Biomass Supply Chains in Post-COVID-19 Recovery

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Researchers investigates how biomass supply chains (BSChs) for bioenergy within the broader bioeconomy could contribute to the post-COVID-19 recovery in three dimensions: boosting economic growth, creating jobs, and building more resilient and cleaner energy systems in four future scenarios, in the short term (by 2023) and long term (by 2030).

Keywords: biomass supply chains ; pandemic ; Delphi ; bioenergy ; bioeconomy ; recovery

1. Introduction

In late 2019 and early 2020, COVID-19 triggered a worldwide recession, in conjunction with a global health crisis and uncertainty that continues to evolve with new virus variants at the time of publication, a combination not encountered in the modern history of a global economy [1]. Governments across the world encouraged different levels of social restrictions, including public health measures, to reduce the spread of the virus and balance the economy. Restrictions have induced abrupt shifts to digital/online business models to compensate for limited mobility that not all industries could uptake swiftly (e.g., tourism, culture, and leisure industries) [2]. Economies with a high integration in global value chains experienced shortages of intermediary goods [2] and other disruptions of trade, while import-dependent economies experienced shortages of both goods and labor [3][4][5]. The uncertainty that the virus brought to society halted consumption among consumers and investment cycles among the industry [4][5][6]. In turn, limited mobility labor, goods and services have affected the mix of energy sources [7], substantially reducing the use of fossil fuels due to travel restrictions but also lowering electricity demand from the industry [8][9][10]. Most, if not all, national economies have suffered a recession, loss of workplaces as well as lack of workers due to safety measures and increased governmental expenditures, namely those related to healthcare, employment insurance and business support. While it was obvious that the global economy experienced a severe contraction, the behavior of individual sectors of that global economy was uncertain. Businesses related to the pandemic (e.g., pulp and paper industry for hygiene products, spirits for disinfectants, online shopping, and delivery services) were gaining momentum, but this was difficult to quantify in a short time span. Governments across the world reacted to the pandemic with different approaches and interventionist measures related to recession and health uncertainties, which gained various levels of support from their citizens [11]. The pandemic has increased the awareness of the role of the government in society with a strong interconnection between the economy and energy and health systems [8][12] where governments are preparing, announcing and implementing recovery plans to re-start and re-shape the economy [13][14][15][16].

The pandemic created demand and supply shocks in almost every area of human activity [17]. The ideal recovery investment would have a short production cycle, based on the available (local) inputs, and exhibit a high multiplier effect that would allow a fast return of the invested money into the economy. Biomass is a locally available source that could have a short production cycle (annual crops and post-harvest residues, manure, industry relying on processing primary biomass, biological part of municipal waste). The International Energy Agency (IEA) recovery plan [18] investigated the effect of clean energy investments on economic growth, jobs and cleaner and more resilient energy systems. It concluded that spending on biofuels had the highest multipliers of investments in the energy sector because of the labor intensity of harvesting and processing feedstocks [18]. Fuel supply distinguishes bioenergy from fuel-less renewable energy sources where the supply allows for more opportunities for interactions with sustainability aspects along the biomass supply chain and not only at the end-use as a renewable energy source [19]. Biomass supply, whether it is used for bioenergy or the broader bioeconomy, has the potential to help drive economic growth, jobs and resilience of an economy, particularly if the cross-sectoral framework is set to maximize the desired and discourage the unintended behavior [20][21].

The biomass supply chain (BSCh) is an integrated network of facilities and processes, each responsible for a range of activities, varying in scale and complexity [22]. Bioenergy comes to the market with three end-uses: bioheat, bioelectricity and biofuel for transport—all behaving differently in both supply and demand, and across net energy importers and net energy exporters. The use of biomass for energy production (heat, power or fuel) has numerous benefits, including

economic, social as well as environmental. It is particularly of interest to create local jobs and support regional bioeconomies for communities, even in areas where biomass availability is low [23]. Simultaneously, the BSCh as part of the bioenergy sector is confronted with large volumes of biomass with low densities, low economic value, and is variable in nature, thus causing high costs in logistic operations [24][25][26][27]. These challenges can affect the continuity of supply, making supply chains susceptible to disruptions [25][26][27]. These disruptions can occur within the operation or technology; however, significant external factors such as a global pandemic or the pandemic's effect on energy demand are hard to predict [28]. The factors affecting the supply of biomass for bioenergy also apply to the broader bioeconomy, where other sectors to which biomass supplies renewable carbon can usually tolerate higher biomass prices and, thus, a wider radius of biomass collection or longer distances for biomass supply.

Physical and financial shocks caused by the pandemic disrupted common commercial practices and highlighted the need for securing supply chains, storage and maintained production [28][29]. Resilient supply chains need to be able to react to interference to overcome the stress placed on the system and mitigate the impact of the disruption swiftly and effectively [24]. All stages of supply chain organization and the three principle competitive priorities: cost efficiency, reliability of supply and sustainability [30], are subject to disruptions from COVID-19.

Modelling and optimization efforts in BSCh design have envisaged the effects induced by the pandemic but would need further refinement to capture observed consequences. Until May 2021, very few publications quantified the impact of the pandemic on BSChs for bioenergy. Traditional assumptions of uncertainty do not sufficiently account for events related to the current pandemic. Uncertainty is typically linked with critical parameters such as biomass demand, prices, resource capacities, availability, quality, and costs [31][32][33]. Zamar et al. [31] applies a quantile-based approach from stochastic optimization under uncertainty, where their approach is to analyze competing supply chains subject to stochastic demand and supply and argue that those critical parameters are usually uncertain in competing supply chains subject to stochastic demand and supply, while the conventional approach assumes that the operational characteristics and design parameters are deterministic. The uncertainty stems from lack of information (e.g., quality characteristics of available biomass feedstock), noise (e.g., lack of data) and events that have not occurred (e.g., energy demand or feedstock supply shortages) which could be applied to COVID-19 effects to some extent. Medina-Gonzalez et al. [32] focus on the potential effects of different quality streams on the overall system, which is argued to have been omitted in previous approaches. This study focuses on the challenges of multi-objective approaches (maximize economic performance while minimizing environmental impact) coupled with uncertainty strategies for a quick response against unpredictable situations (e.g., demand, price, availability, quality). The approach can serve as a framework where uncertainty events such as COVID-19 can be introduced, but it is not discussed as such. Hu et al. [33] use cyberGIS (geographic information science and systems based on advanced cyberinfrastructure and e-science) to address uncertainty in BSChs, which could be expanded for the pandemic. Yet, modelling based on uncertainty requires substantial and reliable data sources which are inherent to all mentioned examples. In the absence of quantitative data, qualitatively modelling methods, such as Delphi, can help assess the possible futures [34]. Sajid (2021) [35] studied the impacts of COVID-19 on the performance of BSChs' modelling risks using a dynamic risk assessment methodological framework, showing a drastic reduction in risk after gradual business re-opening, but the case specificity of the studied value chain vacates space for a more holistic approach, as presented here.

2. SWOT Analysis on BSChs

The SWOT analysis, focusing on both biomass demand and the supply side (Appendix A), identified BSChs as generating strong local impacts because they are based on local supply and typically develop an added value for local farmers, forest managers and industries by valorizing the residues, by-products, and waste of their core business. In addition to the local impact, the expanded view of the local region and the ability of biomass to integrate and service multiple markets were seen as offering a sustainable local impact. The SWOT outcomes also identified clear links to expand local opportunities, acting as a catalyst for jobs related to improved land management made possible by the value added to resulting biomass while offering a sustainable locally reliable energy to support local economic development. Finally, the deployment of readily available commercial solutions using known and reliable technology is a strength that strongly positioned new biomass utilization to fit emerging carbon-constrained, bio-based, and circular economies.

The SWOT identified seasonality of supply, costs, and competitiveness as key threats/weaknesses of the sector. These issues affecting BSCh apply to the different futures, yet the reasons to intervene with investments to secure renewable carbon supply to the economy vary. Other weaknesses identified in the SWOT was an imbalance in supply and demand for bioenergy, storage costs, dependence on co-productive sectors, and price inelasticity.

The SWOT results concerning BSChs were clustered to formulate short- and long-run strategy features of aspirational biomass supply contributions to the post-COVID-19 economy, which were further elaborated to generic investment strategies in Delphi survey.

3. Behavior of BSChs in the Pandemic

The short survey was sent to 61 biomass experts and achieved a 46% response rate (see Appendix B for comprehensive results of the survey). No shortages in energy supply were reported in any sector. Narrowing the question down to bioenergy supply, 93% of the experts reported no shortages, while one expert identified a shortage of solid fuel supply (pellets, briquettes, chips) and gaseous biofuels (e.g., biomethane).

About a third of the experts (37%) reported not knowing if any disruptions occurred in the bio-based industry due to the disruptions in markets during the COVID-19 outbreak. At an aggregated level, 40% of the experts reported no change in production; most negative disturbances were recorded in the wood product manufacturing industry and fresh produce (both 56% and 53%, respectively). Gains were reported by 47% and 29% of experts in the food processing industry and the pulp and paper industry, respectively. Overall, biomass supply was viewed by experts as resilient to the pandemic: 40% of experts reported no change in production due to the pandemic and 19% of experts reported a productivity gain.

When asked to assess the reasons for the negative disturbances, about half of the experts reported not knowing the reason (47%). From the estimations provided by the experts, both lack of workers to harvest biomass and prohibited mobility (lockdown measures) were mentioned equally (24%), whereas the lack of biomass from imports was the least common reason. On the demand side, 44% of experts reported no changes observed. From the reasons for negative disturbances from the demand side, the same reasons for the disturbances from the supply side were reported: lack of workers to harvest biomass (24%) and prohibited mobility (lockdown measures) (18%). In addition, 21% of the experts estimated the loss of export markets as a negative disturbance, with the highest effect in the wood product manufacturing industry (20%). Reduced or stopped supply of biomass from imports was not identified by experts as causing any demand-side economic disturbances. Instead, 28% of experts reported that the market demand increased due to the pandemic, at the aggregated level, with the most being reported in the food processing industry (32%).

4. The Delphi Study: Investments in BSChs That Could Contribute to the Post-COVID-19 Recovery

The Delphi survey captured different waves of the pandemic: the first round of opinions was collected under the impressions of the first reactions, subsiding the pandemic in Europe and various intervention measures across and within the countries, whereas the second round captured the peaks for the number of COVID-19 cases in the regions of the Americas, Europe and Western Pacific.

Given the broad definition of consensus, the experts' opinion gave a general direction on the possible contributions of various investments to BSChs in 84% of the statements after the first round and 95% after the second round.

The bridging-over question to verify is whether the existing bioenergy policies in specific countries with modern bioenergy use are sufficient in supporting investments that would contribute to economic recovery. The experts, without defining what those investments would be, agreed that the existing bioenergy policy is in a range of a scale of "sufficiency" in both time frames for the Global Marketplace scenario, which reflects the times before the pandemic. In all other scenarios, in both time frames, experts agreed that the existing bioenergy policies are insufficient to slightly insufficient to support investments that would contribute to economic recovery.

With respect to the impact of future investments, Delphi survey experts assessed investments in BSChs within the Global Marketplace scenario as having the most impact on economic growth, both in the short and long run. In the long run, the impact of investments in BSChs on economic growth was assessed as "moderate to strong" in all future scenarios (see Appendix C for a detailed breakdown of expert consensus on the various investments to BSChs and their possible contributions to economic growth, job creation and building a more resilient and cleaner energy systems). This section highlights investments in BSChs that a consensus of experts endorsed as having "moderate to very strong" contributions to the post-COVID-19 recovery. The experts reflected in the open-ended questions that "by 2023" is too short a period to see any effects of any investments, regardless of the field, which was true to some extent, as the group assigned more positive effects in the long term than in the short run, in general. One of the experts found the future scenarios as "limiting" since the pandemic has affected the entire fabric of society.

Impacts of technology and infrastructure investments were identified by experts as primarily experienced in the long term. In the short run, positive effects from such investments on economic growth occur in scenarios that assume short virus longevity and digital acceleration (Global Marketplace and Walled Gardens), assuming IT solutions would aid in securing biomass supply to the industry. In comparison, the long-term effects of investments in BSCh-related technology and infrastructure on economic growth range from “weak to moderate” to “moderate to strong” in the Digital Reset scenario. Overall, experts identified investments in small-scale, decentralized bioenergy facilities, coupled with the substitution of fossil fuel use, fit for a local supply chain as having positive effects on economic growth across the scenarios.

Interestingly, investments in tailored programs for preferred bioenergy technology (e.g., the one that would have the desired multiplier effect across the economy) coupled with targeted BSCh (e.g., the one that represents a low-hanging fruit, such as corncobs, or possess environmental risks, such as olive oil cake, or pruning or supporting wood pellets for household heating given a strong domestic industry in pellet stoves) (statement 1) were ranked higher than the investments that let the investors recognize the technology and supply chain (statement 2).

In open-ended feedback, experts suggested additional investments that could have strong impacts on economic growth: local investments that address climate mitigation issues, and investments to further optimize existing well-working BSChs with innovations and better business planning. If biomass is used locally in small-scale facilities, investments in the sector which address problems (air pollution from small combustors, efficient supply chains for residues, improvement in quality, etc.) will lead to the greatest impacts for BSChs. Economies of scale were recognized by experts participating in the Delphi survey, but the ability of supply to meet large biomass demand was controversial among experts. Specifically, large-scale biomass operations were thought to have mixed effects on economic growth depending on whether biomass is imported or locally supplied, and whether the supply is sustainable, or if there is a need for subsidies to operate a large-scale bioenergy facility.

When looking at a specific intervention would “probably” create jobs across the scenarios in the long run. Experts agreed that investments related to growing biomass for bioenergy within the bioeconomy (statements 6–8) would “possibly” have a positive impact on job creation in the long run. BSCh investments were viewed by experts as having only slight effects on job creation. Instead, only in the long-term would these investments “probably not to possibly” (Digital Reset) and “possibly” (Back to Basics and Walled Gardens) or “possibly to probably yes” (Global Marketplace) contribute to job creation.

The experts found investments in BSChs to have a smaller impact on building more resilient and cleaner energy systems (“probably not to possibly” and “possibly” in the short and long run, respectively) compared to investment impacts on overall economic growth. Investments in small-scale, decentralized bioenergy facilities, coupled with the substitution of fossil fuel use, fit for a local supply chain, surfaced again, with the consensus of experts, as contributing to economic growth.

Experts agreed that increasing bioenergy demand that is tailored to the specific end-use of bioenergy and linked with the specific, locally available BSCh would have “moderate to strong” and “strong” impacts on post-COVID-19 recovery in the long run.

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