Agronomy Research **17**(5), 2115–2126, 2019
https://doi.org/10.15159/AR.19.183

A holistic vision of bioeconomy: the concept of transdisciplinarity nexus towards sustainable development

L. Zihare*, I. Muizniece and D. Blumberga

Institute of Energy Systems and Environment, Riga Technical University, Āzenes iela 12/1, LV-1048 Riga, Latvia
*Correspondence: lauma.zihare@rtu.lv

Abstract. Current issue of bioeconomy development has been largely addressed on a linear or interdisciplinary level, however holistic view of bioeconomy requires a transdisciplinary system analysis. Developed methodology clarifies vision on bioeconomy definition, bioeconomy disciplines and disciplinary definition in context of nexus interlinkage, in the result concept of transdisciplinary approach connection to bioeconomy is determined as processes for sustainable bioeconomy, that not only replace fossil resources with biobased resources, but strengthens different disciplines, taken into account interlinkages, knowledge, and stakeholders and limitations set by planetary boundaries, different dimensions should be included in transition towards sustainable bioeconomy. Methodology bases on critical literature analysis. Different bioeconomy disciplines are defined and the obtained results are represented graphically. The obtained results can be used for further research as a transdisciplinarity basis of the bioeconomy, studying specific systems, factors influencing them and evaluating potential scenarios and their impacting tools. Results from implementing holistic vision would provide practical benefit to policy makers and industry actors by providing an analysis how to improve industrial practice, policy and how more effectively transfer to sustainable bioeconomy.

Key words: bio-economy, disciplines, transdisciplinary approach, nexus, sustainability.

INTRODUCTION

In 2013–2015 there were addressed a pathway for need to look on bioeconomy from interdisciplinary point of view, mostly because of novel technologies and need to use side streams, therefore engineering, environmental and socioeconomic challenges affect products and processes (Golembiewski et al., 2015). Also integration of knowledge from different disciplines is necessary (Golembiewski et al., 2015). In 2018 the vision of bioeconomy pathway is determined more complex and one–dimensional approaches are not suited, therefore more holistic and systemic perspective and solutions are needed (Schütte, 2018). According to (Bugge et al., 2016) categories that has been researched in bioeconomy are: biotechnology & applied microbiology, energy & fuels, environmental science, chemistry, multidisciplinary, environmental engineering, food science & technology, chemical engineering, forestry, applied chemistry, agronomy, agricultural engineering, plant sciences, social sciences, biomedical, multidisciplinary sciences (Bugge et al., 2016). Three bioeconomy visions are set in this article – biotechnology vision (research, application and commercialisation), bio-resource vision

(RD&D, biological materials in agriculture, marine, forestry and bioenergy) and bio-ecology vision (potential for regionally circular and integrated processes and systems) (Bugge et al., 2016). In 2009 OECD (Organisation for Economic Co-operation and Development) has created an analysis of future developments of bioeconomy on three sectors – agriculture, health and industry. It has been stated as interdisciplinary research. Implementation pathways determined technology –based approach and socio-ecological approach, where the second includes inter- and transdisciplinary approach in research (Priefer et al., 2017). In other article multi-, inter- and transdisciplinary environment is stated as 'social process of knowledge production' (Klein, 2008).

Current issue of bioeconomy development has been largely addressed on a linear or interdisciplinary level. But the future development of the bioeconomy should be viewed more widely, not as limited system. It involves many, sometimes very radically different, disciplines, both tangible and intangible, which are interrelated and can have an impact on the development of the bioeconomy, both directly and indirectly. For example, natural science –chemistry and social science – economics are related, thus increasing added value by creating new biochemical potential increases economic development. Other example applied science – agriculture and humanities – history and natural science – biology, were history about cultures and field research can improve agriculture practices. Knowledge in physics can improve agriculture technology thus improving efficiency. Including mutual interaction. The increasing demand of food and feed, population growth and climate changes require new holistic vision on bioeconomy, bringing together various stakeholders. It has been acknowledged that holistic view of bioeconomy requires a transdiciplinary system analysis (Schütte 2018). There are some evident need for interdisciplinary approach for bioeconomy (Golembiewski et al., 2015), so it is important to understand if there is really a need for transdisciplinary approach or interdisciplinary approach.

Systemic approach will be achieved by nexus thinking and the concept of transdiciplinary approach in bioeconomy. Transdisciplinary research encompasses broad, deep and equal opportunities with different interests, which usually do not evolve in the study of policy. There is a need to align the principles of circular economy and bioeconomy involving system approaches across sectors and macro regional nexus thinking. This research gives a comprehensive view about holistic vision in bioeconomy and clear concept with a graphical representation of transdisciplinarity nexus. It should be noted that the development of the bioeconomy cannot be promoted in all regions at the same structure, but it is essential to understand the discipline and which factors should be considered in the assessment.

The aim of this study is to clarify the difference between interdisciplinary, multidisciplinarity and transdisciplinary approach in bioeconomy and to develop the concept of bioeconomy transdisciplinarity approach. Therefore, understanding is the bioeconomy transdisciplinarity and what are the essential components of this system. Therefore, critical literature analysis was carried out and holistic approach used to analyse and aggregate the information. Different bioeconomy disciplines are defined and the obtained results are represented graphically. The obtained results can be used for further research as a transdisciplinary basis of the bioeconomy, studying specific systems, factors influencing them and evaluating potential scenarios and their impacting tools.

Hypothesis is that to achieve holistic approach in bioeconomy, transdisciplinarity should be evaluated.

MATERIALS AND METHODS

First to have a clear vision on bioeconomy disciplines and transdisciplinary nature, it is important to clarify bioeconomy definition, discipline definition and disciplinary definition in context of nexus interlinkage, then it should be clear how the disciplinary approach connects to bioeconomy. Therefore, a methodology algorithm was developed for this study (Fig. 1).

Methodology is based on concept development for transdisciplinary bioeconomy nexus, where the result is graphical representation, that can be easy understood and be basis and framework for further studies. Methodology bases on critical literature analysis (step 1), to understand interlinkage from planetary boundaries (step 2) to bioeconomy (step 4) and definition of bioeconomy (step 3), to understanding the disciplines overall (step 5) and in context of bioeconomy (step 6), as well as nexus approach (step 7) and its linkage to transdisciplinarity approach (step 8) and taking it all to account come with concept of transdisciplinary bioeconomy nexus (step 9) with graphical representation (step 10).

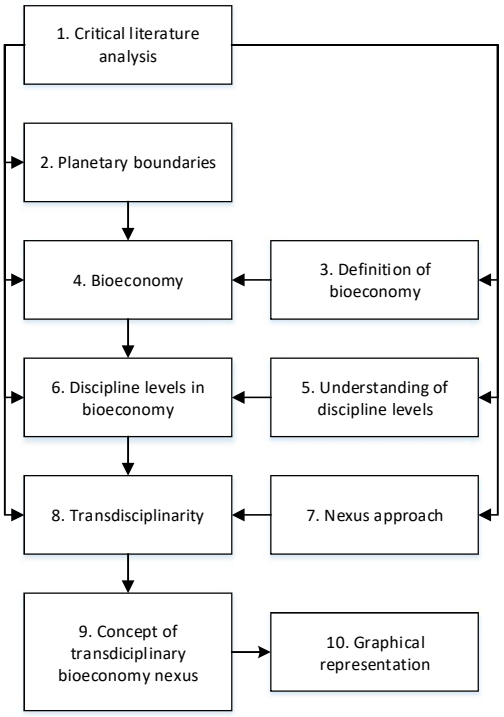

Figure 1. Methodology algorithm.

In first step clarifying that everything should be based on critical literature analysis, it means not quantity, but quality assessment of literature, in the second step, one of the most important factor,that impacts the overall use of resources and limits is planetary boundaries (step 2), that should not be exceeded and suppressed if already is beyond limits. Step three clarifies that bioeconomy has not one clear definition and can be understood with variations, here the several definitions from different perspectives is analysed. Step four elevates bioeconomy concept based on different bioeconomy definitions is created, to understand the complexity and include all the main factors from definitions. Next to build and understand the disciplines in bioeconomy, the overall definition of disciplines is gathered (step5). In step six clarifying the different disciplines in term of bioeconomy is determined. As the last year development shows (Muizniece et al., 2018) that nexus approach should be considered and has strong interlinks with transdisciplinary approach (step7).

Therefore, in step 8 transdisciplinarity definition in terms of bioeconomy is determined, to create concept of transdisciplinary bioeconomy nexus (step 9). In final step, the concept is represented graphically that can be stated as future framework for analysing bioeconomy transdisciplinarity (step 10).

The methodology algorithm is designed to take into account and critically analyse the diversity of opinions. Common to capture links between views from different industries is recorded and compiled. Thus justifying transdisciplinary researched issue.

RESULTS AND DISCUSSION

In order to understand the meaning of bioeconomy on global scale (not only in terms of international but also of ecosystems), it is necessary to identify the bioeconomy area. According to the literature, there are nine planetary boundaries (Mace et al., 2014; Heo et al., 2016; Stockholm Resilience Centre n.d.), which are close related to three bioeconomy main pillars – resource scarcity, climate change and food security (Fig. 2), (Lewandowski 2017). Planetary boundaries are not system that could show development of society, but it can clearly show the boundaries of safe development area and risk zone.

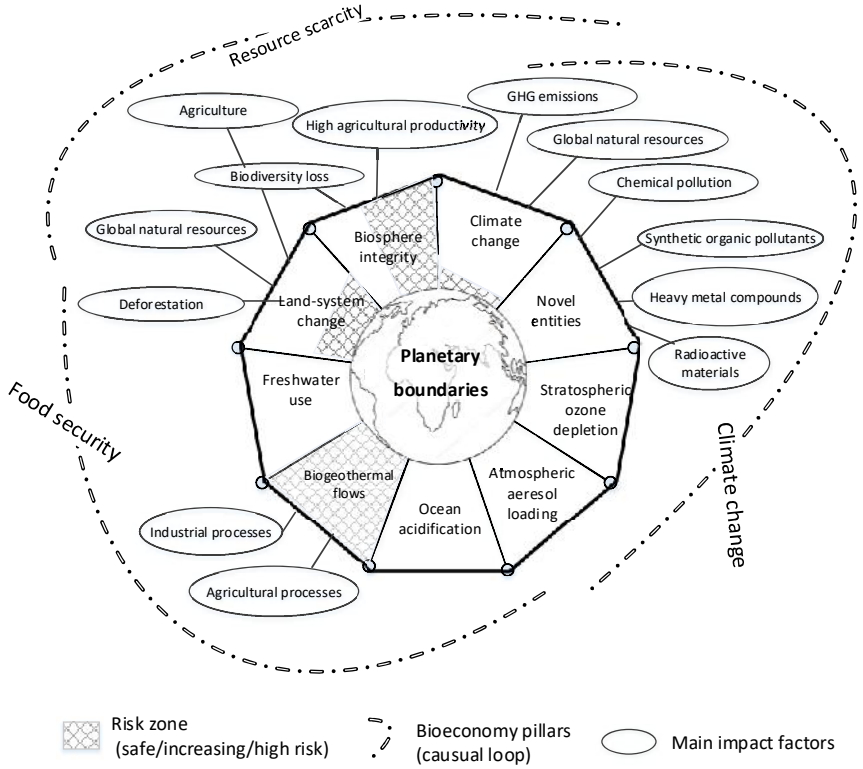

Figure 2. Planetary boundaries and bioeconomy pillars (Lewandowski 2017).

The nine planetary boundaries, that has to be taken into account in bioeconomy development, are:

1) stratospheric ozone depletion;

2) loss of biosphere integrity (functional and genetic diversity), that includes biodiversity loss and extinctions;

3) chemical pollution and the release of novel entities;

4) climate change;

5) ocean acidification,

6) freshwater consumption and the global hydrological cycle;

7) land system change;

8) biogeothermal flows - nitrogen and phosphorus flows to the biosphere and oceans;

9) atmospheric aerosol loading.

Planetary boundaries interlink with bioeconomy pillars, that show the global necessity for sustainable system development, taking into account safe development zone, therefore it shows complexity of the system required and bioeconomy transdisciplinary nature is suspected, but there should be clear division between disciplines and vision on development.

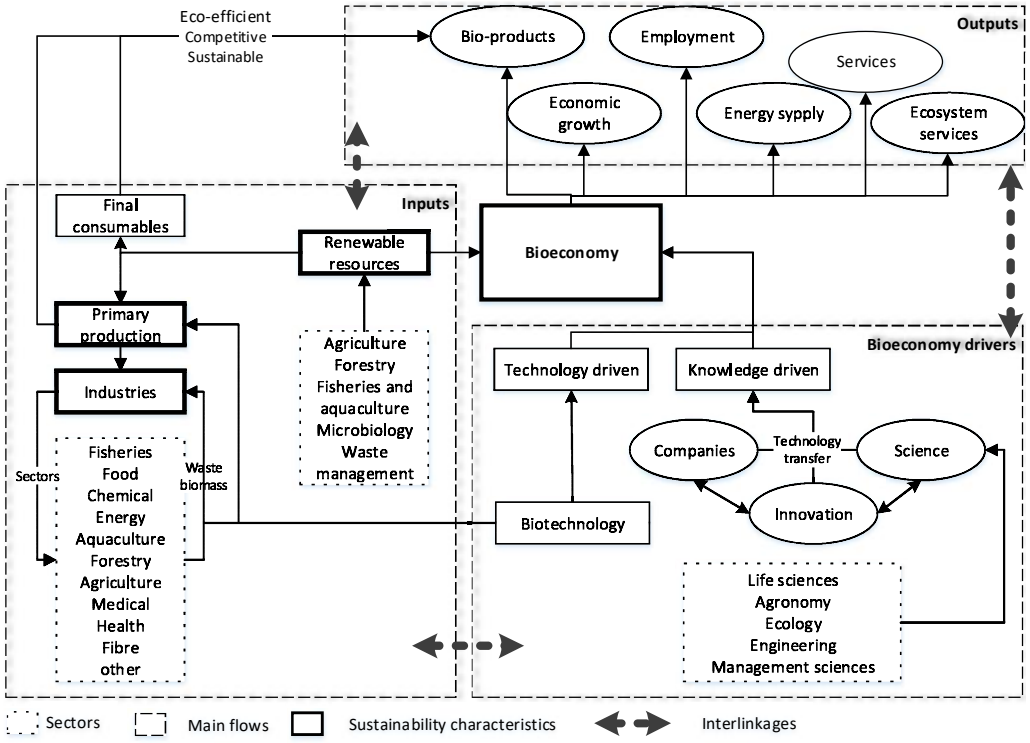

Figure 3. Bioeconomy schematic representation.

From the definition of bioeconomy and the analysis of different understandings, bioeconomy concept is summarized and graphically illustrated in Fig. 3. Bioeconomy is stated as knowledge and technology driven (Golembiewski et al., 2015) and biotechnology is set as first priority (Ahn, 2012). Bioeconomy covers different science fields, that is, but not limited to – life sciences, agronomy, ecology, engineering and management sciences (Golembiewski et al., 2015). According to OECD, bioeconomy is an innovative approach of transforming knowledge into new sustainable and eco-

efficient product that is also competitive (OECD, 2009). Bioeconomy knowledge drivers is not only science, but also innovative companies with large knowledge on bioproducts and services offer (Woźniak & Twardowski 2018).

Bioeconomy interconnect with different topics such as primary resources – forestry, agriculture, fisheries and aquaculture, and sectors- industrial, such as food, chemical, energy, ecosystem services of nature like recreation and wellbeing (VTT, 2018). The main outputs from bioeconomy is sustainable bioproducts, economic growth, energy supply, employment, services (such as health services) and ecosystem services (Woźniak & Twardowski 2018). Bioeconomy also implies the sustainable exploitation of biological resources to produce new bio-based products (Lainez et al., 2018), providing conditions for increased standard of living (Aguilar et al., 2013).

The main bioeconomy system is driven by three main flows – bioeconomy drivers, inputs and outputs, which all are interconnected. It means that changes in one part of the system would have an impact not only on each other, but also directly on the development of the bioeconomy. This demonstrates the crucial role of bioeconomy extensive coverage, which has long exceeded the level of one industry or country. Therefore, it is essential to understand how transdisciplinarity of the bioeconomy is manifested. First of all, it is necessary to understand the essence of transdisciplinarity, which, like the concept of bioeconomy, is interpreted very differently.

Discipline relations in nexus context

Nexus approach is generic-conceptual approach with the aim to find interactions among different processes, that depends on the impact of various factors (Muizniece et al., 2018). There are many illustration options on discipline levels, the one that is closest in order to understand nexus, is chosen.

Crossdisciplinary (Fig. 4, a) concept is viewing one discipline from the perspective of another, crossdisciplinary involves associative relations between different methods that are primarily comparative (Stirling, 2015). Here one discipline, for example agriculture farming interacts with other discipline, for example agriculture economics, to find solution on one issue. Results are solution – oriented.

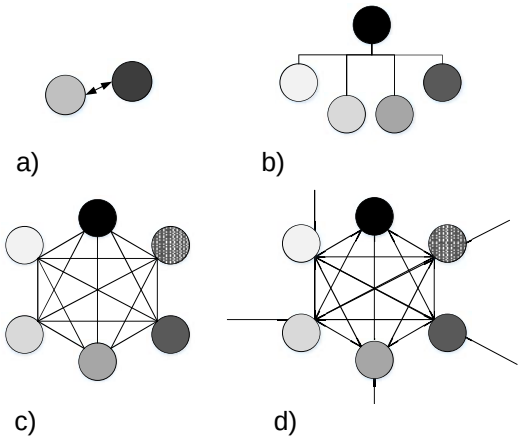

Figure 4. Illustration of discipline levels (Stirling, 2015).

Multidisciplinary (Fig. 4, b) is where people from different disciplines working together, each use their disciplinary knowledge. In multidisciplinary, relationship is usually centralised and hierarchical – it uses the power to define 'discipline' in research, in the language of this word. Thus, a particular discipline (in the academic terms, along with related methods) investigation is a privileged development of other methods of ordering and the final results of the general interpretation (Stirling, 2015).

As for bioeconomy point of view, would be different discipline experts, that are working on the same bioeconomy issue, for example, on issue of using agriculture waste, microbiologist can give his knowledge and expertise on how to add value to agriculture waste, engineer can find solutions for most effective equipment on various solutions and economist can give his expertise on solutions that he believes is the most cost effective. In this stage, they do not interact with each other. Or interaction is stated as weak link. Results is more subjective.

Interdisciplinary (Fig. 4, c) integrates knowledge and methods from different disciplines, using real-world approach of synthesis. In contrast, interdisciplinary has more symmetrical relationship between disciplines, and different methods can be used to address the contrasting aspects of the existing problem. However, even if participatory practice is used in subsequent parts of the process, non-academic interests are often excluded in the most important research, development and interpretation processes (Stirling, 2015). Here the disciplines that interacts are from different basis, they interaction are solution- oriented and with strong links, for example, issue on how to add value on agriculture waste, is a policy question, will it give social benefits and improve national economic situation and on what scale, microbiologist, that can help to find solution, that would give highest added value, economics, that help to find the most cost effective solution and computer science, that can perform modelling on different solution scenarios and their impact to various economic, socioeconomic, health and environmental processes.

Transdisciplinary (Fig. 4, d) creates the integrity of intellectual systems beyond a disciplinary perspective. Only in the field of transdisciplinarity, research or evaluation engages in broad, deep and equal ways with different interests, which are usually left outside the formal processes of policy research. Transdisciplinary engagement not only takes place in disciplines, nor is it the case that certain methods are implemented in a way that is subject to wider involvement (Stirling, 2015). According to J.A. Bergendahl et al., nexus projects are going to be more successful if transdisciplinary approach is applied (Bergendahl et al., 2018). If previous disciplines focused only on academic disciplines, this approach interacts with non-academic disciplines (society) as equals, broadening the view of issue and solution. If we look at previous mentioned example, in this case it would be supplemented with non-academic disciplines – different non-governmental organizations, local communities, local people, industries and also government agencies, etc. It means, we take into account opinions not only on previous mentioned disciplines on agricultural waste management with high added value, but also e.g. farmer's opinion, local communities' opinion, municipalities opinion and industries opinion on different solutions and possibilities to create a new path for bioeconomy development, in this case adding value to agriculture waste by new product production, that is feasible not only in theoretical level, but also realistic on implementation stage, economic and environmental aspect and with market potential.

Transdisciplinary bioeconomy

In order to research, demonstrate and define transdisciplinary approach of the bioeconomy, it is necessary to understand not only the bioeconomy on a largest scale, but also understand what is transdisciplinary nature. Therefore, a broad analysis of the scientific literature was carried out and various opinions on transdisciplinary definition were compiled. Some of them are summarized in Table 1.

Table 1. Evolution of transdisciplinary definition

Definition of transdisciplinary	Reference
'Transdisciplinarity is the incorporation of a broad set of scientific and policy disciplines, including industries and actors, for addressing broad and complex problems, e.g., sustainability. Transdisciplinarity is meant to address concerns of traditional scientific methods relying on reductionist, reasoned, studies that investigate a phenomenon or research question typically from a single disciplinary perspective.'	(Bergendahl et al., 2018)
'Transdisciplinary is the ontological specification of knowledge constructs on a higher, boundary-transcending, level of abstraction.'	(Colpaert, 2018)
'The science of team science: assessing the value of transdisciplinary research problems; meaningful collaborations, particularly between academic researchers and non-academics.'	(Scholz, 2017)
'Transdisciplinarity is seen as a specific methodology of efficient utilization and a way to relay knowledge from practice and science to the management of complex sustainable transitions.'	(Scholz et al., 2014)
'Transdisciplinarity is a reflexive research approach that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extra-scientific actors; its aim is to enable mutual learning processes between science and society; integration is the main cognitive challenge of the research process.'	(Jahn et al., 2012)
'Transdisciplinary studies incorporate interdisciplinary integration and add additional research dimensions by (a) addressing problems that are user inspired and context driven, (b) embracing complexity; and (c) acknowledging and incorporating multi-stakeholder perspectives and values…'	(Roux et al., 2010)
'TR deals with problem fields in such a way that it can: (a) grasp the complexity of problems, (b) take into account the diversity of life-world and scientific perceptions of problems, (c) link abstract and case-specific knowledge, and (d) develop knowledge and practices that promote what is perceived to be the common good […] We define TR by these four requirements for knowledge production.'	(Pohl & Hadorn, 2008)
'Transdisciplinarity is a new form of learning and problem solving involving cooperation among different parts of society and academia in order to meet complex challenges of society. Transdisciplinary research starts from tangible, real-world problems. … Ideally, everyone who has something to say about a particular problem and is willing to participate can play a role. Through mutual learning, the knowledge of all participants is enhanced … The sum of this knowledge will be greater than the knowledge of any single partner. In the process, the bias of each perspective will also be minimized.'	(Zierhofer & Burger, 2007)
'Transdisciplinarity represents a move from science on/about society towards science for/with society.'	(Scholz & Marks, 2001)

All definitions show that transdisciplinary approach is the transition from science to practice, seen as complex and sustainable way to meet complex challenges of society. Transdisciplinary approach itself is complex and consists of four dimensions (Fig. 5).

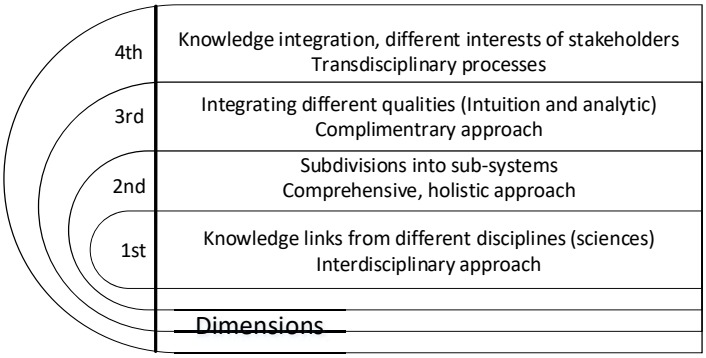

Figure 5. Transdisciplinary approach dimensions (Scholz & Marks, 2001).

Transdisciplinarity processes is way from unsustainable management moving towards sustainable management, covering four dimensions with the aim to connect science (disciplinarities) with practice (stakeholders) (Scholz et al., 2014). According to (Scholz & Tietje, 2002), knowledge that has to be implemented to preceptors go through four dimensions:

1st dimension – helix approach – this dimension brings together different fields from natural – life sciences (biology, medicine, chemistry), economics, applied sciences. It should ensure interdisciplinarity (Scholz & Tietje, 2002).

Different types of helix approach could be implemented: triple helix, quadruple helix or quintuple Helix (Carayannis & Campbell, 2014), see Fig. 6.

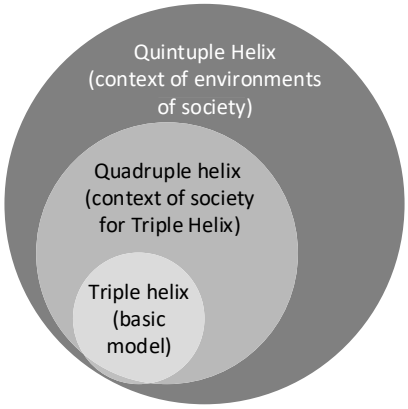

Figure 6. Helix approaches (Carayannis & Campbell, 2014).

2nd dimension – Systems: dividing in subsystems, for example in environmental study can separate regions water, air, soil systems and their interlinkages. For stakeholders it is management, financial and equipment as individual systems or complex systems. Needs to be integrated and related to the soft factors – gives circumstances (Scholz & Tietje, 2002).

3rd dimension Interests: Interests of research or practical perspective. For example different interests of farmers, residents, policy, different interests of stakeholders. Methods are socially integrating and mediating (Scholz & Tietje, 2002).

4th dimension Modes of though; cognitive or epistemological perspecitve analysis or understanding. Methods that integrate different cognitive representations, for example experience of a farmer and the expertise of a scientist (Scholz & Tietje, 2002).

Transdisciplinary processes connects science with society, adapted Brunswikian Lens model (Scholz & Tietje, 2002) in Fig. 7 (Scholz et al., 2014), to adapt this processes for sustainable bioeconomy, that not only replace fossil resources with biobased

resources, but strengthens different disciplines, taken into account interlinkages, knowledge, and stakeholders and limitations set by planetary boundaries, different dimensions should be included in transition towards sustainable bioeconomy. Syntheses is application of methods of knowledge integration (Scholz & O.Tietje, 2002; Scholz et al., 2006).

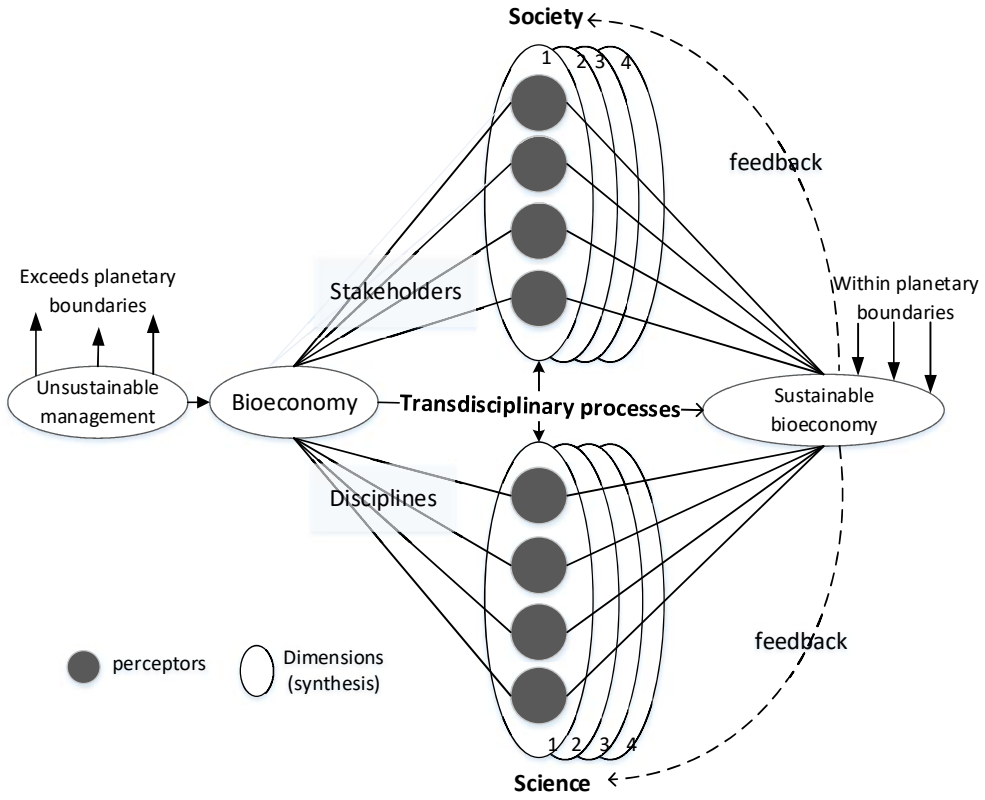

Figure 7. Transdisciplinary process towards sustainable bioeconomy (modified (Scholz et al., 2014)).

The concept of how to view and should act in order to achieve a transdisciplinary approach and outcome for sustainable bioeconomy development (Fig. 7). This type of approach can be used as a basis for developing the research issue into quantitative results, which would allow comparing the situation in different regions of the world and evaluating different development of scenarios, taking into account the views and actions of the various stakeholders. For example, this graphical representation can be used as a basis for creating a system dynamics model.

CONCLUSIONS

By carrying out critical analysis of literature on various bioeconomy perceptions, it was found that bioeconomy is essentially of transdisciplinary nature. An analysis of the understanding of transdisciplinary bioeconomy was also carried out to prove this. By interconnecting these two ideas that are not directly related to each other, an appropriate

approach to expressing the bioeconomics through transdisciplinarity using the Brunswikian Lens model was found.

Developed graphical representation is applicable to further case studies. Methods that is applicable to use in order to achieve best possible result, still need to evaluate and verify.

Further research in the context of bioeconomy should be carried out directly through the prism of transdisciplinary and a solution should be found to quantify this view.

It is clear that bioeconomy should be looked as complex system through transdisciplinary approach, but obstacles have to be determined.

Results from implementing holistic vision would provide practical benefit to policy makers and industry actors by providing an analysis how to improve industrial practice, policy and how more effectively transfer to sustainable bioeconomy by taking into account society opinion, easing practical implementation and transformation to sustainable bioeconomy.

ACKNOWLEDGEMENTS. This research is funded by the Latvian Council of science, Project 'Bioresources Value Model (BVM)', Project No. Izp-2018/1-426.

REFERENCES

Aguilar, A., Bochereau, L. & Matthiessen, L. 2013. Biotechnology as the engine for the Knowledge- Based Bio-Economy. *Biotechnology and Genetic Engineering Reviews* **26**(1), 371–388. doi:10.5661/bger-26-371

Ahn, M.J. 2012. High technology in emerging markets Building biotechnology clusters, capabilities and competitiveness in India. *Asia-Pacific Journal of Business* **4**(1), 23–41. doi:10.1108/17574321211207953

Bergendahl, J.A., Sarkis, J. & Timko, M.T. 2018. Transdisciplinarity and the food energy and water nexus: Ecological modernization and supply chain sustainability perspectives. *Resources, Conservation and Recycling* **133**, 309–319. doi:10.1016/j.resconrec.2018.01.001

Bugge, M.M., Hansen, T. & Klitkou, A., 2016. What is the bioeconomy? A review of the literature. *Sustainability* **8**(7), 691. doi.org/10.3390/su8070691

Carayannis, E.G. & Campbell, D.F.J. 2014. Developed democracies versus emerging autocracies: arts, democracy, and innovation in Quadruple Helix innovation systems. *Journal of Innovation and Entrepreneurship* **3**(12). doi:10.1186/s13731-014-0012-2

Colpaert, J. 2018. Transdisciplinarity revisited. *Computer Assisted Language Learning* **8221**, 1–7. doi:10.1080/09588221.2018.1437111

Golembiewski, B., Sick, N. & Bröring, S. 2015. The emerging research landscape on bioeconomy: What has been done so far and what is essential from a technology and innovation management perspective? *Innovative Food Science and Emerging Technologies* **29**, 308–317. doi:10.1016/j.ifset.2015.03.00

Heo, J., Kang, H., Sang, B., Kim, Y., Min, J., Mitchell, R.J. & Hyung, J. 2016. Bioresource Technology Feasibility of a facile butanol bioproduction using planetary mill pretreatment. *Bioresource Technology* **199**, 283–287. doi:10.1016/j.biortech.2015.08.074

Jahn, T., Bergmann, M. & Keil, F. 2012. Transdisciplinarity: Between mainstreaming and marginalization. *Ecological Economics* **79**, 1–10. doi:10.1016/j.ecolecon.2012.04.017

Klein, J.T. 2008. Evaluation of Interdisciplinary and Transdisciplinary Research. A Literature Review. *American Journal of Preventive Medicine* **35**(2 SUPPL), pp. 116–123.

Lainez, M., González, J.M., Aguilar, A. & Vela, C. 2018. Spanish strategy on bioeconomy: Towards a knowledge based sustainable innovation. *New Biotechnology* **40**, 87–95. doi:10.1016/j.nbt.2017.05.006

Lewandowski, I. 2017. *Bioeconomy: Shaping the transition to a sustainable, biobased economy*. eBook, Springer International Publishing AG. doi:10.1007/978-3-319-68152-8

Mace, G.M., Reyers, B., Alkemade, R., Biggs, R., Jennings, S., Leadley, P., Chapin, F.S., Cornell, S.E., Dı, S., Mumby, P.J., Purvis, A., Scholes, R.J., Seddon, A.W.R., Solan, M., Steffen, W. & Woodward, G 2014. Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change* **28**, 289–297. doi:10.1016/j.gloenvcha.2014.07.009

Muizniece, I., Kubule, A. & Blumberga, D. 2018. Towards understanding the transdisciplinary approach of bioeconomy nexus. *Energy Procedia* **147**, 175–180. doi:10.1016/j.egypro.2018.07.052

OECD, 2009. The Bioeconomy to 2030 Main Findings and Policy Conclusions.

Pohl, C. & Hadorn, G.H. 2008. Methodological challenges of transdisciplinary research. *Natures sciences societes* **16**, 111–121. doi:10.1051/nss

Roux, D.J., Stirzaker, R.J., Breen, C.M., Lefroy, E.C. & Cresswell, H.P. 2010. Framework for participative reflection on the accomplishment of transdisciplinary research programs. *Environmental Science and Policy* **13**(8), 733–741. doi:10.1016/j.envsci.2010.08.002

Scholz, R.W. & Tietje, O. 2002. Embedded case study methods Integrating quantitative and qualitative knowledge. *International Journal of Sustainability in Higher Education* **7**(3), 352–356. doi.org/10.1108/14676370610677892

Scholz, R.W., Lang, D.J., Wiek, A., Walter, A.I., Stauffacher, M., Scholz, R.W., Lang, D.J., Wiek, A., Walter, A.I., Stauffacher, M., Scholz, R.W., Lang, D.J., Wiek, A., Walter, A.I. & Stauffacher, M. 2006. Framework and theory Transdisciplinary case studies as a means of sustainability learning Historical framework and theory. *International Journal of Sustainability in Higher Education* **7**(3), 226–251. doi:10.1108/14676370610677829

Scholz, R.W., Roy, A.H., Hellums, D.T., Ulrich, A.E. & Brand, F.S. 2014. Sustainable phosphorus management: A global transdisciplinary roadmap. *Sustainable Phosphorus Management: A Global Transdisciplinary Roadmap*. eBook, Springer Dordrecht Heidelberg, New York London. doi:10.1007/978-94-007-7250-2

Scholz, R.W. 2017. The normative dimension in Transdisciplinarity, Transition Management, and Transformation Sciences: New roles of science and universities in sustainable transitioning. *Sustainability* **9**(6), 991. doi.org/10.3390/su9060991

Scholz, R.W. & Marks, D. 2001. Learning about transdisciplinarity : Where are we? Where have we been? Where should we go? *Transdiciplinarity: Joint Problem Solving among Science, Technology, and Society*. eBook, pp. 236–237. https://doi.org/10.1007/978-3-0348-8419-8_17

Schütte, G. 2018. What kind of innovation policy does the bioeconomy need? *New Biotechnology* **40**, 82–86. Available at: https://doi.org/10.1016/j.nbt.2017.04.003

Stirling, A. 2015. Developing 'Nexus Capabilities': towards transdisciplinary methodologies. *Transdisciplinary Methods for Developing Nexus Capabilities*. Report of a workshop held at the University of Sussex Junev June 29 and 30.

Stockholm Resilience Centre, The nine planetary boundaries - Stockholm Resilience Centre. Available at: https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html [Accessed February 15, 2019].

Woźniak, E. & Twardowski, T. 2018. The bioeconomy in Poland within the context of the European Union. *New Biotechnology* **40**(1), 96–102.

Zierhofer, W. & Burger, P. 2007. Disentangling Transdisciplinarity: An Analysis of Knowledge Integration in Problem-Oriented Research. *Science Studies* **20**(1), 51–74.