Journal of Cleaner Production 183 (2018) 87–101

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Emerging value chains within the bioeconomy: Structural changes in the case of phosphate recovery

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ARTICLE INFO

Article history:
Available online 15 February 2018

Keywords:
Phosphorus recovery
Emerging value chains
Industry convergence
Bioeconomy

ABSTRACT

The needed transition from a fossil-to a bio-based economy fosters the utilization of biological resources derived from recycled low value by-products and waste streams. Chain actors face multiple challenges associated with the adoption of novel processing technologies. Bio-based technologies might be related to high switching costs, missing downstream processing technologies, lack of quality standards, missing industry standards, emerging regulatory frameworks. Moreover, as previously unrelated actors form new relationships, value chains are moving towards new structural changes. This paper thus seeks to explore the challenges associated with the emergence of novel value chains with an exploratory case study approach that reviews a new process of recovering phosphate - a typical scarce and fundamental resource - from rapeseed oil press cakes. The contribution of our paper is thus not only to provide conclusions for this specific case, but also, and more importantly, to present a blueprint for other cases of scarce resources that require the establishment of novel supply chains to foster cascading usage of by-products. Expert interviews with different value chain actors have been conducted to investigate arising challenges, and derive implications and a further research agenda. Despite the advantages of the bio-based process, interviews revealed several challenges associated with the emergence of novel value chains: hesitation of respondents in making new investments in terms of equipment and know-how, missing complementary competencies, and difficulties in integrating different industrial sectors to engage in cross-industry innovation, such as food processing (rapeseed oil cakes) and specialty chemicals/mineral (phosphate and its derivatives). These exploratory results open the way for some useful recommendations, enabling us to propose an agenda for further research and policy development in areas such as: development of synergies between academia and industry; formulation of management strategies to support the flexibility of firms to capture opportunities associated with by-product valorization; building a systemic approach at a local level to implement bio-based technology clusters.

1. Introduction

Since the last fifteen years, we have been globally witnessing a growing necessity to shift from a fossil-to a bio-based economy (Golembiewski et al., 2015b; McCormick and Kautto, 2013). This shift is driven by both an increasing need to reduce greenhouse gas emissions associated with the usage of fossil resources (Smith, 2004) and the need to find alternative and sustainable sources to replace non-renewable resources, like phosphorus (Staffas et al., 2013). In other words, sustainable production systems are needed to cope with the global challenges of climate change, growing population, and a scarcity of fossil resources (McCormick and Kautto, 2013; Schmid et al., 2012). Across several industries, the bioeconomy is characterized by its cross-industry nature, with a variety of sectors, technology platforms and production systems seeking substitutes for scarce resources by means of waste streams and/or by-products (Staffas et al., 2013). Thus, the entire transformation process in this domain is complex, especially due to the fact that value chains are moving towards structural changes that go beyond the more traditional pursuit of new linkages and re-designs (Sheppard et al., 2011).

When actors and activities are integrated in a new manner

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https://doi.org/10.1016/j.jclepro.2018.02.135
0959-6526/

across the boundaries of prior distinctive industries, the literature refers to this phenomenon as industry convergence (Bröring and Cloutier, 2008). As a consequence, those firms that aim to remain innovative in converging settings require additional knowledge and capabilities from hitherto-unrelated industry sectors (Bierly and Chakrabarti, 2001). Such developments can be expected to trigger the emergence of novel value chains (Vecchiato, 2012). For example, sustainable innovations can generate spillovers via the establishment of a unique technology basis between two or more sectors that were formerly separated, leading to a process of convergence and, consequently, emerging value chains (Bröring and Cloutier, 2008; Golembiewski et al., 2015b). Furthermore, the utilization of biological resources and materials derived from recycled, low-value by-products and waste streams are often associated with novel processing technologies – and thus a tendency towards higher risk perceptions (Ekman et al., 2013). For industrial partners at the business-to-business (B2B) level, technological adoption and diffusion may be hindered by challenges and market barriers like high switching costs (Geroski, 2000), the absence of downstream processing technologies (Mohan et al., 2015), or a lack of existing quality standards, industry standards, novel regulations and lengthy regulatory approval processes (Scarlat et al., 2015).

In spite of the widespread issues for emerging value chain structures in the Bioeconomy, such challenges have barely been addressed in the literature. Although WebOfScience™ lists a total of 1691 publications that use the term “bioeconomy” in the title or abstract, the number of articles associated with “value chain OR supply chain” is only 26. Further, only three publications (Correll et al., 2014; Golembiewski et al., 2015a; Korhonen et al., 2015) refer to the challenges of implementing novel value chain structures. In specific, Correll et al. (2014) explored novel supply chain designs, and logistical cost-savings, in the case of bioenergy and bio-based products. Korhonen et al. (2015) applied a Delphi-foresight method to investigate the effectiveness of environmental regulations vis-a-vis greening the pulp and paper industry. Finally, Golembiewski et al. (2015b) conducted a systematic literature review to summarize the status quo of the emerging research landscape in the Bioeconomy, addressing the specific issue of converging value chains.

Against this background, the present paper seeks to fill the gap in the literature by elucidating not only the main challenges but also the novel structures that arise whenever the competencies and technology platforms of different industries encounter one another, leading to the emergence of entirely new “inter-industry value chains”. To this end, we analyze the case study of an innovative technology rooted in the phosphorus supply chain which facilitates the recovery of this resource from agricultural by-products, e.g. rapeseed oil-press cakes, thereby resulting in a new sustainable source of polyphosphate. The contribution of our paper is not only to provide conclusions for this specific case, but also, and more importantly, to present a blueprint for other cases of scarce resources that require the establishment of novel supply chains to foster cascading usage of by-products: e.g. within the chemical industry (Kircher, 2014) or energy industry (Golembiewski et al., 2015a).

The remainder of the paper is organized as follows. In section 2, the research setting is described by exploring the case of phosphorus and highlighting its pivotal role in the agri-food system, the challenges connected with its extraction, and the necessity to find alternative solutions and production methods. These topics are then used to motivate our research questions. In section 3, the conceptual framework is derived by combining two strands of literature – value chain analysis and convergence - and explaining the mechanisms involved in the process of emerging value chains when industries converge. Further, in section 4, the chosen exploratory case-study methodology, with reference to the case of phosphorus, is presented along with a description of interviewed companies. The results are then reported in section 5, by illustrating, first, how the current phosphate value chains are organized and how they might change when implementing innovative bio-based process of phosphate recovery and, second, by narrating the outcomes of the interviews in terms of challenges and potential emerging value-chain structures. In this manner, we are able to answer the research questions. Finally, the findings are discussed in section 6, while potential avenues for future research as well as some implications are outlined in section 7. Section 8 concludes with a summary.

2. Research setting: the phosphate stewardship and the necessity for alternative and sustainable sources

Phosphorus is essential for the agri-food system given its use as a fertilizer to stimulate food production and plant growth. Moreover, it has other industrial applications (emulsifying agent, moisture retention, etc.) within the food sector as well as in other industries. Notably, this resource is also key for osteoporosis drugs, soaps and detergents, engine oil additives, flame retardants, batteries, water treatment, toothpastes, and asphalt additives (Schipper, 2016). In general, phosphorus derives from rock-mined phosphate, making it a non-renewable resource (Chowdhury et al., 2017; Rosemarin and Ekane, 2016; Scholz et al., 2014; Schoumans et al., 2015). This fact determines the current dependence on phosphate reserves,[1] whose timespan has still been neither clear nor officially established (Edixhoven et al., 2014; Rosemarin and Ekane, 2016; Roy, 2017; Ulrich et al., 2013). According to Cordell et al. (2009), the duration of phosphate reserves will last at most 40 years. However, Wellmer and Becker-Platen (2007) forecast 81 years, whereas Elser and Bennett (2011) argue that reserves might still persist for 400 years, confirming the evaluation of the US Geological Survey in 2011. Though these continuously changing predictions hinder the development of a consistent governance policy, one cannot deny that reserves are progressively diminishing and, thus, that it is necessary to assert that phosphorus represents a scarce resource crucial for ensuring future food security (Chowdhury et al., 2017; Rittmann et al., 2011).

Nevertheless, several issues remain to be tackled concerning its stewardship. The main challenge is the need to maintain phosphorus supply in line with demand. In particular, the demand for fertilizers – representing the main destination use (80%) of phosphate rock (Rittmann et al., 2011) – is predicted to increase (Egle et al., 2016; Rosemarin and Ekane, 2016; Scholz et al., 2014; Withers et al., 2015). Indeed, this forecast is also substantiated by the FAO (2015), which estimates an annual growth rate of 2.2%, especially in developing countries (Rosemarin and Ekane, 2016). Other assessments have also been reported by Chowdhury et al. (2017). The overall growth trend mainly centers on developing and densely populated countries in the far East, where growing population and a shift in consumer preferences towards Western diet patterns represent major drivers for the increasing phosphorus demand (Cordell et al., 2009; Rosemarin and Ekane, 2016;

[1] Phosphate reserves are defined as “geological deposits containing phosphate that can be economically extracted” (Rosemarin and Ekane, 2016, p. 268) using existing technology (Van Kauwenbergh et al., 2013). Reserves must be distinguished from phosphate resources, which instead refer to all forms of phosphate available (including reserves), which may potentially be produced in the future (Van Kauwenbergh et al., 2013).