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Identifying practices of inclusive biobased value chains: Lessons from corn stover in Iowa, sugar cane in Jamaica, and sugar beet in the Netherlands

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ABSTRACT

Including local producers of biomass in the process of developing global biobased value chains offers a way to ensure sustainable and reliable production of biomass while also promoting economic fairness. However, many contextual factors influence the design of inclusive bio-based value chains because their technology and feedstock are diverse. Inclusion is therefore not one-size-fits-all, but rather an approach demanding different strategies depending on the value chain. Given such diversity, how can the development of inclusion strategies in bio-based value chain design be supported? Responding to that question, this article examines and analyzes the practices of biorefineries in the United States, Jamaica, and the Netherlands. We propose a means/goals approach to inclusion that can accommodate a variety of value chains. Moreover, we suggest that the concept of inclusion can realize several societal goals ranging from economic justice to managing uncertainties via various institutional arrangements and design means.

1. Introduction

Over the past decade, the concept of a bioeconomy has offered a compelling vision of a sustainable society in which biomass is the main resource for producing energy, materials, and base chemicals, among many other applications (McCormick and Kautto 2013). In this vision, biorefineries provide renewable chemicals and energy products, contribute significantly to addressing climate change, and promote economic fairness along the value chain. While technologies to process and transform biomass do indeed become increasingly available, proponents of the bioeconomy also have concerns about feedstock availability and quality, sustainability, and production costs. Whereas various studies indicate that the potential availability of biomass would be sufficient to meet the demand for sustainable products (van Zeist et al., 2020; SCOPE Report 2015; Piotrowski et al., 2015), setting up these new value chains also involves societal challenges, such as how to integrate smallholders (Ros-Tonen et al., 2019).

New bio-based value chains converge at the intersection of industrial biotechnology and agriculture: a novel cross-industry area. Yet, with novelty comes uncertainty – much of it due to disruption of existing chains and the impact of new technologies. To ensure sustainable sourcing of biomass (Bos-Brouwers et al. 2012; Asveld et al., 2015), to promote synergy between food security and bio-based products (Kline et al. 2017), and to contribute to the livelihood of all actors along the value chain (Bryden et al., 2017), stakeholders in new bio-based value chains will need to work on further institutional and organizational development.

Practice-based and scholarly debates both revolve around the concept of inclusive bio-based value chains. Such chains imply a fair distribution of risks and benefits as well as increased opportunities for all stakeholders, notably those at the beginning of the chain: the producers of biomass. Increasing the opportunities local stakeholders have to define resource management strategies is a factor in achieving more sustainable outcomes (Rist et al., 2007). However, while inclusion may remedy uncertainties, the novelty and potential disruptiveness of bio-based value chains also makes it difficult to know how inclusion can take shape. Research has discussed inclusion as a concept in the bioeconomy for smallholders (Ros-Tonen et al., 2019), for short value chains (Jakubek and Flora, 2017), for citizens (Mustalahti, 2018), and most of the work has been done in the agri-food sector (Déveaux et al. 2018); these accounts also cover social issues relevant to stakeholders. Our research builds on work concerning inclusion in the agri-food sector, specifically across disciplines: responsible innovation, value chain design, agricultural management and policies, and innovation management. From there, we suggest a broader theoretical framework addressing the challenges of new bio-based values chains.

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Our research team identified four main challenges to design inclusive value chains in the bioeconomy. We did this in discussion with practitioners and on the basis of three case studies, which we detail in Section 3. A first challenge we note is that value chains in the bioeconomy are *global and emerging*; while some areas are rich in biomass productions, their consumers often find themselves elsewhere in the world. These stakeholders need to build entirely anew, often finding their way along existing networks of global agri-food value chains. Second, each segment of the chain has different cultural, political, social, and economic *contexts* in which these emerging novel value chains take shape. Third, value chains involve *different types of stakeholders*, each of whom have roles and obligations in their own segment; rarely are people – for example, farmers and chemical industry members – accustomed to working with each other. Fourth, value chains employ a *wide array of technologies*, ranging from high-tech to low-tech processes; they are therefore hard to compare. These four challenges make bio-based value chains even more complex than existing agri-food value chains.

Given these challenges of global bio-based value chains, the question we consider is: what practices can support the development of inclusion strategies in value chain design? This article examines the concept of inclusion by taking a means/goals approach (i.e. how and what inclusion allows to achieve). Through this lens, we explore three case studies investigating value chains in the bioeconomy: corn stover in the US state of Iowa, sugar cane in Jamaica, and sugar beet in the Netherlands. By critically examining practices in bio-based value chains, this article contributes to identifying upstream practices for developing inclusive bio-based value chains. We show how different means of inclusion can be applied at various segments of emerging bio-based value chains, with a strong focus on upstream segments. The research set-up did not go into depth for downstream elements of bio-based value chain that are also very important. The case studies reveal that institutional arrangements and the design of technologies shape value chains more so than participation. In addition, the relationship between biomass producers and the biorefinery is not only the most essential but also the most complicated part of the entire value chain.

2. Inclusion in different disciplines: a means/goals approach to inclusion

Salient concepts of inclusion across disciplines, as identified by the multi-disciplinary research team (ethics of technology and innovation management), include responsible innovation, value chain design, agricultural management and policies, and innovation management. Iterative discussion among researchers, towards the goal of setting new research agenda setting has been used in other contexts (Kaljonen et al., 2021). Our categorization was not exhaustive, but rather sought broad categories of classification to take stock of a wide range of inclusion practices. We then applied this as an organizational structure for presenting exploratory findings. Referencing both literature and practice, we hope to broaden the concept of inclusion and enable its use in research agenda-setting for inclusive bio-based value chains.

After gathering articles and data, we found that a means/goals distinction is useful in discussing inclusion. Such a distinction is relevant and grounded in the responsible research and innovation literature that makes the distinction between process and purpose, both of which are necessary for responsible innovations (Owen et al., 2012). In this paper, means of inclusion are processes, or instruments; the goals are the societal values, or purposes, achieved by these processes. Applying these analytical dimensions to our research findings allows us to draw general conclusions about inclusive practices from the separate case studies.

2.1. Means of inclusion

Our theory overview identifies participation, institutional arrangements, and design as three categories of means of inclusion. This overview presents salient ideas from the literature under each of these means.

2.1.1. Participation

In the responsible innovation framework (Stilgoe et al., 2013), inclusion refers to participation of all stakeholders – including new and underrepresented voices – in technological choices and design. Participation is a complex means of inclusion wherein dynamics must be considered such as value conflict (Dignum et al., 2016). Participation means stakeholder engagement and involvement, discussed in the context of challenges to society's ability to align goals (Ribiero et al. 2018) and practical barriers impacting individual stakeholders, organizational structures, and the broader context (Kuzma and Roberts 2018). Reflecting this multi-level aspect of participation, inclusive innovation is thus also defined as how innovation activities are carried out, their outcomes, and their governance (Schillo and Robinson 2017). Participation is a process and therefore a means of including different stakeholders through which goals are negotiated.

2.1.2. Institutional arrangements

Agreements can form between private actors, public actors, and/or public and private actors, which can be local or international, such as via NGOs. Ros-Tonen et al. (2019) present five strategies for inclusive bio-based value chains that capture various forms of institutional arrangements: 1) partnerships, such as coalitions between governmental and non-governmental actors (McCarthy 2010); 2) improving workers' rights via small holder empowerment; 3) economic incentives that support farmers in adopting new technologies (Zapata et al., 2010; Hira et al. 2009) or financial policy instruments (Ribiero et al. 2018); 4) diversification of livelihood such as horizontal business models (Marques Postal et al., 2020); and 5) gendered asset ownership and opportunities. These different institutional arrangements enable the achievement of a variety of goals, as defined by the actors.

2.1.3. Design

Designing for inclusion suggests that technologies in the bioeconomy can be chosen for the goal of inclusion vis-à-vis accessibility (Reed and Monk, 2006). For instance, the responsible innovation literature presents user-centered design as a process of inclusion (Stilgoe et al., 2013). Design rationales have been applied in the bioeconomy, taking a systems rather than a user-centered design perspective, such as when designing biorefineries (Palmeros Parada et al., 2017; Palmeros Parada et al., 2020).

2.2. Goals of inclusion

2.2.1. Social development

Inclusion focuses on creating benefits for vulnerable groups, such as smallholders (George et al., 2012; Foster and Heeks 2013; Heeks et al., 2014; Devaux et al., 2018; Ros-Tonen et al., 2019). Bryden et al. (2017), for instance, define inclusive innovation in the bioeconomy, as a "new way of doing things - including technologies, institutions, and other things- that may improve the lives of the most needy." (p.7)

2.2.2. Economic justice and solidarity

Discussions in the literature underline a concern that social development be accompanied by fair income at every point of the value chain for the contributions made (Devaux et al., 2018; Ros-Tonen et al., 2019; Heeks et al., 2014). Meeting these conditions requires access to land, inputs, technology, knowledge, organization, capacity, skill, and infrastructure, which may not exist among some communities or groups of asset-poor producers (Deveaux et. Al 2018).

Table 1
Description of cases.

	High technology availability	Low technology availability
High biomass availability	**Iowa, US** The US case concerns corn stover and involves the POET/DSM biorefinery for second-generation bioethanol Project Liberty. Most of the Iowa's corn is produced for feed or first-generation ethanol, though no livestock industry is nearby. The bales of stover, which are perishable and difficult to transport, therefore have no proximate market. Being the only buyer of corn stover, a lignocellulosic feedstock, the POET/DSM biorefinery is critical to the new value chain. With ten years of experience in setting up the world's largest second-generation bioethanol production, POET/DSM sought to continue improving farmer involvement. At the time of writing, Project Liberty was paused due to non-supportive federal policies for second-generation biofuels.	**Jamaica** The Jamaica case concerns sugar cane and involves farmers with few resources working in the sugar cane industry. Sugar cane is farmed on government-owned land, private estates, and as subsistence farming. Depending on contracts and location, sugar cane is delivered to one of five sugar factories in the country. The Jamaican sugar sector currently produces mostly unrefined sugar and rum. No bio-based value chain for energy in Jamaica exists, yet several parties are considering establishing sugar cane as feedstock or energy crops requiring similar farming practices. For this case, we examined potential ways to diversify existing refineries. These new value chains from sugar cane to biomass intermediates could potentially be exported for further processing as bio-based goods in Europe or the US. Our partners were CarbonAgro and Bio4ever.
Low biomass availability	**The Netherlands** The Netherlands case concerns sugar beet and involves the cooperative Suikerunie. Farmers sell their beets to the Dutch sugar cooperative, which is the only processing firm in the Dutch sugar beet value chain. Suikerunie is part of the agricultural conglomerate Royal Cosun, aiming at optimal valorization of plant-based raw materials for the retail, food industry, feed, chemistry, and energy; advanced processing; and diversification of semi-fabricates in the sugar beet value chain. Its facilities recently expanded to fulfill new bio-based opportunities, especially for sugar beets.	**A fourth case study** Research for another case study was planned for spring 2020, but had to be canceled due to the COVID-19 pandemic.

2.2.3. Autonomy of stakeholders

New value chains struggle to meet the market economy demands. Indeed, a high degree of dependence exits between segments of the value chain. An important aspect to inclusion as a goal is for stakeholders at each segment to retain autonomy in their choices (Bronson, 2018).

2.2.4. Social, economic, environmental, and political impacts

Goals of inclusion are not limited to economic and social dimensions. In some cases, inclusion means accounting for environmental and political impacts. This underlines that new value chains have different dimensions to consider that could support or hamper their success (Schillo and Robinson 2017; Ros-Tonen et al., 2019).

2.2.5. Managing uncertainties

The various stakeholders in value chains have different knowledge and contexts. Farmers supplying feedstock – who may, for example, be doing so for a first time – will need to shift any seasonal planning to long-term thinking. Sharing knowledge along the value chain can help manage these uncertainties (Šūmane et al., 2018).

3. Material and methods

3.1. Choice of cases

Our research was funded by the Responsible Innovation program of the Dutch Research Council. Under this scheme, practitioners could join our research as partners out of an interest in the conceptualization and operationalization of inclusion in the bioeconomy. We sought a diverse set of bio-based value chains representing three distinct contexts of biomass and technology availability to serve as case studies. Table 1 describes the cases, in Iowa, the United States, Jamaica; and the Netherlands. Due to the COVID-19 pandemic, a fourth case study had to be excluded.

3.2. Data collection

Our research collected data by interviewing various stakeholders. Identifying stakeholders in bio-based value chains requires a working understanding of the term. While an engineering perspective sees the different segments of a value chain (Rudi et al., 2017), there is also a view based on social networks of actors in the value chain (Scheiterle et al., 2018). Our analysis combines both conceptualizations by understanding value chain segments as a proxy to identify stakeholders. Table 2 depicts a typical value chain with the most common segments and associated relevant stakeholders. This combines two value chain models: the engineering model with different segments (inspired by Rudi et al., 2017) and the institutional model with different stakeholders (inspired by Scheiterle et al., 2018).

Our data collection comprised semi-structured interviews with stakeholders, site visits, and workshops. Table 3 details our data collection, between May 2017 and May 2019. Sometimes an interview was conducted with a group of interviewees. We also carried out several site visits accompanied by interview-like conversations aiming for deeper understanding of the practices in each case. The interview guide was structured according to the following points of interest and, when possible, in the following order: 1) general information; 2) incentives for joining a value chain; 3) access to technology and acquiring knowledge; 4) ease of doing business; 5) feedstock supply standards; 6) feedstock supply logistics; 7) feedstock supply contracts; 8) risks; 9) availability of demand; and 10) inclusion. Our interactions were under non-disclosure agreements concerning technology, and participants signed consent forms whereby we accordingly anonymize personal information. From hereon, we refer to results from specific activities by codes indicated in Table 3.

3.3. Analysis

Our analysis interprets observations from interviews and site visits. Using an open coding approach, we analyzed interview data according to themes covering each of the separate elements in a global value chain. Next, we identified universal themes for inclusion that transcended the separate elements, which iteratively condensed into the practices for inclusion that we found. These practices are considered at different segments of the value chain. This grounded approach provided our final coding in the results (see Tie et al., 2019). We chose an inductive interpretation because it let us reconstruct existing practices in a variety of value chains using the lens of inclusion as a means and inclusion as a goal.

4. Results: means of inclusion in various practices

This section presents six practices identified in our cases that are not typically considered inclusion practices. Summarized in Table 4, our

Table 2
Identifying relevant stakeholders at different segments in the value chain.

Segment	Biomass supply	Logistics (storage, transport)	Conversion (pre-treatment, processing)	End product
Stakeholders	Farmers, agricultural workers, crop advisors, purchasing and supply cooperatives, implement dealers, landowners, extension services	Farmers, agricultural workers, purchasing and supply cooperatives, implement dealers, landowners, biorefinery operators	Biorefinery operators, cooperatives, universities	Cooperatives, other private companies as suppliers, distributors, policymakers, local government officials

Table 3
Overview of data collection activities.

Data collection	Dates	Number of participants	Activities	Contact time**	Segments represented*	Code for reference in result section***
Meetings with project partners	Between May 2017 and May 2019	Nine	Workshops	Four workshops	L, C, E	PW1
			Interviews	11 interviews	L, C, E	PI2
Jamaica	Between February 12, 2019 and February 25, 2019	13	Interviews	13 interviews	S, L, C	JI3
			Site visits	Five site visits	S	JS4
Iowa, US	October 29 to November 17, 2018 and January 24 to February 1, 2019	14	Interviews	14 interviews	S, L, C, E	II5
			Site visits	Three site visits	S, L, C	IS6
		Eight per workshop	Workshops	Three stakeholder workshops	S, L, C, E	IW7
The Netherlands	Between August and December 2018	11	Interviews	11 interviews	S, L, C, E	NI8
			Site visits	Three site visits	S, L, C	NS9

* S = supply; L = logistics; C = conversion; E = end product (stakeholders from these segments contributed to the data collection).
** Workshops lasted three to four hours, including breaks; interviews typically lasted 60 to 90 min; site visits lasted a minimum of two hours to a maximum of four hours on site, not including travel time and breaks.
*** PW = partner workshop; PI = partners interview; II = Iowa interview; IS = Iowa site visit; IW = Iowa workshop; JI = Jamaica interview; JS = Jamaica site visit; NI = Netherlands interview; NS = Netherlands site visit; each entry is labeled from 1 to 9 and considered a source of data.

Table 4
Practices of inclusion in global value chains.

Practices identified	Value chain segment	Stakeholders impacted	Category of means	Category of goals
Feedstock selection	Conversion	Farmers, agricultural workers	Design	Autonomy, economic justice, considering impacts, managing uncertainties
Learning practices	Biomass supply	Farmers, agricultural workers, companies (including engineers and designers)	Institutional arrangements	Managing uncertainties
Biorefinery design	Conversion	Farmers, agricultural workers, companies (including engineers and designers)	Design	Economic justice, social development, autonomy, considering of impacts, managing uncertainties
Contracts	Conversion	Farmers, agricultural workers, companies (including engineers and designers)	Institutional arrangements	Autonomy, economic justice
Communication	Biomass supply, logistics, conversion	Farmers, agricultural workers, companies (including engineers and designers)	Institutional arrangements	Autonomy, managing uncertainties
Certificates	Biomass supply, logistics, conversion, end product	Depending on the certification scheme, more or fewer stakeholders are impacted by certification	Institutional arrangements	Economic justice, social development, autonomy, considering of impacts, and managing uncertainties

results underline how each practice can be conceptualized as key means to achieve goals of inclusion.

4.1. Means of inclusion: feedstock selection

Value chain segment: In bio-based value chains, the conversion process is crucial to determining which crops – input – will deliver which desired products – output – within a given conversion process. Biorefineries need a stable input of biomass to run their processes in a continuous fashion and sell on the market in a consistent, predictable manner (PI2). The most exemplary case of feedstock selection we observed was among the Iowa biorefinery operators, who chose to design a process around corn stover (II5). From interviews, we learned of three requirements for “a stable input of biomass”: quality and quantity of the biomass; consistency in delivery; and predictability of feedstock type over the long term (at least five years). However, the everyday realties of farming cannot always meet the needs of a modern-day biorefinery.

Stakeholders impacted: These three requirements have implications on farmers and their practices. First, biomass quality and quantity are challenged by unexpected weather events and pests – farmers inevitably face bad seasons. Interviewees pointed to climate change as exacerbating these events. In Jamaica, we witnessed an abnormally longer rain season, with muddy fields making it very difficult for farmers to harvest sugar cane (JI13, JS4). Weather conditions had also diminished the crop’s sugar content. On our first visit there, we observed a similarly extended rain season in Iowa, shrinking the harvesting window from eight to five weeks and delaying it to later in the season, thus increasing chances of corn stover not being dry enough for the biorefinery needs (II5, IS6). By contrast, persistent droughts cut a fifth of sugar beet production per field in the Netherlands in 2019 (Netherlands Statistics, 2019).

Second, because crops need time to grow and cannot be stored long before processing, consistent delivery is a challenge. In Iowa, we learned that corn stover must have enough dry matter content to work with the enzymatic process at the biorefinery, which might be compromised if it rots or is over exposed to humidity (IS6). Our interviews in Jamaica taught us that sugar cane degrades after 72 hours, so must be processed before then by the factory (JS4).

Third, for the sake of long-term predictability, farmers may choose to rotate crops. In Iowa, many farmers rotate soy and corn, but some plant corn exclusively (II5). These decisions, sometimes left to the landowner rather than the farmer, mean that some farmers cannot deliver to a biorefinery every season. As such, the biorefinery cannot always guarantee fulfillment of customer contracts further down the value chain.

In Iowa and the Netherlands, crop selection decisions are made year by year, according to factors such as soil health, market dynamics, farmer preferences, and state incentives (II5, NI8).

Our research also revealed impacts on farmers not bound to logistical or technical issues: uncertainty and its related loss of personal identity. Many interviewees identified as sugar cane farmers or corn farmers. In all three countries, that sense of identity was supported by associations extending farmers membership representation or other advantages. The identity offered an institutional safety net (JI3, II5, NI8), which then felt taken away when questions on new energy crop markets and related income would arise (II5, JI3).

Category of means: Understanding these impacts on farmers invites a turning the tables on companies, including engineers and designers who work with them. This implies seeing feedstock selection as a design choice that goes beyond considerations of a conversion process and takes into account the impacts on stakeholders and the goals to be achieved.

Category of goals: Our analysis revealed four main goals that a more deliberate feedstock selection can achieve. First, respecting farmer autonomy is important for inclusion. In practical terms, let farmers chose what and how they farm. This requires learning more about factors causing optimal and non-optimal harvests, the identity of farmers, and the institutional safety nets they have or need. Choosing a crop that only fits the demands of a conversion process without considering such issues undermines farmer autonomy. Second, to promote economic justice, the chosen crop must have clear economic advantages for farmers and compensation for new uncertainties. Knowing that feedstock selection can contribute to economic justice encourages stakeholders along the value chain to consider risks and benefits as well as be mindful of what kind of institutional arrangements can further the cause. Third, feedstock selection can help account for a wide range of impacts. Such contextual elements can help build new value chains for new markets. Fourth, addressing all these goals – through enabling local strengths, acknowledging local concerns, and addressing both by choosing a crop that will enhance local livelihoods – will also manage some of the uncertainty that comes with a new value chain.

4.2. Means of inclusion: learning practices

Value chain segment: Learning practices consist of culturally and socially informed multi-actor networks in which knowledge is disseminated. They often comprise a combination of informal local knowledge and scientific knowledge (Šūmane et al., 2018). We found that new technological processes not only created requirements for farmers and agricultural workers on which crops to use, but also demanded changes in harvesting practices, for both existing and new crops.

Stakeholders impacted: In Jamaica, factory operators indicated that the way cane was cut impacted the sugar content and, in turn, their output. Thus, optimal cutting practices varied depending on farmers and agricultural workers (JS4). Interviewees described another project involving an energy crop that would lead to higher yields and maintain similar farming practices to the optimal ones for sugar cane (JI3), though this project did not materialize. In Iowa, our interviews revealed the need for a process of learning and adaptation between farmers and the biorefinery before agreeing on best practices for corn stover harvesting (II5). While some farmers subsequently lost interest in participating in the process, with the help of scientists and extension services, the biorefinery and the farmers agreed over time on the optimal amount of collected corn stover. This amount meant that enough stover could stay on the ground for soil health, and enough stover could be harvested for the biorefinery. In the Netherlands, new value chains were set up so farmers did not need to adapt their practices. Farmers would sell their whole produce to the cooperative, unburdening them of dedicated additional labor (NI8).

Category of means: Feedstock selection as a means of inclusion requires awareness of required learning practices, existing socioeconomic structures, and historical factors affecting how farmers (among other farm workers) learn new practices. This type of institutional arrangement might not always be captured under formal institutional settings as it relies on informal networks.

Category of goals: Considering local learning practices connects to the goal of managing uncertainty and encouraging autonomy of local stakeholders.

4.3. Means of inclusion: biorefinery design

Value chain segment: Typically, a biorefinery design will be driven by market demand for a product, which will determine the scale of operation for profitability. In the cases in Jamaica and the Netherlands, the products were still being researched and, in the US, the biorefinery was in a pilot stage, with the technology still being fine-tuned. Interestingly, in all cases, market demand proved to be an uncertainty rather than a driver.

Stakeholders impacted: In Jamaica, discussions about biorefinery design mostly concerned technology choices and the market they wanted to participate in (JI3). For instance, they could choose to do a pretreatment in Jamaica and then export it as pellets, to be converted into energy or base chemicals at another facility in Europe. Alternatively, they could choose to fully convert the biomass to its final products for domestic use or export. Many options were discussed in terms of end products, including energy. A qualitative and quantitative study of Jamaican sugar refineries (Francke 2018) allowed identification of desirable process design choices: staying with the same crop, limiting the number of different types of products coming out of the biorefinery, focusing on improving sugar production, closing energy loops in the factory, and adding one new stream of production.

In Iowa, discussions on biorefinery design considered process optimization based on farming practices (II5). After ten years in the making, this second generation plant for producing of bioethanol was described by an interviewee as having started “too big, too fast” (S1). Learning from mistakes over the years enabled POET/DSM’s process of reverse design to better fit the context (BR3). For instance, operators discovered that stover bales would sometimes hold objects dropped during harvesting and subsequently cause serious damage to equipment in the first stage of treatment; the solution was to incorporate magnets and a sorting stage before grinding (BR3). Another example was biomass being contaminated by rocks and sand, also potentially damaging to the biorefinery process and equipment; the design solution that emerged was linked to a better understanding of the needs for harvesting and bailing machinery (BR3). One interviewee mentioned that while the project was already ten years in the running, it still felt like a pilot because they kept learning and adjusting to local circumstances (BR3). The process of mutual learning between the biorefinery and the farmers, as indicated by our interviewees, reflected great promises that the biorefinery project brought to the local town: more employment, training opportunities, and customers for local businesses (IW7).

In the Netherlands, the development of biorefineries for sugar beets takes place in a way that is very different from the other two cases. In this context, most new value chains are initiated by the cooperative seeking the optimal use of side and waste streams (NI8). Income from those waste streams is redistributed to farmers as part of their annual dividend. In that sense, the cooperative absorbs the burden of making design choices to the extent that they do not affect any of their members’ practices.

Category of means: Linking this design to contextual factors provides a means to consider a wide range of impacts, to encourage local development, and enhance chances of success.

Category of goals: The cases highlight the importance of context-specific design. This includes issues of scale of operation (considering how large the project is and how fast it is developing); technology choice (whether it involves radical or incremental changes); how it builds on feedstock selection; and learning practices. Depending on design choices, a biorefinery can lead to inclusion in terms of autonomy, economic justice, social development, and managing uncertainties for local stakeholders.

4.4. Means of inclusion: contracts

Value chain segment: Contracts are a powerful means of inclusion between biorefineries and farmers, but sometimes also of exclusion.

Stakeholders impacted: In Iowa, farmers could choose between two types of contracts: grower's or custom (II5). In the grower's model, the farmer is responsible for bailing and delivering the biomass; in the custom model, the biorefinery sends bailers to do the work for the farmers. While both have economic incentives, many farmers prefer the grower's because it gives them more harvest. A downside is that it also gives them more work in a short timeframe. The biorefinery has no preference; the landowners entering such a contract often do not farm themselves and are absentee landowners. Landowners and farmers might have preferences for not storing stover bales on their fields because "they look messy" or have practical concerns that they "make it harder to harvest around them" or might "attract rats" (II5). Clearly, contract content goes beyond economic arrangements, as esthetic and practical considerations play a role. Bales can be stored on the land or at the biorefinery, though too many bales on one site present a fire hazard. In general, farmers depend on good relationships with absentee landowners, and fussy landowners and diverging preferences can deter farmers from participating in new value chains.

In the Netherlands, farmers get a fee for selling sugar beets to Suikerunie as well as an annual dividend. The latter is tied to Royal Cosun's profits, which include side stream income from the post-extracted pulp, used as input for advanced bio-based (NI8, NS9). Nowadays climate uncertainties force farmers to absorb high risk should they be unable to fulfill contracts as drought insurances do not exist.

In Jamaica, few contracts are formalized. Although there is a policy-defined sugar pricing formula, it has two main pitfalls. If rain season is heavy, the cane's sugar content diminishes, leading to less income for farmers. And if a sugar factory were to exploit more of the cane – for example, using the bagasse for energy – the farmer has no compensation scheme to benefit from such new streams (JI3).

Category of means: Contracts are a form of institutional arrangements between farmers and companies doing conversion processes.

Category of goals: Devaux et al. (2018) find that contract farming leads to more economic justice, but also acknowledge shortcomings. Contracts are a better fit for crops that produce high-value commodities and also require farmers to work in a way that benefits the contractor (p.106). The above cases present alternatives to contract farming as important means to achieve the goal of economic justice as well as respect for autonomy.

4.5. Means of inclusion: communication

Value chain segment: Communication is a key tool that helps in sharing information among stakeholders in a value chain (Šūmane et al., 2018).

Stakeholders impacted: In the Netherlands, sugar beet farmers sell their produce to the cooperative, which is responsible for adding value to the produce before selling it on the market. Farmers co-own the cooperative, and established channels facilitate communication between farmers and the managers taking care of daily cooperative activities. For example, all the farmers receive regular emails about the cooperative's business choices. With generally a more operational focus, the cooperative promotes IT services for benchmarking and improving the crops (NI8).

In Jamaica, identifying means of communication was harder in data collection. From interviewing agricultural education teachers and a community leader on a small farm, no single means of communication with farmers proved dominant. We did, however, observe the importance of local leadership for passing on types of information or knowledge (JI3, JS4).

In the US, we found many means of communication from the biorefinery, extension services, and various types of advisors. Farmers seemed to prefer to be independent in their gathering of knowledge, relying on multiple sources. At the same time, the biorefinery developed documentation concerning harvest requirements and the process as well as organized visits at the plant. The biorefinery also had a three-employee team dedicated to building and maintaining relationships with area farmers (II5, IS6).

Category of means: Communication as a means of inclusion is an institutional arrangement that can build on formal and informal relationships between stakeholders.

Category of goals: Carefully designing communicating channels in line with existing learning practices, cultural norms, and available technology can further the goals of economic justice, respecting farmer autonomy and managing uncertainties.

4.6. Means of inclusion: certificates

Value chain segment: Certificates can be contentious instruments that have room for improvement (Pols, 2015), but they can also be a means of inclusion coordinated by public and private actors.

Stakeholders impacted: In several interviews (PI2), certificates were mentioned as a key means of inclusion. Although no certificates were used in the case studies, we investigated what kind would impact stakeholders.

In most certification schemes, inclusion is implemented in the form of governance processes where all stakeholders have a say in decisions. The European Union currently has 14 voluntary schemes (at the time of writing) that stakeholders in new value chains for bioethanol and other products are encouraged to adopt. We examined two of the main schemes used: the Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC). Our focus was on inclusion through the schemes' representation of stakeholders, their demands, and markets.

Representation of stakeholders is crucial, as stakeholders help define the standards used in a scheme. These governance structures can be quite complex and are described in detail in the scheme documentation. In its standard development, RSB offers a structure where more stakeholders are represented than ISCC. RSB is also a member of the ISEAL Alliance, thereby complying with the strict ISEAL Code of Good Practice. Because ISCC is not a member and therefore does not explicitly comply with the ISEAL Code of Good Practice, RSB might be a more constructive choice where participation of stakeholders is inadequately governed due to corruption, low literacy, large geographical spreading, or other political contexts.

Participation aside, we were curious as to how economically accessible these schemes were for stakeholders. Furthermore, how we wanted to know how they would play out in informal economies. Participants in our research (PW1) discussed certificates as being both enabling and limiting. There was uncertainty as to which would be the appropriate certification schemes (PI2), with some also noting that this greatly burdened themselves and farmers.

Due to the highly complex certification cost scheme, no conclusive comparison could be made between RSB and ISCC. Nevertheless, research suggests that RSB's higher stringency correlates with higher certification costs (Bor, 2012). This suggests, too, that a scheme demanding more participation will also demand more administration. In addition, we learned that RSB does not have a one-size-fits-all approach. Rather, context-specific indicators and a fee structure correspond to the types of scheme operator on a case-by-case basis.

ISCC has the bigger market share, while RSB has a much smaller market. This is mainly due to the orientation of the schemes. ISCC is market-driven, while RSB is NGO-driven. This suggests that stakeholders in more environmentally, socially, and economically vulnerable positions will benefit more from using a scheme such as RSB to achieve inclusion because of the processes and goals established within RSB. Any – if not all – of the goals we presented could be achieved via a scheme such as RSB. If ISCC were used in an institutionally weak context, there is little chance such a scheme would be instrumental in achieving goals of inclusion.

Category of means: Certificates are formal institutional arrangements.

Category of goals: Choosing the right certificate for the right context contributes to achieving the goal of respect and autonomy of stakeholders in the value chain. Certification schemes strive to ensure social, environmental, and economic sustainability – and thereby foster social development.

5. Discussion

In the discussion section, we hone in three main topics we feel would deserve more attention when examining and designing inclusive biobased value chains in the bioeconomy. This focus stems from the disciplinary backgrounds of the interdisciplinary research team. First we call to think of inclusion as a concept that invites other activities than participation. Second, we underline how our findings reinforce recent scholarship on the role of institutional arrangements in biobased value chains and that these should be a point of further attention. Third we highlight the potential of design in inclusive biobased value chain. Lastly, we point to limitations of this research.

5.1. Inclusion beyond participation for inclusive bio-based value chains

Table 4 shows that participation is not listed in the practices we identify across value chains. It is absent in some of the cases we studied. In Iowa, it was present in early stages of development, but seems to have gone unsustained through more recent years. In Jamaica, there was no intention to have participation in the setup. In the Netherlands, participation was embedded in the cooperative structure. Making use of the right kinds of certificates can remedy the absence of participation. However, true participation requires many specific preconditions, such as equality between participants. As Marques Postal et al. (2020) indicate, in some cultural contexts, institutional conditions make participation problematic and, in such cases, participation can fail to truly bring out the perspectives of vulnerable. Indeed, other ways do exist to achieve goals of inclusion beyond participation.

5.2. Institutional arrangements for inclusive bio-based value chains

Our research reveals that institutional arrangements have the most to offer for inclusive bio-based value chains (see Table 4). This echoes findings of studies on inclusive value chains by Deveaux et al. (2018), Heeks et al. (2014), and Ros-Tonen et al. (2019). Ros-Tonen et al. show that institutional arrangements are present in most approaches to inclusiveness. Considering the diversity of inclusive value chains considered in this article, we also invite a diversity of approaches to governing inclusive bio-based value chains (Macnaghten et al., 2014; Opola et al., 2020). Our research additionally emphasizes the importance of context and informal institutions in establishing institutional arrangements.

5.3. Design for inclusive bio-based value chains

Design is an important means of inclusion because it demands thinking of options to respond to the goals identified. Design thinking emphasizes that strategies of inclusion can be co-constructed and are not fixed – they can be tailor-made and context-specific. Our research revealed that biorefinery design was an excellent example of something with repercussions on other segments impacting goals of inclusion across the board. Our research identified how biorefinery design needed to fit the context of operation. Although the cases showed that context-sensitive design can play a crucial role in developing inclusive value chains, the risk of technological lock-ins looms. If a biorefinery chooses low-tech solutions to match local skills and resources, does that deprive the local community of the chance to build new skillsets? Biorefineries are meant to last a long time – what should happen to them once users have outgrown them?

Along with these considerations come technical concerns about efficiency and process optimization. This can impact scale of operation and, in turn, inclusion, as seen in Francke's design suggestion for incorporating other production streams on existing sugar refineries (2018). Considering contextual and technical constraints, biorefineries could be developed in a modular fashion, allowing the integration of more advanced technologies once local circumstances are fit for that. Or, existing technologies can be appropriated by the local community and adapted to their needs.

5.4. Limitations and further research

Our aim was to broaden the theoretical framework of inclusion to address the challenges of new bio-based values chains. Through this research, we looked across disciplines and in the field itself, seeing where choices in the value chain could have impacts on improving inclusion. We presented these in Section 4.

Global emerging challenges have merited our attention to this matter, examining new contexts, different stakeholders, and a wide array of technologies. Our research did not test our findings on other value chains, nor did it validate their contribution to the goals of inclusion that we identified in the literature and suggested might be impacted in our results. Our findings urge further elaboration on concepts and application in practice as next steps for inclusion research in the bioeconomy. This could lead to developing or refining existing indicators of inclusion for the bioeconomy specifically. Or, it could help develop new categories of inputs and outputs for social life cycle assessments.

Another limitation was the lack of integration of literature on farmer adoption of technology and its intersection with inclusion. Since we looked at the value chain as a whole, it was out of our scope. Factors that influence technology adoption are, however, relevant for participation in new value chains. For instance, Wang et al. (2020) show the importance of personal norms in the case of biogas adoption in rural Pakistan. Combining agent-level insights with the more structural ones we explored could provide salient paths of research.

6. Conclusions

Given the complexity of emerging bio-based value chains, what practices can support the development of inclusion strategies in value chain design? Our research focused on options available to private actors, such as companies, to achieve inclusive bio-based value chains. The main lesson we took is that: 1) there are means to achieve goals of inclusion; and 2) that while these can manifest at different segments within a value chain, the relationship between farmers and the biorefinery is key. Salient means of inclusion that we identified include feedstock selection, learning practices, biorefinery design, contracts, communication channels, and certification schemes. These means have the potential to contribute to goals of inclusion such as economic justice, social development and solidarity, and farmer autonomy. These goals take into account a wide range of impacts and help manage economic and ecological uncertainties that accompany the set-up of global bio-based value chains.

The study we carried out was explorative, interdisciplinary, and aimed to contribute to the scholarship on inclusive bio-based value chains. Inclusion is a concept anchored in practice, and while our analysis considers practices in value chains for corn stover in the US, sugar cane in Jamaica, and sugar beet in the Netherlands, we claim no exhaustive list of means and goals of inclusion.

Still, a means/goals approach to inclusion can help clarify discussions among stakeholders when they say they “value inclusion” or “want to be inclusive.” The approach also shows that inclusion can be achieved by means other than participation, which may not always be feasible in every context. Additionally, this approach empowers a diverse set of stakeholders to initiate activities as means of inclusion and define which goals of inclusion matters to them. Inclusion is something that can take place through various instruments in the value chain and be initiated by many stakeholders. Future research should continue identifying means and goals of inclusion and specify their use for different types of value chains. Reflecting on means and goals of inclusion could be accompanied by a reflection on the levels of integration of this inclusion (Heeks et al., 2014; Bryden et al., 2017). Without first discussing means and goals, inclusion might become little more than a legitimation exercise.

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Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Zoë Robaey: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Lotte Asveld:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Kinsuk M. Sinha:** Methodology, Investigation. **Emiel Wubben:** Methodology, Funding acquisition. **Patricia Osseweijer:** Methodology, Funding acquisition.

Data Availability

The data presented in the paper is the data we were allowed to present as per the agreements with partners and participants.

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