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Biorefineries as models of a sustainable socio-technical transition?

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Summary:

A biorefinery is an agro-industrial facility which creates an interface between the industrial and agricultural worlds: between technological and natural assets. Biorefineries are one element of a global socio-technical system and reflect how the sustainability transition is put in place at the local and regional levels. Analyzed according to the model of transition management, on-going generations of biorefineries are regarded as new niches of innovation and experiment, no longer solely dedicated to biofuel production. The stakeholders involved in their development try to find new processes of biomass transformation, rooted in their local situation, which consume less energy less energy, to use different types of feedstock and produce a variety of final products/ outputs. However, this biomass optimization is a controversial issue because it raises multi-scale societal environmental dilemmas. Based on empirical research this article reflects on the tangibility of socio-technical transitions and their respect for sustainability principles.

Keywords: biorefineries, sustainability transition, multi-level perspectives, socio-technical system, narratives

Biorefineries as models of a sustainable socio-technical transition?

Biorefineries are one component of a global socio-technical system and reflect how sustainability transition is conceived at local and regional levels. Analyzed in terms of the transition management model defined by Geels (2002) and Grin, Rotmans and Shot (2010), successive generations of biorefineries are regarded as new niches for innovation and experimentation, with activities no longer confined to the production of biofuels. The actors involved in their development try to find new biomass transformation processes that consume less energy, that use different types of feedstock and produce a variety of outputs, while remaining embedded within their local context.

This transition towards a new agro-industrial system could be interpreted as a new and more sustainable "green revolution", since it impacts agricultural practices, industrial processes, energy production and distribution. In addition, it leads to changes in human organizations and collective systems of agro-industrial governance, as it is often rooted in principles of industrial ecology (Gobert 2017; Octave and Thomas 2009).

However, biomass optimization of this kind is controversial because it raises multi-scale societal environmental dilemmas (Olsson et al., 2004). The best known is the "food-vs-fuel" debate (Koh et al., 2008), but this is just one of the ethical and societal issues around energy and planning choices that deserves exploration at a variety of levels (Nieddu 2010; Fitzherbert et al. 2008). Moreover, this new way of thinking about an alliance of industry and agriculture to produce energy and materials should perhaps not really be called a "transition" if it does not result in a reduction in resource use and is not correlated with new practices (reduced carbon consumption) or a new "energy democracy" (Feenberg 2004), i.e. a system in which all stakeholders participate in decision-making. In fact, we believe that biorefinery development is often characterized by a disconnect between those who decide and justify these technical changes, consumers, and the farmers who produce the feedstock.

It therefore seems particularly appropriate to explore these ambiguities around the future of biorefineries by combining the perspectives of transition management literature and the multi-level perspectives (MLP) approach with developments arising from critical academic debate, particularly concerning the meaning of sustainability. The aim of this article is to question the narrative of biorefineries' proponents and their linear presumptions through the frameworks of transition management and multi-level perspectives. Indeed "[a]dvocates of sustainable transition management do not always appreciate the deep ambivalence of sustainability as a category and its power as legitimizing discourse" (Shove et al., 2007, p.766). In the case of biorefineries, this transition has not been fully explored, and certain issues relating to sustainability (participation, distribution…) have been neglected.

Empirical studies were carried out in 2012 (Gobert 2016) and then consolidated by other case studies conducted in France between 2013 and 2016 (part 2). They therefore offer an opportunity to reflect on the reality of socio-technical transitions and their adherence to sustainability principles (Allais et al. 2015). Our different case studies showed that the biorefinery industry – with its wide diversity of forms, technical processes and governance systems – is not as "sustainable" as its promoters claim. Certain critical issues regarding bioenergy implementation identified twenty years ago by Roosa et al. (1999) have been not resolved. In fact, while bioenergy has attracted attention and state involvement (through R&D funding, subsidies…), the social and societal issues at different levels have not been fully grasped (Gobert 2016). This is partly because of the "ambiguous meaning of the notion of 'sustainability'" (Redclift 2005). As observed by Voβ (2009, p. 294) "it therefore seems central to strengthen and clarify sustainable development as a policy problem that transition management is addressing".

In analyzing rural biorefineries as socio-technical systems that represent environmental transitions, it is essential to take into account the micro-level (as an innovation niche in which the industrial step and the socio-technical regime coevolve), the meso-level (the biorefinery as the outcome of a specific arrangement of local assets embedded in a localized "path dependency" process) (Gobert et al. 2017), and the macro-level impacts (change in biodiversity and land use, redistribution of power and value) (part 3).

1. Biorefinery as an indicator of environmental and bio-economic transition?

One of the major challenges for western society is to limit climate change, rather than simply reacting to it through changes in urban planning and public and private practices. Since human activities are considered to be the main cause of rising greenhouse gas emissions and natural resource depletion, the responses must entail a radical ecological shift, changes of practice, and multi-scale coordination between governments, experts, private entities and civil society organizations (environmental groups, residents, consumers, etc.). A more sustainable society has to be devised. Although the attempts to tackle this global change through transnational regulation have encountered problems (e.g. the failure of the 2009 United Nations Climate Change Conference, known as the Copenhagen Summit, the US withdrawal from the Paris Climate Agreement), a degree of international consensus (Kyoto Protocol, Rio+20 Conference, the 2016 Paris climate deal, etc.) and a number of supra-regional and national level decisions have opened the way to new societal, economic and environmental initiatives. These are helping to facilitate the quest for a new model. Decision-makers, experts and civil society together are considering a "new policy approach for dealing with persistent and highly complex societal problems such as climate change, loss of biodiversity…" (Loorbach and Kemp 2005). In this new approach, the imperative is to redefine collective action at different scales, with the participation of government bodies, economic actors (particularly industrial concerns) and ordinary citizens, who are collectively and individually responsible for significant negative impacts in their production, consumption and waste practices. This first part describes why biomass transformation is considered as a sustainable transition. It explains what a biorefinery is and how can it be interpreted as a socio-technical system within the framework of transition studies, promoting innovation and incorporating ecological transition.

1.1. Biomass transformation and valorization: A sustainable transition

There is a wide range of definitions of biorefineries: some view them as production systems "that incorporate different firms and factories which may be geographically dispersed and operate throughout the entire value chain from raw material to consumer goods, whereas other definitions focus on the factory which utilizes an undefined set of processing technologies to produce certain products from biomass." (Bauer et al. 2017). The biorefinery can be described as a classic model of a bioeconomy infrastructure, insofar as it is an agro-industrial facility that creates an interface between the industrial and agricultural worlds, between technological and natural assets. A "biorefinery should produce a spectrum of marketable products and energy [from biomass]. The products can be either intermediates or final products, and include food, feed, materials, chemicals, and energy (defined as fuels, power and/or heat) (…) a true biorefinery has multiple energy and non-energy products" (IEA Bioenergy 2009).

The production of energy and materials of different kinds from the conversion of biomass is advocated as a more sustainable process than the use of fossil resources (Naik 2010; Suhag, Sharma, 2015). Biomass can be burned, converted into fuel gas through partial combustion, into a biogas through fermentation, into bioalcohol through biochemical processes, into biodiesel, into bio-oil, or into a syngas from which chemicals and fuels can be synthesized (Laurent et al. 2011). Bioethanol from either sugarcane or maize, and biodiesel from oilseeds, are currently the major products of first-generation biorefining. In economic terms, they continue to be the most productive processes, but they have attracted strong criticism. In response, industrial firms are striving to make the conversion process better and more sustainable by using the whole plant rather than just the edible part.

These incremental innovations are broadly conceptualized in terms of a succession of generations defined by changes in processes, in the biomass used or in territorial integration.[1] The objective for instance, is to consume forestry or agricultural waste residues and more specifically to convert lignocellulosic biomass rather than using only the edible part of the plant. In addition, the principles of "doubly green chemistry" (Nieddu et al. 2010) are applied to demonstrate green credentials. Green because they use renewable bio-material from agriculture or forestry, and because they claim to use safer solvents, design safer chemicals and increase the energy efficiency of synthetic methods (Anastas, Warner 1998). At the local level, the argument is that the new generation of biorefineries will benefit rural communities and old industrial areas by processing forestry and farming resources and thereby providing new sources of revenue (Antizar-Ladislao, Turrion-Gomez 2008).

Globally, industries and governments argue that bioproducts obtained through biorefining are a viable substitute for fossil fuels, and that all the technologies can enhance global productivity without exacerbating climate change, since they result in lower greenhouse gas emissions. Consequently, in social, economic and environmental terms, converting biomass into biofuels and various high-value products is interpreted as an efficient industrial method. It gives the European Union an opportunity to be highly innovative in a specific domain, and to address global concerns while fulfilling its international obligations to reduce greenhouse gas emissions.

1.2. Biorefineries as socio-technical systems in transition

[1] In interweaving the discourses of different stakeholders, we observe significant differences in their understanding of what a 1st or 2nd generation biorefinery is (from one to multiple products). Others distinguish the type of biomass (sunflower, maize, lignocellulosic biomass etc.) or the method of biomass processing.

Making the transition to sustainability is a modern challenge facing public politics, and policy makers at different levels, necessitating a change in existing socio-technical systems (Akrich 1989). The field of "transition studies" employs several different academic frameworks and tackles a range of issues associated with the process: transition management (focusing on coordinated governance models for transitions) (Kemp and Loorbach 2006); strategic niche management (support for niche innovations as a way to trigger transition); and multilevel perspectives and technological innovation systems (Geels and Raven 2007). They deal not only with uncertainty but with complexity, since processes, habits and relationships cannot be isolated or separated from their context of emergence in order to be made "sustainable". Mossberg et al. (2017) explain that sustainability transitions, which entail long-term, multidimensional transformation processes, bring about a shift from established socio-technical systems to more sustainable modes of production and consumption. But this transformation is long and complex, and demands simultaneous changes in different domains and at different levels of action.

Biorefineries are often analyzed as a good example of sustainable transition, using the grid of transition management. The second-generation biorefineries are seen as innovation niches destined to upscale to industrial format and then gradually evolve to become part of the socio-technical regime (Geels, 2002) (dominant technologies, practices, policies, regulations etc). However, this process runs into difficulties because of the numerous barriers to 'full spectrum' innovation – not just in the technological or industrial sphere, but also in social and policy domains. It usually requires a "co-evolutionary process" (Bauer et al. 2017) and an interplay between society, technology and governance across different geographical and temporal scales.

It might be asked whether the dominant narrative around biorefining as a transition pathway does not ignore certain fundamental dimensions of sustainability. Geels (2014) explains "regime stability" in the sector as the outcome of active resistance by incumbent actors. Our contribution argues that this relative regime stability is also due to a very narrow conception of sustainability, because the views of certain stakeholders dominate and exclude some dimensions of sustainability. Here the issue is not so much one of resistance as of only partial adaptation to the principles of a low-carbon society. The dominant players try to devise more environmental trajectories for biomass conversion, without fundamentally changing other components and thereby they do not cause a profound transition. Strategies of this kind allow some stakeholders to maintain their economic and social capital without any change in their roles. In accordance with Wittmayer and Schäpke (2017), we considered that fundamental changes in the roles of actors and in their relations with other are a vital element of transition. The disconnect between technical transition management illustrated by biorefinery evolution and the absence of concertation processes with local stakeholders also raises question (Hendricks, 2009). From this perspective, transition is less a question of innovation and multi-actor coevolutionary process, than of powerful stakeholders gradually adjusting to new environmental constraints.

This narrative is a strategy for agro-industrial groups to legitimize their activities by presenting them as a process of continuous progress towards sustainability and good environmental practice(s). "Narratives contribute to delimiting the space of what is 'politically feasible', thus contribute to the inertia of regimes with respect to socio-technical change beyond technological and political potentials" (Hermwille 2016). They design the framework for their own evaluation. In this way, they seek to stabilize the very uncertain socio-economic environment while imposing their own narrative around biorefineries. In our different case studies, the stakeholders involved explicitly refer to programs described as the "biorefinery of the future", all depicting ambitious technical and economic goals. They emphasize the potential of new bio-based products in order to justify their research and development projects, arguing that they could revolutionize our oil-dependent economy and create the same products as traditional refineries: viscose for the textile industry; bio-pharmaceutical molecules etc. Future expectations create legitimacy as they paint a picture of future technological conditions. Industrialists need to generate belief in these expectations and innovations in order to obtain resources, attract attention and "stimulate agenda-setting processes" (Levidow et al. 2014). Similarly, the concept of "biorefineries of the future" evokes a rosy future and reinforces the widespread view that technical fixes can solve systemic problems like climate change, resource depletion, and biodiversity loss.

2. Methodology and case studies used for this article

This paper is based on the results of qualitative and comparative research which was presented in different articles (Gobert 2017, 2018). This research was part of a regional project (FASE) and a 10-year global study on "the oilseed biorefinery of the future", named PIVERT[2].

We conducted a sociopolitical study based upon a comparison of five biorefineries. The method was qualitative. We read the relevant documentation available relating to the transformation of the industrial process in these territories (annual reports, internal documents, answers to research bids which gave data on the way the biorefinery stakeholders present their project and its story). This "grey" literature was specifically chosen to understand the economic, social, local contexts and provide data about the different routes by which biorefineries emerge.

We also conducted between 5 and 8 semi-structured interviews with different institutional stakeholders and firms involved in the development of the biorefinery project (companies, local academics familiar with the site, representatives of local communities). These interviews were then analyzed using a qualitative method (Beaud and Weber 2003; Lejeune 2014). The analysis grid was focused on the role of the stakeholders in the biorefinery process, how they related the biorefinery story, the relations they had with other actors, their sources of supply and the integration of environmental questions (Table 1).

We decided to select different European Union case studies characterized by both common features and interesting disparities. With regard to the shared characteristics, they are all subject to Europe's regulatory framework and eligible for EU funding. They are industrial

[2] PIVERT for Picardie Innovations Végétales Enseignements et Recherches Technologiques (Picardy Plant Innovations, Teaching and Technological Research) is an Institute of Excellence in plant chemistry, which was selected for support under France's Investment for the Future Programme. The goals of this research are to transform oilseed biomass, i.e. the whole plant, into renewable chemical products for numerous applications. It is built on the concept of industrial ecology: the idea that one company's byproducts can become another company's resource. In the biorefinery concept, all waste is seen as a potential input for another product. Water and energy are to be recycled to limit negative environmental impacts. The biomass refinery must use local agricultural and forestry resources from the region where it is located (Picardy). It is a cross-disciplinary project involving numerous research fields.

sites, located in peripheral zones, which are not new entities but have been recently reclassified as biorefineries. However, they work with different types of biomass, which are seldom a pure local resource. The project to convert biomass into multiple products is either driven by a single main player (a big industrial firm) or by a plethora of stakeholders who have pooled their strengths and resources. In the table shown here, we have distinguished between the project initiator and the project coordinator (a firm or a coalition of persons). It provides a context-rich empirical description that helps us to understand the narratives of innovation deployed in favor of biorefineries.

Table 1. Case studies analyzed and mobilized for this article

	Kalundborg[3] (Denmark)	Wanze[4] (Belgium)	Lestrem[5] (France)	Örnsköldsvik[6] (Sweden)	Pomacle-Bazancourt[7] (France)
Initiator of biorefinery process	Dong Energy (Inbicon) (energy supplier)	CropEnergie (Biowanze) (agro-industrial group - sugar refiners)	Roquette (starch producer)	A coalition of local firms	Different agro-industrial groups
Transformed biomass	Straw	Wheat	Corn - Wheat	Timber	Wheat – Sugar beet
Governance of the biorefinery project	Collective (Cluster Biofuels Denmark)	Individual (Biowanze)	Individual (Roquette)	Collective (Processum)	Collective through different structures
Documents analyzed	- Communication documents from the municipality about its green involvement - Dong Energy's information leaflets and reports - A Specific report describing the results obtained by projects (Integrated Biomass Utilisation System)	- Communication documents from Tierlemont (sugar refinery firm - information leaflets about "l'agrobiopole wallon" - Strategical reports from Sudzücker	- Strategic orientations for innovations in the Pas de Calais Region (2010) - Roquette's Annual sustainable development reports - Public inquiry files for the siting of new production units - Regional sustainable agriculture plan (2013) - Documents issuing from	- Numerous scientific productions concerning the forest industry and transformation - Vinnova reports (Swedish innovation agency) - Annual sustainable reports of the different firms involved in the Processum cluster	- Reports issuing from the pole IAR and the different firms involved in the biorefinery project) - Regional documents concerning bioeconomy and innovation

[3] Kalundborg in Denmark was one suitable example. Although known for the systematic implementation of eco-industrial principles, the industrial area presented one major limitation: the fact that the system of industrial symbiosis depended on the coal-fired Asnæs Power Station, hardly a symbol of sustainability. The goal was to test the possibility of using straw and converting the power plant to biomass. A second-generation ethanol demonstration plant was then built in Kalundborg in the environs of the existing plant.

[4] The Biowanze facility in Belgium converts wheat and sugar beet into ethanol and other associated products. Another current project aims to transform bran into surfactant agents. This biorefinery was presented as a way to find new markets for growers severely affected by European sugar beet quotas.

[5] Roquette is an old, family-owned agro-industrial group, which processes corn and wheat in Lestrem in France and produces starch. The firm has launched different innovative programs (Biohub, Nutrahub…) to test new technical processes (based on green chemistry) and develop their product range (biopolymers, bioplastics).

[6] At Örnsköldsvik, in Sweden, a number of firms located in an industrial zone, largely working in the timber processing sector, decided to form a forestry-based biorefinery cluster (Processum) specializing in the production of bioethanol and cellulose.

[7] The Pomacle Bazancourt biorefinery near Reims in France is a biomass processing site. It encompasses a sugar factory and drying plant, a combined research center, a starch and glucose plant, an ethanol production plant, an industrial demonstrator, a CO_2 collection center, a production and research center specializing in active ingredients for cosmetics, the pilot plant for the FUTUROL second-generation fuel project, and a White Biotechnologies Centre of Excellence, the product of a partnership between academic institutions.

	- PowerPoint presentations made by stakeholders in different conferences		regional clusters (like MAUD: materials for sustainable consumption)		
Interviewed stakeholders	- Two representatives of Kalundborg municipality - A Representative of Inbincon - A meeting with Novozymes and Inbincon to be informed on the refining process - A researcher involved in the R&D projects IBUS and KACELLE - A representative of the Region, to understand the global strategy and the local implementation of Energy Technology Development and Demonstration Program better.	- An Official Manager of the biorefinery - Two researchers involved in biorefinery research projects in the Wallonia region (Valbiom) - A Representative of Wallonia region - A representative of a local environmental grassroots organization - A representative of Wanze municipality	- Representatives of farmer cooperatives (providing feedstock to Lestrem) - A representative of Lestrem municipality and conurbation - A representative of the Pas de Calais Region - A representative of Roquette at Lestrem (manager of innovation affairs)	- A representative of Ovik Energy - A representative of SEKAB producing ethanol, black liquor - A representative of Akzo Nobel (a paints and coatings company producing cellulose derivatives) - A representative of Örnsköldsvik municipality - A representative of the Processum cluster focused on the biorefinery of the future - A representative of Domsjö Fabriker producing cellulose and hemicellulose	- A representative of BioAmber - A representative of Cristanol (sugar refinery) - A representative of ARD (common R&D centre) - A representative of Pomacle municipality - The cooperation manager of the Pole IAR (cluster) - A member of CARINNA (regional innovation agency) - A representative of the Regional Chamber of Agriculture.

Each case was classified as a biorefinery because its technical processes convert biomass into different substitutes for oil-based products, or extend bio-based-production. In many cases, firms launch biorefinery projects to test a new conversion process and to ensure that it meets all the administrative, technical and economic requirements before upscaling to full industrial production. These different sites were relevant to our research in that they had all embarked on a new set of mechanical or chemical operations. Each was therefore facing to uncertainty, which is very hazardous. In consequence, each was interested in building networks and seeking support of different kinds.

3. Biorefineries: an incomplete sustainability process

Biomass processing is the conversion, by means of human intervention, of natural capital – whether domestic or not – into different products: energy, high-value chemicals, purportedly more environmentally friendly and biodegradable bio-products. The dominant narrative advanced in support of biorefinery development claims that the transition from fossil to bio-sourced feedstock is an indisputably rapid and sustainable path. However, it can be argued that the characteristics of the current conversion processes and the social integration of biomass engineering are more consistent with weak sustainability (Vivien 2009; Dobson 1998). Why are we making this assertion?

Firstly, the dominant narrative displaying the bioeconomy and biorefinery as the result of disruptive and innovative strategies can be questioned, insofar as biorefineries, as transition symbols, are more or less embedded in their siting area and exemplify historical innovation and existing stakeholders' relations (subpart 3.1).

Secondly, wherever a high degree of entropy (Samieia and Fröling 2014) continues to be generated (e.g. land-use change, use of genetically modified organisms, pesticides) without consideration of the impacts at all scales and on all affected spaces, the production system will lead to environmental irreversibility (Gobert 2016). Biorefining raises issues around biodiversity and land-use change, plus lack of integration into a global environmental trajectory (subpart 3.2). Moreover, the social and political system that facilitates this development does not contribute to existing value and power redistribution principles: "New energy production is often portrayed as providing economic benefits through new jobs, declining energy prices, and ancillary economic development. Yet, this perspective is often narrowly framed in terms of net benefits to specific regions, ignoring a range of additional considerations" (Miller et al. 2015, p. 78) (subparts 3.3. and 3.4.). We illustrate our argument by referring to the different case studies.

3.1. Territories and path dependency. Innovation pathways designed by the past

The biorefinery projects could be seen as innovation niches, both technical (e.g. lignocellulosic fragmentation), and in some cases organizational: i.e. in the use of new feedstocks or the generation and subsequent sale of new products (Bauer 2017). However, niches do not appear suddenly. They result from a combination of factors, including the willingness and ability of stakeholders to act, local economic culture and know-how.

Our case studies revealed that rural biorefineries are not created from scratch but result from the evolution of previous industrial and agricultural activities, followed by movement along a technological path (Rakotovao et al. 2017). For example, the Örnsköldsvik area was already heavily involved in the timber sector, which had been seriously affected by global competition. It had continuously been forced to adapt following sharp decline in the European pulp and paper industries in the 1990s. Since then, innovations devised by numerous industrial actors had emerged, establishing new technical processes and developing new products (biofuels, bioplastics). Using the vocabulary of biorefining would thus seem to be primarily an attempt to acquire a positive green image as a producer of renewable energy and bio-sourced materials, rather than as reflecting a profound change in the essence of the initial economic project. Likewise, the firm Roquette has been established in the north of France since 1933 and from the beginning has had an activity of starch production, in particular for the local textile industry.

Our comparison revealed that the path dependency processes in play are more significant than the biorefinery players recognize (Pierson 2000). Acknowledging the influence of the past on current choices challenges the idea of disruptive innovations that constitute a break with previous socio-technical and political practices. Industrial trajectories are therefore dependent on the industrial history and resources of the territory, even if some firms have the size and financial capacity to attempt to escape (at least partially) from these dependencies (by relocating, closing plants, etc.) (Arbuthnott et al. 2010). Industrial facilities themselves can reflect this territorial legacy, insofar as their existence, as well as their organizational and institutional links, predates the term biorefinery. A number of academic works have underlined this technical, social, economic and institutional continuity. Béfort and Nieddu (2017) pay particular attention to the material and immaterial nature of production assets. Gobert and Brullot (2017) describe how stakeholders move local assets into or out of a territory, thus creating specific territorialized arrangements, whose study can help us to understand how an agricultural and industrial project may have emerged. For example, Biowanze began processing wheat and sugar beet in 2008, at a time when the region was severely affected by market difficulties in European sugar production and the large-scale closure of sugar refineries. Biowanze proposed new solutions for feedstock processing, using existing assets (water infrastructure, local agricultural production). In the Örnsköldsvik area, a number of firms decided to create a biorefining cluster to produce cellulose and cellulose by-products, such as black liquor, substances that had already been produced during the Second World War because of restrictions, but were not adopted by the market when the conflict finished.

> “Our location is considered one of the birthplaces of Swedish chemical industry, and during the blockade of the Second World War, a chemical industry based on forest raw materials was developed here.” (Interview with a representative of Domsjö Fabriker, 05/2012)

To apply a path dependency framework that identifies the influence of historical, social and economic factors is not to deny the reality of change, caused by different drivers: sudden events, new stakeholders, exogeneous elements such as new legal frameworks or incentives or opportunity windows (Kingdon 1984). It simply takes into consideration the role played in innovation by “historical” and “local” factors (Greener 2005). It also helps us to understand what aspects of territorial and industrial systems can generate inertia. Legacy may be a positive basis for new dynamics, but it may also prevent social and environmental innovation.

Embeddedness and path dependence enable the integration of the different lock-ins which can interfere with innovation into the transition management approach. However, other environmental challenges at local and global scales also have to be taken into account.

3.2. Biodiversity and land use change

Several studies have underlined the negative impacts of the first generation of biofuels: biodiversity erosion (Fitzherbert et al., 2008); landscape fragmentation; food price increases (Mitchell 2008). Moreover, even where biofuels may be more environmentally friendly and economically beneficial to local communities than conventional fossil fuels, some of their effects are ill-understood and underrated (land-use conflict, net energy consumption). Products originating from biomass compromise a number of ecosystems such as food, and freshwater services (Fisher 2009). In examining these criticisms, different scales of impact can be identified. The land-use issue has local, regional and international repercussions (Gawel and Ludwig 2011). Direct land-use change occurs when forests or woodlands are converted into biofuel crops. Indirect land-use change (ILUC) takes place when food or feed crops are displaced by biofuel farming to other places and countries, in other words when this kind of agriculture competes for available land with food crops. Converting rainforests, savannas or grasslands into farmland for biofuel crops releases billions of megatons of CO_2, far more than the annual reduction in greenhouse gas emissions supposedly brought about by the substitution of biofuels for fossil fuels. This process creates a biofuel carbon debt (Fargione et al. 2008) that will take a very long time to repay. For many years, life-cycle analysis methodologies have minimized this ILUC criterion, and the potential displacement of negative effects from one region to another. Another effect is that farmers and agricultural cooperatives may become more dependent on industry for their markets, a shift that could profoundly alter the role of farmers, making them suppliers of “molecules”. In order to meet industrial demand, they may have to employ intensive agricultural or silvicultural methods (short rotation forestry), add polluting external inputs (insecticides, fertilizers) or plant genetically modified crops, which contribute to biodiversity loss. Biomass production also increases water use. Other issues include competition with other investments, limited or uncertain return on investment (Adams et al. 2011; McCormick and Kaberger 2007), that are particularly dependent on a stable policy environment, which is conspicuously absent, and the possible seasonality of bioenergy supply.

The economic and social effects of increased biofuel production (food insecurity, volatile commodity prices, poor working conditions and violations of land rights, unfavorable net lifecycle greenhouse gas emissions), and the reactions to them (Ribeiro 2013), have forced the advocates of biomass conversion as an efficient alternative to fossil resources to improve technical processes, to use biomass differently and to pay more attention to negative impacts. Social learning from the controversy has thus provided impetus for industrial change (Rip 1986). This change is clearly visible in the case studies analyzed, as in each case the project managers are striving to move beyond first-generation biorefining (not using the edible part of the plants, producing products other than fuels) and to obtain their feedstock from “local” biomass. Agro-industrials and cooperatives claim a strict differentiation between their “sustainable activities” and those which lead to deforestation. A representative of the Wanze biorefinery asked for biofuels to be distinguished according their production process:

> "Comparing all biofuels and sources of biofuel production is the main problem at the European and international levels. Because this puts together biofuels coming from agricultural areas with those produced after deforestation. The legislation has to be careful before comparing our products and take into account the production process, the energy consumed … Currently we cannot find a reliable and neutral study" (Interview, 18/06/2012).

According to the actors involved, technical progress and innovation are bringing step-by-step solutions. However, this does not resolve issues such as how these processes fit into a global strategy of decarbonization.

3.3. Poor coordination with other dematerialization and decarbonization strategies

As summed up by Shove and Walker (2007, p. 278): "For all the talk of socio-technical coevolution, there is almost no reference to the ways of living or to the patterns of demand implied in what remain largely technological templates for the future." A basic weakness of biorefinery promotion is the poor coordination with other dematerialization and decarbonization strategies. Firstly, using bio-products and biofuels as a substitute for the petroleum industry is not a preventative but a reactive response to climate change and resource depletion. This biomass conversion system does not deal with problems at source, but consolidates "business as usual" practices and therefore treats biomass as a resource like any other, with the capacity to resolve one major problem (petroleum depletion). It acts as an obstacle to serious changes in consumption, mobility and waste disposal patterns. It does nothing to reverse the dominant economic paradigm, in which economic activities and industrial development are not subject to ecological constraints (Nahrath and Gerber 2014). Biorefining does not call into question agricultural practices or organizational schemes (Shove 2010), but sheds light the technical innovation induced by feedstock fragmentation and transformation. Biomass production for biorefineries often relies on resource and technology intensive modes of agricultural production (Plumecocq et al. 2018) and therefore does not open the way to agro-ecological transitions (Ollivier et al. 2018).

In the interviews conducted for the case studies, the stakeholders in the different biorefinery projects seldom or never mentioned the upstream or downstream changes needed to effect a sustainable transition. Instead, the talk was primarily about local feedstock supplies. In fact, in some cases, even this was not an issue. In Kalundborg, the energy supplier's goal was to obtain low-cost biomass, even if this meant importing it and accepting the longer value chain and the environmental impact of transport. Similarly, Wanze acquires its supplies from a very wide harvest perimeter (300 km).

The main biorefinery stakeholders make no clear temporal and spatial connections between resources, production systems and consumers in their strategy. The resource "biomass" is rarely analyzed in its global context (associated ecosystemic services, production…), but rather as a "normalized" input into the industrial production system. From the institutional point of view, when representatives of state agencies or local communities were specifically asked, biorefinery development was linked to the bioeconomy promises of energy transition and oil substitution, but not to the other essential components of this transition: cutting energy consumption, dematerialization and decarbonization.

3.4. A weak participatory process at the meso and global levels

Transitions are described as "multi-actor processes" (Geels 2010), however, as pointed out by Wittmayer and Schäpke (2017) it is important to understand how actors and their relations evolve in a changing environment.

Some of the academic literature (Feenberg 2014, Rumpala 2013) argued that the development of renewable energy is pushing society to create new technical models (less dependent on very large transport and distribution networks, as production sites are more localized), and therefore new political forms based on new communities of action and practice. In fact, they argue that the transition also has social and political dimensions with its capacity to "nurture public trust in energy decision-making, create a collaborative environment for energy deliberations, and build effective partnerships on wider scales between communities and energy industries" (Miller and Richter 2015, p. 81). As Voβ et al. noted (2009, p. 293), it is particularly important to consider democratic legitimacy, for example by designing new forms of deliberation, new participatory arenas for different kinds of stakeholders. Nevertheless, no such development seems to be visible in biorefining and no avenue for empowerment and redistribution appears (Schreuer 2016), which is visible in the choice of power plant sites.

From a societal perspective, one of the major aspects is that this change in energy and agricultural production does not appear to have any impact in terms of more equitable power and revenue distribution between stakeholders. The "era of biomass transformation" is apparently neither a green nor a societal revolution. At this stage of development, renewable energy has brought about no major change in the incumbent socio-technical regimes (Geels 2002), i.e. no adjustments in other fields and in social representations of the world (Rumpala 2013; Dobigny 2009). Industrialists have consolidated their dominant role in influencing economic orientations and as managers of "environmental change". They dominate at the strategic level, imposing their vision of sustainability and influencing European and national decision-makers through highly effective lobbies (Grossman, 2003). Their strategy is clearly based on efficient networking with influential stakeholders and the construction of powerful coalitions at different levels. Their aim is to formulate long-term goals to consolidate their investments and their markets. At the tactical level, they help to develop public instruments that will be useful to them. At the operational level, they participate actively in experiments (pilot and demonstration units to trial new processes before upscaling to industrial production), which are at the heart of European and national programs to test the technological and economic viability of different processes. This is enables them to bypass legislation and, as far as possible, to reduce uncertainty by influencing regulatory and legislative frameworks. These strategies create carbon lock-ins and can prevent more significant changes in the environmental transition.

In consequence, decisions on the development of biomass conversion are rarely rooted in a participatory process, and do very little to involve local stakeholders and, in particular, public opinion. The following quotation illustrates how the decision is progressively moved away from the farmers, i.e. the biomass producers:

> "A cooperative spirit is important. Cooperation depends on farmers, who get together. Then cooperation depends on cooperatives, which work together and then with the researchers… and other external actors." (representative of Pomacle-Bazancourt biorefinery).

As a result, local renewable energy strategies are not negotiated with farmers and civil society. Although biorefineries do not always generate local opposition and conflict, they acquire “weak acceptability[8]” (Gobert 2016), something that would be worth exploring through specific case studies (McGuire et al. 2018). In fact, biorefinery developers comply with planning procedures and licensing processes, but local authorities do not take the process further by examining the impact that these choices could have on local development and the local environment. In the Biowanze case, a special local committee was created to tackle odor and risk issues, but it did not cover other questions. It was the only example of a participatory forum that we encountered in our research. Even if biorefinery managers are regularly submitted to administrative procedures when they want to expand or transform their facility, the compulsory processes (public consultation, environmental impact assessment) do not cover all impacts of biorefining, seldom involve the participation of the people concerned (Morgan 2012). In fact, they are often not accessible to farmers or inhabitants, because they use expert language and open arenas not usually open to public discussion.

Conclusion

This article has analyzed rural biorefineries as socio-technical systems and as a possible model of environmental transition. It considers the micro-level (the biorefinery as an innovation niche in which the industrial process and the socio-technical regime coevolve), the meso-level (the biorefinery as the outcome of specific arrangements and visions of the future, embedded in a localized “path dependency” process), and impacts at the macro-level (biodiversity loss and land use change, power and value redistribution). This was an opportunity to explore not only the ambiguity of the notion of ‘sustainability’ promulgated in the dominant narrative on biorefining, but also to contribute to the perspective of transition studies. As a matter of fact, representations of biorefineries are dominated by the technical aspect of the biorefinery system and the associated changes, and do not embrace the full meaning of sustainability (participation, social equity, etc.). The different European case studies offered a way to apprehend and question the dominant narrative. What actually emerges is the relative regime stability and the difficulty of effecting societal change in response to the challenge of climate change. This is also linked to a narrow conception of sustainability held by the main stakeholders. In the absence of a common vision of the characteristics and limitations of a desirable future, the likely outcome will be opposition and environmental fallout (transfer of impacts from one locality to another, agricultural intensification).

This is one reason why transition is hard to manage. Transition policies are supposed to coordinate strategies, to encourage global cohesion between the different niches and to stimulate profound and simultaneous transitions in different fields (Kemp 2010). But this would require knowledge management and governance capabilities for example through the creation of arenas where all viewpoints and objections can be expressed and, if not solved, be defined clearly enough so that shared and sustainable transition pathways can be outlined. In

[8] The siting or the development of bioenergy plants is decided by companies and national authorities and not negotiated with all potential stakeholders. The impacts resulting from biorefineries’ growth are not discussed in public arenas (landscape changes, new requirements for farmers…). A strong acceptability would have obliged biorefineries proponents to overcome an ‘end-of-pipe’ acceptability only focused on the technical facility and to enlarge their environmental scope.

fact, it is not sufficient to build biomass conversion facilities and to organize the supply chain, other changes need to take place at the same time: “the challenge is not simply what fuel to use but how to organize a new energy system around that fuel” (Miller, Iles and Jones 2013, p. 139). While biorefinery development has received strong support from public authorities at local and national levels, other dimensions have not been so easily tackled and handled at each level: social acceptance, economic viability relative to oil prices. Moreover, biorefineries have not brought about major changes in the value chain (for farmers or customers).

For all these reasons further research is needed to address more specifically the links between the upstream dynamics of biomass supply (and perhaps provide recommendations on localizing flows and producing feedstock that is more sustainable for the soil, for farmers and for communities). Moreover, research dedicated to bioeconomy would gain credibility by introducing social dimensions (acceptability, changes in social structures), defining new participatory structures (societal consensus on the desirable future), and contributing to the global dematerialization and decarbonization of our societies from the individual to community level. In this way, transition studies which enable us to understand large societal processes, the possible drivers and lock-ins will be closely linked with a reflection on the satisfaction of sustainability principles (Loorbach 2015).

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