International Journal of Standardization Research
Volume 17 • Issue 1 • January-June 2019

Tackling Uncertainty in the Bio-Based Economy

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ABSTRACT

There is a clear overall consensus among international institutions and governments on the need to scale down the reliance of the global economy on fossil fuels. Yet, a sustainable transition from a long-established regime based on rooted production and consumption models, requires tackling a wide array of challenges. Indeed, the transition towards a bio-based economy is still characterized by a high degree of complexity and uncertainty. Managing complexity and accounting for uncertainty entails appropriate and multidisciplinary tools. In this regard, sustainability certifications, standards and labels can play a pivotal role in navigating this transition, creating the conditions to ensure a level playing field between bio-based and conventional products.

KEYWORDS

Bio-Based Economy, Standards, Uncertainty

1. INTRODUCTION

There is a broad consensus among international institutions and governments of industrialized countries for the need to scale down the reliance of the global economy on fossil fuels, paving the way to a more responsible and resource efficient society (Dubois & Gomez San Juan, 2016). This has increasingly led policy makers to pay greater attention to the bio-based economy (Staffas, Gustavsson, & McCormick, 2013), representing one reliable way for transitioning to equitable, sustainable, post fossil-carbon societies (Ingrao et al., 2018). Though biomass has been consistently used as a raw material throughout history, it is only recently that, thanks to the development of new technologies (e.g. biorefineries), biomass deriving for instance from forestry and wood residues, biowaste, algae (Ben-Iwo, Manovic, & Longhurst, 2016) or more traditional raw material such as agricultural biomass, has started to be exploited for obtaining a range of value-added products, (Imbert, 2017), although at varying stages of technical maturity, with some of them being commercially available and others still at the demonstration stage.

Many industries are thereby involved (e.g. agriculture and food, textile, wood and paper, chemical and pharmaceutical), together with an ever-increasing number of actors. These include farmers, waste management companies, converters, innovative startups and medium sized specialist producers as well as global brands (e.g., IKEA, Tetra Pak and Toyota) (Pöyry 2016).

DOI: 10.4018/IJSR.2019010105

In addition to having a lower impact on the environment, the transition towards a bio-based economy, and more specifically to a circular bio-based economy, is also seen as a great opportunity to revive productivity and employment growth (European Commission, 2018b). Specifically, by improving the competitiveness of domestic industries through new technologies as well as by reducing dependence on imported feedstocks, also through the rehabilitation of marginalized lands and the exploitation of a wide variety of locally sourced wastes and residues that will be maximized by fully employing a cascading approach (Corrado & Sala, 2018).

Several combined and interconnected issues, however, negatively affects the market entry of bio-based products. In this context, the implementation of a coherent yet, at the same time, flexible regulatory framework becomes a key factor in ensuring the sustainability of bio-based products (including impacts on health and safety and the environment), as well as improving the functioning of markets (European Commission, 2018a). Throughout this process, the development of standards would help to overcome the high degree of complexity and uncertainty that still surrounds the bio-based economy and that will be discussed in this paper.

2. TRANSITIONING TOWARDS A CIRCULAR BIO-BASED ECONOMY

A sustainable transition from a long-established regime based on rooted production and consumption models, requires tackling a wide array of challenges. As stated by Priefer et al. (2017), despite the bio-based economy being viewed as a "comprehensive societal transition," a number of issues have not yet been fully addressed. In particular, besides rather well-known concerns surrounding the debate on the sustainability of the bioeconomy, including food security, land grabbing, direct and indirect land use changes (LUC and iLUC) and loss of biodiversity, additional issues highlighted by the literature must be taken into account. These include no level playing field with fossil based products, but also within the bio-based economy itself due to the incentives created by the EU's Renewable Energy Directives (RED I and II) and several member countries energy policies, intended for the use of biomass for energy production rather than for material purposes (Carus et al., 2016; Meyer, 2017). Moreover, there are only few product categories, such as bio-based lubricants, to have already benefited from regulatory measures at EU or Member State level (Spekreijse, Lammens, Parisi, Ronzon, & Vis, 2019).

Another aspect that deserves particular attention is represented by demand-side developments, which include consumer willingness to pay for bio-based products and new consumer behavior towards sustainability and related changes in lifestyle. Notably, a major theme strongly interlinked with the bio-based economy is whether society can reach sustainability solely through the development of green innovative processes and products, or whether more far-reaching approaches, including lower consumption levels, should be implemented (Zsóka, Szerényi, Széchy, & Kocsis, 2013). In recent years, several consumption and ownership models are indeed fast being developed (Priefer et al., 2017). These approaches include the extension of a product's life cycle by enabling recovery for repair or reuse and sharing model approaches (Martin, 2016) for example applied to cars (Mounce & Nelson, 2019) and food (Falcone & Imbert, 2017; Morone, Falcone, Imbert, & Morone, 2018). Remarkably, there are several issues debated in the literature such as whether the shift from a fossil-based economy will result in decreased productivity and whether a transition towards regenerative pathways inevitably leads to post-capitalist societies (Bosch & Schmidt, 2019). This debate is also strongly related to the degrowth approach that views a voluntary reduction of overall consumption and production as the main target for societies in order to reach sustainability (Muradian, 2019).

3. DEALING WITH RISK AND UNCERTAINTY IN BIO-BASED ECONOMY

The notions of complexity and uncertainty are not consistent in literature and this produces confusion even among specialists (de Assis et al., 2017). Several definitions have been proposed to show how uncertainty could give rise to potentially negative impacts and thus risks (Aven, 2010). Specifically, the two concepts are mainly related to the context of capital investment decisions (Teece, Peteraf, & Leih, 2016); "*Uncertainty"* relies on the existence of more than one value or the absence of information and being also related to randomness is one crucial element of the risk analysis (Hubbard, 2009). While a *"Risk"* is a random event disturbing the company purposes. If the impacts are positive, it is considered as an opportunity (Vose, 2008).

The bio-based industry is characterized by additional challenges in terms of risk and uncertainty, being in competition with a mature fossil-based system based on higher market efficiency. Relevant challenges for the bio-based industry relate to the availability and variability of feedstocks, the lack of data for the appraisal of socio-economic and environmental sustainability and the uncertainty surrounding the the market uptake of bio-based products (Falcone & Imbert, 2018). Essentially, risk and uncertainty are related to four main key issues encompassing the bio-based economy, i.e.: i) the sustainability of bio-based products, ii), the costs and prices of conventional fossil based products iii) consumer acceptance and demand for bio-based products and iv) the bridging of the circular bio-based economy to other sustainable pathways.

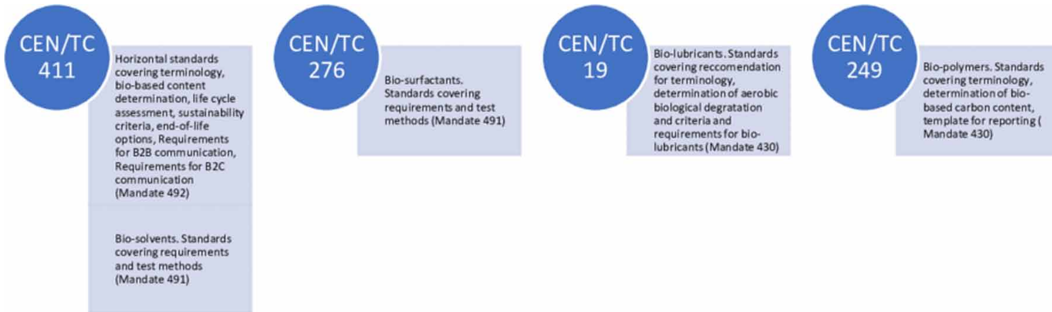
3.1. Sustainability of Bio-Based Products

Firstly, the sustainability of bio-based products is a cross-cutting theme being crucial to both producers and consumers, as well as to policy makers. Part of the uncertainty related to bio-based products indeed surrounds the environmental, social and economic consequences generated by these kinds of products (Hagemann, Gawel, Purkus, Pannicke, & Hauck, 2016). In particular, as for all new products, the uncertainty about the scale of the effects and the irreversibility of a number of them, should be properly considered (Turner, Pearce, & Bateman, 1994). Accordingly, a comprehensive sustainability assessment is of paramount importance, given that bio-based products are not automatically sustainable (Pfau, Hagens, Dankbaar, & Smits, 2014; Laibach et al. 2019). This implies that the full environmental, social and economic costs and benefits associated with bio-based products production should be well understood. Indeed, alongside the benefits, a broad range of possible side effects which could be even more harmful should be taken into consideration, to avoid the cure becoming worse than the disease (see on this Richardson, 2012; Sheppard et al., 2011).

An important concept strongly associated with bio-based products' sustainability is that the producers are responsible for what happens before and after the production stage. The analytical tools used for assessing products' sustainability should be necessarily consistent with this approach looking at the entire life cycle of a product (i.e. from extraction of raw materials to its end of life). Against this background, life cycle sustainability assessments (LCSAs) based on the combination of environmental life cycle assessment (ELCA), life cycle costing (LCC) and social life cycle assessment (SLCA) are considered the most effective way for assessing the environmental and socio-economic impacts of bio-based products (M. Martin, Røyne, Ekvall, & Moberg, 2018). However, many limitations and weaknesses have been outlined, due to different definitions of bio-based products and the broad array of indicators and methods used (Falcone et al., 2019; Spierling et al., 2018).

Against this background, an intense standardization exercise was launched by the EU, in order to provide common guidelines for the classification and evaluation of bio-based products (Ladu & Blind, 2017). More specifically, within the framework of its Lead Market Initiative aimed at boosting the market uptake of bio-based products, the European Commission issued a number of standardization mandates to the European Committee for Standardization (CEN), i.e. M/429 for the elaboration of a standardization program for bio-based products, M/430 on bio-polymers and bio-lubricants, M/491 on bio-solvents and bio-surfactants and M/492 for the development of horizontal standards for bio-based products. As shown by Figure 1, several CEN technical committees are in charge of the afore-mentioned mandates.

Figure 1. CEN's technical committees engaged with bio-based product (Source: Adapted from Ladu and Blind (2017))



3.2. Costs and Prices of Conventional Fossil-Based Products

Better market penetration of new bio-based products necessitates a clear improvement regarding sustainability assessment, as well a sufficient techno-economic positioning compared to fossil-based products (van den Oever & Molenveld, 2017). The large-scale utilization of such products creates some of the major market failures[1] on the planet, especially when the focus is on abiotic resources (Farley & Daly, 2011). There are conditions, in the ways fossil-based markets operate, violating one or more neoclassical economic assumptions that define an ideal market for products or services such as rational behavior, costless transactions, and perfect information (Brown, 2001). The price of fossil-based products does not accurately represent the cost of their production. Therefore, it does not consider the environmental costs, i.e., costs associated with environmental damages imposed on society giving rise to the failure with respect to externalities (Nguyen, Laratte, Guillaume, & Hua, 2016). Such environmental costs involve the reduction in air quality, the contribution to climate change, and the impacts on public health. Looking at coal externalities, for instance, Epstein et al. (2011) estimate that the overall cost of such externalities ranges from 9 to 27 cents per kilowatt-hour (kWh) of electricity generated, with an average of about 18 cents per kWh[2]. It represents a cautious approximation, since the authors do not take all associated impacts into consideration. Undoubtedly, internalizing these negative impacts or environmental costs in the prices of market products is a great challenge to support long term business activities in order to pave the way for sustainability (Brandão & Weidema, 2013). From this perspective, accounting for environmental externalities is of paramount importance for setting the optimal price level; thus, environmental externalities should be monetized whenever possible for the appraisal of the economic costs (Bemow, Biewald, & Marron, 1991).

Several approaches to deal with environmental externalities have been proposed in literature, encompassing quantitative methods (cost of damages, cost of control), qualitative methods (qualitative treatment) and hybrid methods (weighting and ranking) (Blokhin, 2018). ELCA is a hybrid method for the appraisal of the environmental impacts occurring along the whole life cycle of a product from extraction of raw materials to its end of life. ELCA allows characterizing the externalities towards different impact categories according to the environmental impacts they are expected to provide (e.g. climate change, human toxicity, ozone depletion, etc.). Some of the weighting methods in ELCA are built to assign an economic value to the environmental impacts (i.e. monetization approaches) providing a result in monetary terms. The big challenge will be to design an "economic tool" able to adequately account for the socio-environmental costs associated to fossil-based products' externalities.

Considering that most of these external factors do not affect the majority of renewable energy sources, the rational of internalization, is to make people aware about the unsustainability of fossil-based products and encourage them to change their behavior towards new environmentally friendly models of production and consumption. Moreover, the effective internalization of externalities would change the relative price of traditional products (i.e. fossil based) in favor of green counterparts, making them even more appealing for consumers (Nguyen et al., 2016).

3.3. Consumer Acceptance and Demand for Bio-Based Products

The third source of uncertainty is strongly linked to the demand side, since consumers face uncertainties and risks associated with the development of new products (Ferrari, Morone, & Tartiu, 2016). Understanding how consumers react to adoption may help to persuade firms to make the decision to adopt green reverse logistics (Rogers, 2003). Specifically, understanding the consumers perception of risk and uncertainty with respect to their personal values, has important effects on their willingness to pay for green products (Russo, Confente, Scarpi, & Hazen, 2019). Notably, the health and safety of consumers appears to be the factor that most influences the consumer's willingness to pay for bio-based products (Falcone & Imbert, 2018).

Willingness to pay is also strongly related to social acceptability which might represent a dramatic barrier for market uptake. (McCormick & Kautto, 2013). Social acceptability might be triggered by means of the available information of product performance (Martin et al., 2018). However, there is a lack of standardized social indicators for social performance measurements. The development of general social indicators could provide organizations with relevant information to better understand those social factors that might influence the market acceptability of a product (Lamberton, 2005). This, in turn, would support empirical experience and accordingly contribute to the development of the bio-based economy (Kühnen & Hahn, 2017). Moreover, the use of social indicators can assist decision makers in providing a fit-for-purpose social sustainability scheme, including standards, labels and certifications, based on the product-related impacts on the wellbeing of different stakeholders' categories (Jørgensen, Dreyer, & Wangel, 2012). This is in line with literature on green product development proving that consumers, when confronted with eco-friendly purchase alternatives, respond not only rationally but also emotionally (Koenig-Lewis, Palmer, Dermody, & Urbye, 2014).

3.4. Circular Economy and Other Sustainable Pathways

The circular economy approach has the goal to make better use of resources/materials through reuse, recycling and recovery, and also to minimise the energy and environmental impact of resource extraction and processing (Masi, Rizzo, & Regelsberger, 2018). Basically, it denotes new business models which aim at creating industrial systems which are purposely restorative, by reducing unintended negative consequences on the environment of production and consumption processes (Genovese, Acquaye, Figueroa, & Koh, 2017). With the aim of effectively addressing such challenges, sustainability innovations must renovate mainstream practices (Werbeloff, Brown, & Loorbach, 2016) by including renewable resources, reverse logistics, eco-efficiency, green supply chain and the involvement of the entire supply chain (de Vargas Mores, Finocchio, Barichello, & Pedrozo, 2018).

Defining effective ways to align sustainable supply chain practices to circular economy paradigm represent cutting edge topics at the intersection of scientific research and public policy (De Angelis, Howard, & Miemczyk, 2018). In this regard, a sustainable supply chain is not just concerned with the reduction of environmental concerns within the organizations but with a paradigm shift in production philosophy (Howard, Hopkinson, & Miemczyk, 2018). As a consequence, a number of sustainable pathways can coexist and be combined. Just think about the single-use conventional plastics, which have led to radical changes in people's lifestyles. The replacement of such material with bioplastics would be only partially a sound solution as a sustainable bio-based economy would not be compatible with current levels of consumption. Therefore, the above-mentioned alternative consumption and ownership models deserve close attention also in the context of the bio-based economy (Morone, Falcone, & Lopolito, 2019; Vainio, Ovaska, & Varho, 2019).

4. DISCUSSION

As the authors argued above, when considering bio-based products sustainability, a variety of perspectives should be embraced. Indeed, there is a need for research to deepen how the bio-based economy could advance through a greater harmonization with other sustainable production and consumption patterns.

Moreover, in order to boost the development and market uptake of sustainable bio-based products, encompassing the adoption of a more efficient cascading approach, a proactive action from a wide variety of public and private actors is needed (Mengal et al., 2018). This includes setting an adequate legislative framework. In this respect, standards can play a crucial role in strengthening the current regulatory framework and can represent a basis for public procurement (De Besi & McCormick, 2015) and provide the first step towards the creation of labels (Ladu & Blind, 2017). In particular, underpinning the use of standards can lead to overcome a wide range of barriers including mitigating investment risk and improving access to markets. More specifically, the development of standards can generally contribute to: i) increasing economic efficiency by boosting the development of economies of scale; ii) overcoming market failures stemming from asymmetric information between the supply and consumer sides by developing information, measurement and minimum quality standards.

However, despite having made important progress in the standardization of bio-based products, as emphasized in section 3.1, these standards have not yet been fully put into effect by governments of Member States to create incentives and/or market pull initiatives and have still not been provided with defined thresholds (BBP EG, 2017). Moreover, legally binding sustainability criteria are applied only to some bio-based products, leading to leakage effects, limited compatibility between existing sustainability certification schemes and thereby to a lack of harmonization (Majer et al. 2018). With the increase of the cascading-use approach and consequently the increasing interaction among different value chains, a more harmonised approach to sustainability certifications must be supported (Bennich & Belyazid, 2017).

5. CONCLUSION

International institutions are calling for a transition towards more sustainable systems of production and consumption. The production of innovative bio-based products, i.e. products wholly or partly derived from materials of biological origin, deriving from innovative production processes and/or innovative biomass such as food waste or forest residuals, is part of this process. However, while the European Commission since the launch of the Bioeconomy Strategy is supporting the production of renewable biological resources and their conversion into value added products and bio-energy, several issues remain about the sustainability of bio-based products there are also issues about sustainability of bio-based products along the whole life cycle, from feedstock provision to end-of-life (InnProBio, 2018).

In sum, managing risks and accounting for uncertainty entails multidisciplinary tools and approaches, reflecting all the different perspectives and issues described above. Since the sector is constantly updated on account of new knowledge of bio-based products impacts, policy makers must be able to balance the development of a coherent policy framework, through the development of sustainability schemes and standards, which gives security to investors but also remain flexible enough to adapt to the acquisition of new information (Purkus, Hagemann, Bedtke, & Gawel, 2018). With this in mind, the specular aspect on the consumption side should be duly taken into account when designing a sustainability scheme. It is necessary to introduce criteria that take into account the consumption side and not only that of the production side. For example, by considering the expected lifetime of a product, therefore if it goes in the direction of the reuse. Hence, a new perspective which brings technological and behavioral aspects together while balancing different sustainability pillars (i.e., at the same time taking into account environmental, social and economic aspects) is of paramount importance. Against this background, a double symmetric sustainability is needed, bearing in mind that there is no "one-size-fits all" formula since not all the criteria used for a sustainability assessment are suited to every product category. In this perspectives, government policies such as excise tax credits or accelerated depreciation should help bio-based industry development by increasing profitability and reducing risk (Pereira, Dias, MacLean, & Bonomi, 2015).

ACKNOWLEDGMENT

The authors are very grateful to the STAR-ProBio project (Sustainability Transition Assessment and Research of Bio-based Products) for their financial support. The project is funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 727740, Work Programme BB-01-2016: Sustainability schemes for the bio-based economy.

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ENDNOTES

1. Market failures can be viewed as scenarios where individual's pursuit of pure self-interest leads to results that are not efficient – that can be improved upon from the societal point of view (Krugman, Wells, & Graddy, 2007).
2. It represents a conservative estimate, because they have not accounted for every associated impact.

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