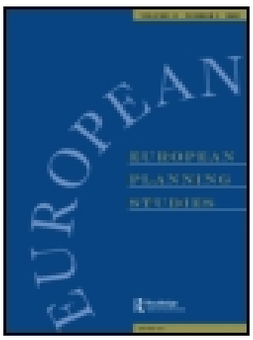

European Planning Studies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceps20

# Territorial governance and actors' coordination in a local project of anaerobic digestion. A social network analysis

Amadou Niang, André Torre & Sébastien Bourdin

**To cite this article:** Amadou Niang, André Torre & Sébastien Bourdin (2021): Territorial governance and actors' coordination in a local project of anaerobic digestion. A social network analysis, European Planning Studies, DOI: 10.1080/09654313.2021.1891208

**To link to this article:** https://doi.org/10.1080/09654313.2021.1891208

EUROPEAN PLANNING STUDIES
https://doi.org/10.1080/09654313.2021.1891208

Routledge
Taylor & Francis Group



# Territorial governance and actors' coordination in a local project of anaerobic digestion. A social network analysis

Amadou Niang[a,b,c], André Torre[a] and Sébastien Bourdin[b]

[a]UMR SAD-APT, INRAE, AgroParisTech, université Paris-Saclay, Paris, France; [b]EM Normandie Business School, Caen, France; [c]Agence de l'environnement et de la maîtrise de l'énergie 20, Angers Cedex 01, France

**ABSTRACT**

Biogas is a process for producing renewable energy, which has recently gained interest in contributing to a territorial strategy for the deployment of the circular economy. The projects, which are collective in nature, bring together multiple actors or local stakeholders from a wide variety of backgrounds. The article proposes to analyze the territorial governance of this type of project by studying the relations of synergy and cooperation between stakeholders in the case study of the Syndicat Mixte du Point Fort (SMPF) of *Cavigny* (France). The results of the analysis of interaction and coordination networks show that local stakeholders develop dense relational networks that vary throughout the project. This high density is indicative of the importance of group cohesion in interactions, which is necessary to create a framework of trust and consultation that favours the success of territorial renewable energy projects. The measure of centrality of the interacting actors shows that the project leader (SMPF) plays the role of assembler and facilitator of the interaction networks facilitating the sharing of flows, knowledge, and collective learning.

**ARTICLE HISTORY**
Received 15 June 2020
Revised 15 January 2021
Accepted 25 January 2021

**KEYWORDS**
Anaerobic digestion; biogas; territorial governance; social network analysis; innovation

## 1. Introduction

As a result of growing environmental concerns and the desire to reduce the consumption of non-renewable resources, in recent years new technologies for transforming biomass into energy and agricultural fertilizers have developed within the framework of circular economy strategies (Wall, McDonagh, and Murphy 2017). This is particularly the case of anaerobic digestion biogas projects. They implement a process of biological degradation of organic residues generated by agriculture, food processing industries, and local authorities and their transformation into biogas and digestate, which are then reintroduced into the production process in energy inputs and organic nitrogen fertiliser (Holm-Nielsen, Al Seadi, and Oleskowicz-Popiel 2009). These biotechnological processes promote the reduction of pollution (Clemens et al. 2006), the revitalization of territories through the creation of new enterprises and locally anchored jobs, as well as the

**CONTACT** Amadou Niang amadou.niang@inrae.fr UMR SAD-APT, INRAE, AgroParisTech, université Paris-Saclay, 16 rue Claude-Bernard, 75005, Paris, France; EM Normandie Business School, 9 rue Claude-Bloch, 14052, Caen, France; Agence de l'environnement et de la maîtrise de l'énergie 20, avenue du, Grésillé- BP 90406 49004 Angers Cedex 01, France

mobilization and cooperation of actors in the territorial governance of rural territories (Guenther-Lübbers, Bergmann, and Theuvsen 2016).

In its desire to ensure the energy transition and the deployment of the circular economy, France has promoted the implementation of multiple biogas projects (Ministry for ecological transition – MTE 2018), which are divided into different development modes depending on the origin of the waste treated and the actors involved. A distinction is thus made between (i) biogas on-farm biogas digester, a small-scale unit generally carried by a farmer who treats most of the waste from his farm (livestock effluents or crop residues), and (ii) collective anaerobic digestion unit, which concerns territorial projects carried out by a group of farmers, local authorities or industries, with a diversity of the types of inputs provided by farms, agri-food companies and local authorities.

The development of this type of project does not always go smoothly, and the organizational difficulties related to the complexity of the relationships between stakeholders and the resistance of local populations fearing negative externalities are the main obstacles to the implementation of biogas units (Zemo, Panduro, and Termansen 2019; Bourdin and Nadou 2020). Work on the analysis of social acceptability issues in biogas projects is increasing (Giuliano et al. 2018; Bourdin, Colas, and Raulin 2019), but research does not focus on understanding the complex relationships built and developed between the local actors involved in anaerobic digestion projects. Little attention is generally paid in academic work to the territorial governance mechanisms at work in these projects, i.e. the way stakeholders or various actors (producers, associations, citizens, private individuals, representatives of public or local authorities …) contribute to the elaboration, sometimes concerted, sometimes conflictual, of joint projects for territorial development (Torre and Traversac 2011).

This article aims to understand the organization of the territorial governance of biogas projects and the dynamics of coordination and cooperation[1] of the local stakeholders, based on a case study located in the rural city of *Cavigny* (Normandy – France). The experience reveals that market coordination is not sufficient in the case of local circular economy experiments and that local agreements need to rely on the cooperation between local actors, to forecast joint projects and to share common expectations for future development projects (Bourdin, Colas, and Raulin 2019). We study the evolution of local relations and of cooperation synergy based on an analysis of the interaction and coordination networks between the actors involved in the project.

The anaerobic digestion project developed by the Syndicat Mixte du Point Fort (SMPF) is a good example of these synergies and territorial approaches to the new valorization of organic waste. It corresponds to the above definition of governance of territorial projects, bringing together multiple actors from different backgrounds and different interests. Because of this diversity, it involves different forms of interaction and coordination that are likely to meet the common needs of stakeholders and generate positive development effects for the territory.

Our analysis is based on the social network approach (SNA). Issued from graph theory (Keast and Brown 2005), which has already been mobilized for analyzing regional innovation systems (Asheim and Isaksen 2002; Cooke 2001), it has recently been applied to organizational issues of territorial governance to describe the structure of local interactions. It has given rise to empirical studies on the dynamics of innovation and governance in rural territories, particularly in the territorial processes linked to the development

of the cork industry in Portugal (Ferreiro and Sousa 2018) or in the Brazilian Amazon between actors of the dairy industry (Torre, Polge, and Wallet 2019). Other studies have focused on inter-organizational networks, applied to stakeholder synergies in clusters (Cruz Sara and Teixeira Aurora 2010), in industrial and territorial ecology (Ashton and Bain 2012), or on local governance and rural development systems in Brazil (Polge and Torre 2017).

The example of the biogas project in *Cavigny* allows us to study the relations of synergy and cooperation between local actors, based on an analysis of the social networks of interaction and coordination and their evolution over the periods of implementation and development. First, we will present our framework of analysis of the territorial governance of biogas projects and its implications in terms of rural territorial development, before detailing in a second part our theoretical approach and the methodology of analysis. We will then present the results that allow to identifying and quantifying the types of links that exist between the actors of biogas and to characterizing the influence and the dynamics of these social networks. We will end by a discussion on these results and the.

## 2. Anaerobic digestion as a tool for innovation and rural territorial governance

Anaerobic digestion is considered as one of the interesting territorial strategy in the framework of the '*energy transition law for green growth*'. More specifically, it is the subject of a so-called plan '*methanisation energy, autonomy, nitrogen*' which aimed to develop 1000 methanisers by 2020 (MTE 2018). It is also part of the European Commission's Bioeconomy Agenda and the European Union's '*Climate and Energy Framework for Action*', committing member countries to increase the share of renewable energy sources to 32% by 2030 (European Commission 2014). This approach is based on operational principles and the promotion of change and greening of the practices of the biogas stakeholders. They must pool their needs, skills and equipment to enhance territorial resources, with the aim of relocating the supply and consumption of local products (Song et al. 2014). Biogas should contribute to the development of a circular economy (MTE 2018), which aims to optimize the use of local biomass to make material and energy flows more efficient and reduce the negative externalities of human activities (Ghisellini, Cialani, and Ulgiati 2016).

Thus, transforming organic waste into local territorial resources intended for the production of renewable energy and organic nitrogenous fertilizer (Holm-Nielsen, Al Seadi, and Oleskowicz-Popiel 2009) constitutes an interesting territorial strategy for implementing circular economy principles in rural territories. Indeed, it contributes to ensure local energy self-sufficiency and energy and nitrogen fertilizer savings in these areas, making it possible to reduce diffuse pollution and greenhouse gas emissions while generating value-creating activities and anchored jobs (Guenther-Lübbers, Bergmann, and Theuvsen 2016). Its local challenges also concern reducing waste management expenditures for communities facing budgetary constraints (Bourdin and Nadou 2020). Thus, anaerobic digestion biogas contributes in some way to territorial development defined as the improvement of the well-being and wealth of the stakeholders of a territory, given their relations of competition and cooperation, their initiatives and their oppositions, and the dynamic of territorial innovations. Thus, it does not rely

solely on the productive actors or the institutions that manage them but involves other stakeholders: local authorities, decentralized state services, consular bodies, associations, etc. (Torre 2019). Anaerobic digestion is also perceived, in the current context of changes in rural areas, as a response to the territorial challenges of remobilizing local actors. Indeed, it introduces new forms of organization and coordination in the governance of flows in these territories characterized by a weakness of interactions between actors, which generates incomplete innovation processes (Camagni 1995). The stakeholders come together in a collective effort in which farmers, industrialists, waste managers, and local authorities mobilize resources to create a project (Reed et al. 2009), conducive to territorial development. But the coordination of actors is not an evidence and requires the building of territorial governance rules. Territorial governance can be defined as a process of building common frameworks to coordinate territorial representations and strategies (individual and collective). Throughout the process, actors interact in a confrontational and/or cooperative manner (Torre and Zuindeau 2009) and make choices to implement territorial development projects. These choices often involve an asymmetry of power between the stakeholders and could lead to a firm rejection of the project. The study of territorial governance, therefore, entails both the analysis of the dynamics of the actors' games (Fournis and Fortin 2017) and the mechanisms and instruments to implement them (Rey-Valette, Lardon, and Chia 2008; Brullot, Maillefert, and Joubert 2014).

Innovations in territorial anaerobic digestion projects primarily concern biotechnological processes for the circular recovery of organic waste, which make it possible to produce and consume renewable energy locally from the resources of the territory and to practice rational agricultural fertilization. The innovations carried out in this framework are also organizational, through the development of networks of actors and collaborative relationships on which the territorial development process is strongly based (Torre and Wallet 2016). These actor coordination networks, while guaranteeing the durability and sustainability of the territorial project (Reed et al. 2009), facilitate the circulation of flows, knowledge sharing, and collective learning, as well as the mobilization of technological innovations and the management of neighbourhood conflicts (Bourdin and Nadou 2020).

All the actors present in the project area are thus geographically close to each other and maintain different types of organized proximity links. This proximity favours direct contact and productive exchanges, in the sense that it facilitates interactions, mutual knowledge, and trust (Dupuy and Torre 2006), which are necessary for the emergence of innovations. The different actors belong to an organization or the same territorial project, resulting from the social ties that are created and developed, facilitates collaboration (Torre 2014; & Torre and Rallet 2005). It is expressed through cooperation and the embedding of relationships (Granovetter 1985) in interpersonal social ties that strengthen the actors' sense of belonging while fostering mutual trust (Hewes and Lyons 2008). Chertow and Ehrenfeld (2012) believe that the climate of trust that is created can renew synergistic relationships and gradually strengthen over the period of evolution and development of interaction networks. In this case, the actors are in a logic of building networks of interaction and coordination relations within which they come together, consult each other, exchange flows, information, and skills and work together around common challenges.

Local opposition to anaerobic digestion projects appears in many territories (Giuliano et al. 2018). According to Bourdin, Colas, and Raulin (2019), they are linked to a lack of trust and consultation between the stakeholders involved in their implementation. They testify to the growing need for coordination between these multiple and heterogeneous actors. Bourdin and Nadou (2020) consider that it is therefore relevant for certain actors to facilitate coordination by acting as intermediaries between the stakeholders to facilitate their adhesion, the local anchoring of projects, and the implementation of governance processes and territorial development (Chodkowska-Miszczuk, Martinat, and Cowell 2019). Along the same lines, recent work on the governance of rural territories (Torre and Wallet 2016 & 2013; Winter 2006; Marsden 2004) testifies to the value of collaboration and coordination of multiple actors in terms of synergy effects on networks of relations, governance, and territorial development.

## 3. Presentation of the case study

To reduce the storage and burial of municipal waste, the *Syndicat Mixte du Point Fort* (SMPF) has committed to a sustainable treatment approach by setting up an environmental waste recovery centre in 2009.[2] The *Point Fort Environnement* (PFE) is a public establishment responsible for organizing selective collection, transport, operating the network of 14 waste collection centres and recovering household waste from the SMPF's member local authorities. Located in *Cavigny*, a small rural commune of 257 inhabitants, the recovery centre includes a sorting centre and a biogas digester treating household and similar waste from 125 communes in Normandy, representing 116,744

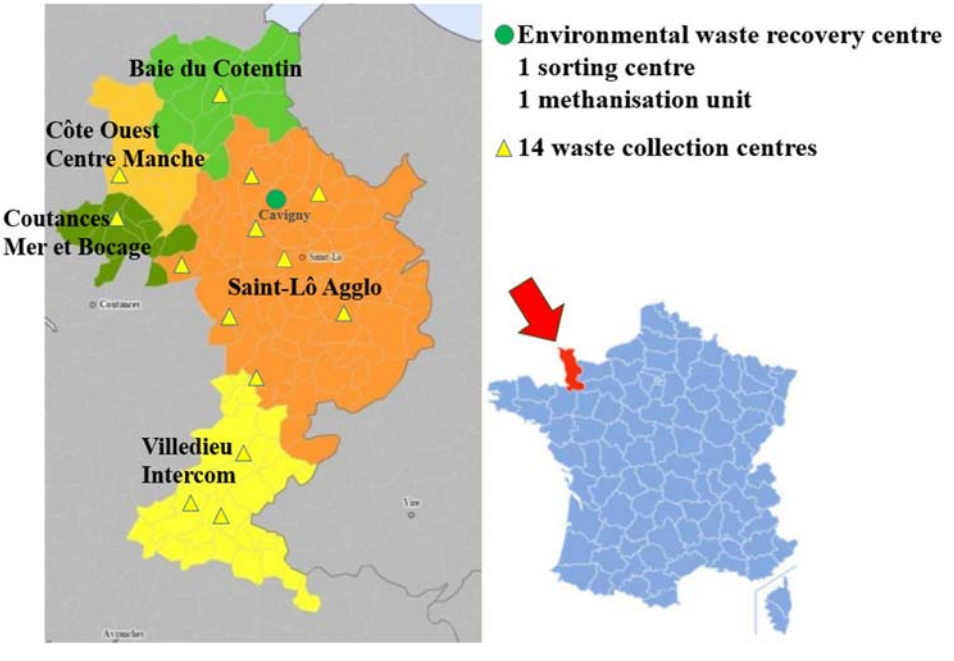


**Figure 1.** Location of SMPF facilities and implementation area for the biogas project in *Cavigny*.

inhabitants (PFE 2020). Figure 1 below shows the scope of the SMPF's competencies covering all the administrative territories of the EPCIs.

The production process of biogas, which favours the reintroduction of energy outputs into the production process, requires an efficient organization of stakeholders for its smooth operation. In particular, the local actors must coordinate around issues of input mobilization, co-product flow, risk management, and social acceptability. Indeed, the different local authorities that are members of the SMPF, as well as non-member client local authorities, contribute to recycling waste under agreements and public contracts with the PFE. Waste managers, professional co-product recovery companies, and farmers who use compost are also involved in the process, without forgetting the local State services in charge of regulatory control of Installations Classified for Environmental Protection (ICPE), as well as an association of impacted local residents (Boursault 2019). Governance mobilizes different categories of actors (see Table 1) operating at various territorial scales. It should be noted, however, that the entire biogas project in *Cavigny* takes place within the jurisdiction of the joint association, under the principle of geographical proximity to the waste production and treatment areas. This is to restrict the extent of flow circulation and guarantee its sustainable nature.

The study of the project makes it possible to distinguish both 1) practices and flows of exchanges of materials and energy (waste, electricity and compost) and 2) communication relationships between the stakeholders in the anaerobic digestion project. The latter is carried out through cooperation and consultation, at the deliberative assemblies of the member authorities, at more or less formal meetings and contacts, and the regulatory meetings of the site monitoring commission. These interactions make possible exchange of materials and energy and the sharing of information.

The site monitoring commission represents an essential framework for exchange and information on risk management (BECP 2019). It involves, in addition to non-member local authorities and co-product recovery companies, all the stakeholders involved in the

**Table 1.** Biogas stakeholders in ***Cavigny*** and their participation in the project.

| Categories of actors | Number 2010 | 2015 | 2019 | Participation |
|---|---|---|---|---|
| Local authorities (members) | 13 | 6 | 5 | Waste collection<br>Deliberating assembly<br>38 elected delegates |
| Local authorities (non-members) | 3 | 4 | 0 | Waste input convention, public procurement |
| Decision-making bodies of the SMPF | 8 elected members to the Executive Board<br>1 technical department (the EFP) | | | Administrative and Financial Management, management and supervision of technical services dialogue and risk management |
| SMPF waste treatment units | 1 Biogas unit<br>1 sorting centre<br>14 waste disposal sites | | | Transport, sorting and treatment of waste, technical services meeting |
| Co-product professionals (Customers) | 1 company<br>1 company<br>Farmers | | | Electricity distribution<br>Compost distribution<br>Use of compost |
| Deconcentrated services of the State | 4 | 4 | 4 | Regulatory monitoring dialogue and risk management |
| Local residents' association | 1 | | | Concertation and risk management |

project, including an association of local citizens. The latter also consult periodically with those in charge of the treatment facilities, particularly about externalities, especially those related to odours and rolling stock circulation. The participation mechanism involves a relational structure of actors using consultation and contractualization as local governance mechanisms.

## 4. Methodology for analysing the territorial governance of anaerobic digestion project

Our analysis of synergy and cooperation between the stakeholders of the biogas project in *Cavigny* is based on a social network analysis approach applied to territorial innovation systems and governance. This approach makes it possible to identify and quantify the types of relationships that exist between stakeholders, to characterize their influence, and to observe the evolution over time of the social networks they form (Ter Wal and Boschma 2009). Thanks to this method, we can describe the relational network of local stakeholders that characterizes the types of exchanges within the biogas project, its main features, but also to assess its evolution and changes over the implementation and development periods. We also look at thenetwork of material flows to compare its evolution with that of the social network and to evaluate their reciprocal influences. Based on the example of biogas, our network approach converges with the industrial symbiosis results by highlighting the importance of the intermediary actors that structure the system and promote productive exchanges (Walls and Paquin 2015), while raising the question of the place of communication flows in the urban metabolism analyses (Rosado, Niza, and Ferrão 2014).

The objective is to carry out, based on primary and secondary relational data, an analysis of material and energy exchange networks, as well as governance and communication networks over the periods 2010, 2015, and 2019. The choice of these periods of analysis was based on the study of the chronicle of events that have marked the local context of biogas development (see Boursault 2019). While the year 2010 corresponds to the start of biogas activities, 2015 is marked by the implementation of the law NOTRE (New Territorial Organization of the Republic) which has led to mergers and integrations of local authorities throughout the national territory that will strongly impact the local biogas system (Bourdin and Torre 2020). Finally, 2019 is characterized by the SMPF's desire to diversify its input to optimize its installations and to respond to the drop in household waste tonnages linked to the introduction of a separate collection of bio-waste.

To better understand the scope of the flows and identify and categorize the actors involved in the project (see Table 1), we conducted an exploratory interview with the SMPF management team beforehand. This method enabled us to apply the 'roster-recall' approach recommended by Ter Wal and Boschma (2009), to draw up the list of stakeholders and select their representatives to be interviewed while ensuring the representativeness of the stakeholders and types of exchanges.

The collection of primary data on interaction relationships required 27 semi-directive interviews with representatives of the organizations and structures involved in the innovation and governance dynamics of the process (see Appendix 1 for details of the interviews). For the data from the temporal dynamic analysis of interaction relations between 2010 and 2015, we applied the methodology for reconstructing the network's history

(Grossetti, Barthe, and Chauvac 2011), interviewing former SMPF managers and employees who had been present since the beginning of the project. An interview guide developed for this purpose was designed to collect quantitative and qualitative relational information from the interviewees.

The primary data corresponding to each type of exchange was supplemented by secondary contextual data (Sousa 2012) on the anaerobic digestion project. We then processed using ARS software (NetDraw and Ucinet), allowing the networks to be represented graphically for visual analysis of the graphs (Card Stuart, Mackinlay, and Shneiderman 1999), and statistical measurements reflecting the local and global properties of the networks (Wasserman and Faust 1994).

With this method, we measured the link density index and detected the presence or absence of cohesive subgroups (n-clicks) in interactions as typical indicators of the structural properties of networks. This approach is complemented using degree centrality indicators (closeness and betweenness) that allow the analysis of the individual characteristics of position and importance of actors in the interaction relationships. More specifically, the indicators used are as follows.

The link density is an overall measure of network structure, ranging from 0 to 1, relating the number of relationships maintained by actors to the number of possible connections. The higher the density, the greater the trust between actors and the group cohesion in interactions. A low-density value, close to 0, therefore reveals the low potential for synergistic relationships within the network.

The n-clicks (Borgatti, 2002), expressed as the number of sub-groups observable within the network, make it possible to identify cohesive groups of actors who are strongly linked to each other, as well as the potential relay actors (intermediaries). They provide the link between the sub-groups. The presence of many n-clicks implies a weakness of relations between actors, resulting in a non-cohesive network. In contrast, a limited number of n-clicks is synonymous with solidarity, social control and information circulation.

The degree of centrality (Freeman 1979), measured by the number of links involving an actor, makes it possible to highlight the central actors in the interaction network. They possess the most significant number of relationships. The higher an actor's degree value, the more central and active he is in the network, playing an essential role in the circulation of flows (Wasserman and Faust 1994).

The betweenness centrality (Newman 2003), highlights, among the central actors with high values, those who act as intermediaries in the interaction relationships. The more a player is associated with a high value of this indicator, the more it occupies an intermediary position of within the network, by linking the other players and by facilitating the circulation of flows of information, knowledge and collective learning, particularly between cohesive subgroups (Diani 2003).

The Closeness centrality (Sabidussi 1966) makes it possible to highlight the peripheral actors of the network, who maintain fewer relationships. The higher the value of this indicator for an actor, the less important it is in the structure of the interaction network.

## 5. Networks of anaerobic digestion stakeholders

Interviews with the project stakeholders made it possible to identify the modalities of productive and territorial partnerships between local authorities producing waste,

public and private companies, waste and co-product managers, specialized public support services, and local population (see Table 1). Indeed, the anaerobic digestion project in *Cavigny* seeks to optimize the local recovery of household and similar waste. It implements a productive partnership between local actors exchanging materials and energy and also involves relations of coordination and governance of the flows and risks associated with the project. These partnerships (which bring together the actors within two networks) correspond to (i) exchanges of material and energy flow taking place in the formal relations of belonging to SMPF and informal relations with customers and (ii) interactions between participants in terms of exchange of information in a collaborative context'.

Based on the data collection, we have developed two categories of graphs representing the social networks of cooperation and interaction, analyzed separately in their dynamics of evolution and development in 2010, 2015, and 2019. The first graph corresponds to the relations of exchanges of materials and energy between local authorities (members and non-members) establishments of the waste management project holder, companies and farmers specialized in the recovery of co-products (Figure 2). The latter correspond to the graphs of the communication network that mobilizes the local population and the technical services of the State within the framework of the shared and concerted regulatory governance of anaerobic digestion flows (Figure 5). They involve only certain actors participating in the exchanges of materials and energy, in particular, the local authorities and the management bodies of the joint association.

### 5.1. The network of exchange of material and energy flows

Analysis of the graphs of material and energy exchange relations (Figure 2) shows that each of the actors is in a direct relationship of sharing inputs (waste) or co-products (heat, electricity, and compost) with at least two other stakeholders in productive

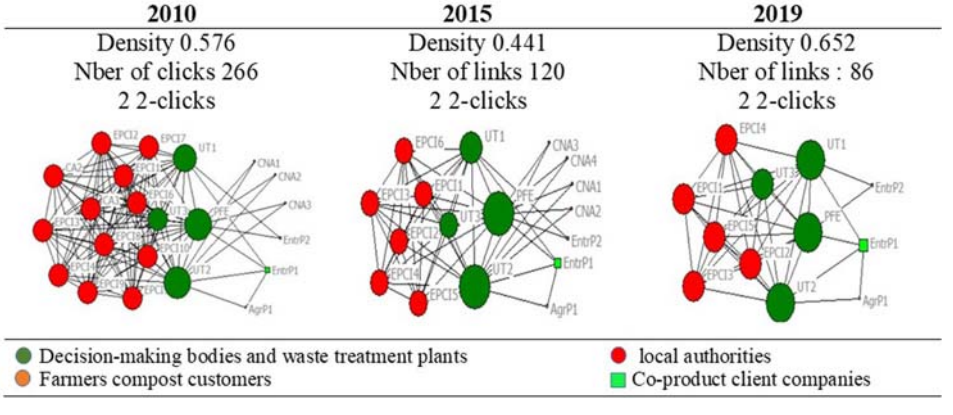


**Figure 2.** Structural characteristics of the material and energy exchange network. Legend: the nodes of the networks represent the actors, the arcs their relations, the shape of the nodes corresponds to the actors' scales of action (the circle at the local level, the triangle at the NUTS-3 level, and the square at the national level). The size of the nodes represents the number of relationships involving an actor in proportion to its degree centrality value.

partnerships. The exchanges are structured around the central actors, consisting of the technical department (PFE), the waste treatment plants (UT1, UT2, UT3), and the project leader (SMPF), who interact more or less with all the other peripheral actors. The local authorities that are members of the SMPF are very strongly connected to the network by the importance of waste exchanges with all the central actors. On the other hand, the non-member local authorities (which establish commercial relations for the supply and treatment of their waste) and the client companies distributing the co-products (EnrP1 and EnrP2) have few ties with the whole set of actors. Given their low level of direct exchanges with the waste treatment plants through agreements and public contracts with the FEP, they can be considered, alongside the farmer's final customers of compost (AgrP1), among the peripheral players with little or no relations with the other participants.

The number of actors participating in the productive exchange network decreases over time, going from 15 member and non-member local authorities to 5 member local authorities between 2010 and 2019. This phenomenon is linked to the desire of the SMPF to encourage the taking of 'competence treatment of household waste' by the communities of communes and agglomeration communities, which are slightly replacing the communes. Following the territorial reform of August 2015, the NOTRe law (Bourdin and Torre 2020), this competence becomes mandatory for these EPCI. As a result, at the local level, in January 2017, the *Département de la Manche* (NUTS 3 level) ended up with only 8 EPCI, 5 of which are currently members of the SMPF.

The measurement of relationships reveals that the network is dense, as shown by the very high-density indices, which represent, over the development period, more than half of the possible combinations of relationships between actors. Indeed, if we see in 2015 a decrease in this proportion of productive exchange relations between the actors, it then increases to become denser again at the end of the period (in 2019).

In terms of individual influence in productive interactions, the measurement of centrality indices shows that the players' positioning has not changed throughout evolution and development of the network, between 2010 and 2019 (see Appendix 2).

The PFE and the waste treatment plants (UT2) are mentioned by the participants as the central actors with the most relationships in the anaerobic digestion production process (see Figure 2). In charge of coordinating the operational implementation at all levels of the biogas project, the PFE, together with the waste treatment plants, is the main intermediate player in the materials and energy exchange network, as shown by its high value of centrality of intermediation (see Figure 3). The waste collection centres owe this dominant position because (i) they organize the transport of waste to the anaerobic digester digester, (ii) the relations they maintain directly as relay collection points, downstream, with the farmers who come to recover part of the compost. The stakeholders who participate the least in these exchanges of materials and energy are the SMPF's customer partners, particularly non-member local authorities that bring waste, and the companies that are customers of the co-products. Characterized by limited exchange relationships (low degree of centrality) and higher proximity centrality values (see Figure 3), these participants only interact with the network through relay actors.

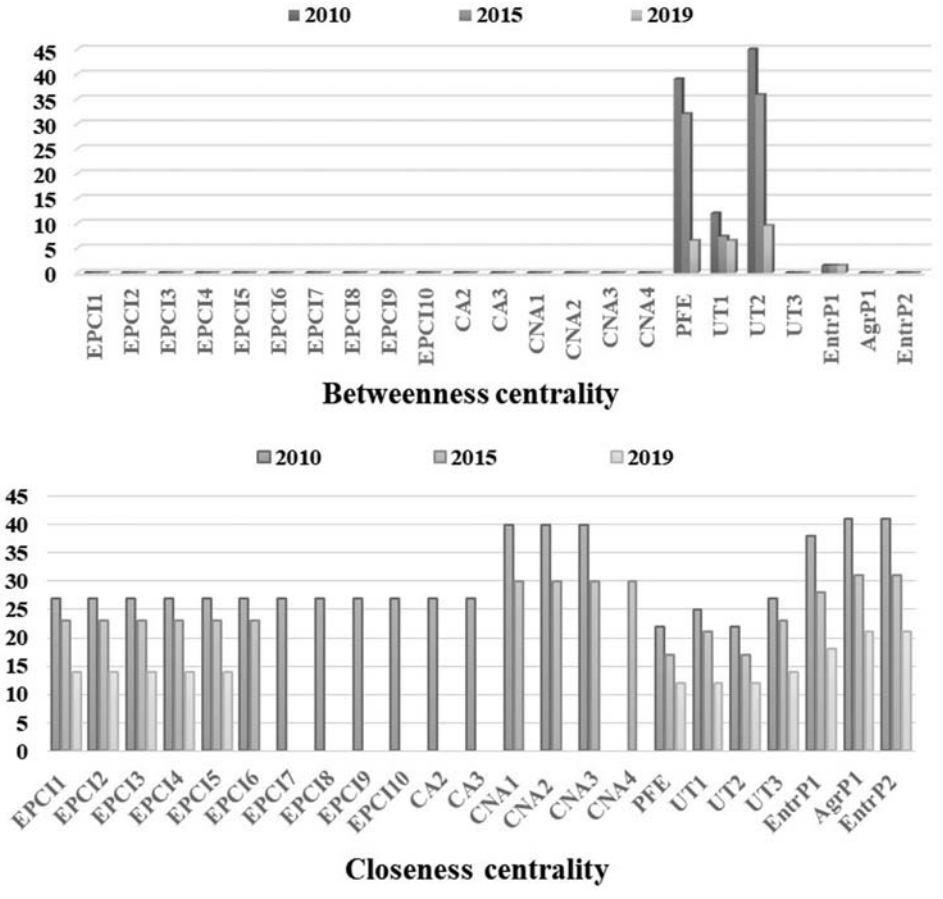


**Figure 3.** Measuring the influence of actors in the material and energy exchange network. Legend: Figures 3 and 5 present the indices of centrality of intermediation (betweeness) and proximity (closeness), characteristic of the positions and importance of the actors in the network structures. In terms of intermediarity, the higher the value of this index, the more the actor is associated with it. The more he is positioned as a relay intermediary with the most control over exchanges and interactions. Whereas actors with high values of proximity centrality have a lower importance in the networks of relations, and on the contrary, the lower this value, the more central the actor is and the easier it is to interact.

### *5.2. The exchange network in terms of communication*

The network of communication relations corresponds to the governance mechanism of the territorial biogas project; it allows the dissemination of information and knowledge, gives the possibility to the local populations to participate in its management, and lessen neighbourhood conflicts. The exchanges and interactions described here take place through face-to-face dialogue and consultation at the deliberative assemblies of the SMPF, more or less formal meetings and contacts, and at the regulatory meetings of the site monitoring commission.

This communication network takes a different form from that of the material and energy flows, It was slightly denser during the first years of project implementation (see Figure 4). Still, the communication interactions have stabilized at the same

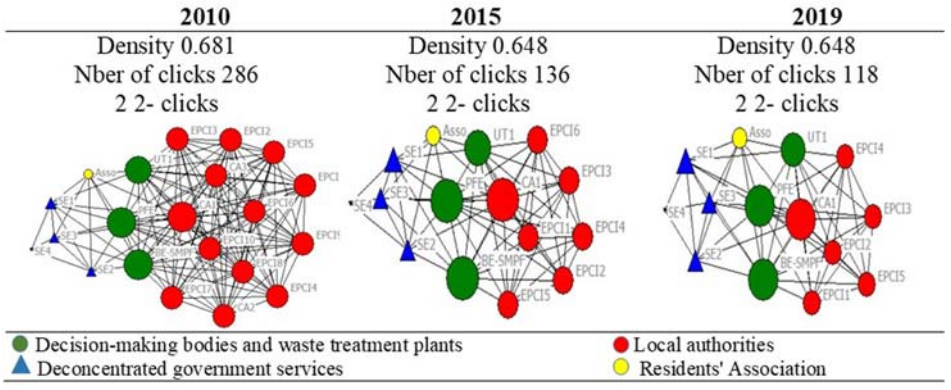


**Figure 4.** Structural characteristics of the exchange network in terms of communication. Legend: the nodes of the networks represent the actors, the arcs their relations, the shape of the nodes corresponds to the actors' scales of action (the circle at the local level, the triangle at the NUTS2 level, and the square at the national level). The size of the nodes represents the number of relationships involving an actor in proportion to its degree centrality value.

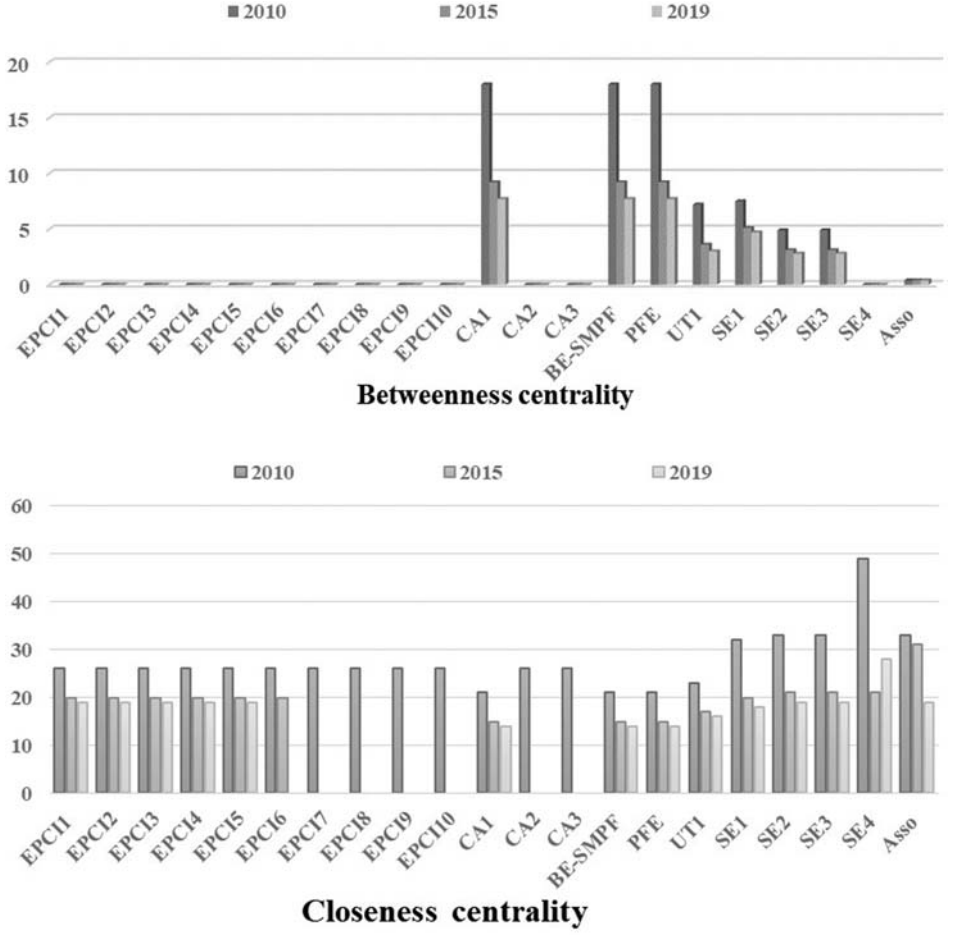


**Figure 5.** Measuring the influence of actors in the exchange network in terms of communication.

density level since 2015, while the relations of productive exchanges of materials and energy became denser in 2019.

Only two cohesive subgroups[3] (2, 2 cliques) interact with each other during the evolution and development of the project. The first is composed of the members of the site monitoring commission involving the decision-making bodies of the project owner (SMPF), the *Cavigny* town council, and the State technical services and the local residents' association in the framework of the regulatory monitoring of the biogas project. The second brings together these players and the local authorities that are members of the SMPF, which are waste suppliers. Only one public stakeholder, SE4 (ADEME) participates in the first cohesive sub-group without being a member of this commission: ADEME (French Agency of Environment and Energy). This institutional structure plays an essential role in developing anaerobic digestion in France, and communicates with the stakeholders through the other deconcentrated State services. ADEME does not support the present biogas project. At the scale of the value chain of the biogas production network, the two cohesive sub-groups overlap and are composed of almost the same people and all the actors, from upstream to downstream of the biogas project: local authorities supplying waste, professionals of the valorization of the by-products (except the electricity customer company and the farmers using compost who each participate separately in a single sub-group), decision making bodies and treatment establishments of the project leader, waste managers.

This governance mechanism is organized around central stakeholders with high degree values (see Figure 4 and Appendix 3 for details). Among them, the PFE (participating in the exchanges of materials and energy) and the executive board of the SMPF, both carrying the biogas project, are established as relay actors with higher values of centrality of intermediation (Figure 5) alongside the *Cavigny* town hall.

*Cavigny* town hall represented by its mayor is the only community at the centre of the operational and regulatory governance of biogas. It is involved in thinking about mobilizing inputs, product disposal, risk management, and local social acceptability. Its central role is reinforced by its position as an ex-officio member of the site monitoring commission, for having hosted the biogas installations. The local authorities involved in the project delegate their functions to the SMPF, the public establishment that is the project leader, which manages their waste. These authorities provide exchange of materials and energy. They also participate in dialogue and consultation through their delegates on the trade union committee and the elected members of the executive board (SMPF) who represent them at the deliberative assembly and on the monitoring committees.

## 6. What are the implications for the territorial governance of anaerobic digestion?

Our analysis of the networks of stakeholders in the *Cavigny* biogas project, first in terms of material and energy exchanges and then in terms of communication relations, led us to identify dense relational structures conducive to stakeholder cooperation and coordination and to analyze how they relate to material flows. The high density of all the networks is indicative of the strong group cohesion in the exchanges of biogas flows. Close professional relations between actors 'facilitate the circulation of flows and the success of

the territorial anaerobic digestion biogas project (Bourdin and Nadou 2020). The presence in the networks of only two interdependent cohesive sub-groups confirms the stakeholders' sense of belonging to the same project. Indeed, a limited number of subgroups is synonymous with solidarity and the circulation of information and knowledge that strengthen social ties and facilitate collaboration (Borgatti, 2002). This logic of belonging, linked to the geographical proximity of the actors, enables the construction and consolidation of relational networks and the cohesion of the network as a whole.

The results also reveal the importance of intermediation in developing interactions (Torre 2014; Bourdin and Nadou 2020). The intermediary actors (the PFE, the SMPF, and the *Cavigny* town hall) maintain more or less strong communication relations with all the other stakeholders, including those who participate the least in the interactions. Their role is all the more critical in the productive and territorial interactions as they guarantee the efficient mobilization of material resources to make the anaerobic digestion plant profitable (Wellinger, Murphy, and Baxter 2013) prevent any conflicts or oppositions that may emerge. Thus, by ensuring the strategic coordination role of the biogas project, they make communication, sharing of material and energy flows, as well as the dissemination of information, knowledge, and collective learning possible (Walls and Paquin 2015). They also foster the emergence and maintenance of trust relationships, often considered as a decisive condition for the success of territorial renewable energy projects (Walker et al. 2010; Bourdin, Colas, and Raulin 2019), and industrial and territorial synergies between companies (Paquin and Howard-Grenville 2012). Our results confirm the results about the social acceptability of wind energy projects (Devine-Wright 2012), the synergy networks in industrial and territorial ecology (Paquin and Howard-Grenville 2012) or the role played by local authorities about the development of biogas projects (Bourdin and Nadou 2020).

However, this approach raises a question about the reproducibility and generalization of the governance mode studied: each anaerobic digestion biogas project is specific to its territory and its stakeholders, and transposition cannot be free of local realities of implementation (Ashton and Bain 2012). Beyond mobilizing inputs (local biomass), the territorial context should encourage the interplay of stakeholders and the interactions. The multi-actor nature of the network structure is not in itself a hindrance to the development of the biogas project but instead enlarges the opportunities to activate the links between the actors. It reveals the influence of geographical proximity in production partnerships and the participation of local authorities and populations, which ensures the sustainability of the process. However, the collective action that emerges is essentially based on the feeling of actors to belong to the same networks. It is also basedon the sharing of similar references concerning environmental values of anaerobic digestion. It also results from the integration of conflicting potentialities and the intermediaries' role that structure the system and promote interactions through moments of exchange and sharing of information. The challenge is to succeed in maintaining these modes of territorial governance, which guarantee the effective mobilization of energy and communication flows for the success of the project and the valorization of local biomass (Wellinger, Murphy, and Baxter 2013), in the hope of reinforcing the emerging dynamics of cooperation and to avoid conflicts.

## 7. Conclusion

Today considered as one of the interesting territorial strategies for implementing the ecological and energy transition, biogas relies for its success on the synergies between public and private actors working together around shared challenges at a local scale. In this context, it is interesting to evaluate the role of the interplay between actors and their governance to highlight their possible contribution to the processes of innovation and sustainable territorial development. The article contributes to identify and characterize, from a network approach, the links existing between the actors of the biogas project to report on the structure of interactions in the territory. It is based on the analysis of the multi-stakeholder interaction relationships built and developed in a collaborative environment between the stakeholders of the territorial anaerobic digestion project of the SMPF in *Cavigny*.

The results show the coexistence of two synergy networks, which correspond to material and energy flow exchange relations and communication relations. They make it possible to account for a relational context favourable to the cooperation and coordination of players as the biogas project evolves and develops over time. The climate of trust between stakeholders was created from the start of the project, then gradually strengthened within the networks, confirming that trust and collective action may take several years to build (Chertow and Ehrenfeld 2012).

One can wonder about the role played by these new territorial dynamics in the processes of territorial development. Our social networks approach has allowed us to identify and discuss the conditions of success and governance of biogas projects. Still, it is indeed challenging to apply to spatial and territorial issues. It is necessary to go beyond the light it sheds on the problems of coordination between actors and governance and find new ways to focus on the emergence of new viable and sustainable projects compatible with a territorial development of anaerobic digestion biogas.

## Notes

1. Let us note that cooperation can be defined as a specific kind of coordination.
2. A *syndicat mixte* is a type of inter-municipal cooperation structure to enable local authorities to join forces with each other or with public institutions.
3. A cohesive subgroup is a subset of actors who are more connected to each other than to the rest of the network, whereby an actor can participate in several cohesive subgroups at the same time. They can be identified in terms of the number of subgroups (n-clicks, with $n = 2$) (Borgatti, 2002).

## Acknowledgements

The authors would like to thank the *Syndicat Mixte du Point Fort* (SMPF) and the people and structures that agreed to collaborate to this research. Our warmest thanks go to Emma BOURSAULT for conducting the interviews and collecting the data that made this work possible. This research has been funded by ADEME and PSDR programmes.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

This work was supported by Agence de l'Environnement et de la Maîtrise de l'Energie: [Grant Number GRANT]; PSDR.

## References

Asheim, B., and A. Isaksen. 2002. "Regional Innovation Systems: The Integration of Local 'sticky' and Global 'ubiquitous' Knowledge." *Journal of Technology Transfer* 27: 77–86.

Ashton, W. S., and A. C. Bain. 2012. "Assessing the 'Short Mental Distance' in eco-Industrial Networks." *Journal of Industrial Ecology* 16: 70–82.

BECP. 2019. Commission de suivi de site du pôle environnement de *Cavigny*. Procès-verbal de la réunion du 3 juillet 2019. Service de la coordination des politiques publiques et de l'appui territorial, préfecture de la Manche, p.7.

Borgatti, S. P. 2002. "A Statistical Method for Comparing Aggregate Data Across a Priori Groups." *Field Methods* 14 (1): 88–107.

Bourdin, S., M. Colas, and F. Raulin. 2019. "Understanding the Problems of Biogas Production Deployment in Different Regions: Territorial Governance Matters Too." *Journal of Environmental Planning and Management*, 63 (9): 1–19.

Bourdin, S., and F. Nadou. 2020. "The Role of a Local Authority as a Stakeholder Encouraging the Development of Biogas: A Study on Territorial Intermediation." *Journal of Environmental Management* 258), 10.1016/j.jenvman.2019.110009.

Bourdin, S., and A. Torre. 2020. "The Territorial Big Bang: Which Assessment About the Territorial Reform in France?" *European Planning Studies*. doi:10.1080/09654313.2020.1777943.

Boursault, E. 2019. Analyse de la gouvernance territoriale de l'économie circulaire appliquée au cas de la méthanisation. Mémoire de fin d'études, Agrosup Dijon, p.53.

Brullot, S., M. Maillefert, and J. Joubert. 2014. "Stratégies d'acteurs et gouvernance des démarches d'écologie industrielle et territoriale. Développement durable et territoires." *Économie, géographie, politique, droit, sociologie* 5 (1): 31. doi:10.4000/developpementdurable.10082.

Camagni, R. 1995. "The Concept of Innovative Milieu and its Relevance for Public Policies in European Lagging Regions." *Papers in Regional Science* 74 (4): 317–340.

Card Stuart, K., Jock D. Mackinlay, and B. Shneiderman. 1999. *Readings in Information Visualization: Using Vision to Think*. San Diego, USA: Academic Press.

Chertow, M. 2000. "Industrial Symbiosis: Literature and Taxonomy." *Annual Review of Energy and the Environment* 25: 313–337.

Chertow, M., and J. Ehrenfeld. 2012. "Organizing Self-Organizing Systems." *Journal of Industrial Ecology* 16: 13–27.

Chodkowska-Miszczuk, J., S. Martinat, and R. Cowell. 2019. "Community Tensions, Participation, and Local Development: Factors Affecting the Spatial Embeddedness of Anaerobic Digestion in Poland and the Czech Republic." *Energy Research & Social Science* 55: 134–145.

Clemens, J., M. Trimbornm, P. Weiland, and B. Amon. 2006. "Mitigation of Greenhouse Gas Emissions by Anaerobic Digestion of Cattle Slurry." *Agriculture, Ecosystems & Environment* 112: 171–177.

Cook, K. S., R. Hardin, and M. Levi. 2005. *Cooperation Without Trust?* New York: Russell Sage Foundation. 268p.

Cooke, P. 2001. "Regional Innovation Systems, Clusters, and the Knowledge Economy." *Industrial and Corporate Change* 10 (4): 945–974.

Cruz Sara, C. S., and A. C. Teixeira Aurora. 2010. "The Evolution of the Cluster Literature: Shedding Light on the Regional Studies-Regional Science Debate." *Regional Studies* 44 (9): 1263–1288.

Devine-Wright, P. 2012. "Fostering Public Engagement in Wind Energy Development: The Role of Intermediaries and Community Benefits." In *Learning from Wind Power: Governance, Societal and Policy Perspectives on Sustainable Energy*, edited by J. Szarka, R. Cowell, G. Ellis, P. A. Strachan, and C. Warren, 194–214. Basingstoke: Palgrave Macmillan.

Diani, M. 2003. "Networks and Social Movements. A Research Programme." In *Social Movements and Networks. Relational Approaches to Collective Action*, edited by M. Diani, and M. Doug, 299–319. Oxford: Oxford University Press.

Dupuy, C., and A. Torre. 2006. "Local Clusters, Trust, Confidence and Proximity." In *Clusters and Globalisation: The Development of Urban and Regional Economies*, edited by C. Pitelis, R. Sugden, and J. Wilson, 175–195. Cheltenham UK, Northampton USA: Edward Elgar.

European Commission. 2014. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. A policy framework for climate and energy in the period from 2020 to 2030. Brussels.

Ferreiro, M. de F., and C. Sousa. 2018. "Governance, Institutions and Innovation in Rural Territories: The Case of Coruche Innovation Network." *Regional Science Policy and Practice* 11: 235–250.

Fournis, Y., and M. J. Fortin. 2017. "From Social 'Acceptance to Social 'Acceptability'of Wind Energy Projects: Towards a Territorial Perspective." *Journal of Environmental Planning and Management* 60 (1): 1–21.

Freeman, L. C. 1979. "Centrality in Social Networks: Conceptual Clarification." *Social Networks* 1 (3): 215–239.

Ghisellini, P., C. Cialani, and S. Ulgiati. 2016. "A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." *Journal of Cleaner Production* 114: 11–32.

Giuliano, A., F. Gioiella, D. Sofia,, and N. Lotrecchiano. 2018. "À Novel Methodology and Technology to Promote the Social Acceptance of Biomass Power Plants Avoiding Nimby Syndrome." *Chemical Engineering Transactions* 67: 307–312.

Granovetter, M. 1985. "Economic Action and Social Structure: The Problem of Embeddedness." *American Journal of Sociology* 91 (3): 481–510.

Grossetti, M., J.-F. Barthe, and N. Chauvac. 2011. "Studying Relational Chains from Narrative Material." *Bulletin of Sociological Methodology* 110: 11–25.

Guenther-Lübbers, W., H. Bergmann, and L. Theuvsen. 2016. "Potential Analysis of the Biogas Production - as Measured by Effects of Added Value and Employment." *Journal of Cleaner Production* 129: 556–564.

Hewes, A., and D. Lyons. 2008. "The Humanistic Side of Eco-Industrial Parks: Champions and the Role of Trust." *Regional Studies* 42: 1329–1342.

Holm-Nielsen, J. B., T. Al Seadi, and P. Oleskowicz-Popiel. 2009. "The Future of Anaerobic Digestion and Biogas Utilization." *Bioresource Technology* 10022: 5478–5484.

Keast, R., and K. Brown. 2005. The network approach to evaluation: Uncovering patterns, possibilities and pitfalls. Australasian Evaluation Society International Conference, South Bank, Brisbane, 10–12 October 2005, p. 10.

Marsden, T. 2004. "The Quest for Ecological Modernisation: Re-Spacing Rural Development and Agri-Food Studies." *SociologicaRuralis* 44 (2): 129–146.

MTE. 2018. Plan de libération des énergies renouvelables, Groupe de travail "méthanisation. Paris.

Newman, M. E. J. 2003. "The Structure and Function of Complex Networks." *SIAM Review* 45 (2): 167–256.

Paquin, R. L., and J. Howard-Grenville. 2012. "The Evolution of Facilitated Industrial Symbiosis." *Journal of Industrial Ecology* 16 (1): 83–93.

PFE. 2020. Rapport annuel sur le prix et la qualité du service public du traitement des déchets 2019. Point Fort Environnement, p. 28.

Polge, E., and A. Torre. 2017. "Territorial Governance and Proximity Dynamics. The Case of two Public Policy Arrangements in the Brazilian Amazon." *Papers in Regional Science* 97 (4): 909–929.

Reed, M. S., A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, et al. 2009. "Who's in and Why? A Typology of Stakeholder Analysis Methods for Natural Resource Management." *J. Environ. Manag* 90 (5): 1933–1949.

Rey-Valette, H., S. Lardon, and E. Chia. 2008. "Governance–Institutional and Learning Plans Facilitating the Appropriation of Sustainable Development." *International Journal of Sustainable Development* 11 (2–4): 101–114.
Rosado, L., S. Niza, and P. Ferrão. 2014. "An Urban Material Flow Accounting Case Study of the Lisbon Metropolitan Area Using the Urban Metabolism Analyst Method." *Journal of Industrial Ecology* 18 (1): 84–101.
Sabidussi, Gert. 1966. "The Centrality Index of a Graph." *Psychometrika* 31 (4): 581–603.
Song, Z., C. Zhang, G. Yang, Y. Feng, G. Ren, and X. Han. 2014. "Comparison of Biogas Development from Households and Medium and Large-Scale Biogas Plants in Rural China." *Renew. Sustain. Energy Rev* 33: 204–213.
Sousa, C. 2012. "Using Social Network Analysis to Study Entrepreneurship: Methodological Issues." In *Social Networks, Innovation and the Knowledge Economy*, edited by I. Salavisa, and M. Fontes, 89–105. London and New York: Routledge.
Ter Wal, A., and R. Boschma. 2009. "Applying Social Network Analysis in Economic Geography: Framing Some Key Analytic Issues." *The Annals of Regional Science* 43 (3): 739–756.
Torre, A. 2014. "Proximity Relations at the Heart of Territorial Development Processes: From Clusters, Spatial Conflicts and Temporary Geographical Proximity to Territorial Governance." In *Regional Development and Proximity Relations*, edited by A. Torre, and F. Wallet, 94–134. Edward Elgar.
Torre, A. 2019. "Territorial Development and Proximity Relationships." In *Handbook of Regional and Development Theories*, 2nd ed., edited by R. Capello, and P. Nijkamp, Vol. 674, 326–343. Cheltenham: Edward Elgar Publishers.
Torre, A., E. Polge, and F. Wallet. 2019. "Proximities and the Role of Relational Networks in Innovation: The Case of the Dairy Industry in Two Villages of the 'Green Municipality' of Paragominas in the Eastern Amazon." *Regional Science Policy & Practice* 11: 279–294.
Torre, A., and A. Rallet. 2005. "Proximity and Localization." *Regional Studies* 39 (1): 47–60.
Torre, A., and J. B. Traversac, eds. 2011. *Territorial Governance. Local Development, Rural Areas and Agrofood Systems*. Heidelberg & N. York: Springer Verlag.
Torre, A., and F. Wallet. 2013. "Innovation and Governance of Rural Territories." In *Renewing Innovation Systems in Agriculture and Food: How to go Towards More Sustainability?*, edited by E. Coudel, H. Devautour, C. T. Soulard, G. Faure, and B. Hubert, Vol. 240, 147–164. Wageningen: Wageningen Academic Publishers.
Torre, A., and F. Wallet. 2016. *Regional Development in Rural Areas. Analytical Tools and Public Policies, Springer Briefs in Regional Science*. Cham: Springer International Publishing AG. p. 110.
Torre, A., and B. Zuindeau. 2009. "Proximity Economics and Environment: Assessment and Prospects." *Journal of Environmental Planning and Management* 52: 1–24.
Walker, G., D.-W. P, S. Hunter, H. High, and B. Evans. 2010. "Trust and Community: Exploring the Meanings, Contexts and Dynamics of Community Renewable Energy." *Energy Policy* 38 (6): 2655–2663.
Wall, D. M., S. McDonagh, and J. D. Murphy. 2017. "Cascading Biomethane Energy Systems for Sustainable Green gas Production in a Circular Economy." *Bioresource Technology* 243: 1207–1215.
Walls, J. L., and R. L. Paquin. 2015. "Organizational Perspectives of Industrial Symbiosis: A Review and Synthesis." *Organization and Environment* 28 (1): 32–53.
Wasserman, S., and K. Faust. 1994. *Social Network Analysis: Methods and Applications*. Cambridge, UK: Cambridge University Press.
Wellinger, A., J. D. Murphy, and D. Baxter, eds. 2013. *The Biogas Handbook: Science, Production and Applications*. Amsterdam: Elsevier.
Winter, M. 2006. "Rescaling Rurality: Multilevel Governance of the Agro-Food Sector." *Political Geography* 25 (7): 735–751.
Zemo, K. H., T. E. Panduro, and M. Termansen. 2019. "Impact of Biogas Plants on Rural Residential Property Values and Implications for Local Acceptance." *Energy Policy* 129: 1121–1131.

# Appendices

## Appendix 1: Interview details.

| Categories of actors | Structure/Organisation | Ref. | Number of interviews/Function | Date of interview |
|---|---|---|---|---|
| Project leader | Executive committee | SMPF | (1) President | 12/06/2019 |
| | | | (1) Former President | 04/06/2019 |
| | | | (3) Vice-presidents | 12/06/2019 |
| | Technical direction | PFE | (1) Director | 05/04/201903/ |
| | | | (1) Deputy director | 06/2019 |
| | | | (1) Head of communication | |
| | Biogas plant | UT1 | (1) Director | |
| | Waste disposal sites | UT2 | (1) Director | |
| | Sorting plants | UT3 | (1) Director | |
| Local authorities | *Saint-Lô* Agglo | EPCI1 | (1) Mayor | 20/05/2019 |
| | *Coutances Mer et Bocage* | EPCI2 | (1) President of the local authorities assembly | 12/06/2019 |
| | *Baie du Cotentin* | EPCI3 | (1) Mayor | 06/06/2019 |
| | *Villedieu Intercom* | EPCI4 | (1) Mayor | 25/05/2019 |
| | *Côte Ouest Centre Manche* | EPCI5 | (1) Mayor | 06/06/2019 |
| | *Cavigny* town hall | CA1 | (1) Mayor | 17/06/2019 |
| Co-product recovery professionals | Customer company compost | EntrP1 | (1) Sales manager | 03/06/2019 |
| | Electricity customer company | EntrP2 | (1) Sales manager | 03/06/2019 |
| | Farmers using compost | AgrP1 | (3) Heads of holdings | 10/06/2019 |
| Government/State services | *Préfecture de la Manche* | SE1 | (1) Waste project manager | 13/06/2019 |
| | DREAL | SE2 | (1) Inspector | 05/06/2019 |
| | ARS | SE3 | (1) Former inspector | 13/06/2019 |
| | ADEME | SE4 | (1) Engineer | 13/06/2019 |
| Residents | Association « *Vivre au pays de Daye* » | Asso | (1) President | 17/06/2019 |

## Appendix 2: Measures of centralities in the material and energy exchange network

| | Degree | | | Closeness | | | Betweeness | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 |
| EPCI1 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EPCI2 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EPCI3 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EPCI4 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EPCI5 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EPCI6 | 15 | 9 | 0 | 27 | 23 | 0 | 0 | 0 | 0 |
| EPCI7 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| EPCI8 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| EPCI9 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| EPCI10 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| CA2 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| CA3 | 15 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 |
| CNA1 | 2 | 2 | 0 | 40 | 30 | 0 | 0 | 0 | 0 |
| CNA2 | 2 | 2 | 0 | 40 | 30 | 0 | 0 | 0 | 0 |
| CNA3 | 2 | 2 | 0 | 40 | 30 | 0 | 0 | 0 | 0 |
| CNA4 | 0 | 2 | 0 | 0 | 30 | 0 | 0 | 0 | 0 |
| PFE | 20 | 15 | 10 | 22 | 17 | 12 | 39 | 32 | 6,5 |
| UT1 | 17 | 11 | 10 | 25 | 21 | 12 | 12 | 7,33 | 6,5 |
| UT2 | 20 | 15 | 10 | 22 | 17 | 12 | 45 | 35,83 | 9,5 |

(*Continued*)

Continued.

| | Degree | | | Closeness | | | Betweeness | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 |
| UT3 | 15 | 9 | 8 | 27 | 23 | 14 | 0 | 0 | 0 |
| EntrP1 | 4 | 4 | 4 | 38 | 28 | 18 | 1,5 | 1,5 | 1,5 |
| AgrP1 | 2 | 2 | 2 | 41 | 31 | 21 | 0 | 0 | 0 |
| EntrP2 | 2 | 2 | 2 | 41 | 31 | 21 | 0 | 0 | 0 |

## *Appendix 3: Measures of centralities in the network of communication relationships.*

| | Degree | | | Closeness | | | Betweeness | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 | 2010 | 2015 | 2019 |
| EPCI1 | 15 | 9 | 8 | 26 | 20 | 19 | 0 | 0 | 0 |
| EPCI2 | 15 | 9 | 8 | 26 | 20 | 19 | 0 | 0 | 0 |
| EPCI3 | 15 | 9 | 8 | 26 | 20 | 19 | 0 | 0 | 0 |
| EPCI4 | 15 | 9 | 8 | 26 | 20 | 19 | 0 | 0 | 0 |
| EPCI5 | 15 | 9 | 8 | 26 | 20 | 19 | 0 | 0 | 0 |
| EPCI6 | 15 | 9 | 0 | 26 | 20 | 0 | 0 | 0 | 0 |
| EPCI7 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| EPCI8 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| EPCI9 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| EPCI10 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| CA1 | 19 | 13 | 12 | 21 | 15 | 14 | 18 | 9,2 | 7,7 |
| CA2 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| CA3 | 15 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 |
| BE-SMPF | 19 | 13 | 12 | 21 | 15 | 14 | 18 | 9,2 | 7,7 |
| PFE | 19 | 13 | 12 | 21 | 15 | 14 | 18 | 9,2 | 7,7 |
| UT1 | 17 | 11 | 10 | 23 | 17 | 16 | 7,2 | 3,6 | 3 |
| SE1 | 8 | 8 | 8 | 32 | 20 | 18 | 7,5 | 5,1 | 4,7 |
| SE2 | 7 | 7 | 7 | 33 | 21 | 19 | 4,9 | 3,1 | 2,8 |
| SE3 | 7 | 7 | 7 | 33 | 21 | 19 | 4,9 | 3,1 | 2,8 |
| SE4 | 3 | 3 | 3 | 49 | 21 | 28 | 0 | 0 | 0 |
| Asso | 7 | 7 | 7 | 33 | 31 | 19 | 0,4 | 0,4 | 0,4 |