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## DEVELOPING A SOCIO-ECONOMIC FRAMEWORK FOR THE ASSESSMENT OF RURAL BIOREFINERY PROJECTS

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**ABSTRACT:** A rural biorefinery is a facility set up in a territory which transforms local biomass into a wide range of products and energy. Contrary to the port biorefineries where raw materials are mainly imported, their sourcing is carried out on a more restricted area or even on a local area. Indeed, they are characterized by the importance of their integration process as they maintain more or less close links with the territory, especially with the farming community. In addition to being a source of income for farmers, these biorefineries create new opportunities for non-farm sectors. Recently, research has been conducted to assess biorefinery sustainability. However, the balance between the three pillars of sustainable development is not established as studies focus more on environmental assessments to the detriment of socio-economic dimensions. In addition, socio-economic assessments of rural agro-industrial projects are often limited to economic indices, which are not sufficient to evaluate the fallout on the territory. Then, the purpose of this paper is to propose a socio-economic evaluation grid to measure the territorial embeddedness of rural biorefineries. **Keywords:** rural biorefinery, socio-economic impact, assessment, territorial embeddedness

### 1 INTRODUCTION

In recent decades, energy transition has been at the heart of debates and priorities of public and private actors. The scarcity of fossil energy sources, coupled with the fight against greenhouse gas emissions, presents significant challenges from technological, economic and ecological points of view. Adopting cleaner energy has become an imperative. The concept of the biorefinery has appeared as a possible solution. It refers to the conversion of biomass feedstock into a host of valuable chemicals and energy with minimal waste and emissions [1].

From an environmental point of view, biorefineries seem to converge towards the objectives of sustainable development since they not only focus on the processing of renewable raw materials, but their manufacturing processes are considered cleaner compared to oil refineries [2]. Therefore, an abundant literature is devoted to the environmental assessment of these systems with a focus on environmental impacts such as greenhouse gas emissions or air pollutants. Nevertheless, although the environmental component is a key element in the evaluation of such projects, it seems that the economic and social pillars of sustainable development are less mentioned. Indeed, the literature review indicates that, to date, few of socio-economic impacts studies have been undertaken on biorefineries, contrary to environmental aspects [3]. In addition, most of the evaluations carried out focus on bioenergy projects, while biorefinery units do not only transform energy, but also and in particular, products based on plant resources. Based on these findings, this study targets to assess the economic and social impacts of a biomass valorization project implemented in rural areas and studies their territorial embeddedness. The choice of regional scale as research area is based on the observation that contrary to port biorefineries, rural biorefineries tie stronger relationship with the production area through the exchange of flows with local farmers. According to Papendiek et al. [4], they provide new outlets for farmers and create links between the industrial and agricultural sectors. Lopilito et al. [5] argue that, in addition to being a source of income for farmers, these biorefineries create new opportunities for non-farm sectors. In other words, rural biorefineries give the impression to promote the rural economic development of the regions where they are located. However, the socio-economic impacts of the

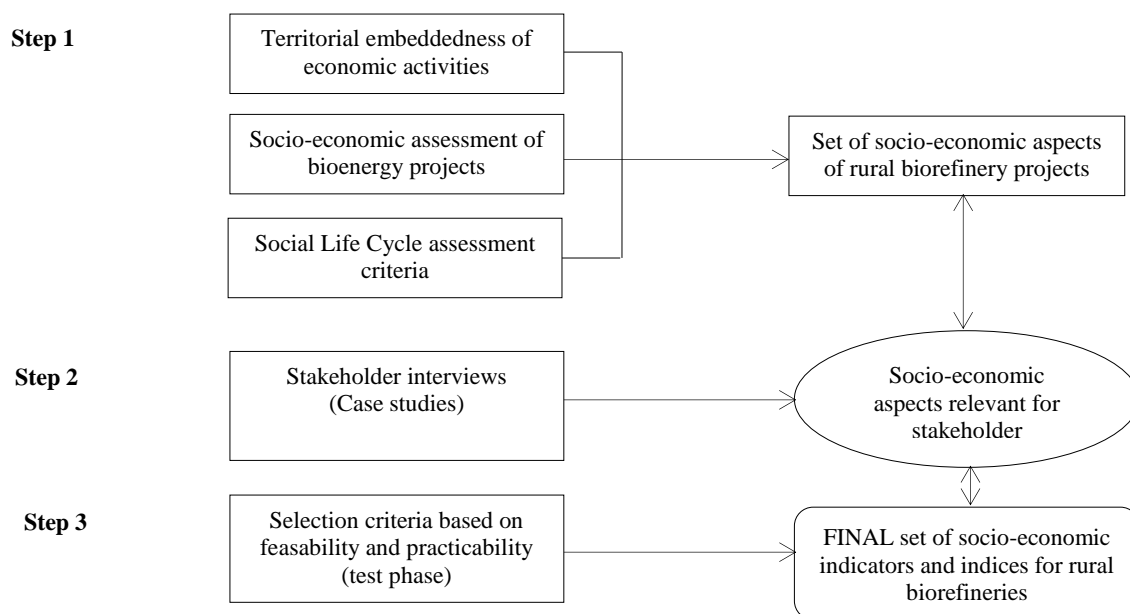
biorefinery on its host territory cannot be limited to economic indices only. Indeed, territorial issues are more complex and embrace economic, social, institutional and cultural aspects [6]. But to date, there are few socio-economic assessment tools for biorefineries, and even fewer that take into account the specificities of the territories as well as the actors involved in this kind of project. Nonetheless, before producing the desired effects at the global scale, biorefineries first, generate both positive and negative impacts at the micro level.

Under these circumstances, this work is proposed as a decision support tool for economic operators and territory managers. It aims at including a methodology to appraise socio-economic impacts of rural biorefineries in sustainability assessments, and addresses the following question: What economic and social criteria must be considered and evaluated to measure the territorial embeddedness of a rural biorefinery project?

To address this question, a review of existing literature on socio-economic appraisal of bioenergy projects, social life cycle assessment (SLCA) and territorial embeddedness of economic activities has been undertaken. These concepts have been mobilized first to identify the different stakeholders involved in a such project and then to detect the main criteria that are taken into consideration for the assessment. Subsequently, two case studies in France were conducted to understand the economic and social environment of rural biorefineries, as well as related socio-economic issues. This approach targets to verify the completeness and relevance of the framework. Then, the assessment grid which is developed has been evaluated by both academic and professional experts. This methodological approach is summarized in Fig.1.

### 2 CONCEPTUAL FRAMEWORK OF SOCIO-ECONOMIC ASSESSMENT CRITERIA

#### 2.1 Literature review on socio-economic assessment of bioenergy projects



**Figure 1:** Research steps taken to select and develop socio-economic framework for rural biorefinery assessment

While some methods have been developed for the socio-economic appraisal of bioenergy projects, there are none that focuses solely on the biorefinery systems assessment. Indeed, there is a great distinction between bioenergy and biorefinery. While bioenergy units produce only energy, biorefinery can transform both energy and high value-added products from biomass. Accordingly, the development of this model is inspired by criteria used in

socio-economic assessment of bioenergy units. In addition, the criteria used in Social Life Cycle assessment have been considered as this method takes into account the stakeholders involved in the product life-cycle. Undeniably, the actors' identification is an important step of the assessment. The main findings on these subjects are presented in Table I.

**Table I:** Main criteria in Socio-Economic Assessment of Bioenergy Projects and Social Life Cycle Assessment

Approach	Categories of impacts	Potential indicators
Global Bioenergy Partnership Sustainability indicators for bioenergy [7]	Social	Price and supply of national foodbasket; Allocation and tenure of land for bioenergy production; Change in income; Jobs in the bioenergy sector; Change in unpaid time spent by women and children collecting biomass; Bioenergy used to expand access to modern energy services; Change in mortality and burden of disease attributable to indoor smoke; Incidence of occupational injury, illness and fatalities.
	Economic	Productivity; Net energy balance; Gross value added; Change in consumption of fossil fuels and traditional use of biomass; Training and requalification of the workforce; Energy diversity; Infrastructure and logistics for distribution of bioenergy; Capacity and flexibility of use of bioenergy.
Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures [8]	Social well-being	Employment; Household income; Work days lost due to injury; Food security
	Energy security	Energy security premium
	External trade	Fuel price volatility; Terms of trade; Trade volume
	Profitability	Return on investment ; Net present value
	Resource conservation	Depletion of non-renewable energy resources; Fossil energy return on investment.
Socio-Economic Impacts of Biomass Feedstock Production [9]	Social acceptability	Public opinion Transparency; Effective stakeholder participation; Risk of catastrophe.
	Contribution to local economy	Production costs ; Value-added ; Taxes ; Contributions to the local economy through operations with related industries; Involvement of smallholders or small suppliers; Employment; Ratio between local and foreign workers; Percentage of permanent employees; Employee training; Community investment.
	Rights and working conditions.	Personal income; Social advantages; Income devoted to basic needs; Working hours; Freedom of association.

	Health and safety	Work accidents and diseases; Individual protection equipment; Training in safety and health at work.
	Gender	Benefits created for women
	Land rights and conflicts	Legal title; Public / communal land; Land conflicts
	Food security	Land use change; Availability of food; Time spent on subsistence farming.
Modeling Socio-Economic Aspects of Bioenergy Systems [10]	Social dimension	Standard of living improvement (environment, health, education); Social cohesion and stability (migratory effects, regional development, rural diversification).
	Macroeconomic level	Security of supply, regional growth, reduction of the regional trade balance, export potential.
	Supply level	Increase of productivity, improvement of competitiveness, work and mobility of the population (induced effects), improvement of the infrastructure.
	Demand level	Jobs, Income and wealth creation, induced investment, support of related industries.
Social Life Cycle Assessment [11]	Employees (Human Rights)	Freedom of association and collective bargaining; Child labor; Working hours ; Forced labor ; Equal Opportunities / Discrimination; Health and security ; Just wage; Social benefits / Social security.
	Local communities (Working conditions)	Access to tangible resources; Access to intangible resources; Migration; Cultural heritage; Healthy living conditions Respect for indigenous rights; Community engagement; Local employment: Secure living conditions.
	Society (Health and Safety)	Public commitments to sustainability issues; Contribution to economic development; Conflict prevention and management; Technology development; Corruption.
	Consumer (Cultural Heritage)	Health and security ; Feedback mechanism; Confidentiality; Transparency; End of life liability
	Value Chain Actors Excluding Consumers (Governance, Socio-Economic Impacts)	Fair competition; Improvement of social responsibility; Supplier relationships; Respect of the right of intellectual property.

This table indicates that several stakeholders' interests should be considered to assess the socio-economic fallouts of agro-industrial projects. This includes not only value chain actors such as employees, suppliers or related industries, but also external actors, in particular local communities. Furthermore, particular criteria are not reproducible in certain territories. As examples, the "Change in unpaid time spent by women and children collecting biomass"; the "Change in traditional use of biomass", or even the "Food security" are not necessary relevant in developed countries. Indeed, a comprehensive socio-economic sustainability framework should determine appropriate criteria to address the biorefinery's impacts on the socio-technical systems in which it operates.

In order to analyze in depth the specificities of a biorefinery territory as well as the criteria that should be integrated in the socio-economic assessment of that kind of project, the concept of territorial embeddedness has been used.

## 2.2 Literature review on territorial embeddedness

Generally speaking, embeddedness refers to the quality of being firmly and deeply ingrained or fixed in place [12]. In other words, to become embedded is to settle down, to take root in a place, in a context. Then, the territorial embeddedness of a biorefinery refers to its rooting in the territory. However, this quality is not only the result of a physical process because embeddedness is also the action of "fixing or deeply instilling a sense, a culture". That goes us back to the intangible aspect of

embeddedness. Setting up on the territory implies for the biorefinery, to embrace its values. Frayssignes [13] defines the territorial embeddedness as a set of interlinkages that unite an economic activity (actor, company, sector, etc.) with a territory. Boons and Howard-Grenville [14], for their part, describe this phenomenon as the contextualization of economic and organizational activities at the heart of social arrangements and processes. In short, the territorial embeddedness is based on the coordination with the actors of the territory.

Nevertheless, the measurement of an economic activity territorial embeddedness is very partially investigated in the scientific literature. The best-known research on this concept was conducted by Granovetter in 1985 [15] in the field of economic sociology. He argued that in modern industrial societies, economic activities should not be considered as atoms outside a social context; they are integrated into a system of concrete and continuous social relations. Although the author widely addresses the question, he did not provide a model to assess it. Those who gave practical details about it are Boons and Howard-Grenville [14]. They described the different components of territorial embeddedness. In a similar vein, some French scientists developed the concept of "Proximity dynamics" to measure the degree of openness of economic activities to their socio-economic environment. Finally, the territorial embeddedness can be judged by the ability of industrial operators to mobilize the various territorial capitals like raw materials, human resources and skills, infrastructures, technical capital, etc. [16]. Regarding the operational landscape, two toolkits

have been developed to estimate the territorial embeddedness of an economic activity. More details about each finding are presented in Table II.

**Table II:** Criteria used to measure the territorial embeddedness of economic activities

Approach	Categories of impacts	Potential indicators
Proximity dynamics [17 ; 18]	Geographical proximity	Spatial vicinity of organizations physical locations.
	Organisational proximity	Interactions between stakeholders in formal and informal organizations.
	Institutional proximity	Stakeholder buy-in to a set of rules, representations and values that will guide their strategies and lead to regular coordination of behaviors.
	Cognitive proximity	Knowledges and skills sharing.
	Social proximity	Impact of social relations on economic outcomes, including collective learning and innovation.
Social embeddedness of Industrial Ecology [14]	Cognitive/Cultural embeddedness	Influence of collective representations and common standards on economic and organizational behavior
	Structural embeddedness	Degree of influence of the structure of social interactions between actors on information flows and the formation of economic exchanges and other forms of exchange.
	Political embeddedness	The way, in which the economic institutions and their decisions are shaped by a struggle for power, involving economic actors, non-market institutions, especially the government (local authorities) and social classes.
	Spatial and temporal embeddedness	The way in which interactions are influenced by physical proximity and time.
Territorial capital mobilization for the development of Industrial ecology approaches [16]	Organizational capital	Power relationships, informal relationships, trust, formalized relationships.
	Cultural capital	Shared values, history of the site, experiences.
	Cognitive capital	Knowledge useful for projects and innovations, Universities and Research and development centres.
	Technical capital	Skills, know-how
	Natural capital	Landscape, Raw materials
	Institutional capital	Public authorities commitment, norms and customs
ELIPSE project framework [19]	Infrastructural capital	Transport networks, spatial planning and development
	Stakeholders cooperation	Networks of actors, sustainability.
	Flows looping	Prevention of resources consumption, waste production prevention and environmental impacts, flows exchange between the actors of the territory, local supply and resources valorization.
Territorial embeddedness of firms [20]	Local wealth	Services to the actors of the territory, economic and social performance of companies, attractiveness and territorial development.
	Dialogue with local actors	Meeting between the Executive management and local stakeholders, training guides (dialogue and knowledge of the local environment), stakeholder mapping tools, participation in a regular dialogue forum with local stakeholders, image survey with local residents, general public information reports on the activity of the site, formalization of local partnerships.
	Economic local development	Amount of financial contributions granted to the creation / support of local businesses, number of local businesses supported; survival rate of businesses created / supported and jobs created; shares of local purchases made with local suppliers; number of people trained in knowledge transfer; report of accompanied employees in the context of spin-off activities; amounts of credit granted to the population.
	Economic changes management	Number of direct and indirect jobs (subcontractors) affected by the restructuring; percentage of employees who found a job; proportion of sites benefiting from redeployment plans in case of closure or reduction of activity; number of jobs created in communities; number of agreements signed with the State under the law (French specific indicator)

	Local social development	Voluntary contributions to the development of social infrastructures; development of local employability (direct and indirect); support for the public in difficulty, adaptation of products and services to the local population.
	Consideration of Human Rights	Number of employees trained in Human Rights or ethics Number of units with a specific Human Rights training program.
	Income redistribution at the local level and fight against corruption	Monetary cash redistributed to local stakeholders; Revenue by geographical area of level of corruption.

Compared to the criteria found in classical socio-economic assessments, those used to measure the territorial embeddedness of an organization take more into account the impacts at the local level. In addition, the scope of the evaluation is broader and is not limited to economic and social aspects but it highlights the relational aspect of the activity integration by taking into account organizational, institutional and cultural dimensions. Another kind of impact has also appeared; this concerns the effects of the activity on time and space.

In light of these findings, these criteria have been confronted with the context of biorefineries. Considered as fixed ground installations, they depend on agriculture to sustain their activity. Moreover, as they are assimilated to niche innovations [21], the research and development component is also important, as is the exchange of information, material and energy flows with local stakeholders.

### 3 VERIFICATION AND VALIDATION OF THE RELEVANCE AND COMPLETENESS OF SOCIO-ECONOMIC ASSESSMENT CRITERIA

The second phase of the model construction corresponds to the verification of the set of socio-economic criteria obtained from the documentation by means of case studies in order to test their relevance and completeness. Since the aim of the model consists on assessing the socio-economic impacts and the territorial embeddedness of biorefineries with regard to gain the best possible understanding of their relationship to the territory and its resources, two biorefinery units that belong to two different corporate groups and operating in different regions were chosen as fields of investigation. These are starch biorefineries that transform wheat and maize into a variety of high value-added products intended for the pharmacy, cosmetology, biochemistry, food and feed markets. If the choice was focused on starch biorefineries, this is because France is the largest producer of cereals in the European Union. Indeed, cereals cover 60% of French arable land. As a consequence, more than 50% of existing biorefineries in the country are sugar/starch-based plants [22].

Furthermore, the choice to study two biorefineries processing the same type of biomass is justified by the need to have the same elements and units of comparison such as the volume of feedstocks processed; their equivalents in terms of surface; the mobilization of the same knowledges and skills, etc. In contrast, two different locations were assumed in order to highlight the specificities of the territories. In other words, even though both facilities treat the same biomass, they might not have

the same impacts and they might be differently embedded to the territory.

Considering that the approach aims at understanding the socio-economic issues of rural biorefineries and their impacts on the production territories, semi-structured interviews were conducted with various stakeholders: biorefinery managers, biomass producers, storage agencies such as agricultural cooperatives and agricultural traders, carriers, local authorities at different level (municipalities, inter-municipal cooperations, departments and regions) and regional consular chambers. These interviews have deepened two key elements: first, the impacts of the activities on each of them and their operations; secondly, each stakeholder brought his own definition of territorial embeddedness. Subsequently, experts from the academic and operational world were interviewed in the interest of validating or disproving these criteria regarding their applicability and feasibility. It should be noted that these cases studies are not designed to allow a generalization of the findings, especially since statistical analysis cannot be applied. The cases are not samples and cannot be considered as such. They are used as part of an exploratory phase of the analysis of socio-economic issues of biorefineries established in rural areas.

The first finding is that the main dimensions of the conceptual framework, namely the economic, social, spatial, temporal, organizational, institutional and cultural dimensions, were confirmed as important by different categories of stakeholders. These seven dimensions of the assessment are divided into 16 criteria and 21 sub-criteria (Fig. 2). Secondly, it has been established that the impacts of bio-industries on the agricultural world did not appear in the literature review. Indeed, the impacts generated by the exchange of flows between industrialists and farmers were not significantly considered in the socio-economic assessment of bioenergy systems. However, the case studies have shown that the link between these two branches is crucial for the development of the sector, so that ignoring this will render the assessment incomplete. In fact, the particularity of the territorial embeddedness of an agro-industrial project lies in taking into account the socio-organizational aspects between industry and agriculture, where the issues of resources and actors are of great importance and is considered as an essential condition to an effective territorial integration. The table 3 highlights the different criteria retained for the assessment (Table III). On the one hand, it makes a comparison between the results obtained from the literature review and the realities of the field. On the other hand, it presents the relevant criteria according to each stakeholder.

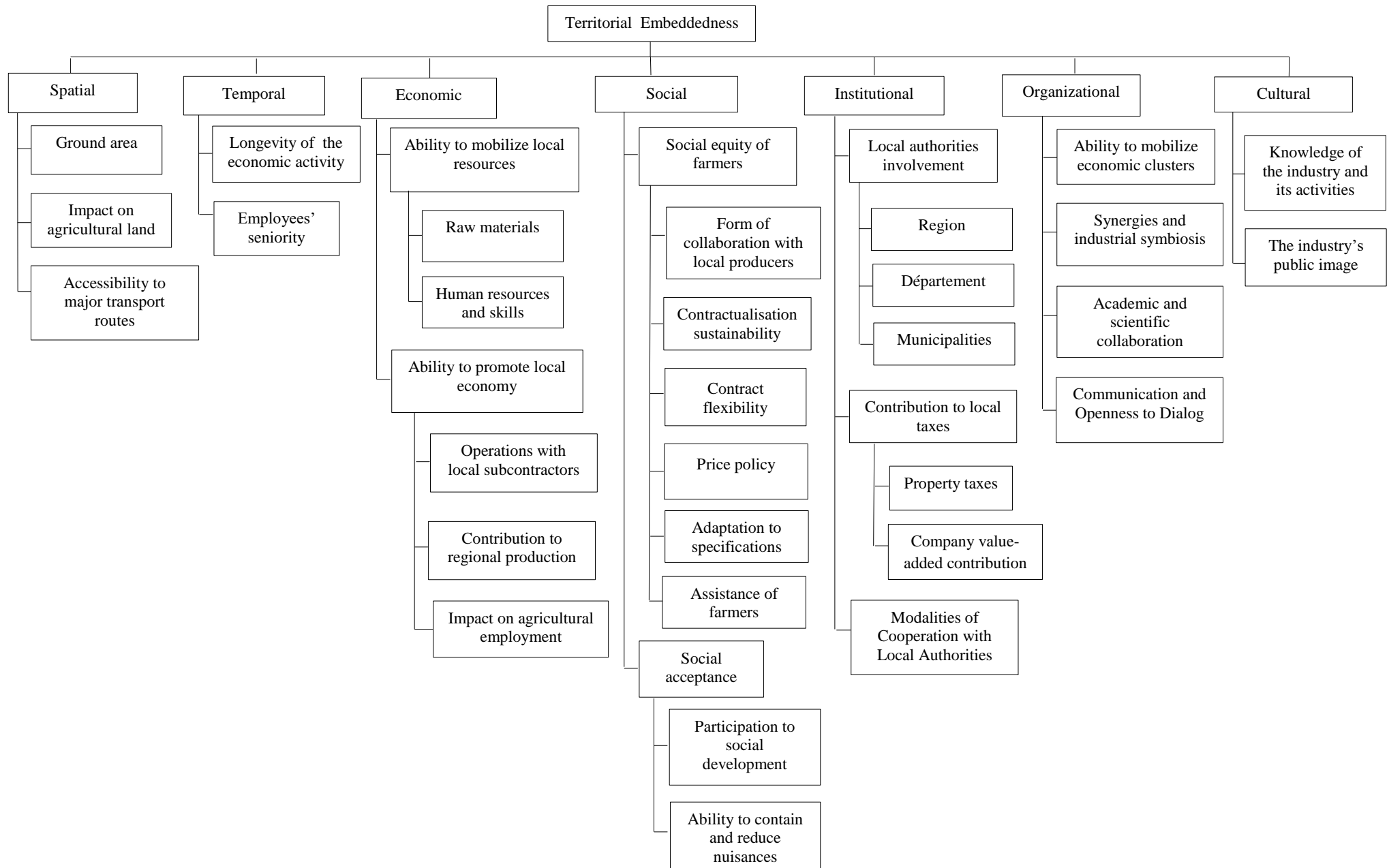


Figure 2: Set of socio-economic criteria to assess the socio-economic impacts and territorial embeddedness of rural biorefineries

**Table III:** Origins of selected criteria

Dimension/ Criterion	Documentation		Case study 1				Case study 2				Experts
	SEA (1)	TE (2)	F (3)	AC (4)	Brf (5)	LA (6)	F (3)	AC (4)	Brf (5)	LA (6)	
<b>Spatial dimension</b>		XX			X				X	X	
Ground area					X	XXX				XX	X
Impact on agricultural land				X		XXX				X	XX
Accessibility to major transport routes		X		X		XXX				XX	X
<b>Temporal dimension</b>		X							X		
Longevity of the economic activity									X	X	
Employees' seniority					X				X		
<b>Economic dimension</b>	XXXX	XX		X	X				X		
Ability to mobilize local raw materials	X	XXX	XX	X	X	X		X		XX	
Ability to mobilize local human resources and local skills	X	XXX			X	XX			X	XX	X
Operations with local subcontractors	XX	X				XX				XX	
Contribution to regional production	XXX								X		X
Impact on agricultural employment		X	XX	X			X	X			
<b>Social dimension</b>	XXXX	XX									
Form of collaboration with local producers				X	X			X	X		
Contractualisation sustainability				X	X			X			
Contract flexibility				X	X						
Price policy			XX	X			X	X	X		
Adaptation to specifications			X	X			X	X			
Assistance of farmers				X							
Participation to social development	X	X				XX				X	



Ability to contain and reduce nuisances		X							XX	
<b>Institutional dimension</b>		XXX								
Local authorities involvement		XX			X			X		
Contribution to local taxes	X					X		X	X	X
Modalities of Cooperation with Local Authorities						XXX			X	
<b>Organizational dimension</b>		XXX		X	X			X		
Ability to mobilize economic clusters		XXX						X		
Synergies and industrial symbiosis		X				X		X		
Academic and scientific collaboration				X	X			X		
Communication and Openness to Dialog		X	X	X		XX		X	X	X
<b>Cultural dimension</b>		XX								
Knowledge of the biorefinery and its activities						XX			X	
The biorefinery's public image		XX				XX			X	

- (1) Socio-economic assessment on bioenergy; (2) Territorial embeddedness; (3) Farmers; (4) Agricultural cooperatives; (5) Biorefinery; (6) Local authorities.

#### 4 ASSESSMENT CRITERIA DESCRIPTION

##### 4.1 Spatial dimension

As we have seen above, embeddedness is above all a physical process. The spatial or geographical embeddedness concerns the physical implantation of the economic activity. In other words, the spatial embeddedness refers to the reciprocity between the facility and the spatial dimension. Thus, the biorefinery is evaluated according to the physical changes that occur in the territory in relation to its establishment and development. For its part, the ability of the territory to boost the development of the biorefinery is also assessed. For these purposes, three main criteria are considered:

- Ground area:  
This criterion measures the extent of the physical anchorage in order to know its impact on the geographical area of the territory. It estimates the area occupied by the facility on the territory, compared to other activities in the same category. This criterion is not specifically mentioned in the literature but is considered important by some stakeholders, especially the representatives of biorefineries and local authorities.
- Impact on agricultural land:

An agro-industrial activity such as a biorefinery generates a strong interweaving between the industrial sphere and the agricultural sector. While biorefineries provide new opportunities for farmers [4], they largely depend on the availability of agricultural resources to grow their business. This criterion was implemented to measure the share of farms involved in supplying a biorefinery unit at the local level. As in the previous case, the impact of biorefineries on the agricultural land was not identified in the literature. However, it had been mentioned by agricultural cooperatives and all local authorities interviewed.

- Accessibility to major transport routes:  
For an agro-industrial plant, the circulation of physical flows such as inputs, outputs, materials and energies, is an important dimension that has a significant impact on the profitability. In fact, transportation and logistics costs play a major role in the cost of supplying biomass plants. As a result, strategic choices must be made by decision makers in order to optimize logistics costs; and these choices are based on a number of factors. Among them, we distinguish the provision of transport infrastructure by the

territory. It is obvious that the modal choice of decision-makers depends on the existing transport systems as well as the transport networks and infrastructures available on the territory. This criterion had been selected to that end. It aims at evaluating not only the supply of transport networks by the territory but also the geographical accessibility of the biorefinery to these infrastructures.

#### 4.2 Temporal dimension

Colletis et al. [23] argued that the phenomenon of territorial embeddedness of an economic activity takes time; the time consists for the organization to construct its territorial environment. Indeed, time is an important factor of the embeddedness because the evolution of industrial systems is usually segmented in long periods. Furthermore, time also counts because it is the "measure" by which other embeddedness dimensions can be accumulated [14]. Two major criteria related to temporal aspect were identified in case studies:

- Longevity of the economic activity:  
The aim of this criterion is to estimate the time anchoring of the activity through its existence in the region. This criterion was particularly highlighted by the stakeholders of the second case study, for which the activity has been present on the territory for more than 80 years now.
- Employees' seniority:  
The longevity of the economic activity is not sufficient to judge its temporal embeddedness. Indeed, since the biorefinery is a generator of employment, it is essential that the industry be able to preserve its employees and consequently the employment in the home territory. Then, employees' seniority was designed to measure the ability of the biorefinery to retain its employees.

#### 4.3 Economic dimension

The economic aspect is the most developed dimension in the scientific literature on socio-economic impacts of industrial projects. However, most of them have been conceived to assess the economic benefits of the facility such as profitability, return on investment, net present value, etc. In addition, those which concern the economic impacts of the activity on the territory are often limited to economic indices like job creation or regional economic development. Nonetheless, they are not sufficient to measure the real fallouts of such projects in the territory. As part of this work, the economic dimension of the assessment refers to the ability of the biorefinery to generate economic benefits for the territory, while mobilizing both its tangible and intangible resources, and by developing the sectors of activity concerned by the operations of the economic activity. Indeed, embeddedness is defined, *inter alia*, as an intentional process of mobilizing territorial resources [13]. For this purpose, five criteria have been selected regarding the documentation and the cases:

- Ability to mobilize local raw materials:  
According to Diniz et al. [24] a company is highly integrated locally when a large part of its supplies takes place in the territory to which it belongs. In this perspective, the use of local raw materials by the biorefinery is evaluated through

this criterion. Otherwise, this criterion has been widely agreed among stakeholders, in particular, farmers and agricultural cooperatives, but it was also judged as an important factor of embeddedness by all local authorities.

- Ability to mobilize local human resources and local skills:  
For numerous stakeholders interviewed (biorefineries, local authorities, professional experts), employment is the main embeddedness factor. This is also one of the most documented socio-economic criteria in the scientific literature. However, there are different ways to measure it, depending on the objectives of each assessment. Since the purpose of this work consists on assessing the territorial embeddedness of the biorefinery, the evaluation criterion for employment is the local recruitment rate by the total number of employees.
- Operations with local subcontractors:  
In principle, the development of an industrial activity (that generally belongs to a multinational corporation) on the region should promote local SMEs and subcontractors. In fact, an industrial operation is led to outsource several activities of its value chain, for instance the storage, the transport of raw materials, semi-finished and finished products, the packaging, etc. However, the use of local businesses for this type of service is not usual. Sometimes, transactions are concluded at the group level with large service delivery companies. This shows how local units can be heavily dependent on the groups to which they belong. Thus, this criterion measures the ability of the biorefinery to transact with economic operators of the region.
- Contribution to regional production:  
This criterion measures the capacity of the biorefinery to create value for the territory through its production activity. It will be appraised through its contribution to regional value added.
- Impact on agricultural employment:  
This criterion corresponds to the proportion of local farmers involved in supplying the biorefinery. It is obtained by the ratio between the number of farmers providing the biorefinery and the total number of farmers of the region for a given crop. According to farmers and agricultural cooperatives, the ability of the biorefinery to represent an agricultural outlet is crucial.

#### 4.4 Social dimension

In the same way as for the economic aspect, social dimension is largely discussed in research on socio-economic impacts of industrial projects. It is mainly devoted to the impacts of the activity on local communities. This is one of the aspects of the assessment addressed in this section, particularly the extent to which the industry takes into account the population well-being, as well as the way in which the managers are involved in the social life of the community. Furthermore, the social dimension of the assessment concerns also the cooperation arrangements made between the biorefinery managers and local farmers. Indeed, social embeddedness refers to the

impacts of the activity on the social systems in which it operates, as well as the relationships it develops with its stakeholders [25]. In this vein, six criteria pertaining to the social equity of local farmers have been identified. In this particular case, the term social equity is used to qualify the ability of the biorefinery to build and maintain strong relationships with local farmers while contributing to their economic and social well-being through the transactions made with them.

- Forms of collaboration with local producers:  
From our interviews with various stakeholders in the field of valorization of agricultural biomass, two forms of collaboration have been discerned. The first one is called “integrated sector”: biorefinery operators conclude a supply contract with an agricultural cooperative where farmers deliver their crops. It allows biorefinery operators to develop a close relationship with the cooperator. This proximity gives them the freedom to ask farmers to meet their needs both in terms of quantity and quality; this strategy represents a significant competitive advantage. Also, it ensures farmers to be able to sell their crops. The second form of cooperation is known as the “independent model”: biorefinery operators purchase their feedstocks directly on the market by targeting the most attractive price. They will have the choice between two families of suppliers: agricultural cooperatives and agricultural traders. With this model, the biorefinery does not necessarily represent a reassuring outlet for local farmers as they might not be competitive on this market.
- Contractualisation sustainability :  
This criterion aims at assessing the stability of the cooperation between the biorefinery managers on the one hand and local farmers and storage agencies on the other hand. The measurement is done through the duration of the supply contracts established between the two entities.
- Contract flexibility:  
The agricultural market is subject to many climatic hazards that could significantly reduce the price of crops or even make them unfit for sale. Negotiations are often conducted in the face of such circumstances in order to find the most suitable solutions for both parties. This criterion had been conceived to measure the degree of flexibility of the biorefinery managers in this context.
- Price policy:  
In the agricultural sector, the prices of feedstocks are governed by a global market. For example, a starch biorefinery sources according to world cereal prices, while a sugar biorefinery purchases based on world sugar beet prices. Similarly, the farmer sells his crop according to this equilibrium price between world supply and demand. However, depending on the forms of cooperation that exists between industrial operators and farmers, some biorefineries grant premiums to biomass producers in order to motivate them while others do not.
- Adaptation to specifications:  
This criterion measures the impacts of the biorefinery on farmers' practices. These changes

are usually due to specific requirements of high value-added products processed by biorefineries such as grain protein content, etc.

- Assistance of farmers:  
Given these requirements, this criterion aims at assessing if strategies have been implemented by the biorefinery operators for accompanying farmers. There are different ways of accompaniment such as training in cultivation techniques, awareness meetings, financial supports, etc.
- Participation to social development:  
This criterion measures the ability of biorefinery operators to participate in the social life of the local community. It can be manifested in different forms such as the contribution to the development of social infrastructures (hospitals, associations, nurseries, etc.), the support for social and professional integration, the sponsorship of cultural activities, etc.
- Ability to contain and reduce nuisances:  
Without going into questions relating to environmental impact assessment, this criterion aims to evaluate the ability of biorefinery operators to provide solutions to the different genes generated by their activities and which is likely to affect local communities' health and well-being. These nuisances can be sound, olfactory or visual.

#### 4.5 Institutional dimension

The institutional embeddedness characterizes the relationships between the biorefinery and the local authorities. Indeed, the public authorities play a decisive role in the functioning of economic activity. Even if the economic entity gives impetus to the construction of territorial resources and their development, it almost simultaneously requires the intervention of a political power to ensure its organization and enable its regulation [6]. However, the organization and regulation by the public authorities are not sufficient to characterize the relationships between local authorities and economic activity. The case studies revealed that reciprocal relations exist between the two entities. In addition to working on the economic attractiveness of their regions, local authorities undertake to support economic operators in consolidating the economic choices related to their location. In other words, local authorities play a key role in the territorial embeddedness of economic activities since they are one of its vectors. In return, the company pays their taxes in the said territory. Three main criteria are proposed to appraise the ties of the biorefinery with the local authorities as well as its institutional embeddedness.

- Local authorities involvement:  
French local authorities are divided into three independent levels: the region, the department and the municipality. These entities are differently involved in the economic activity, in accordance with their respective responsibilities as provided for in the regulatory documents. The purpose of this criterion is to evaluate the commitment of each category of local authority in supporting biorefineries. The results of the surveys showed that the local authorities' commitments can take different forms such as subsidies, guarantees, services to employees, adaptation of urban plans, financing of transport

infrastructure to improve the access to the facility, etc.

- Contribution to local taxes:  
This criterion measures the proportion of taxes paid by the biorefinery managers on the total revenue of local authorities. It should be noted that in France, two kinds of taxes are paid by the companies: the property taxes and the company value-added contribution.
- Modalities of cooperation with local authorities:  
This criterion was considered as particularly important by all local authorities surveyed. Indeed, they unanimously declared that dialogues, information and communication campaigns, as well as the formalization of public-private partnerships serve to reinforce the links between economic activity and local communities, and consequently the institutional embeddedness of economic activity.

#### 4.6 Organizational dimension:

The organizational dimension of embeddedness in this context refers to the capacity of the biorefinery to integrate and activate different types of networks in the territory. In other words, this criterion assesses the degree of openness of the industry to its economic and social environment. In fact, by opening up to the territory (both through market and non-market transactions), the biorefinery managers increase their social capital. The fact is that as the biorefinery operators interact with the territory's stakeholders, they increase the notoriety of their activity and, consequently, its territorial embeddedness. Indeed, "the volume of the social capital possessed by an economic agent depends on the size of the network of connections he can effectively mobilize and on the volume of the capital possessed in his own right by each of those to whom he is connected" [26]. Four main criteria are proposed to measure the organizational embeddedness of the biorefinery:

- Ability to mobilize economic clusters:  
Typically, an economic cluster refers to a geographically bounded group of similar, interconnected and often complementary firms that share infrastructures and a common institutional environment [27; 28]. There are several clusters in the field of biomass valorization. The participation of the biorefinery in these networks is important because not only does it demonstrate its openness to the local economic community, but these networks also promote the dissemination of technical and professional knowledges.
- Synergies and industrial symbiosis:  
This criterion aims to evaluate the collaboration of the biorefinery operators with related industries through the exchange of flows and materials. Indeed, synergies represent an important dimension of their activities insofar as they seek to minimize the impacts and processes of waste production.
- Academic and scientific collaboration:  
As an innovative industry, research and development is essential to the biorefinery. Indeed, these industries mobilize both fundamental and application research. Thus, this criterion measures the collaboration of the

facility managers with the universities and R & D centers of the territory.

- Communication and Openness to Dialog:  
Almost all stakeholders that interact with the biorefineries (economic operators, farmers, the civil society, etc.) emphasized the importance of communication and openness to dialogue. That is the reason why this criterion is proposed.

#### 4.7 Cultural dimension:

Cultural embeddedness is defined as the influence of collective understandings and shared norms on economic and organizational behavior [14]. In other words, it characterizes the perception of the biorefinery and its activity by the general public. For some actors interviewed, embeddedness is primarily cultural. Cultural understandings may be shared at a national level, regional level or on smaller scales, but they help to define what is legitimate and valued within a certain sector of economic activity. To appraise the cultural embeddedness of the biorefinery, two main criteria are suggested:

- Knowledge of the biorefinery and its activities:  
Through this criterion, it is possible to deduce whether the general public is aware of the biorefinery and its activities or not. As the biorefinery is primarily focused on the primary transformation of biomass, its production is principally aimed at industrial customers. Therefore, its leaders must redouble their efforts in terms of information and communication campaigns to become known to the general public in order to establish the ideological and cultural embeddedness of the activity.
- The biorefinery's public image:  
Contrary to the previous criterion whose objective is to analyze the knowledge of the activity by local communities, this second criterion consists in evaluating the image of the biorefinery. In other words, the evaluation focuses on the perception of the activity by the local communities, as well as its collective representation.

## 5 CONCLUSION

This paper highlights social and economic stakes for rural biorefineries. It suggests a framework to assess that kind of activity by emphasizing the interest to integrate territorial dimensions in the assessment. Two case studies were investigated to better understand the impacts of the biorefinery on the production territory. In this regard, interviews were conducted with stakeholders in the territory namely biorefinery operators, biomass producers, storage agencies, local authorities and both academic and professional experts. The results show that the territorial dynamics and particularly the links between the agro-industrial project and the rural environment do not appear significantly in existing impact studies. In addition, to clarify the modalities of territorial embeddedness of the biorefinery, it is necessary to explore more deeply the economic, social, institutional and organizational relations of the industry with its stakeholders. In short, all of these elements are crucial for the completeness and effectiveness of the socio-economic assessment of rural biorefinery projects.

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