the scientific literature, bioeconomy is not a fully developed economic scheme; 44/92 terms of the network are science (technical) related, while the absence of socioeconomic terms is obvious. Bioeconomy is still techno-oriented.

The domination of technological aspects of bioeconomy can also be, clearly, pointed out by the Cited Sources network, as we observe in the following paragraph.

Co-citation / Cited Sources/ Fractional Counting. We use the Co-citation type of analysis parenthetically to emphasize the importance and domination of the tech-factor within the frame of bioeconomy.

As we can see in Figures 8 and 9, the majority of sources (and most important) related to bioeconomy are science-related, while the socioeconomic cluster is less dense at the right bottom of the density network. This confirms the previous claim of a techno-oriented bioeconomy.

In order to emphasize how directly the scheme of bioeconomy is connected to the different stages and levels of biotechnological maturity, we take as an example the following graph (Figure 10), which shows the environmentally-compatible agricultural bioenergy potential according to the EAA.

What we notice, at first glance, is the transition starting from 2010 and the crops for ethanol to 2020 and the crops for ligno-cellulosic ethanol and afterwards to 2030 the rise of the crops for biogas. As a start we will include a brief technical interpretation of these transitions and afterwards we will attempt a bibliometric network approach.
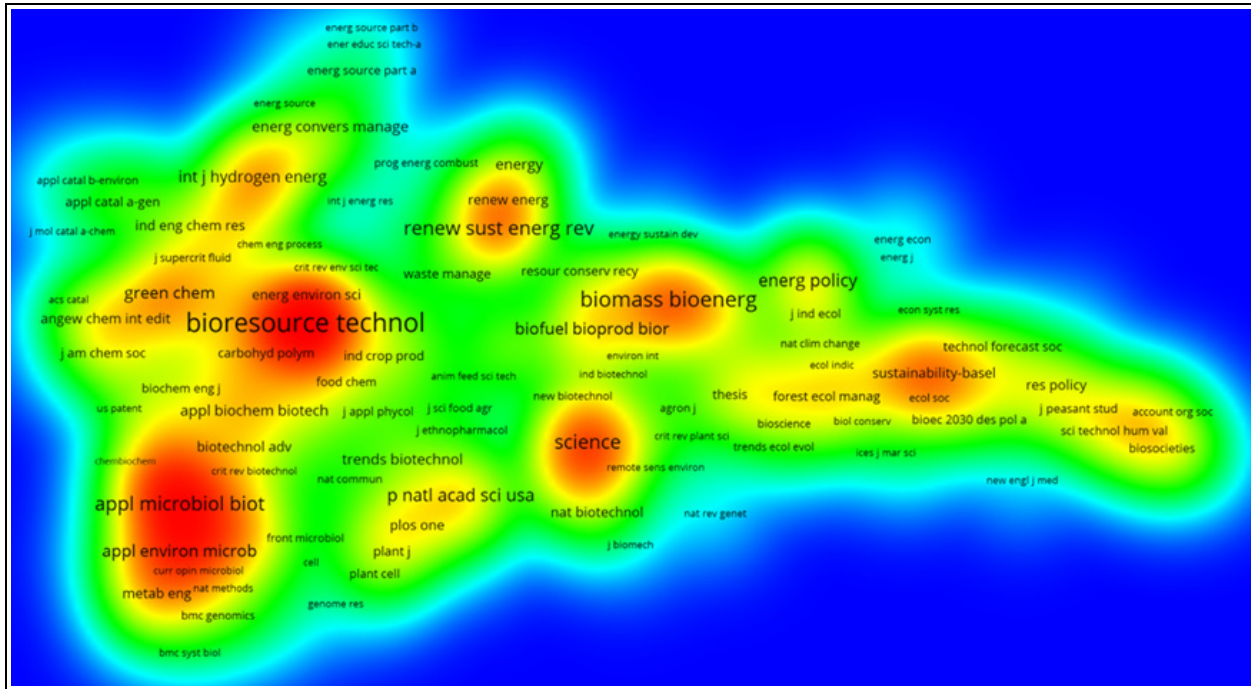
Figure 9. Co-citation/ cited sources/ fractional counting/ density visualization.
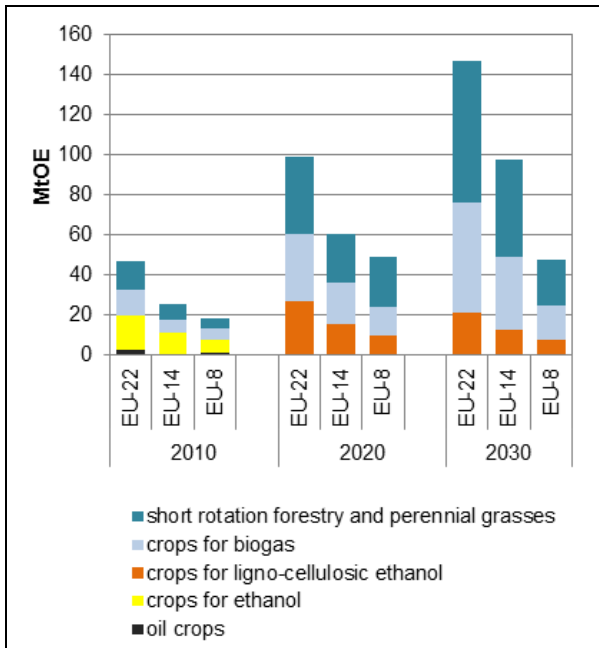

Figure 10. Environmentally-compatible agricultural bioenergy potential (EEA 2006).

Figure 11. Types of feedstock for ethanol production.
Source: Rutz and Janssen (2007)

The most important difference between the different types of feedstock for ethanol production is that the cellulose is the only one which is not used for feed (Figure 11). This constitutes a core differentiation under the scope of the globe's future population growth and, fur-
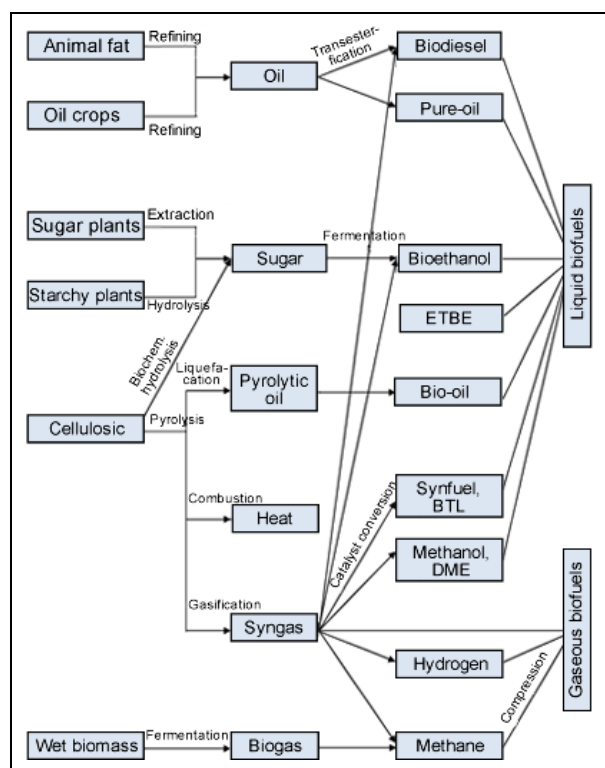
Figure 12. Pathways of different biofuels.
Source: Rutz and Janssen (2007)

thermore, is the most common carbon-containing element in the geosphere. Thus, the real question is "why was humanity not oriented towards this solution already before 2020?" The answer to this question comes from the diagram in Figure 12.

As we can observe, the conversion of sugar and starchy plants to bioethanol is a much simpler (and thus more economic) technical procedure compared to the conversion of cellulosic biomass, while the main technological impediment to more widespread utilization of lignocellulose for production of fuels and chemicals is the lack of low-cost technologies to overcome the recalcitrance of its structure (Van Zyl et al., 2007).

But, what kind of answers can we extract from the bibliometric network regarding those three elements (bioethanol, lingo-cellulosic ethanol, biogas)? In order to extend our analysis, we focused on those three different terms in our network. By putting those terms in the proper chronological framework, we can safely claim that the term bioethanol (2012) mostly refers to sugar and starch-produced bioethanol, the term lignocellulose to cellulosic biomass, while the term biogas does also include the term syngas as the biogas-node is, at the

same time, connected to the term anaerobic digestion (biogas) and gasification (syngas).

As we can see, the differences that we mentioned above are also imprinted, in an even more detailed way, in our network. The difference between bioethanol (Figure 13) and lignocellulose (Figure 14) is, indeed, the more developed relation between the lignocellulose node and the advanced-complex technologies such as metabolic engineering and biocatalysis. Furthermore, concerning the biogas node (which is related to lignocellulosic through syngas; Figure 15) the extremely interesting observation is its relation with 2017-set terms waste management and circular economy, which are connected to neither bioethanol nor lignocellulose.

To sum up our example, it is now clear how closely connected-dependent are the shape and pursuits of bioeconomy on the different stages of technology. Having said that, we could claim that the passing to greener future technologies passes through the today's technological status-quo. It is, thus, necessary to examine the possible synergies between the contemporary form of bio-technology and the transition, the self-reform, to a new one.

Item Density

The utility of the density visualization (van Eck & Waltman, 2009) is to trace the denser-central areas of the network. As expected, the denser point of the network is located around the bioeconomy node, due to the fact that the majority of the references is oriented towards that term (Figure 16). The interesting part, though, is that energy/fuel-related terms form a separate dense group of nodes next to the bioeconomy area.

We could assume that the group of those terms, although connected to the bioeconomy node, shows a relative autonomy. That autonomy indicates that those terms possess their own substance; they are not special features, invented by and intensively dependent on bioeconomy, but rather formed the actual scheme of today's bioeconomy and not the other way around.

Combining our earlier findings, we are allowed to claim that the transition to bioeconomy came almost naturally, resulting from the necessity of capitalism to give bio-solution, regarding the negative signs of resources insufficiency, to modern technical challenges especially in energy/fuel demand—consumption dipole.

Thus, the particular feature of the transition towards bioeconomy is that we cannot identify a radical multilayered turn, such as the transition from feudalism to capitalism through the industrial revolution, but rather a
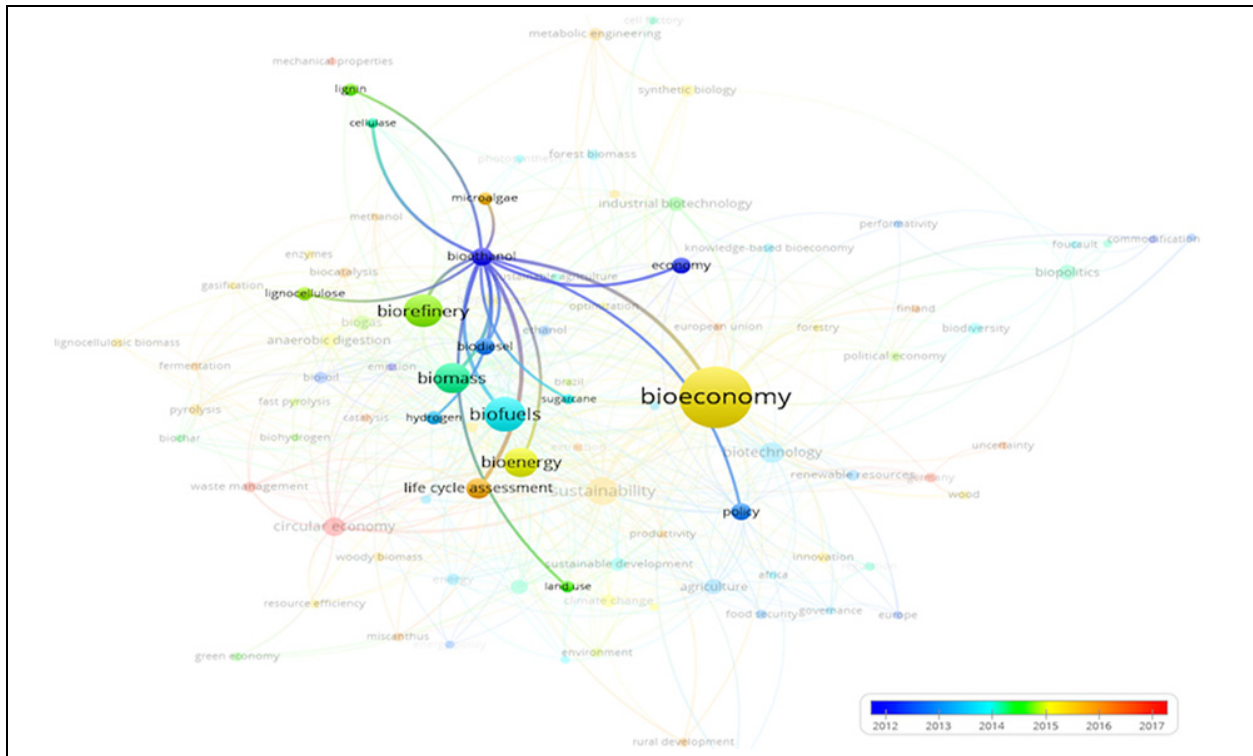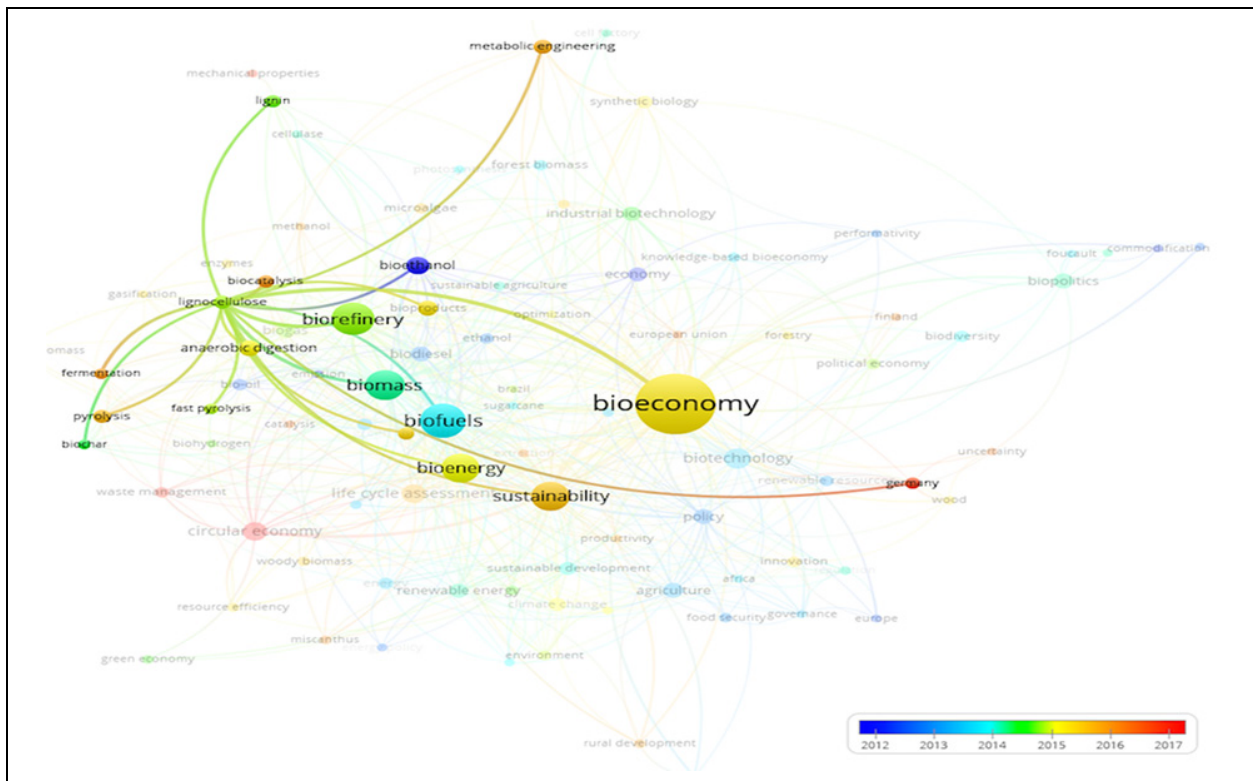
Figure 13. Bioethanol node.

Figure 14. Lignocellulose node.

Figure 15. Biogas node.

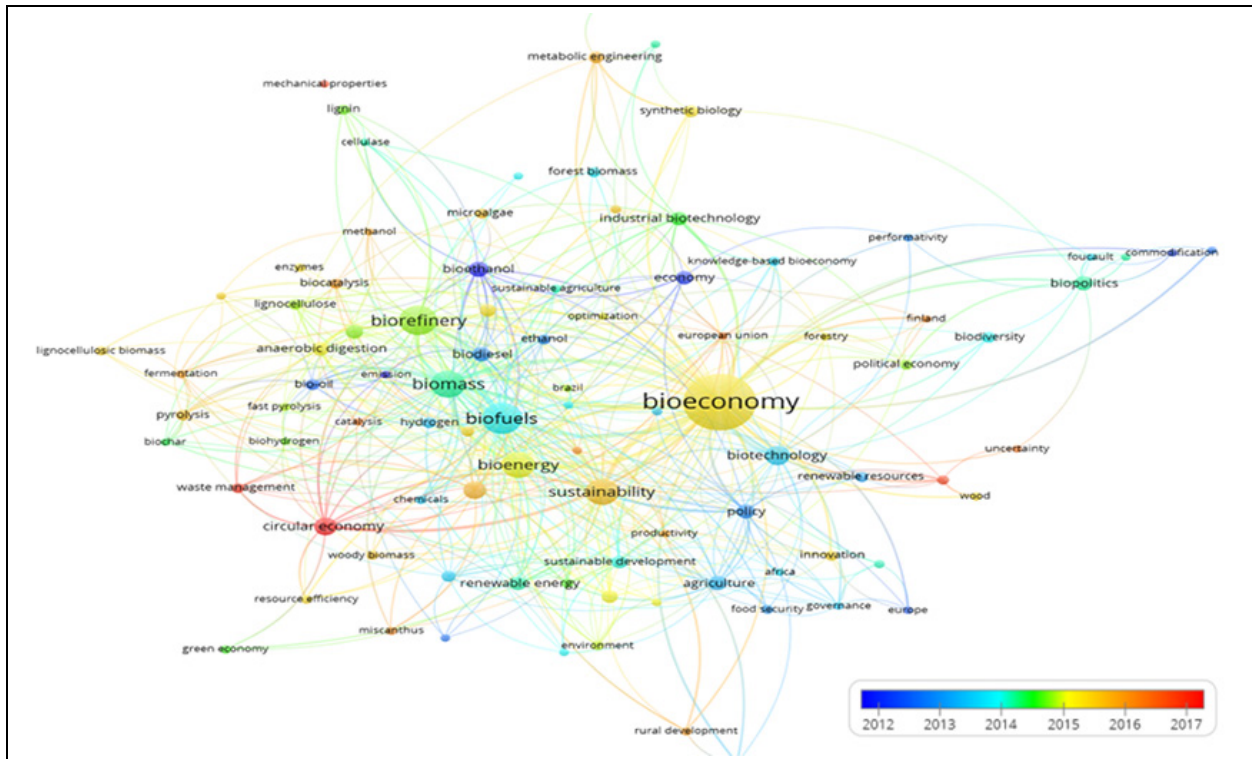**Figure 16. Bioeconomy network, kernel width.**

Figure 17. Bioeconomy network, Overlay visualization.

more sensible eco-management through the usage of means, tools, and inventions of traditional capitalism.

Overlay Visualization

By examining the overlay network, and the detection of the most important nodes (the term bioeconomy has been excluded) of the network through the statistic indices of degree and eigenvector centrality, we can come up with a chronological separation of bioeconomy in order to perceive it as a constantly evolving scheme.

We cannot claim with certainty from which one scientific literature and policy regulation proceeds; we could assume that there is an interactive relationship, an open dialogue between them. For example, the discussion, on a policy formation level, regarding the re-evaluation of previous policies induces a scientific effervescence which, through different pathways of inclusion, shapes the final scheme of the policy strategy. What we can safely support, is the rapid change of scheme; the different sovereign terms in each year reveals the dynamics of the scheme.

There are two possible hypotheses to explain the bioeconomy's current evolutionary state (Table 5). It either can be seen as a technocratic capitalistic trend or

Table 5. Time dimension and evolution of bioeconomy concept.

2013-2014	Biotechnology, biofuels
2014-2015	Biomass, biorefinery
2015-2016	Sustainability, life cycle assessment
2016-2017	Circular economy, waste management

it truly represents a step of a radical transition away from linear fossil-based model. The answer is given through the Overlay Visualization network which imports the parameter of time evolution (Figure 17). As we mentioned above, the central terms biomass, biofuels, and biorefinery were under discussion before the rising interest in bioeconomy which is observed after 2015. The central point, though, of the overlay visualization which needs to be pointed out is the relation of bioeconomy with circular economy, concerning that the node of circular economy is most cited during the last years. There are two possible scenarios which could explain this observation.

- First is the idea that bioeconomy cannot meet sustainability needs, claims, or aspirations (Székács, 2017), so a transition to a new economic model (cir-

cular economy) is inevitable (O'Brien, Wechsler, Bringezu, & Schaldach, 2017).

- The second hypothesis is that bioeconomy strengthens by collaborating with circular economy to overcome any internal efficacy issues.

In order to examine the possible scenarios, it is necessary to define the concept of circular economy and its differences from bioeconomy.
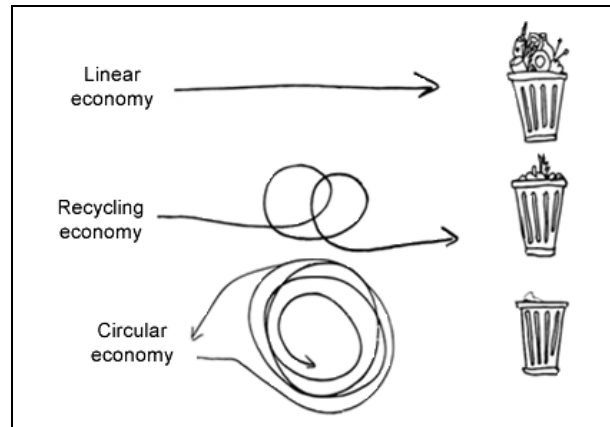
Circular Economy

The central idea of circular economy originates in two concepts, industrial ecology and industrial metabolism, dating from the 1970-80s; therefore, it cannot be considered as new. However, during recent years a rising interest of scientific literature on this matter is observed.

Industrial ecology (Frosch & Gallopoulos, 1989) sets the circular course/trajectory of materials and energy as its objective, which allows the re-creation of nature and, therefore, its preservation forever, while at the same time it tries to apply the gained knowledge to the industrial ecosystem. In simpler terms, the perfect analogy for industrial ecology is nature as the ideal factory or process in terms of conservation of resources and energy. Industrial symbiosis and industrial metabolism are basic categories of industrial ecology.

Industrial symbiosis (Chertow, 2007) originates from the branch of biology and the idea of symbiotic relations of mutual benefit, which develop, until recently, between non-cooperative species and ensure that all individual sides have the necessary energy and material to survive. The adaptation of the notion of symbiosis to the industrial branch can be interpreted as the cooperation of independent or even competitive companies with regard to the provision of raw materials or energy. Such a condition can prove to be particularly beneficial for the companies, which develop cooperative relations that can help mitigate any differences, as well as contribute to the overall viability and more even utilization of available resources. These resources cannot be considered as property of the companies, but of the community and, in that way, they can contribute to the financial, economic, and environmental prosperity of the societies they belong to.

Industrial metabolism, which was proposed by Ayres (1988), originated from the physical significance of metabolism in the human system, namely the necessary mechanisms of a cell, which allow it to bind and utilize the provided materials and energy in the optimal way in order to reproduce. The adaptation of that notion in


Figure 18. Sketching circular versus linear economy.
Source: École des Ponts, Business School, CERC

industry signals the evolution of the production process in fields which question the very character of production, as to lacking providence for future preservation, and suggest investing in knowledge about the holistic effect of resources on society and the actual place of production relative to the wider society in which it belongs.

In conclusion, circular economy marks a model different than the pre-existing one, which clearly separates itself both from the linear production process and from subsequent regulatory and partially interventional actions, such as recycling (Figure 18). Its main differentiation is that, while recycling defines the reusability of downgraded or partially used materials in a univocal way, circular economy focuses on value grades/tiers of materials and correlates the temporality of every process (cascading principle) with quantitative and qualitative data of other processes and creates complex, co-dependent temporal and quantitative-qualitative circular levels of production. Circular economy is an internal process, while recycling is an external one. This means that it requires the existence of an external relation-interaction with processes of a different kind than those from which the material came in the first place. As a result, a gap of utilization is created, which is a different temporal or modal production level and, as such, its quality is downgraded and useless materials and waste are produced.

On the contrary, circular economy focuses on the adaptation of individual productive processes with certain qualitative and quantitative characteristics, so-called value layers, of the products. Its implementation results in the adaptation of the materials to the process and the process to the materials.

Thus, the main difference that distinguishes bioeconomy from circular economy is that bioeconomy is
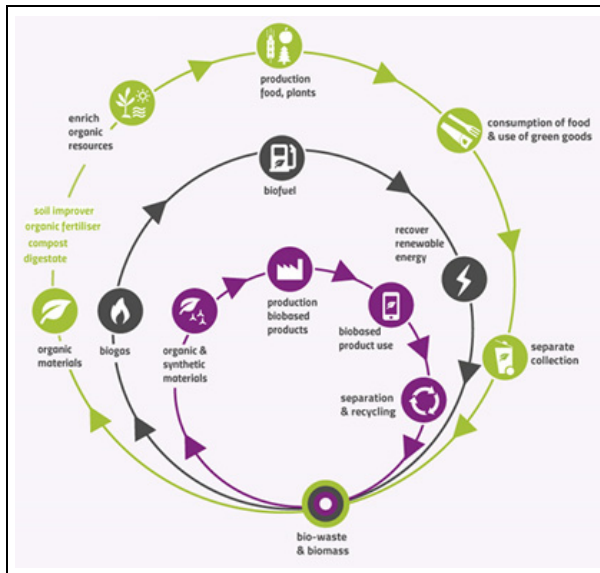
Figure 19. Biological cycle in the circular economy.
Source: European Compost Network

resource-dependent; the bio-nature of processed raw materials differentiates it from linear fossil-based model. Circular economy is process-dependent; its particular feature is the dependence on the circularity of the processes independently from the raw material.

We can now imagine that by creating synergetic relations between the two schemes both the "linear" and "fossil" term from the economy system would be eliminated. The idea of a circular bioeconomy could combine the acquired bioeconomy experience, the bio-technological innovative tools, and the bio-raw materials with the circular process mentality in order to create a self-feeding bio-processes model that will ensure both environmental sustainability and the full economic exploitation of raw materials. Thus, the idea of a circular bioeconomy must not be considered utopian as it combines inherent structural elements from both bioeconomy and circular economy (Figure 19). From the side of bioeconomy the bioresources are renewable due to the material circularity of nature while from the side of circular economy, its circular mentality is based on the imitation of the bioresource's behavior. The idea of a circular bioeconomy imprints a nature-mimic economy.

We can illustrate the synthesis of the above reasoning towards the so-called circular bioeconomy successor of the IT economy using as an example the sustainable development of bioenergy in China (Li, 2018). Through the integration of social network analysis and multi-level perspective theory, the evolution of bioenergy in Yangtze River Delta area, the most developed region in
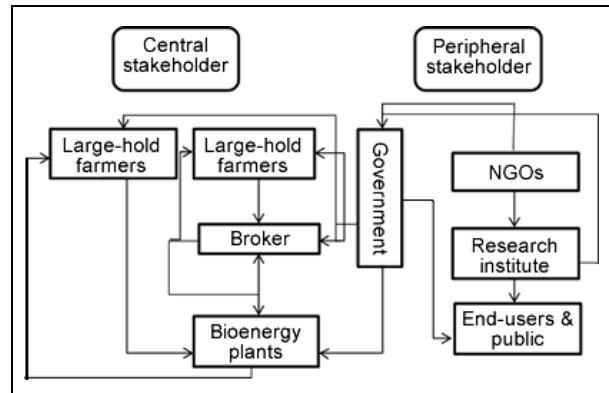
Figure 20. The social network of bioenergy stakeholders.

China, is analyzed and discussed. Some major elements and results of this study concern:

1. *Social network and Social network analysis of bioenergy stakeholders.*

   Through Social Network Analysis, the relationship among the stakeholders is a network which is based on central stakeholders who are involved in the material flow, drawn as influenced by multiple peripheral stakeholders (Figure 20). Through social network analysis, we summarized the aspects of bioenergy stakeholders' interaction that need to be improved: the material flows lack of commercial development experience, the bioenergy market has yet to develop a successful commercial model in the market, the key technologies of bioenergy production and utilization have not been advanced, and the policy system is scattered. Thus, it is difficult to form resultant force; the infrastructural storage and transportation system of bioenergy is not well established, the awareness of bioenergy in society is not sufficient. These are restricting the development of bioenergy.

2. *Dynamic analysis based on multi-level social network theory.*

   As shown in Figure 21 an integrated, multi-level social network model has been established to mimic the development of bioeconomy in China. China is under energy transition, and this profound social-economic change shapes the landscape at the macro level for bioenergy. The occurrence and development of biotechnology and bioenergy in niche level (micro level) and these innovations in niches level promotes related social revolutions in regimes (meso-level).
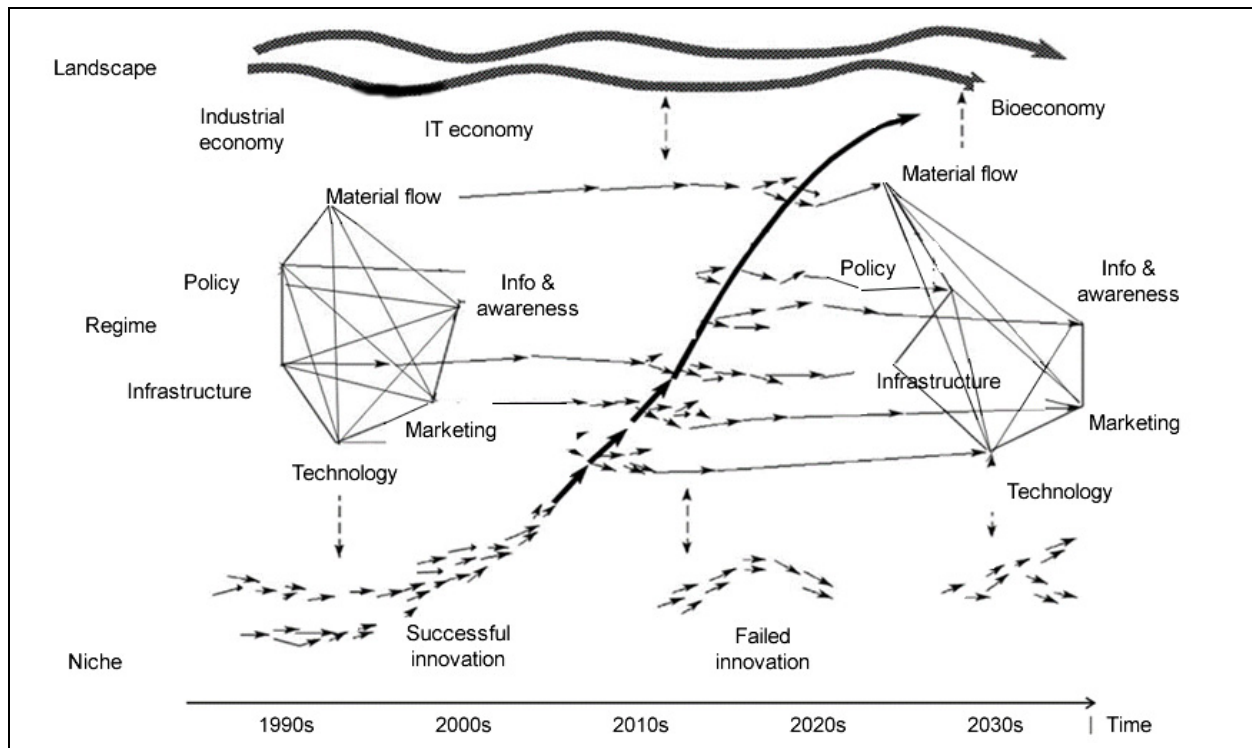
Figure 21. Multi-level social network.

Under the scope of Multi-level social network, we can analyze the gap between the Industrial economy era and bioeconomy era (Table 6), hence to predict or guide the development of social regimes.

Conclusions

As a start, if we should give a definition of bioeconomy, that would be "a constantly evolving, institutionally designed, economic model in which both economic and environmental sustainability is based on the renewability of bio-resources and whose structure is keenly related to different levels of technological maturity."

As shown previously, social and political economy terms are missing while energy demand terms cover a large, dense part of the network, indicating that social aspects of bioeconomy have not yet developed and remain within the frame of "bio-market." Furthermore, our overlay network analysis showed that the energy demand terms, which form a dense cluster next to bioeconomy, are mostly mentioned before the emergence of "bioeconomy" term. We can claim that bio-tech innovation and evolution eventually lead to the appearance of bioeconomy. Thus, according to the socio-tech imagi-

nary, those tech-related terms that shaped bioeconomy carry the pre-bioeconomy mentality and visions.

This conclusion on energy demand terms combined with analysis of national strategies constitute a complex and interesting motive for future research on how a technology-product, developed within the frames of a system that constantly seeks the deregulation of the institutional-state intervention, transforms the whole market structure towards purely regulated international and state-defined; Foucault, Davidson, and Burchell (2008) were probably accurate when they emphasized that "neoliberalism should not therefore be identified with laissez-faire, but rather with permanent vigilance, activity, and intervention."

We have summarized three major conclusions concerning the network analysis, and separate them according to the chronological order which corresponds to the past, present, and future of bioeconomy.

Past

The bioeconomy scheme was formulated by the same roots as the existing model as a necessity to respond to environmental and economic instabilities and a more and more intense awareness of the natural limits of the

Table 6. Multi-level social network analysis.

Elements of social regime	Industrial economy (IT economy)	Bioeconomy
Material flow	The centralized exploitation, long-distance transportation and centralized utilization of fossil fuels	Biomass will be harvested, processed and utilized on site
Technology	The harvest, transportation and utilization technology of bioenergy is not developed	Advanced bioenergy technology
Policy	The economy relied on the usage of fossil fuels, the policy is different depends on different authorities	Bioeconomy is the core of social development. Policy is clear and resonant
Infrastructure	Infrastructure to collect, store, and transfer is not well established, the electricity network is expanding from urban to rural	Well established collect, store and transfer system, rural area provides energy for the city
Marketing	Bioenergy is considered as supplementary energy, market is limited	Bioenergy is the base of the development of economy
Information and awareness	People have little knowledge and awareness of bioenergy	Bioenergy is broadly used and the concept of sustainable development is well accepted by public

geosphere. It is characteristic that it is not bioeconomy that invented the bio-oriented energy terms but rather the opposite way as shown both in Figures 16 and 17. The transition towards bioeconomy followed the biological law. According to the law, the accumulation of small, quantitative differentiations leads to qualitative differentiations. Respectively, small technical differentiations from the linear fossil-centered model, driven by objective environmental uncertainties, tend to reorient the whole structure of the model towards a new one. In the new model, some elements from the previous model will be sustained but radically distinctive qualitative parts which make the model a new one would also be contained.

Present

Today's form of bioeconomy acts on four main levels that we set as: energy demand, land demand, governance, and interaction with other schemes, presented with the most central terms that they include.

Future

The overlay network showed that the most recent scientific references relate bioeconomy with circular economy. We analyzed the meaning of circular economy and we suggested that the ideal scenario would be a synergetic relation of bioeconomy and circular economy that would relate the bio-resource bioeconomic principle with the circular-processes mentality of circular economy, which would abolish both the "linear" and "fossil" terms from production.

References

Ayres, R.U. (1988). Barriers and breakthroughs: An "expanding frontiers" model of the technology—Industry life cycle. *Technovation*, *7*(2), 87-115.

Biomass Research and Development Board. (2018, October). *The bioeconomy initiative: Implementation framework* (DOE/EE-1865). Washington, DC: Author. Available on the World Wide Web: https://biomassboard.gov/pdfs/Bioeconomy_Initiative_Implementation_Framework_FINAL.pdf.

Bonacich, P. (1987). Power and centrality: A family of measures. *American Journal of Sociology*, *92*(5), 1170-1182.

Borg, I., & Groenen, P. (2003). Modern multidimensional scaling: Theory and applications. *Journal of Educational Measurement*, *40*(3), 277-280.

Bringezu, S., Ramaswami, A., Schandl, H., O'Brien, M., Pelton, R., Acquatella, J., et al. (2017). *Assessing global resource use: A system approach to resource efficiency and pollution reduction* (Report). Nairobi: United Nations Environment Programme.

Bugge, M., Hansen, T., & Klitkou, A. (2016). What is the bioeconomy? A review of the literature. *Sustainability*, *8*(7), 691.

Chertow, M.R. (2007). "Uncovering" industrial symbiosis. *Journal of Industrial Ecology*, *11*(1), 11-30.

European Commission. (2012). *Innovating for sustainable growth: A bioeconomy for Europe*. Brussels: European Commission.

Foucault, M., Davidson, A.I., & Burchell, G. (2008). *The birth of biopolitics: Lectures at the Collège de France, 1978-1979*. Springer.

Frosch, R.A., & Gallopoulos, N.E. (1989). Strategies for manufacturing. *Scientific American*, *261*(3), 144-153.

Grafton, R.Q., Kompas, T., & Van Long, N. (2012). Substitution between biofuels and fossil fuels: Is there a green paradox? *Journal of Environmental Economics and Management*, *64*(3), 328-341.

Kalamaras, D. (2014). Social Networks Visualizer (SocNetV): Social network analysis and visualization software. *Social Networks Visualizer.*

Koschützki, D., Lehmann, K.A., Peeters, L., Richter, S., Tenfelde-Podehl, D., & Zlotowski, O. (2005). Centrality indices. In *Network analysis* (pp. 16-61). Berlin: Springer.

Levidow, L., Birch, K., & Papaioannou, T. (2012). EU agri-innovation policy: Two contending visions of the bio-economy. *Critical Policy Studies*, *6*(1), 40-65.

Li, Y. (2018). *Study of dynamic evolvement of bioenergy industry based on multi-level social network theory* (Master's thesis). Shanghai: Fudan University.

O'Brien, M., Wechsler, D., Bringezu, S., & Schaldach, R. (2017). Toward a systemic monitoring of the European bioeconomy: Gaps, needs and the integration of sustainability indicators and targets for global land use. *Land Use Policy*, *66*, 162-171.

Organisation for Economic Co-operation and Development (OECD). (2009). *The bioeconomy to 2030: Designing a policy agenda*. Paris: OECD Publishing.

Rutz, D., & Janssen, R. (2007). Biofuel technology handbook. *WIP Renewable Energies*, *95*.

Székács, A. (2017). Environmental and ecological aspects in the overall assessment of bioeconomy. *Journal of Agricultural and Environmental Ethics*, *30*(1), 153-170.

The White House. (2012, April). National bioeconomy blueprint. *Industrial Biotechnology*, *8*(3), 97-102.

Thompson, J.B. (1982) Ideology and the social imaginary: An appraisal of Castoriadis and Lefort. *Theory and Society*, *11*(5), 659-681.

United Nations (UN), Department of Economic and Social Affairs (DESA). (2010). *World population prospects: The 2008 revision*. New York: UN DESA, Population Division.

van Eck, N., & Waltman, L. (2009). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523-538.

Van Zyl, W.H., Lynd, L.R., den Haan, R., & McBride, J.E. (2007). Consolidated bioprocessing for bioethanol production using Saccharomyces cerevisiae. In *Biofuels* (pp. 205-235). Berlin: Springer.

Waltman, L., & Van Eck, N.J. (2013). A smart local moving algorithm for large-scale modularity-based community detection. *The European Physical Journal B*, *86*(11), 471.

Waltman, L., Van Eck, N.J., & Noyons, E.C. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics*, *4*(4), 629-635.

Wiegmann, K., Fritsche, U., & Elbersen, B. (2005). Environmentally compatible biomass potential from agriculture (Consultancy report to the EEA). Copenhagen: European Environment Agency (EEA).

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