Chapter 3
The Emergence of Bioeconomy in the 6th Kondratiev Wave of Change: A Horizon Scanning-Based Approach

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Abstract This paper reports research results on the assessment of the emergence of bioeconomy as part of the mega-wave of socio-technical change that has taken off with the global financial crisis of ca. 2008 and is expected to peak around 2030. The appearance of bioeconomy-related phenomena on this wave is strongly related to the formation of clusters of opportunities, problems and other key factors. Nine such clusters were identified with the use of previous foresight exercises following the Horizon Scanning approach, with the help of a specially designed for the needs of this work Questionnaire, focusing on major expectations, worries and modes of action. A tenth, "mystery" cluster was found necessary to cover collectively the effects of disrupting factors. The various interactions of the identified clusters can explain the so far sporadic and sometimes inconsistent observations on the emergence patterns of bioeconomy as part of a Kondratiev Wave.

Keywords Bioeconomy · Foresight · Horizon Scanning · Kondratiev waves · Problems · Opportunities · Actions · Clusters

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E. Koukios, A. Sacio-Szymańska (eds.), *Bio#Futures*,
https://doi.org/10.1007/978-3-030-64969-2_3

1 Introduction

1.1 Defining Bioeconomy

The term "bioeconomy" includes all industrial and economic sectors that produce, manage and otherwise exploit biological resources, and related services, supply or consumer industries, including the following major examples (European Commission 2012; Cichocka et al. 2010):

- Agriculture, fisheries, forestry, aquaculture
- Agro-food, wood, fibre and other bio-industries
- Human and animal health, pharmaceuticals
- Biochemicals, biomaterials, "green" bio-chemistry
- Bioenergy, biofuels, other bio-products
- Bio-remediation, bio-waste management
- Bio/eco-systems management, rural development

1.2 A Lot at Stake

According to various indications (Koukios 2017), the new mega-wave of socio-technical change, expected to peak after 2030, will include the emergence of bio-economy, i.e. the whole spectrum of applications of biological sciences and technologies in all socio-economic areas and sectors, radically transforming our societies and the world as we know it.

The object of the research presented in this chapter is to foresee, map and assess the emergence of this great wave we call *BIO-TSUNAMI*, thus preparing societies to harness its huge potential for health, work, prosperity and quality of life, while avoiding getting crashed by its risks and side-effects.

Recent research activities by our group include the identification of critical technological breakthroughs affecting the bio-tsunami's emergence, and the socio-economic clusters describing its main pathways of social change (Koukios and Sacio-Szymańska 2018).

1.3 Risks and Opportunities

The emergence of bioeconomic applications is linked with a great number of strategic opportunities, and major risks and threats for Europe and the World (European Commission 2010; Koukios et al. 2005; Koukios 2015):

- The former includes a great innovation potential; environmental "greening"; mitigation of climatic change effects; substitution of fossil fuels; generation of

employment; food quality and safety; growth of new SMEs and other businesses; policy coordination; regional development and smart specialization; and international cooperation.
- The latter list soil erosion and desertification; high-intensity farming; food imbalance (malnutrition vs. wastes); food chain and water supply risks; societal reactions to some biotechnologies; extreme pressure on resource; dominant culture of youth and beauty at all costs; centralized governance of systems; unauthorized use of genetic information; and bio-ethics.

1.4 Research Objective

The target of the work reported here is to initiate a foresight exercise on the emergence of bioeconomy, considered as a fast-approaching mega-wave of socio-technical transformation, following the Information and Communication (ICT) one, and defined as "bio-tsunami", which is built by a wide spectrum of converging elements, clusters and fields: biology, biotechnology, bio-engineering, new agriculture, novel foods, health, quality of life, cosmetics, bioenergy, environment, water, sustainability, education, knowledge management, design of smart applications and more. The bio-tsunami tends to "absorb" selective elements from the previous one, thus multiplying its power and enhancing its applications range, e.g. in bio-informatics.

2 Methodology

2.1 Riding the Kondratiev Wave of Change

The model of socio-technical change adopted in this work is that of Kondratiev's (K) long cycles, of 40–60 years each, starting since the industrial revolution. According to this concept, the K1 wave, dominated by textile and other industries, deployed between 1771 and 1829; K2, powered by steam and railroads, ran in 1829–1875; K3, driven by steel and heavy engineering, ran in 1875–1908; K4, dominated by petroleum, electricity, automobiles and mass production ran in 1908–1970; K5 was driven by information and telecommunication, in the period 1970–2010; and finally, K6 is the current wave (2010–2050?), which is to be explored for its bioeconomic elements (Nefiodow and Nefiodow 2014; Wilenius 2017).

In the first step of our approach, we reviewed the existing literature on the present Kondratiev Wave (K6) and identified wave features having any relevance with bioeconomy. In Table 3.1, we summarize the results of our literature survey of K6 elements relevant to bioeconomy, either directly or indirectly, i.e. through interaction

Table 3.1 Main literature suggestions for K6 elements

Health, especially Holistic Health Applications
Psycho-Social Health
Biotechnology
Biomedical Applications
Nano-Molecular Applications
Nuclear Energy Developments
Renewable Energy Breakthroughs
Hydrogen Energy
Robotics, Intelligent Machines
Artificial Intelligence
New Leadership and Management
ICT to support the above – Post-Info Applications
Converging Technologies (info-bio-nano, etc.)

Source: Nefiodow and Nefiodow (2014), Wilenius (2017), Mason (2015), Goldschmidt and Hilbert (2009), Smihula (2010), Wilenius (2014), Toffler (1980)

and convergence. From that list we can see that there is no clear pattern of bioeconomy emergence, with some authors even almost eliminating bioeconomy from their describing of K6 actions (Mason 2015; Goldschmidt and Hilbert 2009).

2.2 Horizon Scanning Approach

The method selected for the foresight of the bioeconomy emergence during K6 is the Horizon Scanning one (Horizon Scan Report 2007; OECD 2016). Specifically, we have assessed the available information on the problems and the opportunities as identified from previous Horizon Scans, having the same or a similar time horizon, in order to isolate the most relevant, directly or indirectly, to bioeconomy (OECD 2009a, b; Koukios 2014; Geels and Schot 2007).

In addition, we have used a tailored designed Questionnaire, shown in Table 3.2, in order to focus on the expectations, the worries and the preferred modes of action of experts and lay persons, including students and other youth. More than 100 responses were collected in the period of March–June 2017, from audiences in Poland, Greece and Italy.

The various types of parameters used in our analysis of the Horizon Scanning process are described by the following symbols:

A: FOCUS ON EXPECTATIONS according to Questionnaire
B: FOCUS ON WORRIES according to Questionnaire
C: FOCUS ON PROPOSED ACTIONS according to Questionnaire
P: PROBLEMS identified by Horizon Scanning
O: OPPORTUNITIES identified by Horizon Scanning

Following the identification of the most relevant to bioeconomy features, a number of Clusters will be put together, consisting of appropriate combinations of A, B, C, P and O.

Table 3.2 Questionnaire on major bioeconomic driving forces and barriers

The term "Bioeconomy" refers to the applications of biological sciences and technologies to Economy and Society. To help our project tentatively map such a complex landscape, please share with us your related major wishes and visions, as well as fears and threats.
A. **EXPECTATIONS** (*Please, select no more than 4 of the following*):
A1. Achievement of longevity _____
A2. Fighting of serious illnesses _____
A3. Quality foods – Fighting hunger and obesity _____
A4. A new generation of cosmetics _____
A5. Clean biofuels _____
A6. New bio-materials for quality of life _____
A7. Reproduction and regrowth of organs _____
A8. Protection of environment and ecosystems _____
A9. New employment possibilities _____
A10. Regional development _____
A11. New national development model _____
A12. Other (please, explain) _____
B. WORRIES (*Please, select no more than 4 of the following*):
B1. Hyper-intensive farming of plants/animals/others _____
B2. Genetically modified foods _____
B3. Cloning/genetic improvement of humans _____
B4. A culture of beauty and youth at any cost _____
B5. Biological weapons – Bio-risks _____
B6. Domination of large multi-national companies _____
B7. Control of bio-innovations through patents _____
B8. Increase of unemployment due to new technologies_____
B9. Lack of protection of personal biological data _____
B10. Bio-ethics and morality issues _____
B11. Other (please, explain) _____
C. PROPOSED ACTIONS (*Please, select no more than 3 of the following*):
C1. Research and innovation _____
C2. New investment projects _____
C3. New forms of project financing _____
C4. Environmental management _____
C5. Social tasks and initiatives _____
C6. Education and training _____
C7. Art and culture _____
C8. Youth initiatives _____
C9. Integrated policy framework _____
C10. Citizens information/awareness _____
C11. Other (please, explain) _____

3 Results and Discussion

3.1 Identification of the Most Relevant to Bioeconomy Opportunities

Table 3.3 presents the results of our assessment of the list of 73 opportunities already identified by Horizon Scanning (HSc) from the point of view of our foresight study, i.e. regarding the emergence of bioeconomy (Wilenius 2014; OECD 2009b).

Table 3.3 List of very high bioeconomy relevance opportunities identified by HSc

O01	ATMOSPHERE: Climate change
O05	HYDROSPHERE: Minerals and gas hydrates from ocean floor
O08	BIOSPHERE: Inspiring life processes
O09	BIOSPHERE: Focused development of marine and other wild environments
O10	BIOSPHERE: (Re-) creating a living environment can contribute to more life
O11	BIOSPHERE: Intervention in humankind's own evolution
O17	FOOD – AGRICULTURE: Strategic function agriculture
O18	FOOD – AGRICULTURE: Modern craftsmanship
O19	FOOD – AGRICULTURE: Healthy, eating patterns-based, functional foods
O24	HEALTH CARE: Monitoring/developing vaccines for infectious diseases
O26	HEALTH CARE: Preventive medicine
O28	ENERGY PRODUCTION: Robust strategy for energy supply
O33	SCIENCE & TECHNOLOGY: Threats as leitmotif for innovation
O34	SCIENCE & TECHNOLOGY: Promising new fields of science
O35	SCIENCE & TECHNOLOGY: Converging technologies (CT)
O36	SCIENCE & TECHNOLOGY: CT for human cognition and communication
O37	SCIENCE & TECHNOLOGY: CT to improve health and physical capacities
O38	SCIENCE & TECHNOLOGY: CT to improve group and social processes
O39	SCIENCE & TECHNOLOGY: National security
O44	SCIENCE & TECHNOLOGY: Understand disease with developmental biology
O45	SCIENCE & TECHNOLOGY: Biological research into pathogens
O46	SCIENCE & TECHNOLOGY: Biomedicine and the prolongation of life
O49	EDUCATION: Educational system keeping up with global knowledge increase
O50	EDUCATION: Creativity in education
O53	SOCIAL, FAMILY, WORKING LIFE: Ageing as Silver Fleet
O54	SOCIAL, FAMILY, WORKING LIFE: Ageing actively
O59	NATIONAL ECONOMY: Employment at all education levels
O60	NATIONAL ECONOMY: Country branding
O61	NATIONAL ECONOMY: The right economic growth
O63	NATIONAL ECONOMY: Entertainment industry
O64	NATIONAL ECONOMY: Wellness
O65	NATIONAL ECONOMY: No use made of unique features
O67	NATIONAL ECONOMY: New technical products and services

The level of the bioeconomic relevance of each opportunity was expressed on a five-level scale (where + = Very Low, ++ = Low, +++ = Moderate, ++++ = High and +++++ = Very High). The 33 factors listed in Table 3.3 (45% of the total) are those ranked at the top level of the assessment. The numbers of the opportunities are those of the initial list in the literature (Horizon Scan Report 2007). The capital letters indicate the respective section of the opportunities list, whereas the identified opportunity is shown in lower case letters.

3.2 Identification of the Most Relevant to Bioeconomy Problems

Table 3.4 presents the results of our assessment of the list of 86 risks and problems already identified by Horizon Scanning (HSc), from the point of view of our foresight study, i.e. regarding the emergence of bioeconomy (Wilenius 2014; Toffler 1980; Horizon Scan Report 2007; OECD 2016, 2009a, b).

The level of the bioeconomic relevance of each problem was expressed on a five-level scale (where + = Very Low, ++ = Low, +++ = Moderate, ++++ = High and +++++ = Very High).

The 21 factors listed in Table 3.3 (25% of the total) are those ranked at the top level of the assessment. The numbers are those of the initial list (Horizon Scan Report 2007). For the use of capital and lower case letters, see above.

3.3 Identification of the Most Popular Options for the Emergence of Bioeconomy

Table 3.5 presents some results from the use of the Questionnaires. The spread of the responses was such that almost all options appear to be statistically significant. The relative emphasis of responses was given to opportunities, followed by actions to be taken and less so on risks and problems. The latter seem to be linked to unexpected/disrupting factors. Another interesting finding of the Questionnaires was their potential to express the attitude of the responding by their answer profile.

Table 3.4 List of very high bioeconomy relevance problems identified by HSc

P11	BIO-SPHERE: Loss of natural resources
P13	BIO-SPHERE: Infectious diseases constitute a permanent threat
P19	FOOD – AGRICULTURE: Hunger
P20	FOOD – AGRICULTURE: Obesity increases
P36	SAFETY AND EMERGENCY SYSTEMS: Crisis control
P37	SECURITY: No rational security policy
P41	BUSINESS OF S&T: Insufficient knowledge management
P42	BUSINESS OF S&T: The leading role of Europe is in danger
P43	BUSINESS OF S&T: Threat to intellectual property rights
P44	BUSINESS OF S&T: Decreasing confidence in science
P45	SCIENCE & TECHNOLOGY: New risks, ethical issues and social problems
P46	SCIENCE & TECHNOLOGY: Custom-made man
P47	SCIENCE & TECHNOLOGY: Developments give criminals opportunities
P48	SCIENCE & TECHNOLOGY: Robots ousting humans
P50	EDUCATION: Insufficient educational level of population
P51	EDUCATION: Educational system not attuned to the educational biography
P78	INTERNATIONAL SYSTEM: International agreements on tech developments
P79	TENSIONS: Shortage, a breeding ground for conflicts
P83	NATIONAL STATE: Lack of government, business and social partnerships
P84	NATIONAL STATE: Insufficient reflexive/strategic capacity of governments

Table 3.5 List of the ten most significant Questionnaire results

A1	Achievement of longevity
A2	Fighting of serious illnesses
A3	Quality foods – Fighting hunger and obesity
A8	Protection of environment and ecosystems
B3	Cloning/genetic improvement of humans
B10	Bio-ethics and morality issues
C1	Research and innovation
C6	Education and training
C9	Integrated policy framework
D	Other priorities indicated by survey participants and literature (see Table 3.6, below)

Symbols as defined in Table 3.2

Table 3.6 Possible disrupting trends (D) for bioeconomy in the period 2016–2018

(a) Disrupting socio-economic trends relevant to bioeconomy	
D1.	In the new brand experiences are more important than products
D2.	Shift from sharing economy to on-demand economy
D3.	Digital Darwinism of Companies towards social trends
D4.	Dynamic customers change brand dynamics away from legacy strategies
D5.	New jobs for tasks that computers need humans to complete – education as a constant
D6.	Marketing–innovation–technology–Human Resources synergies
D7.	Shift from R&D Departments to Innovation Centres
D8.	Investing in Culture 2.0!
D9.	Businesses operate under radical transparency to gain trust by customers
D10.	Schools pay students to learn how to become agents of expertise
(b) Disrupting technology trends relevant to bioeconomy	
D11.	Web transformed by mobile-first behaviour
D12.	The new Machine Age – Intelligent systems for all everyday life and work uses
D13.	From reactive to proactive medicine
D14.	Plugging tech into the Human Operating System (HOS) to create new "ecosystems"
D15.	Vertical uses of drones for care, delivery, exploration and more
D16.	3D printing applications disrupting supply chains in vertical industries
D17.	Autonomous, self-driving cars transforming transportation and infrastructures
D18.	Experiences get real virtual by immersive computing and next-gen imaging
D19.	In-home battery systems for eco-friendly power of households and cars
D20.	Smart fabrics and bluetooth tech in clothing for body and environment control

Source: Solis (2013)

3.4 Clustering of Opportunities, Problems and Actions

By combining the results of the previous two tables and those of the Questionnaire, we have been able to identify among the huge number of possible combinations (more than half a million) the following nine Clusters of socio-technical action (Geels and Schot 2007).

In parenthesis, we suggest the use of an appropriate for each Cluster symbolic figure taken from history, literature or mythology (Kereńyi 1951).

With asterisks (*) we indicate factors shared between Clusters.

CLUSTER #1: The Silver Society (Gilgamesh)
This cluster is formed by a rather small, but clear – and clearly opportunistic – presence on the horizon of the emerging bioeconomy.

A1 Achievement of longevity
O46 SCIENCE & TECHNOLOGY: Biomedicine and the prolongation of life
O53 SOCIAL, FAMILY, WORKING LIFE: Ageing as Silver Fleet
O54 SOCIAL, FAMILY, WORKING LIFE: Ageing actively

The story of Gilgamesh, the hero who wished eternal life to find out its limitations, could serve as an appropriate lesson to be learnt from the "silver" vision of longevity.

CLUSTER #2: The Cure and Care Economy (Aesculapius)
This cluster shows also a strongly opportunistic presence on the horizon of the emerging bioeconomy, with the exception of just one problem-limitation (P13) that could come as a warning: beware of the permanent threat of infectious diseases.

A2 Fighting of serious illnesses
P13 BIO-SPHERE: Infectious diseases constitute a permanent threat
O24 HEALTH CARE: Monitoring/developing vaccines for infectious diseases
O26 HEALTH CARE: Preventive medicine
O37 SCIENCE & TECHNOLOGY: CT to improve health and physical capacities
O44 SCIENCE & TECHNOLOGY: Understand disease with developmental biology
O45 SCIENCE & TECHNOLOGY: Biological research into pathogens

The case of Aesculapius – the founder of medicine and proponent of a holistic approach - could serve as the key lesson to accompany the emergence of a Cure-and-Care approach.

CLUSTER #3: The Horn of Affluence (Amalthea)
This cluster shows a more balanced emergence, as its foreseen opportunities appear to be of equal power to its scanned problems, in clear contrast to the Health Cluster.

A3 Quality foods – Fighting hunger and obesity
B1 Hyper-intensive farming of plants/animals/others
B2 Genetically modified foods
P19 FOOD – AGRICULTURE: Hunger
P20 FOOD – AGRICULTURE: Obesity increases
O17 FOOD – AGRICULTURE: Strategic function agriculture
O18 FOOD – AGRICULTURE: Modern craftsmanship
O19 FOOD – AGRICULTURE: Healthy, eating patterns-based, functional foods

The story of Amalthea, the sacred goat who secretly fed the hiding baby Zeus, offering him a Horn of Affluence full of the food of gods, could serve as the key symbol of the role of nutrition.

CLUSTER #4: The Garden of Mother Earth (Gaia)

This is the cluster of Green and Sustainable Development, full of opportunities, with just a touch of management and some pressure on resources. The list of features covers a variety of "Green" applications, with emphasis on energy.

A5 Clean biofuels
A6 New bio-materials for quality of life
A4 A new generation of cosmetics
A8 Protection of environment and ecosystems
C4 Environmental management
P11 BIO-SPHERE: Loss of natural resources
O01 ATMOSPHERE: Climate change
O05 HYDROSPHERE: Minerals and gas hydrates from ocean floor
O09 BIOSPHERE: Focused development of marine and other wild environments
O28 ENERGY PRODUCTION: Robust strategy for energy supply
O64 NATIONAL ECONOMY: Wellness
O67 NATIONAL ECONOMY: New technical products and services*

The case of Gaia represents a story of the Garden of Eden revisited, in which the green-ness could concern several elements of the emerging bioeconomy: resources, processes, products, services, social practices, etc.

CLUSTER #5: The Green Governance (Nemo)

This cluster is one of the richest in converging elements, including several Action and Management options. In addition, the cluster appears well balanced with respect to problems and opportunities – in contrast to some of the other clusters.

A11 New national development model
A10 Regional development
A9 New employment possibilities
B8 Increase of unemployment due to new technologies
C2 New investment projects
C3 New forms of project financing
C9 Integrated policy framework
P48 SCIENCE & TECHNOLOGY: Robots ousting humans
P78 INTERNATIONAL SYSTEM: International agreements on tech developments
P83 NATIONAL STATE: Lack of government, business and social partnerships
P84 NATIONAL STATE: Insufficient reflexive/strategic capacity of governments
O59 NATIONAL ECONOMY: Employment at all education levels
O60 NATIONAL ECONOMY: Country branding
O61 NATIONAL ECONOMY: The right economic growth
O63 NATIONAL ECONOMY: Entertainment industry
O65 NATIONAL ECONOMY: No use made of unique features
O67 NATIONAL ECONOMY: New technical products and services

Captain Nemo, the hero created by the pen of Jules Verne, would be the ideal leader to navigate the emerging bioeconomy in the rough, uncharted and uncertain waters of the twenty-first century.

CLUSTER #6: The Human Re-engineering (Pygmalion)
This cluster represents a case of almost balanced emergence, as opportunities are of the same power as problems. We also note that opportunities are mostly affected by health-care aspects, whereas problems by moral and ethical issues.

B3 Cloning/genetic improvement of humans
A7 Reproduction and regrowth of organs
B4 A culture of beauty and youth at any cost
P46 SCIENCE & TECHNOLOGY: Custom-made man
O08 BIOSPHERE: Inspiring life processes
O10 BIOSPHERE: (Re-) creating a living environment can contribute to more life
O11 BIOSPHERE: Intervention in humankind's own evolution

Pygmalion, a superb sculptor, created Galatea so perfect that he fell in love with his creation, with dire consequences. This story could teach Human (Re-) Engineers a great lesson.

CLUSTER #7: The New Risk Bio-Society (Sphinx)
This cluster is dominated by several types of problems and people's worries, whereas the opportunities are minimal. The multitude of such emerging bioeconomy features indicate that a new type of action territory will be spreading, whereas appropriate action plans are missing.

B5 Biological weapons – Bio-risks
B6 Domination of large multi-national companies
B7 Control of bio-innovations through patents
B9 Lack of protection of personal biological data
B10 Bio-ethics and morality issues
C5 Social tasks and initiatives
P36 SAFETY AND EMERGENCY SYSTEMS: Crisis control
P37 SECURITY: No rational security policy
P43 BUSINESS OF S&T: Threat to intellectual property rights
P45 SCIENCE & TECHNOLOGY: New risks, ethical issues and social problems*
P47 SCIENCE & TECHNOLOGY: Developments give criminals opportunities
P79 TENSIONS: Shortage, a breeding ground for conflicts
O33 SCIENCE & TECHNOLOGY: Threats as leitmotif for innovation*
O39 SCIENCE & TECHNOLOGY: National security

The new bioeconomic landscape of the emerging risks and worries can find its proper mythological symbol in the enigmatic smile and the deadly riddles of the Egyptian Sphinx.

CLUSTER # 8: Shaping the Future (Leonardo)
In this cluster, opportunities seem to be the main driving forces, but problems are also present and acting; with the whole equilibrium being regulated by a relevant action plan. Overall, this cluster represents forces that are shaping up the whole emerging bioeconomy.

C1 Research and innovation
P48 SCIENCE & TECHNOLOGY: Robots ousting humans*
P41 BUSINESS OF S&T: Insufficient knowledge management*
P42 BUSINESS OF S&T: The leading role of Europe is in danger*
O33 SCIENCE & TECHNOLOGY: Threats as leitmotif for innovation*
O34 SCIENCE & TECHNOLOGY: Promising new fields of science
O35 SCIENCE & TECHNOLOGY: Converging technologies (CT)
O36 SCIENCE & TECHNOLOGY: CT for human cognition and communication
O38 SCIENCE & TECHNOLOGY: CT to improve group and social processes

Proposing Leonardo's story as a symbolic element of the particular type of bioeconomy emergence was not because of Gioconda's enigmatic smile, but for Leonardo as an innovator, being well ahead of its time – a warning to colleagues aiming to shape the future by their research actions.

CLUSTER #9: For a Skilful Society (Piaget)
In contrast to research (Cluster #8), the main driving forces in the field of education in bioeconomy seem to be the problems, worries and risks. The second in power factors are those of action planning and management, with creativity and educational innovations playing a key role.

C6 Education and training
C7 Art and culture
C8 Youth initiatives
C10 Citizens information/awareness
P50 EDUCATION: Insufficient educational level of population
P51 EDUCATION: Educational system not attuned to the educational biography
P41 BUSINESS OF S&T: Insufficient knowledge management*
P42 BUSINESS OF S&T: The leading role of Europe is in danger*
P44 BUSINESS OF S&T: Decreasing confidence in science
O49 EDUCATION: Educational system keeping up with global knowledge increase
O50 EDUCATION: Creativity in education

The story of Jean Piaget has covered educational theory and practice in ways that have influenced, and keep affecting, educators and institutions. So, his story is useful as a shaping factor of people's minds, skills and lives, especially those involved in the emerging bioeconomy.

CLUSTER #10: "Mystery" Cluster – Action of Disrupting Forces (Agatha Christi)

The above-listed nine Clusters provide less than 50% of the explanatory power of the assessment; therefore there is a need to define a 10th Cluster, which can be justified as the result of disrupting forces. In Table 3.6, we present a list of possible disrupting trends in action for the current period of research.

The story we associate to this "mystery" cluster is the one of the most famous mystery story-teller, Agatha Christi; the basic element of her stories is the one of surprise and of an emerging unexpected outcome, which looks a posteriori normal and predictable with lots of hindsight.

3.5 Emerging Bioeconomy: The Role of Clusters

Using the Clusters identified as determining the dynamics of bioeconomy emergence, we can now revisit the list of factors presented in Table 3.1. Table 3.7 summarizes the effect of Clusters on the emergence elements, almost all of which can be expressed as the result of the interaction of a minimum of two (2) Clusters. Of particular importance are two of the nine clusters: Cluster #4 (Garden of Eden) and Cluster #8 (Shaping the Future), as well as their multiple combinations and interactions on energy and nano-molecular applications.

4 Concluding Remarks

The foresight of the emerging bioeconomy based on a Horizon Scanning approach has made possible the identification of the nine essential Clusters of opportunities, problems and stakeholder actions, as shown in Table 3.8.

Table 3.7 Emergence of bioeconomy in K6 explained by Clusters

Health, especially Holistic Health Applications **#1, 2**
Psycho-Social Health **#2, 7**
Biotechnology **# 3, 4**
Biomedical Applications **# 1, 2**
Nano-Molecular Applications **# 4, 8**
Nuclear Energy Developments **# 4, 7**
Renewable Energy Breakthroughs **# 4, 8**
Hydrogen Energy **#4, 8**
Robotics, Intelligent Machines **#6, 9**
Artificial Intelligence **#6, 9**
New Leadership & Management **#5, 7**
ICT to support the above – Post-Info Applications **#8, 9**
Converging Technologies (info-bio-nano, etc.) **#8, 9**

Table 3.8 The essential Clusters of emerging bioeconomy

#1: *The Silver Society* - Ageing and Demographic Barriers
#2: *The Care and Cure Practice* – Towards Holistic Health
#3: *The Horn of Affluence* – Food for 10+ B People on Earth
#4: *The Garden of Mother Earth* – Green Biobased Economy
#5: *The Green Governance* – New Type of Managers and Leaders
#6: *The Human Re-Engineering* – Re-Designing Nature
#7: *The New Risk Bio-Society* – Re-Setting Boundaries
#8: *Shaping the Future* – Smart-to-Wise Research Priorities
#9: *For a Skilful Society* – Training Brains for the 10 Clusters
#10: *"Mystery" Game Changers* – Surprise Disrupting Factors

The products of interaction between those nine Clusters can explain the various empirical observations of emergence phenomena reported by various researchers, e.g. (Koukios et al. 2018; Timmis and Timmis 2016).

Of particular value is the possibility of this approach to explore the content of the ongoing Kondratiev Wave of socio-technical change (2010-?) with respect to its bioeconomy-relevant elements.

Acknowledgments The research for this chapter took place at the Innovation Strategies Department of the Institute for Sustainable Technologies – National Research Institute, in Radom, Poland.

This work was prepared in the frame of the research project titled "The New Tsunami of Socio-Technical Change: Foresight of Agro/Bio/Chemo/Eco/Cogno...Convergence (BIO-TSUNAMI)", supported by the POLONEZ 1 Programme of the National Science Centre (NCN) with contract no. UMO-2015/19/P/HS4/04103. This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie grant agreement No. 665778.

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