Digitalization of Bio-Based Value Chains

Heikki Ruohomaa[1](✉), Tapani Pöykkö[2], and Vesa Salminen[1]

[1] Hame University of Applied Sciences, Vankanlähde 22, 13100 Hameenlinna, Finland
{Heikki.Ruohomaa,Vesa.Salminen}@hamk.fi
[2] Myllykulmantie 45, 13330 Harviala, Finland

Abstract. Bioeconomy is one of the key areas to find new approaches to manage bio-based resources by sustainable and efficient way. Sustainable chains have to be efficient to use recourses by optimized way and to return nutrients back to field for future agriculture. The important issue also is to process biowaste as biofuels. Biomaterial chains are often long and complex including processing, transportation, storages side flow and energy. Because of this it has not been possible to optimize the value chain and production the same way as in manufacturing industry.

To create efficient bio-based value chains, organizations need to create value and share the information to partners in the ecosystem. Standardization as well as harmonization of data is needed to make it possible. All the data should be integrated and processed to optimize operations of the whole chain. Industry 4.0-framework provides standardization, RAMI architecture, as a reference databased business architecture for this development.

The aim of this article is to create an innovation ecosystem concept for the development of bio-based value chain more efficient and enable a more efficient circular economy. This article introduces as a case study an implementation of a framework on digitalization of farming ecosystem.

Keywords: Ecosystem · Digitalization · Industry 4.0 · Circular economy · Bioeconomy

1 Introduction

"There are currently underway two areas of radical change, unprecedented in human history. One is a human created, rapidly worsening systemic, ecological and social crisis. The other is a rapidly evolving, deeply systemic, human created digital technology revolution" [1]. This has opened a need for transformation of the economy systems from the linear model to circular one.

The need of transformation is widely discussed. The key elements of discussion are well summarised in Industry 4.0-framework: The Circular Economy by Nishimura [2]: "The circular economy represents alternative to the linear take–make–consume–dispose economic model that currently predominates industrial processes, supply chains as well as consuming models. The linear economic model has brought economic growth and welfare but has run its course. Products and production systems need to be designed for circularity, materials need to be efficiently processed, and waste needs to be sorted

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2021
J. I. Kantola et al. (Eds.): AHFE 2021, LNNS 267, pp. 111–118, 2021.
https://doi.org/10.1007/978-3-030-80876-1_16

and recycled. The value chain needs to be revisited in terms of its circularity function, and customers provided with services rather than throwaway products. This requires a change in mentality – a different way of looking at and organising our production and consumption processes".

The fourth industrial revolution and the new technologies and increasing amount of data will change society and structures of business. This move towards the ICT based technologies will happen unexpected fast including exponential growth of data. It is essential to have strategic view and understand the change to see the key elements of development and the new opportunities. Industry 4.0 technologies like sensor, IoT-platforms, artificial intelligence, cloud computing, give new possibilities to develop efficient, sustainable and more customer driven supply chains including nutrients circulation as well as new services for bioeconomy.

"Industry 4.0 technologies catalyse and facilitate the transition from a linear economic model to a circular model. This requires closer cooperation between the research, technological, and business communities and the creation of an enabling policy, and an institutional, business, and financial environment that will make this cooperation possible" [2]. "Raw material extraction, processing, and production companies can use Industry 4.0 technologies more efficiently, while the same technologies can be used for more efficient resource management and turning waste into 'new' raw material, closing the material cycle" [2].

There is a need to apply systemic approach in the circular (bio)economy to make it more visible. According to Zihare [3] "systemic approach will be achieved by nexus thinking and the concept of transdisciplinary approach in bioeconomy". This approach will be advanced by applying the concept of Industry 4.0 as standard data-based business architecture.

"The key factor influencing our future is the urgent need for ecological reconstruction: how do we respond to climate change, decreasing biodiversity, the dwindling availability of resources and waste-related problems. Technology is embedded in everything: it is becoming a part of society and everyday life" [4]. There is number of examples in agricultural field production [5] and horticulture [6] as well as forestry of new technologies pawing the path towards the application of The Industry 4.0.

The aim of this article is to create an innovation ecosystem concept for the development of bio-based value chains to benefit applied research and education resources in digital transformation process. That is the way it is possible to meet the challenge of digitalization to make bio-based value chains more efficient and enable a more efficient circular economy.

This article introduces a case-study on bioeconomy area and an implementation of RAMI- architecture framework concept on digitalization of farming ecosystem in Finland.

2 Theoretical Framework

"The new technologies of the Fourth Industrial Revolution have the potential to transform the global geography of production" [7].

"The widespread adoption of information and communication technology is increasingly accelerating the obscure of boundaries between the real physical world and the virtual one. The linkage is becoming increasingly Smart" [8]. Industry 4.0 development will give opportunity to renew the business, value chains create new business model and create new business models by taking use new technologies.

"The term "Industrie 4.0" was initially coined by the German government. Industry 4.0 describes the organization of processes based on technology and devices autonomously communicating with each other's along the value chain" [9]. "Industry 4.0 architecture takes account of the increased digitalization of various industries where physical objects are seamlessly integrated into the information network, allowing for decentralized production and real-time adaptation in the future" [9]. Industry 4.0 is an umbrella term characterizing digitalization and integration of the whole industrial value chain [10]. "Adapting Industry 4.0 framework as a basis for development activities is expected to provide an opportunity for remarkable competitive advantage for businesses but also for regions" [11]. "In agriculture, it also seems to be clear that there are substantial potentials in applying the principles from 'Industry 4.0' in the further planning and development of the field production. The concept of 'Industry 4.0' also implies guidelines for planning and decision-making and in this way also be a tool which brings the source of any decision back to the farm and the local economy and conditions there" [5].

"Innovation performance of an economy depends on how institutions and companies interact with each other's as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as legislation, norms and values)" [12]. Miller and Langdon [13] introduce how to manage disruptive innovation by managing platform, product and process innovation in continuous cycles. It is important to see the world as a complex system and it must be understood that it is impossible to change one thing alone as everything is connected to something else [14].

"It is clear that bioeconomy should be looked as complex system through transdisciplinary approach, but obstacles have to be determined" [3]. "Therefore, a research into those factors that affect the bioeconomy and the identification of their interlinkages and their quality would promote faster implementation of bioeconomy and increase sustainable use of bioresources" [15].

3 Research Questions and Methodology

"The bioeconomy is the knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system. (Definition of the Bioeconomy Council) The bioeconomy, or biobased economy, is a new model for industry and the economy. It involves using renewable biological resources sustainably to produce food, energy and industrial goods. It also exploits the untapped potential stored within millions of tons of biological waste and residual materials" [16].

The main research questions and discussion topics are:

1) Should whole bio-based chain to be known in order to develop profitable value chain for bioeconomy?
2) Should the whole biobased value chain to be digitalized in order to be efficient and sustainable?

3) Should data to be structured and harmonized before efficient digital value chain can be created?

This article describes ecosystem- based development concept in bioeconomy. Case study concentrates on bioeconomy faculty at Häme university and the ecosystem around it.

This article is based on qualitative analysis of gathered data and experiences from several bio-based projects experiences.

4 Bio Based Value Chain in Digital Context

"The circular economy is an umbrella term used for industrial process and business models that do not generate waste but instead reuse natural resources repeatedly. At its core, the circular business is about economics and competitiveness. Its approach to resource efficiency integrates cleaner production and industrial ecology in a border system, encompassing industrial firms or network of firms to support resource optimization" [17].

"The term goes beyond the mechanics of production and consumption of goods and services, in the areas that it seeks to redefine (examples include rebuilding capital including social and natural, and the shift from consumer to user). The concept of the circular economy is grounded in the study of non-linear, particularly living systems [18]. This ensures enhanced flows of goods and services."

"Sustainable development and the circular economy are two important issues for the future and the competitiveness of businesses. The programs for the integration of sustainability into industrial activities include the reconfiguration of production processes with a view to reducing their impact on the natural system, the development of new eco-products and the redesign of the business model. This paradigm shift requires the participation and commitment of different stakeholder groups and industry. It will completely redesign supply chains, aiming at resource efficiency and circularity. Developments in key ICT technologies, such as the Internet of Things (IoT), help this systemic transition" [19]. To ensure material efficient flows the transparency and traceability are the key factors for efficient circular economy and material recourse efficiency.

> *Industrial symbiosis is an industrial ecosystem in which unused or residual resources of one company are used by another. It is a process involving several companies, that complement one another through efficient use of raw materials, technology, services and energy.*

Business ecosystems based on industrial symbiosis (Fig. 1) provide more added value by using fewer natural resources than traditional industrial value chains. "In industrial symbiosis, industrial operations, energy production, primary production, waste processing and the services supporting these are functionally integrated to form an entity that provides products and services for end-user needs, while at the same time optimizing resource use" [20]. Organization exists in multiple business ecosystems. The digital ecosystem influences enterprises, their social and business networks.

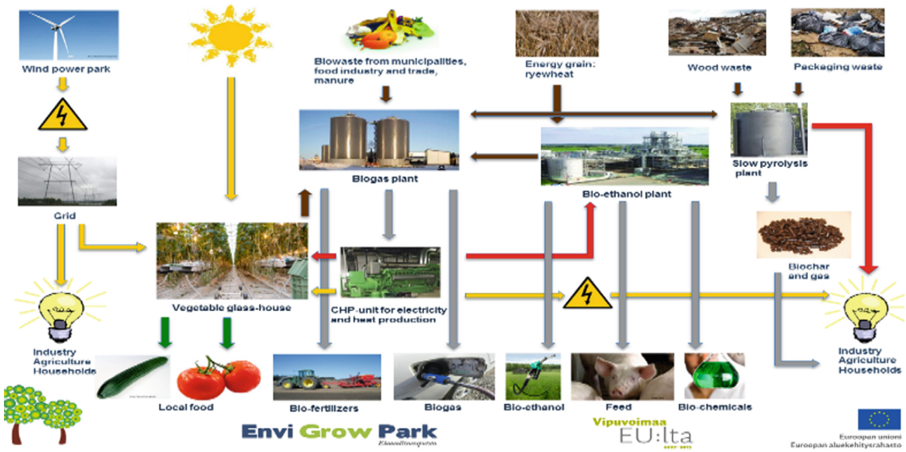

Fig. 1. Example on bio-based symbiosis (Forssa town region)

"Transparency requires linking a digital data flow to the physical material flow. The important data pieces to generate and make accessible are; provenance of materials and components; how these were assembled into a product; product condition and ownership during use; and product lifecycle journey" [7].

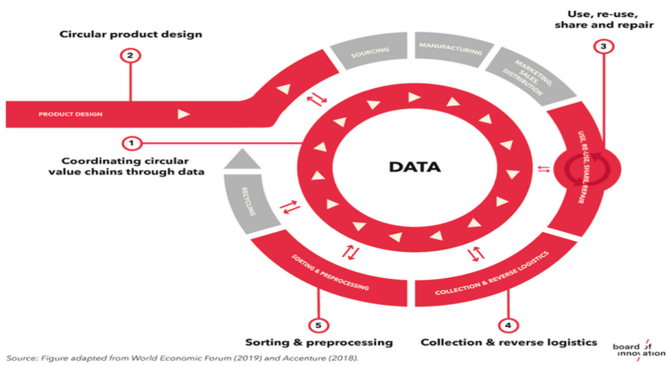

Fig. 2. Overview of shared challenges along the value chain (Accenture, 2018)

"For visibility on materials that are put on the market, collected and treated, product passport data should feed into the internet of materials (IoM), a decentralized data system connecting data on different products and materials through standardized communication protocols. Data should be supplied by producers as products are sold, tying in data on material provenance and product design. Ensuring data confidentiality and anonymity are key here to avoid competitive and anti-trust challenges" [7].

"Like the regular internet, the IoM requires parties to agree on standardized datasets and communication protocols. It could be managed by a neutral governing body working with industry players to define data standards, privacy requirements and related access authorizations. Anonymized aggregated data can be provided open source to visualize material flows across markets" [7].

RAMI4.0 is three- dimensional model to visualize the most important aspect of Industry 4.0. It ensures that participants have common understanding and view.

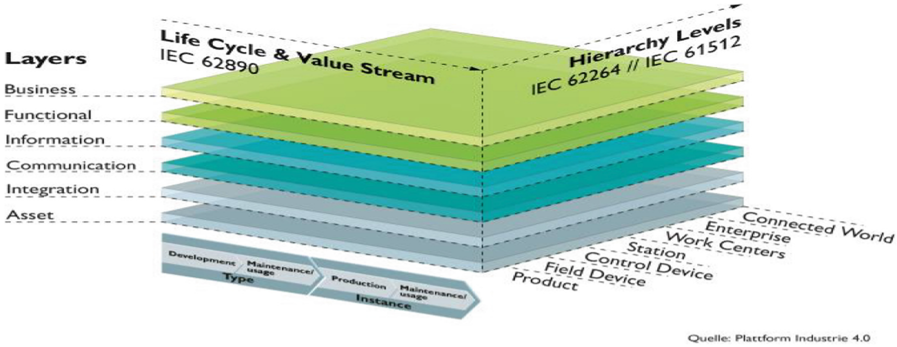

Fig. 3. RAMI Reference architecture model

The RAMI 4.0 reference architecture model expands the hierarchy levels by adding the 'Product' level at the bottom, and the 'Connected World' going beyond the boundaries of the individual factory at the top (Fig. 3) [21].

The importance of RAMI is to harmonize and standardize the data and thus make data possible to have full benefits. RAMI architecture gives the framework for solid fundament for development and ecosystem development (digital ecosystems).

5 Conceptual Model for SmartBio Value Chain

Countryside is facing fast and big structural changes and is forced rethink structures and building new networks and ecosystems for business and development.

"Exponential growth of data also indicates changes on value chains, services, business models and ecosystems. The development requires greater connection and collaborations. This is where the 'explosion' of platforms and ecosystems is occurring" [22].

"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" [3].

When analyzing new value chains in the bioeconomy and the related complexity, material efficiency and utilization of side streams, the economic interest of all actors in the entire value chain, data collection, harmonization must be considered, so that data enables the overall efficiency of bio-based value chains.

For this reason, HAMK, as the leading agricultural institution in Finland, will respond the digital transition in bioeconomy by developing "**SmartBio"- innovation ecosystem concept** in "real life" environment for applied research and piloting new technologies and creating new value chains in complex and fast changing business environment. That is the way it also provides platform for innovations and start-ups and for disruptive change (Fig. 4).

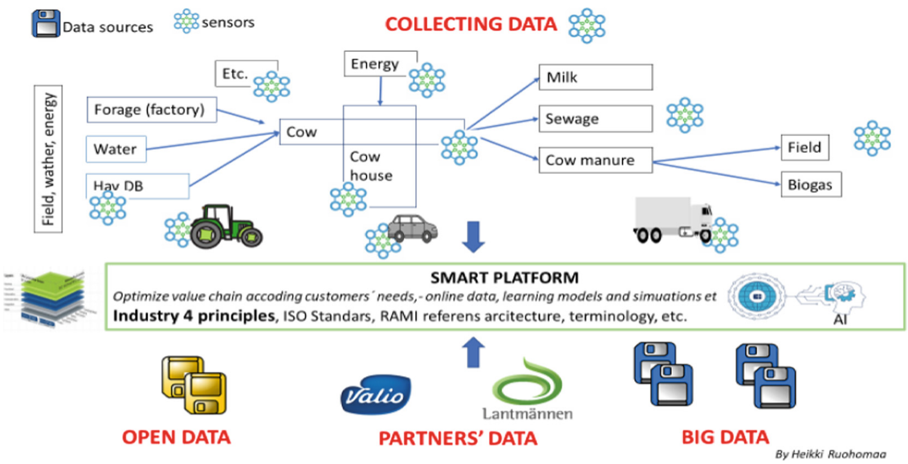

Fig. 4. Framework of "SmartBio"-digital innovation ecosystem.

The development activities by "SmartBio - innovation ecosystem concept" have been linked according "Industry 4.0" framework to ensure compatibility. At this moment "Industry 4.0" gives more framework for development than given accurate model, orders or rules.

6 Conclusions

Digitalization of bio-based value chains is a necessity to facilitate a system transition from a linear fossil economy to data-based circular (bio)economy. It makes possible to connect horizontal processes with each other vertically to from ecosystems that are resource efficient, sustainable and resilient.

"SmartBio" is a multidisciplinary learning and research platform combining knowledge of different faculties. Joint working in multidisciplinary environment will create transdisciplinary learning processes leading on new skills, which are needed in circular economy and bioeconomy based on Industry 4.0 standardization. Thus, it is following the education 4.0 concept. The key issues are the utilization of the possibilities of 4^{th} industrial revolution technologies and the increasing amount of data. This mean that there have to be common understanding on standards, harmonization of data, but also the sharing and ownership of data. Industry 4.0 and RAMI reference architecture gives starting point for development. Critical issue is also to have common platform and testing environment. Essential issue for successful digital transition is to have strategy which includes also business ecosystem, digital ecosystem, and innovation ecosystem strategies.

References

1. Cole, D., McNaughton, B., Hersh, S.: Towards sustainability - the circular economy, Industry 4.0 and the global, research, innovation and discovery centre (GRID) Conference Paper November 2019 (2019)
2. Nishimura, H.: Forwords in Industry 4.0: empowering ASEAN for the Circular Economy Edited by Venkatachalam Anbumozhi and Fukunari Kimura (2018)
3. Zihare l., Muizniece I., Blumberga D.: A holistic vision of bioeconomy: the concept of transdisciplinarity nexus towards sustainable development. Agron. Res. **17**(5), 2115–2126 (2019). https://doi.org/10.15159/AR.19.183
4. Sitra: Mekatrendit (2020). https://media.sitra.fi/2019/12/15143428/megatrendit-2020.pdf
5. Jørgensen, M.H.: Agricultural field production in an 'Industry 4.0' concept. Agron. Res. **16**(1), 94–102 (2018). https://doi.org/10.15159/AR.18.007
6. Hart, J., Hartová, V.: Development of new elements to automatized greenhouses. Agron. Res. **16**(3), 717–722 (2018). https://doi.org/10.15159/AR.18.105
7. World Economic Forum: Harnessing the Fourth Industrial Revolution for the Circular Economy , January 2019, Geneva, Switzerland (2019)
8. Lusch, F.R., Vargo, S.L., Gustafsson, A.: Fostering trans-disciplinary perspectives of service ecosystems. J. Bus. Res. **69**, 2957–2963 (2016)
9. European parliament, briefing: 4.0 Industry digitalization for productivity and growth (2015). http://www.europarl.europa.eu/thinktank
10. Deloitte: Industry 4.0 challenge: Challenges and solutions for the digital transformation and use of exponential technologies (2015)
11. Ruohomaa, H., Mäntyneva, M., Salminen, V.: Renewing a university to support smart manufacturing within a region. In: Digital Transformation in Smart Manufacturing-Book, Chapter 8, InTech -Open Science|Open minds (2018)
12. Clarke, T., Chelliah, J., Pattinson, E.: National innovation systems in the asia pacific: a comparative analysis. In: Clarke, Thomas, Lee, Keun (eds.) Innovation in the Asia Pacific, pp. 119–143. Springer, Singapore (2018). https://doi.org/10.1007/978-981-10-5895-0_6
13. Miller, W., Langdon, M.: Fourth generation R&D: Managing Knowledge, Technology, and Innovation. Wiley, Toronto (1999)
14. Sterman, J.: Business Dynamics: Systems Thinking and Modeling for a Complex World. The McGraw-Hill Companies Inc., London (2005)
15. Kubule, A., Indzere, Z., Muizniece, I.: Modelling of the bioeconomy system using interpretive structural modelling. Agron. Res. **17**(4), 1665–1678 (2019). https://doi.org/10.15159/AR.19.170
16. Bioeconomy BW: https://www.biooekonomie-bw.de/en/bw/definition
17. Di Maio, F., Rem, P.C.: A robust indicator for promoting circular economy through recycling. J. Environ. Prot. **6**, 1095–1104 (2015)
18. World Economic Forum Report: Towards the circular economy: accelerating the scale-up across global supply chains. 4, Geneva, Switzerland (2014)
19. Garcia-Muiña, F.E., González-Sánchez, R., Ferrari, A.M., Settembre-Blundo, D.: The paradigms of Industry 4.0 and circular economy as enabling drivers for the competitiveness of businesses and territories: the case of an Italian ceramic tiles manufacturing company. Soc. Sci. **7**, 255 (2018)
20. Sitra: Industrial Symbiosis- One man's waste is another man's raw material (2018). https://www.sitra.fi/en/topics/industrial-symbiosis/#what-is-it-about. Accessed Mar 2018
21. Platform Industrie 4.0 (pub.): Industrie 4.0 Implementation Strategy; V1.0. Accessed Apr 2015
22. PwC report: 4.0 Industry: Building the digital enterprise. Global Industry Survey (2016)