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Overcoming the challenges of securing secondary resources in circular economy projects: The case of anaerobic digestion

Thèse de doctorat de l'Institut Polytechnique de Paris
préparée à l'École Polytechnique

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Thèse présentée et soutenue à Palaiseau, le 16 septembre 2024, par

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Titre : Surmonter les défis de la sécurisation des ressources secondaires dans les projets d'économie circulaire : Le cas de la méthanisation

Mots clés : économie circulaire ; ressources secondaires ; gouvernance collaborative ; territoire ; arrangements de marché ; méthanisation

Résumé : Les défis liés à la sécurisation des ressources secondaires représentent une difficulté majeure pour la viabilité économique et la faisabilité opérationnelle des modèles d'économie circulaire, compte tenu de leurs caractéristiques spécifiques telles que la variabilité de qualité et de quantité, ainsi que la dispersion locale des gisements détenus par différents acteurs. Cette thèse s'interroge sur l'organisation des acteurs pour faire face à ce problème empirique de sécurisation des ressources secondaires, très peu étudié.

Pour répondre à cette question, notre recherche menée se concentre sur le cas de la méthanisation. Ce cas a été choisi en raison de son intégration des principes de l'économie circulaire, de la concurrence et des complexités réglementaires entourant l'utilisation des ressources biologiques, ainsi que des processus multi-acteurs socialement complexes impliqués dans la mise en œuvre de ce type de projet. La méthodologie est compréhensive s'appuyant sur 70 entretiens semi-directifs, de l'observation et des données secondaires. Nous avons retenu une étude longitudinale du développement de quatre projets de méthanisation. Nous avons développé un cadre analytique articulant trois perspectives théoriques portant sur la gouvernance, le territoire et l'émergence de marché. Il permet de mieux comprendre les dynamiques en jeu dans la mise en œuvre d'initiatives d'économie circulaire et la sécurisation des ressources secondaires.

Nous mettons en avant plusieurs résultats. Premièrement, nous identifions un processus en trois phases pour sécuriser les ressources secondaires, et soulignons les approches stratégiques adoptées par les parties prenantes pour assurer la viabilité des projets de méthanisation. Deuxièmement, nous montrons comment, en vue de la sécurisation des ressources secondaires, les parties prenantes développent des outils et des modalités d'échange pour définir les prix des ressources et sécuriser les approvisionnements, alors que les marchés pour ces ressources n'existent pas. Troisièmement, nous soulignons des proximités territoriales dans les projets circulaires, en discutant différents rôles des acteurs publics qui les favorisent. Enfin, nous analysons les structures de gouvernance des projets de méthanisation, et différencions des modèles centrés sur l'entreprise et des approches collaboratives impliquant les fournisseurs de ressources.

Cette thèse contribue à une meilleure compréhension des défis des projets d'économie circulaire en apportant une vision stratégique du processus de sécurisation des ressources secondaires. Elle montre aussi comment l'articulation des différentes perspectives théoriques constitue un cadre théorique éclairant pour ces projets.

To Ziad and Faten
To Marianne, Abdallah and Racha

The circles of Colleagues, Friends and Family

These past three years have been a period of immense personal growth and intellectual discovery. I am incredibly fortunate to have had the opportunity to pursue a PhD. It is a unique learning process in one's life. A privilege that has allowed me to indulge my curiosity, ask a lot of questions, research, wander, be amazed and surprised, and delve into the depths of knowledge. Mostly, it allowed me to get lost in my reading, thoughts and reflections.

While the journey of a thesis may seem solitary (and it is most of the time), I must emphasize that the culmination of this work is due to my fortunate circumstances of being surrounded by an incredibly supportive circle of friends and family. I will always hold deep gratitude towards those who have supported and accompanied me throughout these years. I am convinced that, in Life, very few succeed solely on their own. Indeed, behind every great PhD student stand colleagues, friends, and family.

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The Circle of Family

I have been fortunate to receive unwavering support and love from my family throughout this thesis, even during moments when I have been challenging to deal with. I am eternally grateful to my extensive family circle of uncles, aunts, cousins, and relatives who never faltered in their support.

Furthermore, beyond their unconditional support during this journey, it is my parents, Ziad and Faten, whom I owe my academic and professional trajectory to. I could never thank them enough for the education and opportunities they allowed me to access.

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Although I dislike categorizing people and, even more so, ranking them, there was no frivolous choice in the lineup, as friends are not more important than family; colleagues are no less indispensable for support than fellow students. It is clear that the boundaries of these circles are quite flexible, and I am grateful for the colleagues who have become friends and for the friends who have become family throughout these three years.

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Preamble

Before delving into this thesis, it may be useful to shed some light on the intellectual journey that led me to this manuscript.

Belonging to a generation that grew up amidst the alarming realities of climate change portrayed through various media channels¹, I became acutely aware of the promises, both fulfilled and very often unmet, made by public and private entities to combat its consequences. Consequently, echoing Bruno Latour's poignant inquiry, 'One cannot help but wonder about the effect on our mental state of the daily news regarding the state of the planet. How can one not feel internally destroyed by the anxiety of not knowing how to respond?' (Latour, 2017, pp. 15–16), I assert that I cannot help but feel utterly devastated and anxious.

I decided to pursue a degree in environmental engineering with the hopes of bringing about the changes I wished for in the future. It was then, in a small classroom at the Ecole Supérieure des Ingénieurs de Beyrouth, in 2017, that I first encountered the concept of Circular Economy. I was fascinated by the concept presented as a solution to current environmental challenges. Upon completing my degree, I decided to pursue studies in environmental management, to learn what organizational solutions are discussed by world's leading economies. I enrolled in a master's program in prestigious institutions - Ecole des Mines, in France and Tsinghua University in China - who were considered pioneers in environmental themes. However, throughout the courses and while researching and reading, I quickly noticed a lack of practical implementation of this concept and started to wonder why.

I immediately knew I wanted to stay in France and delve deeper into this problem. I soon realized that I wanted to contribute to the continuum of research focusing on the concrete implementation of Circular Economy Business Models, which is still significantly under-discussed in the literature. Ultimately, my interest lies in modestly contributing to determining the organizational modes and business models that genuinely and effectively facilitate a circular economy. Therefore, the proposition to undertake a thesis in management at the

¹ The media have devoted three times more time to the environment in television news since the end of the 1990s https://larevuedesmedias.ina.fr/environnement-jt-information-television-energie-climat-pollution-biodiversite#:~:text=La%20progression%20du%20temps%20de,cours%20des%20deux%20derni%C3%A8res%20ann%C3%A9es.https://reportersdespoirs.org/wp-content/uploads/2020/07/Etude_Climat_ReportersdEspoirs_07072020.pdfhttps://www.cairn.info/revue-reseaux-2009-5-page-157.htm

Preamble

Management Research Center of Polytechnique on this subject aligned well with my aspirations.

Yet, there was something frightening about it: I was well aware that I got very minimal exposure to management and organizational theories. Paradoxically, this realization fueled my determination. Indeed, it has been a long journey transitioning from the scientific mindset of a rigid engineer to grappling with social and managerial sciences. As I engaged further in my Ph.D., I swiftly recognized the invaluable insights gleaned from direct interactions with individuals. I became convinced that actually talking to people could reveal insights that numbers could not. Moreover, what intrigued me most was the stark contrast between the “predictability” of hard sciences – where, to simplify, $1+1$ will always equal 2, regardless of the methodology to resolve the issue - and the “multifaceted” nature of management sciences, where a problem can be approached from various angles and theories, yielding diverse and compelling outcomes, depending on the chosen perspective. I am very aware that viewing or approaching the research problem I tackle in this thesis from other angles could lead to other equally interesting results.

Also, I simply strongly believe that thinking circularly could lead to many creative circular solutions and open doors to innovative collaborations that one might not have considered. The metaphor of the circle triggers creative thinking, and provides a popular and powerful discourse (Fitch-Roy et al., 2019). Unfortunately in contexts (other than theories or political discourse), creating these loops is not so evident. Indeed, a circle may seem simple to draw. So, we naively assume that establishing a circular economy is similarly straightforward. However, I came to realize that several challenges arise. What seemed to just be a matter of a perfect circle soon became a complex web of intertwined drawings of multiple circles and curved lines. Transforming an economy is no small feat. An economy cannot be assembled and disassembled like pieces of LEGO®. And let's say it outright: any response to the question of how to transform our economy into a circular one will always be somewhat disappointing. The responses provided in this thesis are imperfect and incomplete. However, they are based on the data I had access to, with the aim to build upon previous work and collectively address this challenge. The important thing is that we have tools at our disposal, that we initiate the right discussions and engage in the most pertinent debates.

Preamble

Ultimately, this manuscript is the result of numerous crafting iterations. Starting with a blank canvas, erasing, redrawing, and remolding it to create a document that is appreciable enough (at least for me). This has been an opportunity for me to experience the creative process an artist undergoes, as well as the fears - of the blank canvas, of the scrutiny of others - and the final relief once the piece is finished, as well as the argumentative process of defending a creation of your own. Yet upon completing this manuscript I cannot but resonate with the words of Isaac Newton. Indeed, during these three years *'I have been like a child playing on the seashore, diverting myself now and then by finding a smoother pebble or prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.'*

List of Acronyms

AD	Anaerobic Digestion
ADEME	Agence de la transition écologique (Agency for Ecological Transition)
AFNOR	Association Française de Normalisation (French Standardization Association)
ANRT	Association Nationale de la Recherche et de la Technologie (National Association for Research and Technology)
ATEE	Association Technique Énergie Environnement (Technical Association for Energy and Environment)
CBM	Circular Business Model
CE	Circular Economy
CIFRE	Convention Industrielle de Formation par la Recherche (Industrial Training Agreements for Research)
CIVE	Culture Intermédiaire à Vocation Énergétique (Intermediate crops for energy recovery)
CNG	Compressed Natural Gas
CNRS	Centre National de la Recherche Scientifique (National Center for Scientific Research)
CRE	Commission de Régulation de l'Énergie (Energy Regulation Commission)
CSF	Comité Stratégique de Filière (Sectoral Strategic Committee)
CTBM	Comité Technique national du Biogaz et de la Méthanisation (National Technical Committee for Biogas and Anaerobic digestion)
EBA	European Biogas Association
EMAA	Energie Méthanisation Autonomie Azote (Energy Anaerobic digestion Nitrogen Autonomy)
EU	European Union
GIS	Geographic Information System

List of Acronyms

ICPE	Installation Classée pour la Protection de l'Environnement (Classified Installation for Environmental Protection)
IE	Industrial Ecology
IEA	International Energy Agency
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
LTECV	Loi de Transition Énergétique pour la Croissance Verte (Energy Transition Law for Green Growth)
NGV	Natural Gas Vehicle
OECD	Organisation for Economic Co-operation and Development
OFATE	Office Franco-Allemand pour la Transition Énergétique (Franco-German Office for the Energy Transition)
PPE	Programmation Pluriannuelle de l'Énergie (Multiannual Energy Programming)
RED 2	Renewable Energy Directive II
SAS	Société par Actions Simplifiée (Simplified Joint-Stock Company)
SNBC	Stratégie Nationale Bas-Carbone (National Low-Carbon Strategy)
SPAN	Sous-produits animaux (Animal By-Products)
WEEE	Waste Electrical and Electronic Equipment
WWTP	Waste Water Treatment Plant

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Chapter 1 - Introduction

“Earth provides enough to satisfy every man’s need but not enough for every man’s greed.”

– *Jeremy Rifkin, Economist*

1. The circular economy, a potential solution to the problem of finite resources

1.1 A finite natural resources system under pressure

Over the past century, exponential growth (Parrique, 2022) has led to the consumption of ever more resources and energy (Lieder & Rashid, 2016). Indeed, 101.4 billion tons of raw material were extracted in 2021, a 3.5-fold increase compared with 1972 (Circle Economy, 2023). Furthermore, the energy usage reached 13.1 billion tons of oil equivalent in 2019 (Schwab, 2019). This growth applies pressure on global natural resources while leading to a critical situation of waste accumulation, disregarding their end of life (Ellen MacArthur Foundation, 2013).

Several authors qualify by "linear model" the dominant model supporting this growth in which "take, make, use, dispose" are the golden rules (Salvador et al., 2020). They emphasize that economic activities have consistently assumed an abundance of natural resources, envisioning them as boundless (Meadows et al., 1972). This misleading representation of the physical world was inherited from the initial industrial revolution. It is a core flaw in most economic thinking, succinctly expressed by Jean-Baptiste Say in 1803 in his *Treatise on Political Economy*, where he asserted that "*natural resources are inexhaustible, as we obtain them freely. Since they cannot be multiplied or depleted, they lie beyond the realm of economics.*"

Adding to this critique, Latour (2017) challenges the realism of modernization projects that have, for two centuries, overlooked the reactions of the Earth to human actions. He questions the acceptability of economic theories whose objectives fail to incorporate the scarcity of resources, even though predicting depletion was supposed to be their goal: *“How can one consider realistic a modernization project that has forgotten for two centuries to anticipate the reactions of the Earth to human actions? How can we accept that the objectives of economic theories are incapable of integrating the scarcity of resources, which they were supposed to predict exhaustion of?”* (Latour, 2017, p.86)

Thus, while current consumption and production patterns raise environmental concerns, the circular economy appears to be a strategic alternative to the depletion of natural resources, as it fulfills the dual promise of reducing stress on natural resources, and mobilizing other biological and technical nutrients (Ellen MacArthur Foundation, 2013; Lewandowski, 2016) of value that were once considered waste. These "nutrients" come from technical flows, such as recycled, reused, refurbished, remanufactured materials, and/or biological flows, such as organic waste, agricultural residue, food waste, etc. Throughout the remainder of this study, we will refer to these nutrients as "secondary resources."

Indeed, according to Kirzherr et al. (2017), the circular economy is presented as *“an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers.”*

According to the Ellen MacArthur Foundation, implementation of the circular economy is projected to enhance material productivity and diminish resource demand (Ellen MacArthur Foundation, 2013). As depicted in the Foundation’s model (Figure 1), circular practices are expected to affect the extraction of virgin materials, as they prioritize the utilization of reused, recycled, and refurbished resources (upper graph). The Foundation predicts that by replacing virgin materials with those from circular activities, there will be a reduction in landfill waste and total material stock (lower graph). It is worth noting that the model assumes that retaining

materials and resources within the system is more economically beneficial than extracting virgin materials, thus favoring the circular setup.

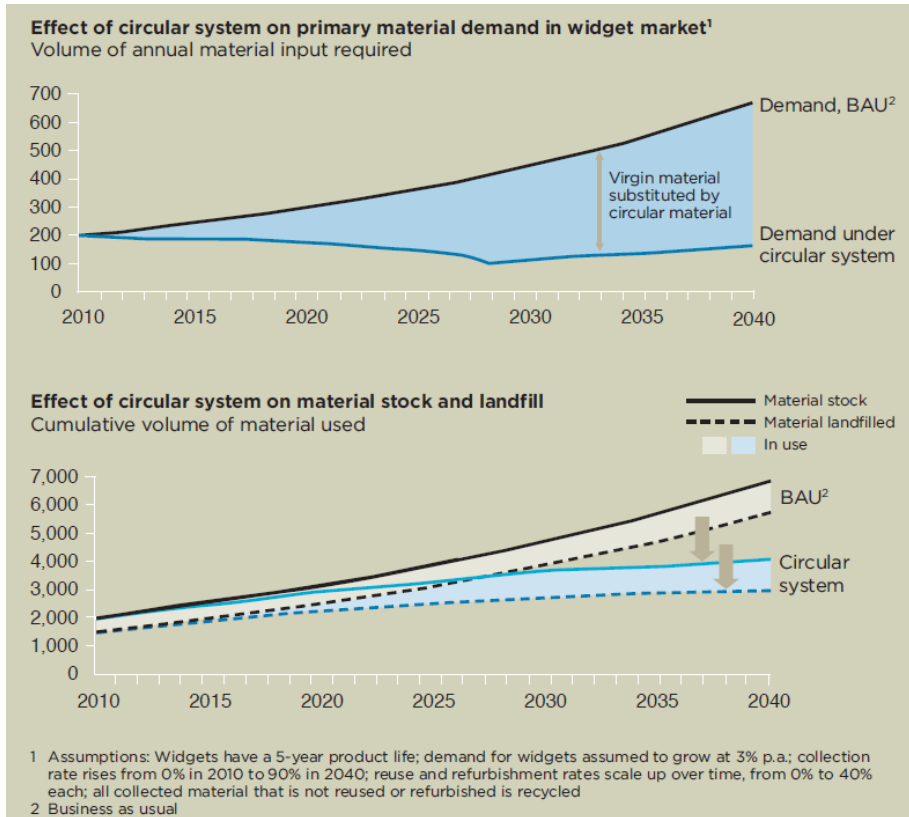


Figure 1 Estimation of resource consumption and landfill accumulation in Business as Usual and Circular system - Source: EMF, 2013

As of 2015, the concept of the circular economy has attracted increasing attention from politicians, industrialists, and academics (Figure 2). To delve into the reasons behind such budding enthusiasm for this concept, we will first briefly give a historical perspective on the evolutionary trajectory of the circular economy.

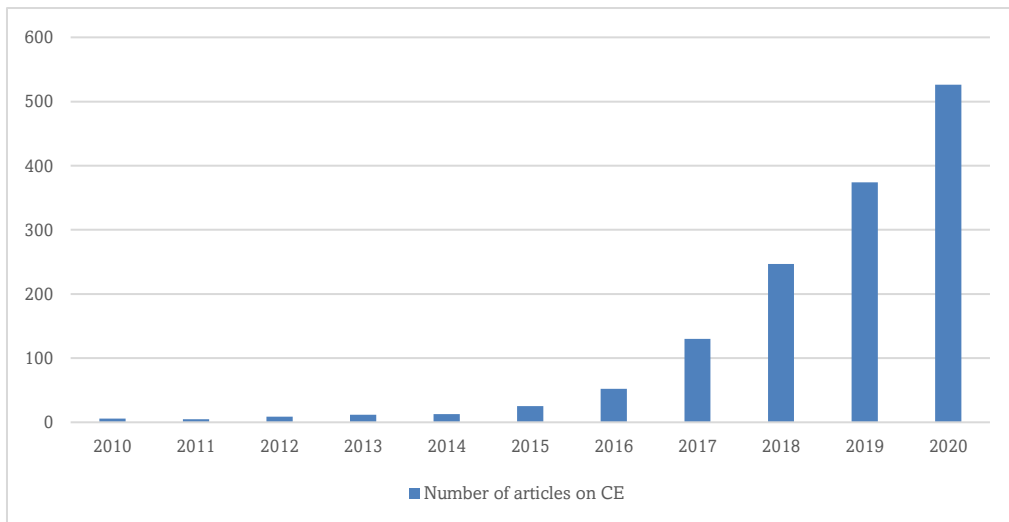


Figure 2 Annual scientific publications on the circular economy - Source: Alhawari et al.2021

1.2 A brief history of the circular economy concept leading to a collective utopia

Despite the dominant linear model in today's economy, the promotion and practice of circular activities dates back several decades, although it may be observed as early as the 19th century (Barles, 2005). The embryonic idea of circularity is believed to have first been brought up by Kenneth Boulding in 1966. Boulding defined the “spaceman” economy, where he compared Earth to a single spaceship with limited resources. It was characterized by less production, less consumption, maintenance of stock and any technological change that could facilitate maintenance (Boulding, 1966). Following this initial concept, the subsequent years witnessed a proliferation of different interpretations and approaches to the paradigm of circularity and the issue of waste management. However, up until 1985, waste was still seen as a burden. The debates on the management of waste and resources focused on solutions to reduce the damage created downstream of economic activities, for example by removing the waste and contamination of a polluted river (Reike et al., 2018).

Pearce and Turner were the first to coin the term “circular economy” in their book *Economics of natural resources and the environment*, published in 1990. It presented a new way of thinking aiming to reduce not only the downstream impacts of industrial activities but also the upstream impacts, by making industrial processes more efficient. Such initiatives are related, for instance, to the optimization of packaging, eco-design, or revaluation of by-products through other processes. Waste is now perceived as a “positive force” to be exploited so as to

create value (Blomsma & Brennan, 2017). These approaches remained essentially confined in academic, engineering, and territorial thinking. Nevertheless, the interest in industrial and territorial ecology—a global approach to the industrial system proposing an application of the natural ecosystem model to exchange material and energy flows between industries in the same territory—remained prominent during this period (Beulque, 2019). Industrial ecology is a concept that emerged in the late 20th century, pioneered by Frosch and Gallopoulos (1989), who advocated for an integrated and environmentally sustainable model for industrial activities. Jelinski et al. (1992) further expanded on this, defining it as a new approach to the industrial design of products and processes. Contributing to the discussion, Erkman (1997) defined industrial ecology as the study of material and energy flows within industrial ecosystems. Ayres (2002) has since described it as a field that examines the interactions between industrial systems and the environment. A crucial aspect is the notion of industrial symbiosis, whereby waste from one industry is repurposed as a valuable input for another, resulting in interconnected networks that strive to optimize resource utilization and reduce environmental impact. Industrial ecology is often seen as a precursor to circular economy research, providing a foundation for the analysis of industrial systems and operational optimization (Ellen MacArthur Foundation, 2013; Geisendorf & Pietrulla, 2018). However, distinguishing industrial ecology (IE) from the circular economy (CE) can be challenging, as noted by Bourg and Erkman (2003). Several studies have addressed this issue, highlighting the similarities between IE and CE, such as promoting resource efficiency and adopting a system's thinking approach (Blomsma & Brennan, 2017; Geisendorf & Pietrulla, 2018; Reike et al., 2018). Despite these similarities, there are distinctions between CE and IE. CE focuses on creating a restorative and regenerative economic system, ensuring that products, components, and materials maintain their highest utility and value at all times (Bocken et al., 2016; Geissdoerfer et al., 2017). On the other hand, IE primarily concentrates on analyzing industrial systems and optimizing operations (Geisendorf & Pietrulla, 2018; Saidani et al., 2020). The evolution of the two concepts also differs. IE has been extensively theorized over the last two decades by academics and engineers (Beulque, 2018), while CE is just starting to reach a consensual conceptualization (Kirchherr et al., 2023; Saidani et al., 2020).

There has been considerable scholarly interest in understanding the reasons behind the increasing prevalence of the circular economy. It is argued that a crucial catalyst in the rise of references to the circular economy, which surpassed IE around the year 2014 (Alhawari et al., 2021; Kirchherr et al., 2017; Saidani et al., 2020), was the change in the communication

targets to which the discourse is addressed (Beulque, 2019). Indeed, CE has made significant progress in institutionalization, benefiting from legal frameworks and policies (Saidani et al., 2020). The adoption of IE by businesses appears modest, and mainly demonstrated by the approach of eco-industrial parks. A case in point is that the new promoters of the circular economy are targeting companies and government actors as a priority, a shift that requires a simplification of the semantics used to make it more unifying. The metaphorical and visual representation of cycles (Figure 3) provided a framework to comprehend how resources and energy can cycle in systems (Johansson & Henriksson, 2020). This in turn fueled the conceptualization of the circular economy.

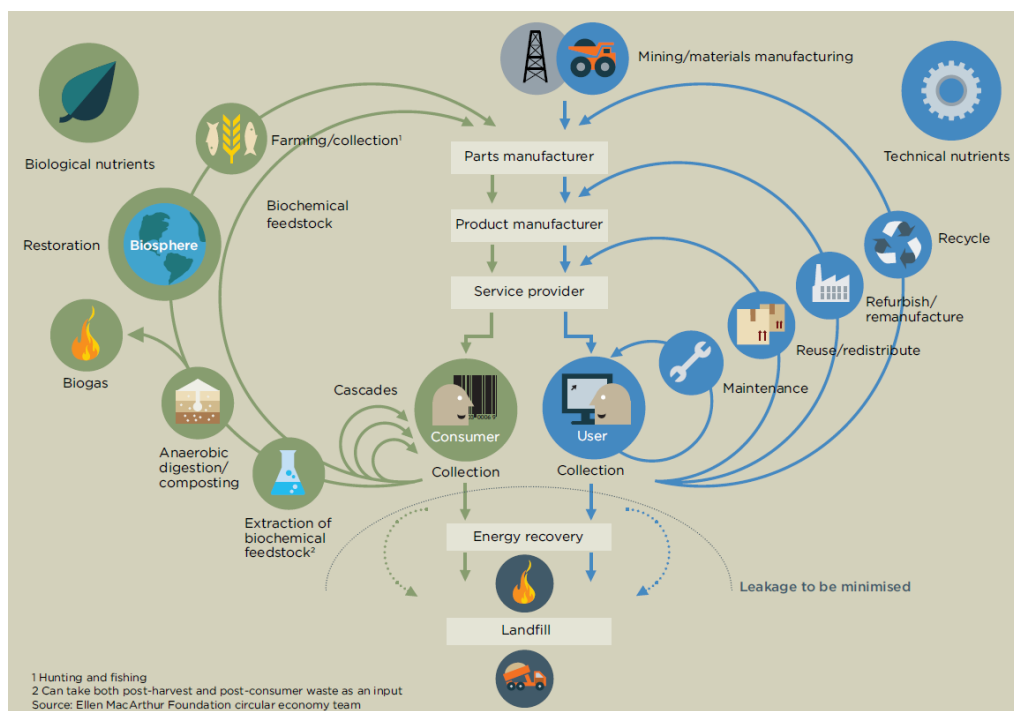


Figure 3 The butterfly diagram - Source: EMF, 2013

Simultaneously, the European Union's action plan, the Ellen MacArthur Foundation's initiatives, and China's promotion law on the circular economy all played pivotal roles in giving momentum to this concept. Thus, as highlighted by Nicolas Buclet (2015), the circular economy is a concept first carried by political actors. It is also mobilized by companies, consulting firms and so-called civil society structures.

Furthermore, the strategies discussed in the discourses aim to extend the life of resources and materials, to give them added value and specifically to reduce the destruction and value loss. The novelty brought by a circular economy mindset is the association of flow analysis with the value dimension. For instance, economically, waste is no longer considered a cost in the

sense that to get rid of waste, a fee must be paid. Through the prism of the circular economy, waste is perceived as a cycle of positive value to be retained in the economic system (Blomsma & Brennan, 2017). In addition, the circular economy tackles issues arising from the fact that economic activities operate in a context of finite natural resources.

In conclusion, the literature on the circular economy emphasizes the finite aspect of natural resources and asserts that waste is valuable. Stakeholders' momentum acted as a catalyst to the diffusion of the concept. Following the initiatives led by a group of thought leaders in the public sector and business world, the circular economy became an object of public policy and management (Beulque et al., 2016). Currently, circular economy discourses hold the promise of an applied model of sustainable development that would be capable of reconciling economic growth, innovation, environmental preservation, and job creation (European Commission. et al., 2014; Ghisellini et al., 2016). These promises have triggered a true dynamic creating a “contemporary genuine rational utopia” around the circular economy (Ntsondé & Aggeri, 2022). Many companies have therefore started to experiment and implement new circular activities (Beulque, 2019; Bocken et al., 2018).

Circular solutions appear as a way for companies to increase resource security and reduce supply chain complexity. In fact, the recirculation of resources and energy, the minimization of demand on resources, and the recovery of value from waste, is considered to have numerous advantages (Ormazabal et al., 2018). It avoids exhausting a finite environmental stock of materials (Tibbs, 2006). It guarantees an infinite supply by relying on biological and technical 'nutrients' to be continuously re-used at the same quality (Homrich et al., 2018). The objective behind this recirculation is to reduce dependence on sourcing new materials and to be independent of nature's capacity (Tibbs, 2006). Thus, authors such as Bocken et al. (2016) explain how circular economy activities could reduce the pressure on natural resources. First, by “slowing loops”, the period of utilization of products is extended and intensified. This strategy is achieved through activities such as repairing, maintenance and remanufacturing. It results in a slowdown of the resource extraction flow and a longer utilization of these resources. Second by “closing loops”, resources are recycled and reinjected into the system to create a circular flow of resources. This strategy is achieved through recycling activities or industrial symbiosis. Also, by “narrowing resource flows”, fewer resources per product are mobilized. This strategy is achieved through eco-design activities.

The most frequently cited examples are companies such as Miele, Rolex, Patagonia, Interface, Xerox, and Philips. These companies have successfully integrated various circular offerings, such as selling durable products with repair services, reselling used and refurbished items, and providing access or performance-based solutions. It is noteworthy that these examples often pertain to premium and luxury brands, niche players, or companies that adopt such circular activities to enhance their reputation and ensure long-term competitiveness while still coexisting with linear models oriented towards growth, like H&M's clothing return initiatives or automobile manufacturers' car-sharing initiatives (Hofmann, 2019). Thus, despite widespread support for the circular economy concept, its actual implementation has been limited thus far (Kirchherr et al., 2018).

1.3 Nonetheless, a timid successful application

Studies have assessed that the current level of circularity in the world remains as low as 7% (Circle Economy, 2023). More precisely, the global circularity rate has witnessed a declining trend, with figures decreasing from 9.1% in 2018 to 8.6% in 2020, and further dropping to 7.2% in 2023. This signifies that the proportion of materials re-entering the global economy as secondary materials after their useful life currently stands at 7.2% of all material inputs into the economy. Furthermore, at the European Union level, 60% of materials are not subject to any recycling, composting or reuse at the end of their life, and follow this linear pattern (Ellen MacArthur Foundation, 2013). Also, 65% of WEEE escapes the treatment sector even though they are secondary resources with high potential (Micheaux, 2017).

Thus, one may ask if the proclaimed advantages of the circular economy are evident, why is it that the successful implementation of circular business models is still limited?

Circular business models are a way of operationalizing the principles of circular economy in organizations. Geissdoerfer et al., (2018) define circular business models as sustainable business models that aim to contribute to the circular economy. They argue that these models strive to create additional monetary and non-monetary value by actively managing a circular value chain and aligning incentives among stakeholders.

However, the ability of these circular business models to generate and capture economic value is subject to contradictory conclusions in the literature (Corvellec et al., 2021; Manninen et al., 2018). Beulque (2019) highlights examples of the recycling sector with negative margins, surcharge and structural deficits in competitiveness (Nouvelle, 2016). Many authors have taken an interest in this matter by highlighting barriers that hinder the implementation of

circular business models. A wide range of challenges has been reported that may be social and cultural, technical and operational, economic and financial, or institutional and regulatory, for example (de Jesus & Mendonça, 2018; Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Oghazi & Mostaghel, 2018). Despite some insights on the barriers, it appears that the recommendations and prescriptive efforts in place may not suffice to overcome them, and further knowledge is required to successfully operationalize the circular economy (Bocken & Geradts, 2022). Some scholars have emphasized a lack of company engagement, which would explain a timid dynamic (Kirchherr et al., 2018). Others highlight extremely contrasting situations and find the identification of opportunities for economically viable circular activities to be a complex and uncertain exploration process, involving numerous iterations (Linder & Williander, 2017). Another less discussed challenge on which the viability of circular activities depends is securing secondary resources. In the following section, we will provide a detailed presentation of this challenge.

2. The challenges of securing secondary resources

In the following section, we focus on the issue of securing secondary resources, which is a condition for economic viability and operational feasibility of the circular economy but raises considerable challenges. This issue has been little studied. In fact, in the literature on the circular economy, some authors advocate that it is a solution to the problems of the finiteness of natural resources and would offer independence from these natural resources (Bocken et al., 2016). However, less attention is given to the inherent challenges that the circular business model faces concerning the dependence on secondary resources.

We focus our research work on this issue. First, the literature on the economic challenges (2.1) and actors' interdependencies (2.2) resulting from secondary resources is extensively discussed. Next comes a presentation of approaches found in the literature discussing how actors secure secondary resources (2.3). The limited literature on possible approaches to overcome the challenges entailed in securing secondary resources further justifies our research focus.

2.1 The challenges of economic viability

Secondary resources can come from recycling, reusing, refurbishing, or remanufacturing processes, and are called either “technical” or “biological”, which covers such resources as organic waste, agricultural residue, and food waste (Ellen MacArthur Foundation, 2013). One of the conditions for setting up circular economy models is to ensure the continuous supply of secondary biological and technical flows with the same quality and quantity (Homrich et al., 2018).

Authors argue that secondary resources condition the economic viability and operational feasibility of circular activity. For instance, (Gupta & Palsule-Desai, 2011) emphasizes the challenges related to delivery timing, the impact of quality and quantity, the pricing strategy of products, the investment required to get better information on secondary flows, and the level of secondary material to incorporate in the final design. More specifically, (Linder & Williander, 2017) explain that the unpredictable quantity and quality of secondary flows make it hard for business developers to establish their business plan accurately, resulting in shortcomings in their revenue model. Other authors even claim that *“It is sometimes difficult to see why anyone would be interested in using waste as a resource in a circular economy*

instead of the well-functioning value chains with primary resources, especially because waste-based resources typically have a lower quality than primary resources” (Johansson & Krook, 2021).

This issue of securing secondary resources for circular activities has been highlighted by scholars as a major challenge impeding implementation of the circular economy. Korhonen et al., (2018) confirm that the circular economy faces “*challenges in the governance and management of interorganizational and intersectoral material and energy flows*”(Korhonen et al., 2018, p. 45). Corvellec et al. (2021) acknowledge the complexity of manipulating these resources in circular activities.

More specifically, scholars describe a complex secondary resources landscape characterized by volatile prices (Hart et al., 2019; Kanda et al., 2021; Kirchherr et al., 2018; Oghazi & Mostaghel, 2018), unpredictable availability (Oghazi & Mostaghel, 2018; Paes et al., 2019), uncertain quantity and unpredictable quality (Bocken et al., 2018; Frei et al., 2016; Govindan et al., 2015; Gupta & Palsule-Desai, 2011; Hopkinson et al., 2018; Linder & Williander, 2017; Vermunt et al., 2019; Werning & Spinler, 2020; Zhou et al., 2017), unreliable timing, with a variety of insufficiencies: lack of adequate infrastructure (Aggeri et al., 2023; Tura et al., 2019; Werning & Spinler, 2020), of information sharing and visibility (Tura et al., 2019; Werning & Spinler, 2020), of citizen engagement (Govindan et al., 2015) and of skills, knowledge and technology to manipulate these resources (Oghazi & Mostaghel, 2018; Tukker, 2004). The table 1 below underlines challenges that have been specifically underscored in the case of the circular economy and differentiates authors having focused on technical secondary resources from those focused on biological ones.

Challenges	References on technical secondary resources	References on biological secondary resources
High prices for materials and marked volatility	Hart et al., 2019; Kirchherr et al., 2018; Oghazi & Mostaghel, 2018; Kok et al., 2013	Zils et al., 2017
High prices for skills and technology, insufficient knowledge for treating secondary resources	Oghazi & Mostaghel, 2018; Tukker, 2004	
Lack of availability according to the region	Oghazi & Mostaghel, 2018; Kok et al., 2013	Paes et al., 2019

Unreliable timing	Linder and Williander, 2017; Vermunt et al., 2019; Bocken et al., 2018; Govindan et al., 2015; Gupta & Palsule-Desai, 2011; Hopkinson et al., 2018	Paes et al., 2019; Cerca et al., 2022; Yue et al., 2014
Unpredictable quantity	Linder and Williander, 2017; Vermunt et al., 2019; Werning & Spinler, 2020; Zhou et al., 2017; Bocken et al., 2018; Govindan et al., 2015; Frei et al., 2016a; Gupta & Palsule-Desai, 2011; Hopkinson et al., 2018	Paes et al., 2019; Cerca et al., 2022; Zils et al., 2017
Uncertain and Unpredictable quality	Vermunt et al., 2019; Werning, 2020; Zhou et al., 2017; Garcés-Ayerbe et al., 2019; Bocken et al., 2018; Govindan et al. 2015; Frei et al., 2016a; Gupta & Palsule-Desai, 2011; Hopkinson et al., 2018	Paes et al., 2019; Cerca et al., 2022
Lack of infrastructure for collection and access	Werning & Spinler, 2020; Tura et al. 2019	
Cost of collection and treatment	Frei et al. 2016; Werning & Spinler, 2020	Paes et al., 2019; Cerca et al., 2022
Lack of information-sharing about status. Lack of forecasting capability and visibility	Werning & Spinler, 2020; Tura et al., 2019	
Citizens' willingness to return or sort	Govindan et al., 2015	

Table 1 Challenges impacting economic viability of an identified circular business model using secondary resources

Implementing circular activities thus necessitates overcoming the issue of securing secondary resources, which is a novel challenge for actors (Corvellec et al., 2021; Korhonen et al., 2018).

2.2 The challenges of actors' interdependence

In a linear economy, resources are made available at any time for businesses (Ghisellini et al., 2016; Tukker, 2015). The conventional linear economy puts into play several stakeholders in a competitive setting. This competitive configuration incites suppliers of resources to standardize them in terms of quality, price and timing (Porter, 1980). In a circular economy, this dynamic is somewhat different, as the suppliers of resources are not assumed to be

entirely in competition and cannot promise standardized quality and quantity (Micheaux, 2017; Beulque, 2019). Indeed, authors confirm circular economy needs shift from pure competition to coopetition (Kirchherr et al., 2018) Furthermore, according to Aggeri et al. (2023), identifying, securing, and manipulating secondary resources requires economic actors to develop specific knowledge, skills, infrastructure, and logistics.

Strong interdependency exists between suppliers of secondary resources and users. These interdependent dynamics do not exist as such in linear activities (Aggeri et al., 2023). First, in a circular economy, resource flows can be categorized into two distinct types: primary resource flows and secondary resource flows (Farooque et al., 2019a), contrary to traditional linear activities relying strictly on primary resources. Primary resource flows pertain to the forward movement of goods in linear supply chains. On the other hand, secondary resource flows encompass the various "re-" type flows of goods, materials, and energy, encompassing circular activities such as recycling, retention, reuse, repair, remanufacturing, refurbishing, and recovery.

Another differentiating element is the structure the resources are transitioning on. For a linear activity, the flow consists of a one-way structure (Ying & Li-jun, 2012) that is both linear and open (De Angelis et al., 2018), whereas for circular activities it is rather more complex: There is a linear structure where limited natural resources are used, as well as a combination of reverse chains to recover secondary resources from end consumers or any other stage of the supply chain to feed them back into the supply network for reuse, remanufacturing, recycling for other circular activities or proper disposal. These reverse supply chains can be closed when products are returned to their original manufacturer and for their original purpose, or open if an independent company takes over (Frei et al., 2016) from the same sector or outside of it (Farooque et al., 2019b). Therefore, a network of interconnected and intertwined chains develops, where the downstream chains of one company create the upstream supply of secondary resources for another. It is also argued that circular activities require novel collaborations across the downstream and upstream parts of the supply chains (Aarikka-Stenroos et al., 2022; Masi et al., 2017).

Authors highlight the practical difficulties for actors of interconnecting these streams (Zink & Geyer, 2017). Indeed, this interdependent dynamic is rather counterintuitive for economic actors. The dogma of economy is to put actors in competition (Porter, 1980). Collaborating within ecosystems and along circular supply chains raises issues like legalities around engagement (Straub et al., 2023). It also require sharing information transparently and engaging in relations that are based on trust amongst actors (Leising et al., 2018).

This shift in dynamics requires investigation on how to implement it. There is a need to highlight the specificities of these interdependencies and analyze the underlying mechanisms.

2.3 Limited literature on approaches to overcome the issue of securing secondary resources

Few authors have explored approaches aimed at alleviating challenges associated with the securing of secondary resources. This section aims to detail identified approaches for technical and biological secondary resources. Research on biological secondary resources is even scarcer. We present the specificities highlighted in the literature in dedicated sections for technical (2.3.1) and biological (2.3.2) secondary resources.

2.3.1 Approaches to secure technical secondary resources

Geyer et al. (2004) apply a managerial instrument called the “Supply Loop Framework” in two circular activities—recycling and reusing—in the steel industry. The framework is designed with a twofold objective. Primarily, it is geared towards discerning advantageous supply loops by appraising the environmental and economic consequences associated with different alternatives. Additionally, it endeavors to determine the optimal extent of secondary resource retrieval. This is accomplished by evaluating three factors that impose limitations on secondary resources during the phase of collection and reprocessing: limited availability, feasibility of reprocessing, and market demand. Authors also stress the acquisition of dependable data and high-quality market insights for enterprises actively investigating potential supply loops.

Another research project emphasized the capabilities and skills cultivated by "Ricoh," a renowned Japanese multinational specializing in printers, imaging, and original equipment manufacturing (OEM) for documents (Hopkinson et al., 2018). With a well-established history in product manufacturing, remanufacturing, and asset reuse, the study underscores the strategy adopted by Ricoh. The approach involves the company devising and enhancing its own channels for collecting secondary resources, a process that underwent evolution and refinement over a span of 35 years split into four distinct periods. The initial phase involves the establishment of effective reverse logistics mechanisms and the deployment of a comprehensive team of field engineers. During phase two, the focus shifts towards enhancing recovery and recycling facilities to achieve economies of scale and scope. This also includes the development of a material requirement planning strategy, which encompasses the implementation of the Comet Circle framework. phase three entails the adoption of asset-

tracking tools to enhance monitoring capabilities. The expansion and extension of the reverse network's capacity and reach, along with the establishment of network infrastructure for remote core treatment, are key components. The decision-making process involves deliberating whether to actively recover third-party markets or collaborate with intermediaries to attain advantages in terms of scale, scope, and density. The overarching aim is to broaden the reach of the reverse network to serve major markets across Europe. Furthermore, a pivotal aspect of phase three is rooted in a "value realization cascade" decision-making tool crafted to ascertain the optimal value achievable from the return of assets. The final phase is characterized by an advanced focus on real-time visibility, data intelligence, and holistic management integration across all loops of the Comet Circle. This phase also includes the strategic targeting of collection volumes in specific regions, elevating recovery rates from both customers and gray markets, and capitalizing on economies of scale, scope, and density. Furthermore, there is an increased emphasis on optimizing the outer loops of the Comet Circle framework.

Bressanelli et al. (2018) examined four cases involving circular practices (such as PSS, reconditioning, refurbishment, and eco-design) within the washing machine industry, encompassing diverse roles (retailers, spare part distributors, self-service laundries, manufacturers). Their research facilitated an exploration of how these companies tackled prevalent challenges concerning secondary resources. These challenges encompassed uncertainties in return flows, transportation and infrastructure deficiencies, dearth of suitable partners, coordination, and information-sharing gaps, as well as product traceability shortcomings. The mechanisms by which these companies addressed the challenges involved forging robust relationships with fellow actors along the supply chain. This is underscored by the recognition that complete vertical integration and sole control over production, distribution, and consumption processes are often constrained. Companies also embraced other strategies, including the implementation of Internet of Things (IoT) technologies for remote asset and product monitoring, the introduction of take-back incentives, and the adoption of access-based or servitization models.

The latter approach has also been confirmed as a way for companies to retain the ownership of secondary resources (De Angelis et al., 2018; Masi et al., 2017). In addition, Frei et al. (2016) argue that strategies including incentives for clients to return their product (such as replenishment of gas canisters) could improve the quality and quantity of the return flow.

After investigating the case of a French automotive company engaged in recycling and reusing activities, Beulque (2019) proposes adopting an approach that he labels as "industry engineering." He defines it as a collaborative effort aimed at generating common goods that facilitate the development of new economic activities and their organization within networks or value chains, and then within sectors involving an increasing number of actors at each level. At the core of this process, he highlights the importance of structuring access to reserves of secondary resources. This process unfolds in two stages: firstly, the establishment of standards to ensure quality; secondly, the directing of reserves toward value chains, networks, and sectors of appropriate quality, through activities such as local-level collection, aggregation and massification, and ultimately through the collective creation of outlets or uses for these secondary resources. The author emphasizes that this collaborative approach is an essential prerequisite for the development of robust economic models and their long-term sustainability.

Research by Micheaux (2017) aligns with these perspectives of collective action around the collection of secondary resources by highlighting the process of extended producer responsibility in France in the sector of waste from electrical and electronic equipment (WEEE). She points out that the procedure hinges on public authorities instituting a shared objective, progressing through two phases. Firstly, leaders are selected and then a group of actors emerges (or potentially multiple groups, such as eco-organizations for producers and the sector commission for stakeholders). Subsequently, these participants foster strong connections that bind them to rigorous partnerships. Notably, eco-organizations have facilitated substantial economies of scale by introducing collective logistical arrangements and orchestrating the setting up of sectors dedicated to the collection and treatment of secondary resources.

Other scholars suggest employing top-down approaches to tackle issues associated with secondary resources, more specifically their availability and prices (Genovese et al., 2017). These authors contend that entities such as central government departments, local authorities, and Chambers of Commerce can contribute by charting the trajectory of secondary resource movement. These entities have the potential to facilitate harmonious interactions by aligning demand with corresponding supply, thereby mirroring a fundamental industrial ecology approach tailored to specific geographic regions. This aligns with De Angelis' suggestion of fostering collaboration both within and beyond industrial confines, involving public entities in the development of standards for material composition and post-use handling. As an example, the authors discuss the case of the plastic industry, where the European Commission

committed to establish quality standards. Indeed, the European Commission highlighted in a white paper in 2015 the presence of fundamental obstacles to the adoption of secondary raw materials throughout Europe given the uncertainty surrounding material composition.

To conclude, the literature gives an understanding of secondary resource management. Studies suggest technical approaches to address the challenge of secondary resources. For instance, concepts like design for disassembly and the exclusion of toxic materials in initial designs have been put forth (De Angelis et al., 2018). Nonetheless, in scenarios where a production system involves numerous stakeholders, the complexity increases. In such instances, companies within the supply loop must convince the entities overseeing the primary supply chain to implement such modifications or adjust their procedures to accommodate the end-of-life products they retrieve and recycle (Geyer & Jackson, 2004).

Different strategies are described in diverse industrial contexts, from the steel industry (Geyer & Jackson, 2004) to printers and imaging (Hopkinson et al., 2018), washing machines (Bressanelli et al., 2019), automotive recycling (Beulque, 2019), and electronic waste (Micheaux, 2017). Some studies have described a gradually-evolving firm-centric perspective through in-house frameworks and instruments (Hopkinson et al., 2018) or IoT technologies to monitor the flow, and access-based models to retain ownership (Bressanelli et al., 2019). Very few studies analyze more collaborative approaches integrating other actors in the supply chain, identifying win-win opportunities in secondary resource exchanges (Bressanelli et al., 2019; Geyer & Jackson, 2004). More specifically, Beulque (2019) and Micheaux (2017) highlighted collective organization to orchestrate logistics, aggregate resources, and streamline processes to achieve greater efficiency. Finally, top-down approaches involving government and public entities have been discussed (Genovese et al., 2017; Micheaux, 2017). The diverse industrial contexts and multiple strategies showcased in these studies emphasize the importance of context-specific approaches to secondary resource optimization.

2.3.2 Approaches to secure biological secondary resources

The research area focused on integrating the principles of the circular economy into the management of biological secondary resources is a recently developing field (Paes et al., 2019). Nonetheless, a few studies have started to bridge the links between them.

Cerca et al., (2022) conduct a detailed study on two types of biological resources (aquatic and terrestrial): seaweed and grass in the context of multiple biorefinery technologies for added value. They emphasize that the availability and management of biological resources are

constrained. They develop a framework to overcome these constraints and increase the efficiency and effectiveness of resource management. They argue that enhanced planning using artificial intelligence and information-sharing mechanisms could improve planning processes for accessing resources, focusing on local and regional levels. They also suggest in their framework considering supplier engagement and motivation. Moving beyond mere financial incentives, the framework advocates for a comprehensive understanding of suppliers' motivations to participate in projects. It underscores the importance of recognizing non-monetary factors that drive supplier engagement. Moreover, the framework emphasizes the need to reassess and redesign incentives and compensatory structures, particularly in cases involving farmers as suppliers. This entails investing in shared ownership of infrastructure, including suppliers in planning and design stages, and fostering a sense of collective responsibility.

Gontard et al. (2018) dressed a detailed state of the art of the agriculture waste sector, valorized through biorefineries. They specifically investigated the case of anaerobic digestion as a solution for this type of secondary resource waste. They advocate for the cultivation of a cross-sectoral vision that bridges the domains of management sciences and agriculture sciences. This approach aims to cultivate innovative business synergies rooted in local contexts. This endeavor is supported by a holistic perspective that seeks to amplify the exchange of both materials and knowledge. In this context, they propose the utilization of established tools like material flow analysis adapted to territorial contexts. They introduce the notion of "territorial cyclifiers," individuals and entities that serve as pivotal connectors in the flow of materials. These connectors are nurtured through the establishment of collaborative platforms and other joint structures designed to foster stakeholder engagement. Furthermore, they stress the importance of a comprehensive examination of circular economy principles. They emphasize the significance of scrutinizing the cascading pathways of secondary resources before these resources are channeled into anaerobic digestion entities. This meticulous evaluation is predicated on the belief that by adopting a biorefinery configuration for anaerobic digestion, heightened value can be generated from these resources.

To conclude, the studies linking the circular economy to the issue of biological secondary resources is starting to gain attention in the academic field. However, the studies remain focused on potential valorization methods as well as the obstacles to implementing the associated technologies. Few authors have discussed the processes required to secure biological secondary resources in a circular activity.

Nonetheless, it is important to note that other studies related to secondary biological resources, not specifically tied to the circular economy literature, have advocated for a more comprehensive approach to address the challenges posed by these resources. For example, Iakovou et al., (2010) highlighted that challenges related to biological resources such as sourcing, location, and quality have predominantly been approached through technological means (as reiterated by Cerca et al. 2022). So far, studies have endeavored to address concerns by utilizing GIS tools and other methodologies to map potential and allocate biomasses (as seen in the work by (Ekşioğlu et al., 2009). These studies have also proposed strategies and approaches that encompass policy and government involvement, the establishment of standards for resources, the internalization of externalities, economic incentives, price supports, and performance evaluation (as demonstrated by (Pan et al., 2015). Nevertheless, (Iakovou et al., 2010) have identified the need to shift the focus of these approaches towards a more systemic and interconnected perspective in addressing the management of resources. This entails a network approach that incorporates environmental, economic, and social dimensions within the analysis.

Table 2 below summarizes the approaches identified to address the challenges of secondary resources.

Table 2 Approaches identified in the literature to overcome the challenges of securing secondary resources

Approaches	Description of approaches to secure secondary resources	Potential challenge addressed (Table 1)	Authors (Year)	Type of secondary resources – Industry/Circular Activity
Firm-centric – Supply Loop Framework	Discerning advantageous supply loops by evaluating environmental and economic consequences Developing reliable data and market insights.	High material prices – Marked volatility Lack of availability according to region Unpredictable quantity	Geyer et al. (2004)	Technical: Steel Industry – Recycling and Reusing
Firm-centric – Gradual Four Phases implementation	Developing channels for collecting secondary resources Specialized teams of engineers Construction of recovery and recycling facilities Tracking and planning of material requirements through specific cascade loop frameworks	High skills and technology prices and knowledge required to treat secondary resources Lack of infrastructure for collection and access	Hopkinson et al. (2018)	Technical: Manufacturing printers – Recycling and Reusing
Collaborative	Building robust relationships among the supply chain actors Using IoT technologies Proposing take-back incentives Developing access-based and service models	Lack of infrastructure for collection and access Lack of information-sharing about status – Lack of forecasting capability and visibility	Bressanelli et al. (2018); De angelis et al. (2018); Masi et al. (2017); Frei et al. (2016)	Technical: Remanufacturing Washing Machine Industry - Reconditioning, refurbishment, and eco-design
Collaborative – “Industry Engineering”	Relying on local level collection, aggregation and massification	Lack of infrastructure for collection and access Unpredictable quantity	Boulque (2019)	Technical: Automotive Industry -Recycling
Collaborative	Enhancing management of secondary resources using AI, information-sharing Engaging suppliers beyond financial incentives	High skills and technology prices and knowledge required to treat secondary resources	Cerca et al. (2022)	Biological: Aquatic and Terrestrial

	Developing shared ownership of infrastructures and inclusion in planning and design steps to enhance sense of responsibility	Lack of information-sharing about status – Lack of forecasting capability and visibility		
Collaborative	Developing a cross-sectoral vision, collaborative platforms, and territorial cyclifiers to amplify material and knowledge exchange.	Unreliable timing Unpredictable quantity Uncertain quality \ Unpredictable Lack of information-sharing about status – Lack of forecasting capability and visibility	Gontard et al. (2018)	Biological: Agriculture Biowaste Sector
Collaborative – Partnerships between private & public actors	Implementing extended producer responsibility emphasizing collective action including partnerships between public actors and eco-organizations	Lack of infrastructure for collection and access Cost of collection and treatment	Micheaux (2017)	Technical: Electrical and Electronic Equipment Industry
Involvement of public actors	Involving public entities such as government departments, local authorities, and Chambers of Commerce to chart the trajectory of secondary resource movement by aligning demand and supply	Unreliable timing Unpredictable quantity Uncertain quality \ Unpredictable	Genovese et al. (2017)	Biological: Waste cooking oil
Public actor involvement	Developing standards for material composition and post-use handling.	Uncertain quality \ Unpredictable	De Angelis et al. 2018 ; Beulque et al. 2018	Technical: Plastic Industry Automotive Industry
Technological	Using GIS, material flow analysis & other biomass mapping	Lack of availability according to region Lack of information-sharing about status – Lack of forecasting capability and visibility	Iakovou et al. (2010) ; Gontard et al. (2018) ; Cerca et al. (2022)	Biological: Biomass

3. Research Question

In the previous sections, we were able to narrow down our research focus.

First, we emphasized the importance of investigating how actors develop circular activities. This process, which can be compared to an innovation process, involves numerous iterations, and entails uncertainties that require the cultivation of specific competencies and solutions. Our objective is to shed light on how actors navigate these complexities to set up circular activities.

Second, we underscored the challenges related to the specific issue of managing secondary resources and its crucial role in the economic viability and operational feasibility of circular business models. The literature on secondary resources in circular activities is still limited. This justifies further research to investigate the processes and groups of actors formed to identify, secure, and utilize these secondary resources, which also have been less explored in the literature (Beulque, 2019).

Finally, we observed that studies linking the circular economy with biological secondary resources are relatively recent, and that the topic has received little attention in the literature compared with technical secondary resources. Additionally, considering the many challenges involved in securing biological secondary resources, in-depth case analyses are needed to better understand processes enabling them to be secured, and to highlight their specificities and some crucial influencing factors.

Consequently, our focus is on theorizing **the processes through which actors organize themselves to secure biological secondary resources within the context of circular business models.**

Our approach in this manuscript entails investigating a case of circular activity by describing how interdependent actors secure secondary resources. We highlight specific obstacles related to secondary biological resources as well as steps and approaches taken by actors in order to overcome them. Indeed, the issue of securing secondary resources is a specific activity to be mobilized to design a circular business model.

In this research, we had the opportunity to investigate the case of anaerobic digestion, with a focus on the process whereby secondary biological resources were secured (we will further

detail how we had access to this case in chapter 2). Anaerobic digestion (AD), also called anaerobic digestion, is a biological process that occurs naturally in an anaerobic environment through the decomposition of organic matter (of plant and animal origin) by microorganisms. In an extended sense, anaerobic digestion refers to the technology designed to replicate this process under controlled conditions and in an anaerobic environment. This technology degrades organic matter and produces biogas and digestate.

This case is an appropriate and representative example of the issue of secondary resources and is relevant to our research question. Below, we outline three primary reasons why this case could provide valuable insights for our research.

First, anaerobic digestion is considered to integrate the principles of the circular economy (Kanda et al., 2021; Lewandowski, 2016; Ellen Macarthur Foundation, 2015). Further, it is one of the most discussed technologies in the studies linking CE and biological resources (Paes et al., 2019). This may be due to the European taxonomy highlighting the role of waste to energy technology, more specifically anaerobic digestion, in the circular economy framework. Anaerobic digestion pertains to the bioeconomy model, which is by nature a circular process (Arfaoui et al., 2022). Indeed, it puts in place a closed loop through biological cycles enhancing soil by inputting the resulting amendments of nitrogen, phosphorus, and potash and through the value added to this organic material that would otherwise be wasted (Hagman et al. 2019). It also aims to add value to by-products such as CO₂ and sludge generated by the industrial process, thereby closing the loops (Fagerström et al., 2018). Anaerobic digestion reduces the extraction of fossil resources, substituting them by added-value bioresources, agriculture or household waste in energy production cycles (Al Seadi et al., 2018). This results in the shrinking of resource loops where fewer fossil resources are extracted and used.

Second, anaerobic digestion manipulates biological resources. In France, biological resources are subject to competition due to multiple valorization options and their use is highly dependent on regulations and national objectives in the energy waste and agriculture sectors. Anaerobic digestion is intricately linked to a multitude of environmental challenges at different scales (Berthe et al., 2020). Indeed, the practice of anaerobic digestion serves a range of pivotal purposes: the valorization and management of waste materials, the reduction of nitrate and ammonia pollution within the agricultural sector (Alaterre et al. 2015), and the decarbonization of energy sources. Anaerobic digestion aligns with the European Commission's bioeconomy agenda and the "Green Pact for Europe," which envisions the

transition to a resource-efficient and climate-neutral society by 2050 (European Commission, 2019). The aim of accelerating the energy transition has led to anaerobic digestion being perceived as a sustainable, local and circular solution by the Ministry of Ecological and Solidarity Transition (Bourdin & Nadou, 2020).

Third, implementing anaerobic digestion projects implicate complex processes undertaken by various actors. These projects are not only a technical and biological construct, but also a socially complex construct anchored in a territory (Arfaoui et al., 2022). Indeed, they are constructed through specific economic and political relations as well as an appropriation of actors from different categories (Lévy, 2003, p.908). It involves various relationships with communities in which the anaerobic digestion plant is constructed, energy and waste management facilities, as well as legislators to lend impetus to the development of projects through specific governmental support, incentive schemes, and regulatory frameworks.

The significance of probing into this research question is further underscored by our investigation of the anaerobic digestion case study. We will see that securing resources extends beyond a mere operational activity of a circular business model during the lifespan of the anaerobic digestion plant. It transcends a one-time task essential solely to the plant's design process. On the contrary, the securing of secondary resources is a comprehensive process. It commences during the early stages of designing an anaerobic digestion plant, and involves an examination of accessible resources, the definition of technological process parameters for their digestion, a consideration of their variability, and the establishment of relationships with providers of secondary resources. This process persists throughout the operational phase, facilitated by the early design's capacity to allow for adaptation and informed decision-making during plant operations.

For companies, engaging in a circular business model involves different approaches. Several approaches encompassing a broad spectrum of strategies aimed at integrating circular economy principles into business operations have been proposed (Geissdoerfer et al. 2020). However, Mentink (2014), Micheaux (2017) and Geissdoerfer et al. (2017) have pointed out a gap in the literature, highlighting the importance of tailored approaches to assist organizations in navigating the intricate process of developing a circular business model in practice. To address this issue, Geissdoerfer et al. (2020) have put forward the 'Cambridge Business Model Innovation Process', which is a comprehensive framework consisting of three phases: concept design, detail design, and implementation. This structured approach facilitates the development and improvement of circular business models. This framework aims to facilitate the adoption of circular business models and promote sustainable transformation across

organizations by providing systematic guidance throughout the innovation process. Numerous authors have delved into the intricate processes of the business model innovation framework, each shedding light on different aspects. For instance, concept design is investigated by Geissdoerfer et al. (2016) and Brown et al. (2021). Micheaux (2017) details the detail design phase. Beulque (2019) examines the implementation processes. However, the step of securing the secondary resources is often omitted. While we have detailed some approaches to secure secondary resources in the previous sections, in this research work we provide a renewed vision by analyzing the processual securing of secondary biological resources through the case of anaerobic digestion in France.

Synopsis of thesis

The thesis is structured in three parts. The first part presents the research setting and the methodology adopted—a longitudinal approach at the anaerobic digestion project level (chapter 2), the analytical framework constructed to analyze the process of securing secondary resources during the development of anaerobic digestion projects (chapter 3), and a description of the case studied, including the evolving regulatory context and technical aspects of anaerobic digestion (chapter 4). The second part presents the results of our research, detailing the narratives of four anaerobic digestion projects and emphasizing the challenges and actions of actors during the resource-securing phase (chapter 5). The final part presents the interpretation of the results (chapter 6), as well as the contributions and limitations of this research (chapter 7).

Part 1: Research setting

Chapter 2: Methodology

This chapter presents the methodology employed in this doctoral research. It begins by detailing the origin of the thesis and the role of the doctoral student within three structures housing the thesis: Engie Lab Crigen, Veolia, and the Management research center at École Polytechnique. Following this, we detail the qualitative methodological approach used to explore the research question, and describe the data collection and analysis process. A qualitative longitudinal approach was adopted to examine how actors organize the development of anaerobic digestion projects and secure adequate secondary resources.

Chapter 3: The analytical Framework

This chapter presents the analytical framework, introducing and articulating the concepts of governance, territory, and the market. We draw on literature that sheds light on the determinants, factors, and analytical perspectives that enhance our understanding of the dynamics involved in implementing circular economy initiatives. By analyzing these three areas of literature, we construct an analytical framework to study our case and examine the processes by which secondary resources are secured in projects. Based on this framework, we divide our research into three separate questions: *(1) How can forms of governance and their specific characteristics contribute to securing secondary resources in CE projects? (2) To what extent and how do circular economy projects leverage territorial proximities in order to secure secondary resources? (3) In premarket conditions for secondary resources, what are the processes of market arrangements enabling agreements to be reached?*

Part 2: Results

Chapter 4: Anaerobic digestion in France: Regulations, Processes, and Stakeholders

This chapter delves into the evolution of regulations and laws in France relevant to anaerobic digestion, as well as the key public actors driving and supporting its advancement. By exploring the regulatory landscape of energy, waste, and agriculture, we provide insights into the foundation upon which anaerobic digestion initiatives have flourished, highlighting the main types of plants that have emerged in France and that we will be investigating. We also present a technical description of anaerobic digestion and describe the secondary resources used. The objective is to provide empirical evidence of the complex characteristics of these secondary resources, explain how they are used, and highlight the challenges inherent in manipulating them, thereby preparing the groundwork for a deeper understanding of the process of securing them during projects.

Chapter 5: Securing secondary resources for anaerobic digestion projects in practice

This chapter details and analyzes the processes of securing biological secondary resources through the narratives of four anaerobic digestion projects.

Subchapter 5.1: Case selection

This subchapter offers an overview of the emergence of anaerobic digestion projects within three distinct organizational settings: an agricultural cooperative (EMC2), an energy company

(Engie), and a waste, water, and energy company (Veolia). We posit that investigating the perspectives of these three different sectors on the development of anaerobic digestion projects could provide valuable insights into the process of securing secondary resources, as anaerobic digestion intersects with energy, waste, and agriculture. Our doctoral research context facilitated the investigation of anaerobic digestion development within Engie and Veolia, and provided the opportunity to explore anaerobic digestion within an agricultural structure (EMC2). This subchapter elucidates the rationale and criteria behind our selection of four specific anaerobic digestion projects: Landres, Methamoly, Caux Vallée de Seine, and Sibiom.

Subchapter 5.2: Narratives of the development of four projects

This subchapter describes the processes of securing biological secondary resources, as they played out in the four projects. It is divided into four sections, each focusing on a specific project: Landres, Methamoly, Caux Vallée de Seine, and Sibiom. Within each subsection, we explore the narrative of project development as provided by key actors during interviews, supplemented with insights from sources such as documents from interviewees, newspapers, and local media. We then present the main characteristics of each project, including technical specifications of the plant—such as size and type—along with relevant geographic details, and financial and biological aspects. Each subsection includes a detailed look at the inception phases, explaining how the project was initially conceptualized, the motivating factors, and the key actors involved. This is followed by an in-depth exploration of the phase related to secondary resource procurement, highlighting the strategies and actions employed by actors to navigate challenges and secure the necessary secondary resources.

Part 3: Analysis and insights

Chapter 6: Discussion

This chapter seeks to discuss our results. Upon analyzing the four anaerobic digestion projects, we reveal four key themes that shed light on the intricacies of securing secondary resources. First, our investigation highlights a comprehensive three-phase process for securing secondary resources. We discuss the strategic approach adopted by stakeholders to ensure the long-term viability and success of local anaerobic digestion projects during these phases. Second, we address the challenging nature of securing secondary resources in poorly structured markets. Stakeholders strive to establish tools and instruments for defining

secondary resource prices and develop tailored exchange conditions and rules to secure these resources. Third, we emphasize the mechanisms of territorial anchoring in local circular projects. We discuss the evolving and dynamic role of public actors as facilitators in initiating, supporting, and facilitating local anaerobic digestion projects—from fostering collaboration through their relational ties with the local network to providing financial support. Lastly, we analyze governance structures within anaerobic digestion projects, which range from firm-centric models to diverse configurations of collaborative approaches involving secondary resource suppliers. We discuss how involving suppliers challenges the conventional view of governance.

Chapter 7: Contributions, limitations, and future avenues of research

This chapter provides a summary of results and a related discussion. The general conclusion outlines the theoretical, methodological, and empirical contributions. Finally, it acknowledges the limitations of our research and the research prospects opened up by this thesis.

Chapter 2. Methodology

“It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience.”

– Albert Einstein, Physicist

In this chapter, we will first detail the research context in which the thesis took place. We will next detail the origin of the thesis, as well as the position occupied by the doctoral student in the structures housing this research (1). We will then delve into the qualitative methodological approach that served to investigate the research question behind this thesis (2) and give a detailed description of the data collection process and subsequent analysis (3).

1. The doctoral research context

This doctoral research was conducted in a CIFRE setting (*Conventions Industrielles de Formation par la Recherche*, or Industrial Training Agreements for Research). It is supported by the National French Association for Research and Technology (ANRT, *Association Nationale de la Recherche et de la Technologie*). CIFRE is financed by the French Ministry of Higher Education, Research, and Innovation. Its purpose is to encourage collaboration and exchanges between academics and private companies.

Signed in March 2021, the CIFRE agreement initially focused on an exploratory research project concerning the development of circular business models in large established companies, notably at Engie and Suez. This project had the advantage of being broad enough to allow the thesis to evolve as research progressed. Thus, the purpose of this part is to highlight how the subject of this research evolved. To do so, I will detail the empirical question at the origin of this research project as well as the expectations of the company and the doctoral student. In addition, I will specify the role that I occupied as a young researcher during these three years of research within the companies.

1.1 The origin of this CIFRE thesis

In 2019, an idea was born around the work on the circular economy conducted by ISO, the International Organization for Standardization.

Engie Lab Crigen and Suez, represented by a former employee of Engie Lab Crigen (Delphine) and a current Suez employee (Catherine), were involved in establishing ISO standards for the circular economy, beginning in 2019². The two company representatives considered it relevant to investigate the topic of the circular economy through a thesis. They decided to propose a CIFRE thesis on the topic of the circular economy.

In 2020, the internship at Engie Lab Crigen

The idea was to frame the subject of the thesis through a 6-month research internship that I undertook. The primary objective was to explore the business models within Engie pertaining to the circular economy. The two other purposes were to choose the academic partner to

² <https://www.iso.org/committee/7203984.html>

support this thesis, and draft the document reflecting the empirical interest of the two companies to be presented to the ANRT.

To fulfill the primary objective, I proceeded with a literature review of business models and the circular economy. First, I had to investigate what a business model was in the literature and compare it with the company's understanding. Next, I investigated the literature on the circular economy, and developed a framework to assess the activities of an energy company, since no framework was identified in the literature at the time. This step proved to be particularly challenging, first because I had to manipulate mature literature on business models on the one hand, and on the other hand, rather nascent literature on the circular economy, where the subject was not clearly delimited. The outcome of this work was a master's thesis. The main results were to provide (1) a detailed state of the art on business models, the circular economy, circular business models and the challenges identified to implement them (2) a framework to assess circular activities within an energy company (3) an assessment of the current situation within Engie as well as the identification of an area of development based on the framework.

This research internship allowed me to familiarize myself with (1) the organization of Engie, (2) comprehension of the circular economy and the activities in place and (3) the team in which I did my internship (getting to know their projects, constructing knowledge about the circular economy since the team was recently created).

To fulfill the second objectives, the choice was made to collaborate with the *Centre de Recherche en Gestion* (CRG, Management Research Center) of Ecole Polytechnique. Engie Lab Crigen had already worked with the CRG on an industrial and territorial ecology tool developed by an internal team at Engie Lab Crigen.

The thesis topic was initially defined by the economic actors, Engie Lab Crigen and Suez. Nevertheless, the results of the master's thesis, although relatively modest, served to outline and refine the orientations of the thesis project with these economic actors. It was then reviewed by an academic actor affiliated with the CRG (the thesis supervisor) through several meetings. The issue of developing innovative business models to support a transition to a circular model was a challenge for Engie and Suez. This challenge led the two companies to finance this thesis to study the processes by which companies can adopt new business models encompassing the principles of the circular economy, and identify opportunities for developing new business models and new value creation models.

In 2021, the realization of a tripartite collaboration

As the project was accepted by the ANRT, the thesis began in March 2021. I was employed by Engie Lab Crigen and co-supervised by Suez. I also benefited from supervision from the Management Research Center (CRG) through my thesis director. The research needed to be relevant at both the academic and company levels. The final objective was therefore to make practical contributions for Engie and Suez and theoretical contributions for academia.

Following the first year of exploration, the topic expanded significantly, leading to a broader reflection on the concept of the circular economy and its relationship to resources, as well as the selection of a case to study. I will return to the progression of this reflection in depth in subsection 2.

In 2022, a shift in economic actors.

Nearly six months into the research project, on the evening of July 29, 2021, Veolia formally launched a public takeover bid to acquire the remaining capital of Suez that it did not yet own. Suez was closed on January 18, 2022. The duration of the takeover bid created a temporary gap in thesis supervision and data collection from Suez. Veolia's Department of Multifaceted Performance and Sustainable Development took over the thesis supervision in March 2022, marking the beginning of the second year of doctoral research. The initial empirical interest of the thesis remained the same as originally supported by Engie Lab Crigen and Suez. Indeed, the supervisor of the thesis remained the same in the new Veolia structure.

1.2 A challenging position for a doctoral student

Under the CIFRE program, the researcher benefits from immersion within the partner company. These benefits are twofold. For the doctoral candidate, who is also a research apprentice, this format:

- (1) enables personal interactions with representatives from both the company and the laboratory (Levy & Woessner, 2007).
- (2) allows the doctoral student's theories and experimentation to be challenged while proposing ideas and contextualizing the research thanks to daily proximity to the key stakeholders. (Levy and Woessner, 2007).

Interacting with three structures

In my particular and unique case, the CIFRE program brought together two companies (structures 1 and 2) alongside the research laboratory (structure 3)

Structure 1: Engie, Engie Lab Crigen, Circular Economy Team: A structure familiar with research

Engie Lab Crigen is a structure well-versed in the realm of research, being part of the Engie group specializing in energy and the transition towards carbon neutrality. I occupied the role of a research engineer in the Lab Environment and Society, in the team Circular Economy. The Lab's research expertise encompassed in-house tools for the assessment of industrial ecology, impact studies, evaluations, and life cycle assessments, as well as eco-design and biodiversity expertise. I actively participated in bi-weekly lab and team meetings, contributing to the team's roadmap and project selection. I provided support for various projects, such as the development of a circularity indicator framework. Additionally, I engaged in monitoring (mostly regulatory and particularly ISO standards, best practices, and study cases), proposed a study on the distribution of value in a circular economy to RECORD (network fostering research collaboration between industries, public organizations, and researchers), and participated in its follow-up. I also participated as a jury member to evaluate circular economy start-ups in the competition organized by Clean Tech Open France. Finally, I had several occasions to present my work at Engie Lab Crigen during doctoral students' days, during work reporting day of the program funding my thesis, as well as during team and lab meetings (Table 21, Annex). This allowed me to gain valuable insights and perspectives on the empirical work undertaken.

Structure 2: Veolia, Multifaceted Performance and Sustainable Development Department, Circular Economy and Resource Scarcity Team: A structure familiar with standards and regulations

Veolia's Multifaceted Performance and Sustainable Development Department specializes in water and waste management as well as energy services. The department tackles strategic subjects such as climate change mitigation, reduction of greenhouse gas emissions, biodiversity as well as societal aspects.

The team Circular Economy and Resource Scarcity, while not as research-oriented, holds a strategic position and engages in lobbying initiatives as well as knowledge and regulatory monitoring. The team leader is chair of the ISO Circular Economy Technical Committee responsible for drafting standards. During my time here, I provided support for a project related to the evaluation of the optimal set of circularity indicators for Veolia, drafting a positioning note on the circular economy, and participated in interviews to assess Veolia's circularity using the framework I developed during my internship.

Structure 3: The Management Research Center (CRG): An expert in intervention research

Founded in 1972 by École Polytechnique, the CRG became the first management research laboratory recognized by the CNRS in 1980. It specializes in three key research areas—innovation strategy and organizational management, societal dynamics of implemented innovation, and the responsible aspects of innovation. Its approach and expertise are characterized by strong links with the organizations under study, leading to rich empirical fields.

My doctoral assignments included writing memos, reports, data analysis, and participating in various academic conferences and colloquia. I also had several occasions to present my work to fellow researchers and doctoral students for discussion (Table 21, Annex). This allowed me to challenge the theoretical groundings of my work.

In addition to my doctoral research, I was assigned specific tasks to contribute to the CRG's academic environment. I was part of the team in charge of organizing the weekly research seminars. I also taught courses on business models and the circular economy. This was an occasion to put my research into perspective and test my work. I was also involved in student thesis defense juries presenting an organizational analysis of the companies hosting their internships. Finally, I evaluated the sustainability certificates presented by students at the end of their internships.

Mediating between three structures

The interaction with the research laboratory was consistent throughout the thesis. As for interaction with the companies, it was variable and asymmetrical. I was contractually employed by Engie from the start of the CIFRE agreement. It was not until the second year that I was able to effectively engage with Veolia. I divided my weekly schedule so as to be present at least one day per entity to engage as much as possible with the three structures.

To conduct objective and relevant research, and to reconcile the interests of all the collaborators in this tripartite thesis, I had to find the right posture. Indeed, the doctoral candidate plays a central role as a mediator (Levy, 2005) between the university and the companies, effectively transcending the boundaries of both. This was not an easy task. Indeed, the operational interactions with two organizations sometimes in competition regarding activities, required a certain number of precautions to be taken. On the one hand it consisted of finding an equilibrium between the two companies. On the other hand, it consisted of

finding a subtle balance between integration and distancing from the two companies in which the research took place (Girin, 1989).

Figure 4 gives an overview of the main interactions with the three structures.

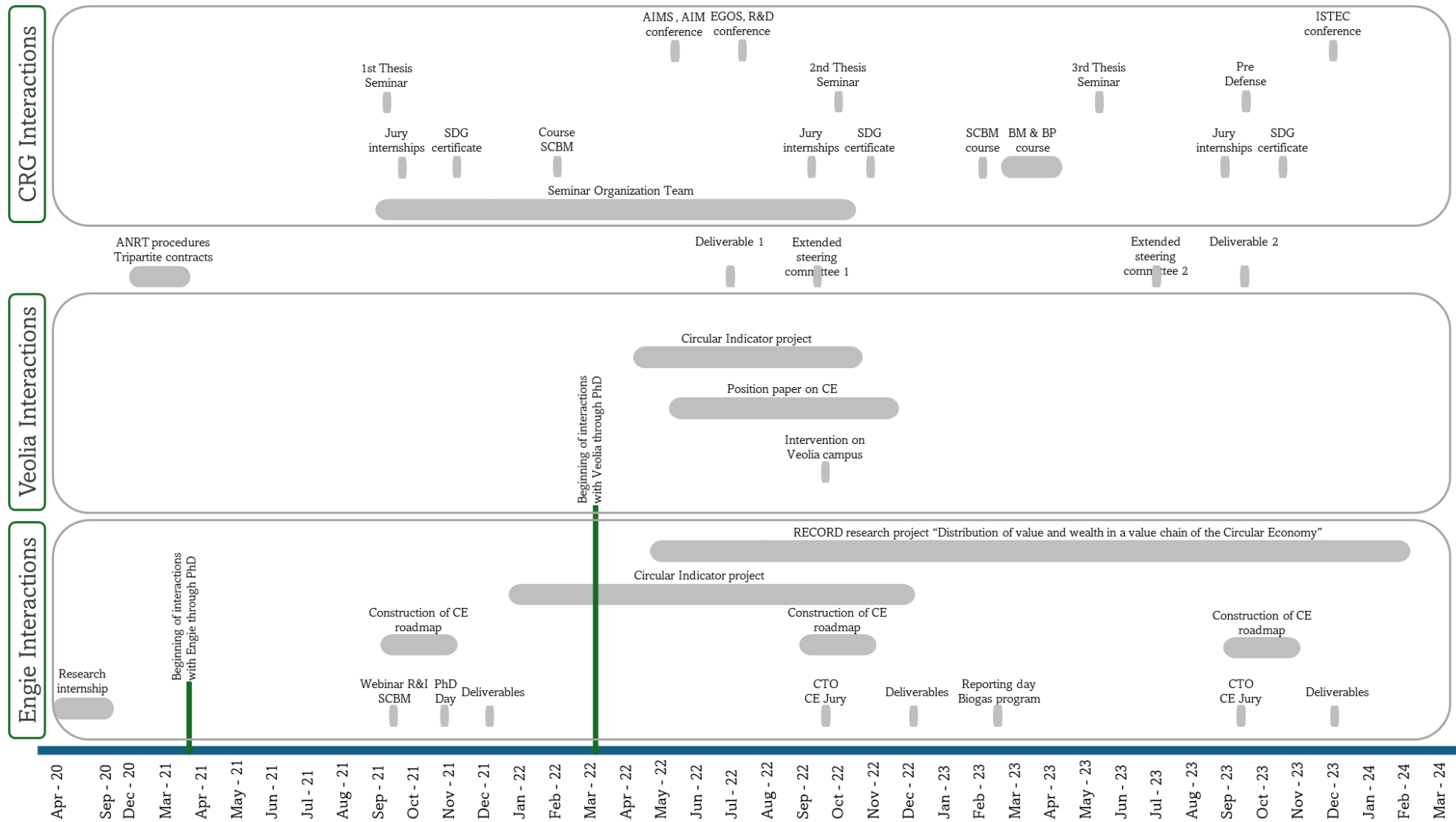


Figure 4 Overview of thesis progress and the main missions in the three structures

This section will describe the methodology used to investigate anaerobic digestion and answer the research question. We provide an explanation of the methodology employed in this research (2) as well as detailed insights into the collection and qualitative processing of data (3) (including their nature), the methods used for data collection, and the analytical procedures conducted within this study.

2. Combining comprehensive and exploratory research

The approach adopted in this study is rooted in an exploratory methodology grounded in the epistemological constructivist pragmatic paradigm (2.1). Additionally, the study employs a comprehensive and longitudinal approach to investigate the factors influencing the securing of secondary resources and its significance in the implementation of circular business models (2.2). By combining these approaches, the research aims to provide a nuanced understanding of the complex processes involved in anaerobic digestion projects within the context of circular economy initiatives.

2.1 Exploratory approach

Like any CIFRE research, the initial question evolved significantly during the thesis, as did the levels of analysis, with new questions and hypotheses being added to the reflection process along the way. According to Girin (1989):

“In the field of research on management and organizations, it is clear that unexpected and noteworthy events are likely to disrupt any research program, and that the real issue lies not in complying with the program, but in intelligently grasping the opportunities for observations offered by the circumstances” (own translation ³).

Faced with the complexity of the empirical problem, such as that of anaerobic digestion, defining a research design in advance proved challenging. Thus, we adopted a flexible

³ *“Dans le domaine de la recherche sur la gestion et les organisations, il est clair que les événements inattendus et dignes d'intérêts sont propres à bouleverser n'importe quel programme de recherches, et que la vraie question n'est pas celle du respect du programme, mais celle de la manière de saisir intelligemment les possibilités d'observations qu'offrent les circonstances”*

methodological approach characterized by processes of exploration and inspection (Blumer, 1986; Dumez & Toussaint, 2022), which was suited to the progressive discovery of the case. Rather than imposing predefined frameworks onto the research terrain, we embraced a fluid methodology that accommodated the iterative nature of knowledge generation, allowing for adaptability and responsiveness to the unfolding narrative of our case study.

Our research approach was fundamentally exploratory, evidenced by the notable evolution of the research question over time. Initially, the topic defined by the two companies did not precisely align with the focus ultimately addressed in this research. Originating from an empirical question posed by Engie and Suez—how can their business models innovate to fit into the circular economy?—our aim was to initiate a program of introspection centered around the novel principle of the circular economy, rather than delivering a pinpoint response to this specific inquiry.

Following a constructivist epistemological paradigm, questions continuously emerged through encounters, contextual changes (economic, political), and discoveries, much like an ongoing inquiry. The exploratory investigation progressed through numerous interviews with stakeholders (see Table 3) across the value chain. Our approach actively engaged with stakeholders, examined empirical evidence, and iteratively refined our conceptual understanding. Through this iterative process, the contours of our research problem gradually crystallized, informed by the rich tapestry of insights gleaned from our interactions with the anaerobic digestion ecosystem. These exchanges not only facilitated an understanding of the sector's intricacies but also led to the emergence of additional ideas, discoveries, and the formulation of new hypotheses and questions, such as specific relationships and the involvement of actors and their organizations during projects.

Thus, the research question evolved from circular business models to a focus on securing resources and its articulation with collaborative governance and the territorial dimension. The subsequent paragraphs detail the entire exploratory journey undertaken to refine this reflection.

Year 1: Questions related to business models and circular business models

Neither company had a clear definition of the circular economy or a dedicated strategy. The first year was dedicated to selecting a study case which (1) could be considered circular based

on the framework developed during my internship and (2) constitute a strategic interest for both companies and simultaneously belong to their core businesses.

The framework developed during the internship served as a foundation and allowed us to structure our selection and refine the discussions to identify what could be considered circular. Following a diagnosis resulting from several meetings between economic actors, Engie Lab Crigen, Suez, and academics, it was agreed that anaerobic digestion would constitute the empirical basis of our study. Although several case studies were envisaged at the outset and met our selection criteria, we ultimately chose to focus solely on the anaerobic digestion case due to its complexity and wealth.

Initially, the analysis focused on the mesoscale of the anaerobic digestion sector. We explored the field to understand the key issues limiting and favoring the sector's development. At the same time, this first year was the stage when we took stock of the situation. It was based on the initial issues put forward by Suez and Engie concerning the lack of a circular business model. We thus delved into the literature on the levers favoring the implementation of circular business models. Based on a diagnosis, it appeared that circular business models, limited to a firm-centered logic, did not allow enough impetus to be created to sustain the momentum needed for a transition towards a more circular model.

Thus, the practical issue of a circular business model and its articulation with collaboration and cooperation of diverse actors appeared central.

Year 2: The question of securing secondary resources

In the second year, more targeted discussions with stakeholders allowed us to characterize how large companies were building their anaerobic digestion models through collaboration and cooperation, creating connections with new actors (farmers, local businesses, etc.). Expanding the initial diagnosis and basing our problem formulation on the interviews conducted with actors engaged in different anaerobic digestion projects, it became apparent that the empirical challenge in establishing these new relationships for Engie was related to the securing of secondary resources and finding outlets for their circular models with these new actors. For Veolia, the issue of securing secondary resources also arose, but in a different way. It was about maintaining control and keeping its collaborators engaged in the face of increased competition from newcomers to the market who could leverage these same secondary resources through other value-adding means.

Based on the specific interviews conducted we could postulate a preliminary hypothesis in which companies developed specific relationships with the external actors involved in this circular business model to deal with the challenges of secondary resources.

It was, therefore, a matter of examining the issues related to relationships and partnerships that connect these actors, the role of key actors in mediating between different parties. In a broader sense, it also involved exploring the role of the territory in shaping these relationships, as well as the effects of public policies in promoting the provision of additional secondary resources and, consequently, new actors.

By taking a step back from circular business models, this second year made it possible to significantly deepen the concept of collaborative governance and distinguish the dominant mechanisms of collaboration. Indeed, the step of securing secondary resources appeared to be crucial in this collective action to implement circular business models. We were able to extend it and detail the process with a complementary approach by investigating several anaerobic digestion projects.

Simultaneously, from a review of the literature we were able to highlight a paradox in the circular economy discourse (presented in the introduction to this thesis). Indeed, the objective of a circular economy is to recover waste, which we call secondary resources, in closed loops. In the collective imagination, there are large quantities of readily available secondary resources. However, in reality, securing enough high-quality secondary resources to allow the proper functioning of a circular ecosystem appears to be a challenging but strategic step for CE actors. Extensive additional bibliographic research has been completed on strategies for securing secondary resources for circular models (presented in the introduction to this thesis). Thus, in this second year, following these empirical insights from our investigation of anaerobic digestion sectors, specific projects and our literature review, the analysis moved away from the meso-economic scale towards a more micro-economic approach focusing on the strategies and processes used to secure secondary resources that we discovered while studying different anaerobic digestion projects.

Year 3: The question of collaborative governance, territorial embeddedness, and market emergence

The hypothesis emerged that, through specific competencies mobilized by actors, collaborative governance could promote the development of relationships between actors of distinct types on a specific territory, leading to security and mitigating the issue of secondary resources. Therefore, this collective dynamic could facilitate the emergence of circular models

among actors who previously had no economic relations. A literature review was conducted to deepen the concepts of collaborative governance, territorial embeddedness and market arrangements and create an analytical framework (detailed in chapter 3).

In this perspective, given that collaborative governance and territorial anchoring appeared to play a crucial role in circular business models, we proceeded with additional interviews to validate the narrower issue based on the securing of secondary resources as a decisive component of anaerobic digestion projects.

Thus, the third year focused on putting into perspective the accumulated knowledge on collaborative governance, territorial embeddedness and market arrangements. The aim was to test out this idea by concretely specifying these dimensions at the micro-economic level of businesses when implementing anaerobic digestion projects.

Finally, the pragmatic and exploratory approach based on field work allowed us to easily move between the field and the theory, each part feeding the other. It is through this abductive process that we could formulate the overall research problem and question the issue of securing secondary resources for circular business models. This process is typical of the constructivist paradigm inherent to a comprehensive research process in social sciences (Dana & Dumez, 2015; Dumez, 2016). These elements also explain why, beyond the theoretical framework related to circular business models, other literature—namely that on governance, territory, and the market—has been used, reflecting the iterations between empiricism and theory that have characterized this work. This back-and-forth between empiricism and theory, as well as the continuous production of knowledge that can readjust the theoretical framework, reflects the fundamentally creative abductive approach.

2.2 Comprehensive and longitudinal approach

In the academic literature, we observed that the circular economy may be studied at various levels, ranging from macro-scale analyses of sectors to micro-scale examinations of individual projects or products (Bocken et al. 2016; Kirchherr et al. 2017). During our exploration and inspection phases (as described in section 2.1), we initially approached our investigation from a highly macro-sectoral level concerning anaerobic digestion. However, our focus gradually shifted towards a specific issue: the securing of secondary resources, which is a crucial step for the development of circular projects. To delve into the intricate

process of securing secondary resources and to illuminate the micro-level development of circular projects in detail, we deemed necessary a comprehensive and longitudinal approach, which enabled us to progressively elucidate the mechanisms and the key stakeholders involved in securing resources throughout the lengthy duration of anaerobic digestion projects.

Thus, the exploratory nature of our approach led us to adopt a comprehensive and longitudinal qualitative approach, aligned with the epistemological paradigm of pragmatic constructivism. It is noteworthy that qualitative studies on the anaerobic digestion sector, particularly within the context of the circular economy, are scarce. Most studies on anaerobic digestion projects have focused on evaluating the performance of established systems against predefined quantitative objectives, and few investigations have been conducted regarding the social acceptability of anaerobic digestion plants in the social sciences. The studies conducted by French researchers on social and organizational aspects of anaerobic digestion plants in France are scarce (Alaterre et al., 2015; Niang et al., 2022a). Few works address the issue of organizing actor games and coordinating local stakeholders in anaerobic digestion projects (Niang et al., 2022b). Furthermore, links to the circular economy literature remain limited (Kanda et al. 2021; Arfaoui et al. 2022; Niang et al., 2022a) and very recent, as shown in Figure 5⁴.

⁴ We initiated a comprehensive search using the keywords "anaerobic digestion" within Scopus, resulting in the identification of 39,487 documents. In order to tailor our research to the specific focus of our inquiry, which aims to comprehensively understand the key topics pertaining to anaerobic digestion within our field of study, we narrowed our query to encompass select academic fields. These fields included social sciences, business management and accounting, economics, econometrics, and finance, yielding a subset of 1,938 documents. To gain specific insights into the predominant subjects under discussion within the French research community, we refined our search to include only studies conducted in France, leading to the identification of 56 pertinent documents. Our analysis was grounded in textual data, with a specific focus on term co-occurrences within the abstracts and titles of these 56 documents.

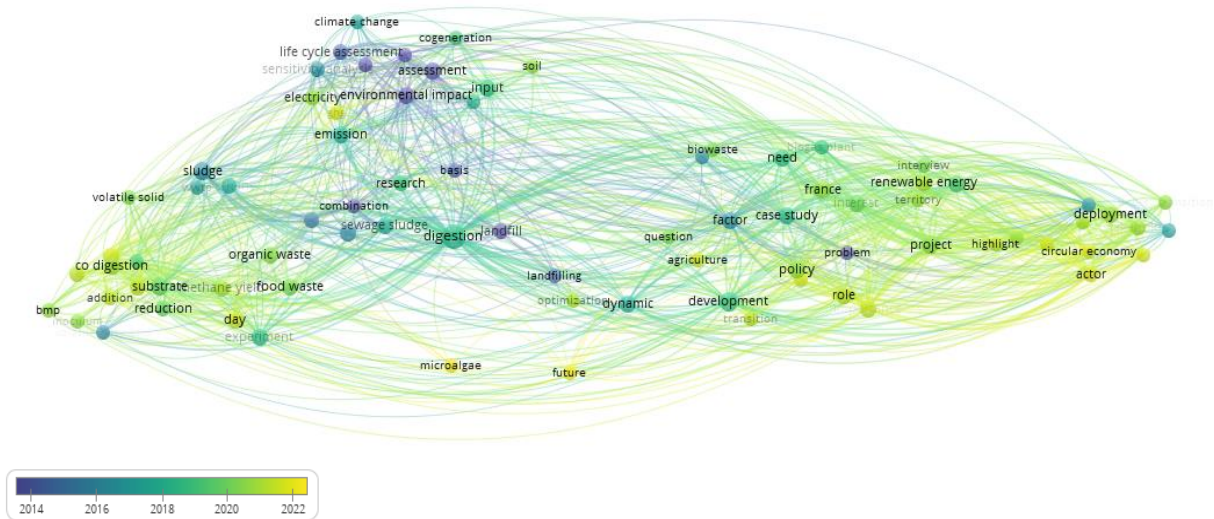


Figure 5 Co-occurrences of terms based on a Scopus dataset search for “Anaerobic Digestion” – Vos Viewer (the author, 2023)

Authors call for the adoption of a systemic approach to discuss anaerobic digestion and the necessity to depart from a linear and relatively short-sighted perspective (Alaterre et al., 2015). Indeed, a significant percentage (ranging from 20% to 30%) of biogas projects are abandoned (Bourdin & Nadou, 2020). The authors emphasize that among factors contributing to these failures are inter-stakeholder coordination challenges.

Given these insights, a comprehensive method appeared appropriate. The objective was to understand the organization of a broad set of actors, linked through formal and informal ties, and to highlight their role, actions, and competencies in the process of securing secondary resources leading to the creation of circular business models. Comprehensive research aims at providing a “*detailed and thorough analysis of the phenomena being studied, including description and narration, presenting the actors and their actions and interactions, their discourse and interpretations, and highlighting the underlying mechanisms of dynamics and processes*” (own translation⁵, (Dumez, 2011, p. 56) Furthermore, *this type of approach focuses on the actors who act and interact, that is to say, think, speak, and decide, whether in a routine or innovative way. The researcher stands as close as possible to the situations in which these actions and interactions take place, whether by reconstructing them (historian),*

⁵ “Une analyse fine, détaillée des phénomènes étudiés, incluant la description et la narration, présentant les acteurs et leurs actions et interactions, leurs discours et interprétations, et la mise en évidence de mécanismes sous-jacents aux dynamiques et processus”

observing them (observation, participant observation), or by working in collaboration with the actors being studied (action research) (own translation ⁶, (Dumez, 2016, p. 6))

We also adopted a longitudinal approach. Rather than providing a static description of stakeholder perceptions and strategies, anaerobic digestion is viewed as dynamic and process-oriented. Given the extended duration of project development, particularly the critical timing involved in securing secondary resources, we found that a longitudinal approach would be conducive to theory building. Employing a narrative approach (Dumez, 2011), we aimed to capture the emergence of the anaerobic digestion sector, the evolving interests and strategies of stakeholders, and the specific development projects, with a focus on the process of securing secondary resources.

This thesis focuses on theorizing the process of securing secondary resources in circular business models, more specifically in anaerobic digestion. Initially, we provide a narrative tracing the evolution of anaerobic digestion in France, highlighting key regulations and influential actors that have led to the prevalence of two distinct models mobilizing specific secondary resources (detailed in Chapter 4). Our analysis then delves into narratives of four anaerobic digestion projects, each presented in chapter 5, with the aim of extracting theoretical principles related to the securing of secondary resources. In this context, our approach has been historical in nature, focusing on reconstructing the emergence of anaerobic digestion in France. The manuscript begins by offering a historical perspective on the emergence of anaerobic digestion in France, detailing the evolution of sectoral issues and the roles of various actors. Subsequently, we examine the emergence of anaerobic digestion projects within three organizations: an energy company (Engie), an agricultural cooperative (EMC2), and a waste and energy company (Veolia). We considered that shedding light on the perspectives of these three sectors involved in anaerobic digestion could yield interesting insights regarding the process of securing secondary resources. We will further explain how we had access to these organizations and the criteria used to select anaerobic digestion projects in subchapter 5.1.

⁶ *"Le projet de connaissance de ce type de démarche [compréhensive] se centre sur les acteurs agissants et interagissant, c'est-à-dire pensant, parlant, décidant, de manière routinière ou novatrice. Le chercheur se place au plus près des situations dans lesquelles se déroulent ces actions et interactions, soit qu'il les reconstitue (historien), les observe (observation, observation participante) ou qu'il agisse de concert avec les acteurs étudiés (recherche-action)."*

3. Collection and qualitative processing of data

The thesis is based on a study of the case of anaerobic digestion, using a set of primary and secondary data. Given the complexity of the case, and for the sake of scientific rigor, the data collected are varied in nature. In this section, we return to the methods that guided the process of data collection (3.1) and triangulation (3.2), specifying the methods of analysis (3.3) and the methodological limitations associated with this research (3.4).

3.1 Data Collection

In this research, we collected data through two streams. Primary data were mainly gathered through interviews (3.1.1). This collection was supplemented with various forms of secondary data (3.1.2). Each will be detailed in the following subsections.

3.1.1 Primary data collection

A total of 70 semi-structured interviews were conducted between April 2021 and December 2023. They were conducted in person or remotely. The interviewees were mainly based in France and in Europe (Belgium and Germany). The interviewees belonged to different organizations: private companies, universities, regional agencies. Within these organizations, they held various positions: technical expert, engineer, managing director, strategy manager, sales manager, logistics and transport manager, etc.

The table 3 below presents the interviews conducted in each organization as well as the position of the interviewee.

Categories of actors		Position of interviewees and number of interviews
Private companies	Engie (26)	Research engineer (2); Bioz General Director (1); Business Developer (8); Process biology manager (1); Project Manager (5); Biogas Expert (3); Digital Performance Manager of biomethane plants (1); Biomethane Strategy Advisor (1); Logistics and Transport Manager (1); Agricultural development officer (1); Agricultural Development Manager (1); Biomass Analyst (1)
	Veolia (10)	Research and Innovation (2); Anaerobic digestion Site operation manager (1); Technology Sales Manager (2); General Director of Energy & Decarbonization Offers (1); Director of the Organic

		Division (1); Anaerobic digestion founder and site operation manager (1); Operations manager of biowaste treatment plant (1); Head of Biological Treatments division (1)
	GRDF (2)	Biomethane development manager (1); General Director of foundation (1)
	TotalEnergies (1)	Assistant to the management of the Biogas working group of the NSE sector strategic committee (1)
	Suez (2)	Sales and Development Engineer (1); Digital platform for biological secondary resources Product Owner (1)
	Valotech (1)	Biological engineer and Unit performance manager (1)
Agricultural Cooperatives	EMC2 (5)	Agricultural Technician (1); Regional development manager (1); Project Manager (1); Agronomy Director (1); Operation Director (1);
Startups	Founders (5)	Decentralized anaerobic digestion solution (2); Liquified anaerobic digestion solution (1); Biowaste Treatment solution (1); Digital platform for biological secondary resources (1)
University (4)		Professor and Researcher (2); PhD Student (2)
Public (3)		Mayor (1); ADEME Expert (1); Director of Community of municipalities' Ecological Transition public service (1)
Consulting Services (3)		Biomass Analyst (1); Biomethane Analyst (1); Biomethane Expert (1)
Investment Funds		Investors (2)
Territorial Development Agency (3)		Director of energy and sustainable solutions branch (1); Development and marketing manager of anaerobic digestion and gas mobility (1); Development manager, Circular Economy, Industrial Ecology & Energy Transition (1)
Other SAS biomethane plants (3)		Site operator (1); Manager biogas production (1), President of SAS biomethane plant (1)
Collective (1)		<i>Collectif scientifique national méthanisation raisonnée</i> (National scientific group for reasoned anaerobic digestion) (1)

Table 3 Semi-structured interviews conducted during research

Initially, a deliberate, structured approach was employed, such as conducting interviews with stakeholders from Engie and Veolia. The list of contacts was compiled as the research progressed, partly using the snowball sampling principle. To begin with, we approached engineers, as well as experts in biomethane in both companies (first at Engie, then EMC2 and later Veolia), to gain insights into the technical and biological aspects of anaerobic digestion.

Consistent with our exploratory methodology, a significant portion of the data collection occurred in an unplanned manner, meaning it unfolded spontaneously. This unscheduled data gathering unfolded during interviews, after asking interviewees for the contact details of one or more other people to be interviewed. This evolving process from one contact to another led to pivotal interviews to be conducted. In fact, these initial interviews with key informants provided us with a certain amount of secondary data, as well as contact details that were considered “more operational” in the field of anaerobic digestion. Based on these elements, the research was extended to a second, more operational circle, yet less accessible.

Type of interview series	Dates	Description
Preliminary	April 2021 – September 2021	First series conducted with informants to understand the technical and biological process of anaerobic digestion
Principal	March 2022 – October 2023	Second series conducted with diverse profiles, with a focus on informants involved in more operational tasks on anaerobic digestion plants

Table 4 Series of interviews

The structure of interviews was flexible and adapted to the interviewees. The exact focus of inquiry was not always defined from the outset. That is why the conducted interviews were intentionally open-ended and semi-structured, allowing for fluid and spontaneous conversations. The series of questions asked during the interviews evolved throughout the investigation, notably with an increased frequency of questions aimed at understanding the process during the initial learning phase on the subject. Gradually, the questions became more refined to address the organization of actors and to better understand the issue of securing secondary resources.

It was a deliberate choice not to place the entire burden of recording on all interviewed individuals. This decision was informed by the understanding that the topics under discussion often held great sensitivity for individuals operating within a fiercely competitive sector. Consequently, a real-time note-taking approach occurred during interviews. Additionally, the feedback provided by the thesis supervisor played a valuable role, offering an external perspective and an opportunity to gain perspective on the collected information, ultimately paving the way for new avenues of exploration.

Finally, the research focus is on the process of securing secondary resources; so we chose to highlight several anaerobic digestion projects (see Table 5) from the different organizations: Engie, Veolia and EMC2

When looking specifically at the centralized and farm model, Engie had more than 20 operational projects, Veolia had two operational projects, and EMC2 had one operational project. Initially, we prioritized projects offering extensive opportunities for engagement with various actors and stakeholders involved. The purposeful selection aimed to provide a thorough and detailed account. Consequently, we selected three projects at Engie, strategically chosen to illustrate Engie's trajectory and operationalization in anaerobic digestion projects: Methamoly, Caux Vallée de Seine, and Sibiom. At Veolia, we did not select any project due to the difficulties in having access to data and historically reconstructing its evolutions and development. Finally, we selected the first operational project at EMC2.

The selection of the four projects was derived not only from opportunistic access and readiness and availability of actors but each one was also meticulously representative of the strategic objectives and vision of the three organizations. Further details will be provided in subchapter 5.1 to explain project selection considering the strategy of each organization.

Organization	Case	Interviewees
Engie	Methamoly (6)	President of SAS biomethane plant (1); Investor (1); Project Manager Engie (1); Sales and Development Engineer Suez (1); Mayor (1); Director of Community of municipalities' Ecological Transition public service (1)
	Caux de Vallée de Seine (5)	Development manager Circular Economy, Industrial Ecology & Energy Transition at Territorial Development Agency (1); Business Developer Engie (2); Agricultural Development Manager Engie (1); Logistics and Transport Manager Engie (1)
	Sibiom (4)	Business Developer Engie (2); Biomethane Strategy Advisor Engie (1); Director of energy and sustainable solutions branch at Territorial Development Agency (1)
EMC2	Landres (5)	Agricultural Technician (1); Regional development manager (1); Project Manager (1); Agronomy Director (1); Operation Director (1)
Veolia	Méetha (2)	Anaerobic digestion founder and site operation manager (1); Responsible of Biological Treatments division (1)

Table 5 List of interviews conducted per organization and position

3.1.2 Secondary data collection

Secondary data are a vital component of the research materials used in this study. They come in various forms, including specialized scientific literature (see Table 6), proceedings from international conferences, official documents and reports issued by states, legislative and standardization texts, analyses by international organizations such as the OECD, IEA, ATEE, as well as promotional materials and presentations on specific projects. These data collectively provide a complementary asset to the primary data collected through interviews and observations. Access to the data was facilitated through various means.

The interviewees played a crucial role in providing access to secondary. During the interviews, the participants often referred to or provided examples from external sources to illustrate their points or support their arguments. These sources included industry reports, market analyses, regulatory guidelines, and organizational documents. By utilizing the knowledge and perspectives of our interviewees, we obtained valuable supplementary data that enhanced and enriched our primary data collection efforts.

Additionally, we conducted our own comprehensive online research, which involved extensive searches across various academic databases, digital libraries, and reputable websites. On the one hand we could collect additional information related to the four projects. For instance, we had access to press releases and online communications. Furthermore, we had access to the official public documents to comply with the French regulations for classified installations (ICPE) that include technical plans of the installation, site location plans, consultation reports from relevant authorities such as permit construction, public meetings with citizens and evidence of financial guarantees. On the other hand, by using specific keywords related to our research topic, we identified and accessed relevant scientific articles, conference proceedings, official reports, and regulatory documents. This systematic approach ensured comprehensive coverage of available secondary sources, enriching our understanding of the research context, and informing our theoretical framework. We were also able to attend several conferences with members of the community (Table 22, Annex). This enabled us to find out about other actors and anaerobic digestion projects.

Type of secondary data	Examples
Scientific	Articles from specialist journals such as <i>Journal of Cleaner Production</i> ,

bibliography	<i>Journal of Environmental Management, Business Strategy and the Environment, Bioresource Technology, etc.</i>
Conferences and webinars	<i>The circular economy in the context of a limited supply of biomass - Ways forward to address biodiversity loss and climate change</i> (European Commission and the European Economic and Social Committee, June 2023) <i>Les modèles d'affaires pour le biométhane</i> (OFATE, May 2023), etc.
Official Reports	From actors in France (ATEE, ENEA, ADEME, France Stratégie, GRDF, Comité de Filière Stratégique) or abroad (EBA, OFATE). Examples: <i>Méthanisation, feuille de route stratégique</i> (ADEME, 2017); <i>Biomasse agricole : quelles ressources pour quel potentiel énergétique ?</i> (France Stratégie, 2021); <i>Tracking biogas and biomethane deployment across Europe</i> (European Biogas Association, 2023) French Senate information reports: <i>Méthanisations : au-delà des controverses, quelles perspectives ?</i> (Report No. 872 - 2020-2021); Parliamentary reports: <i>De la biomasse à la bioéconomie : une stratégie pour la France</i> (Report No. 380 - 2015-2016)
Public documents (ICPE) of projects	Centrale Biométhane Caux Vallée de Seine : https://www.seine-maritime.gouv.fr/Actions-de-l-Etat/Environnement-et-prevention-des-risques/Enquetes-publiques-et-Consultations-du-public/Consultations-du-public/00-ENREGISTREMENT-ICPE/2020/SAINT-JEAN-DE-FOLLEVILLE/Centrale-Biomethane-Caux-Vallee-de-Seine-methanisation-Epandage-digestats-52-communes-76-et-27
Legislative and regulatory texts on anaerobic digestion	European Directives, Articles on Code of Environmental, Law and Regulations, Decrees on LegiFrance Examples: <i>ICPE heading 2781, specific to methanisation</i> ; <i>The anti-waste law for a circular economy (AGEC)</i> ; <i>The French Act on Energy Transition for Green Growth (LTECV)</i>
Internal Documents from Engie, Veolia and EMC2	Access to Biogas Community of Practice: database of internal documents regarding feedstocks, operation and management of plants, guidelines, and business development - Technical description of plants available online (Engie) PowerPoint presentations and minutes of the public consultation meeting for a project - Technical description of plants available online (EMC2) Technical Reports on anaerobic digestion and Report on Anaerobic digestion Task Force - Technical description of plants available online (Veolia)

Videos and press communication	Presentation of anaerobic digestion entities. Examples: https://www.emc2.coop/actualite/la-premiere-unite-de-methanisation-de-la-cooperative-emc2-inauguree-a-landres/2638/ ; https://www.youtube.com/watch?v=7UUINOv1lZw Interview with stakeholders in anaerobic digestion entities Examples: https://www.youtube.com/watch?v=L2w0dKOV9yY ; https://www.youtube.com/watch?v=Pgh_u2nZqpl Specialized magazine: Innovation24 Biogaz Magazine
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Table 6 Examples of secondary data sources

3.2 Triangulation and data saturation

Data triangulation is a fundamental practice in qualitative research (Eisenhardt, 1989; Yin, 2011). To uphold triangulation in this thesis, we employed several strategies. The heterogeneous nature of the data collected in this research, comprising both primary and secondary sources, facilitated triangulation—a method particularly crucial in qualitative inquiry (Dumez, 2011). It also involves cross-referencing data to ensure its relevance and to avoid reliance on a single perspective.

3.2.1 Diversification of sources and data

We intentionally diversified our sources and data by sampling and varying the interviewees across different sectors and positions within organizations (see Table 3). This approach, recommended by Dumez (2016), allowed us to compare viewpoints and obtain the most objective information possible. Given our proximity to the companies studied, which could potentially introduce researcher bias, triangulation was especially critical. Therefore, in addition to the contacts and documents provided by Engie, Veolia or EMC2, we actively sought information from other sources such as the internet, libraries, conferences, and personal networks to ensure a comprehensive perspective. Finding sources through other avenues was imperative for the validity of our research. Therefore, in addition to the contacts and documents provided by interviewees, we tried to explore other sources of information (via the internet, libraries, conferences, other contacts, etc.) and establish additional personal networks to enable a more comprehensive perspective comparison.

3.2.2 Cross-referencing data

We cross-referenced primary and secondary data, utilizing certain documents to supplement explanations. For instance, a conference on macroeconomic analysis on secondary resources enabled us to corroborate and verify interviews regarding the competitiveness of biological secondary resources and the challenges developers face in securing them. Similarly, administrative reports helped us examine regulatory developments, enriching our understanding of the role of regulations in facilitating access to secondary resources and guiding the transition towards specific circular models.

3.2.3 Validation of research findings

We validated our research exploration and findings by presenting our work internally to strategic committees. This was underpinned by an engagement with the companies, involving numerous exchanges through committees and multiple exchanges designed to probe research questions and put them through rigorous testing. Additionally, we designated specific representatives to ensure continuous contact. We can characterize our research as collaborative (Shani et al., 2007) with Engie and Veolia, but distinct from intervention research. Indeed, the objective is not to directly intervene and accompany an organization on a specific issue over an extended period (Aggeri, 2016). We also presented our work externally, in conferences for instance or in academic seminars. This helped ensure thoroughness and rigor. Table 21 in Annex outlines the presentations and their purposes.

3.3 Data analysis

Both primary and secondary data comprised a significant and diverse body of material, crucial to the depth and breadth of this study. Primary data, collected through evolving questionnaires, encompassed a spectrum of inquiries ranging from technical aspects of the anaerobic digestion process to organizational considerations surrounding plant governance structures. Similarly, secondary data varied widely, ranging from biomass analyses in France to national strategic initiatives and objectives.

Data processing was conducted manually, employing a variety of techniques tailored to the nature of the sources and the specific research objectives.

Firstly, we undertook a comprehensive review of all interview transcripts, engaging in attentive reading (“*attention flottante*”) to immerse ourselves fully in the content (Ayache & Dumez, 2011). Subsequently, using Excel, we assigned the main themes covered during each

interview, facilitating the organization of the data, and providing an initial understanding of the topics covered. The themes ranged from national anaerobic digestion strategies in France to regulatory frameworks, technological descriptions, project overviews, and organizational strategies. Similarly, secondary data were categorized in folders following the same categorization of themes. The last column of the Data Sources table (Tables 22, 23 and 24 in Annex) specifies how various sources were processed and used in the thesis manuscript.

Secondly, we grouped and linked parts of interviews that addressed similar overarching themes. This allowed us to write memos (Dumez, 2013). We thus synthesized the data into several memos enriched with PowerPoint presentations, and diagrams to fuel reflection. These memos included analyses on the technological aspects of the anaerobic digestion process, the landscape of anaerobic digestion in France, and the approaches to anaerobic digestion within the three organizations under study.

Thirdly, we conducted a detailed review of interviews specifically related to the projects under scrutiny and the interviews presenting the organizational strategies and objectives regarding anaerobic digestion. This meticulous examination involved coding clusters of phrases into thematic groups. The themes included partnerships, relationships, contracts, exchange modalities, local contexts, secondary resources, financing mechanisms, outreach strategies, skills and tools, key actors, project durations, uncertainties, etc.

Following our abductive approach between the field investigated and the theory (detailed in subsection 2.1) we were able to develop an analytical framework based on three main dimensions: Governance, territory, and the market. These dimensions have been recognized by scholars interested in the circular economy as pivotal in the implementation of circular business models. It was used as a guideline for analyzing our four anaerobic digestion projects. Thus, during this analysis, themes found in the third step were clustered under the three dimensions of the framework.

Upon developing a narrative of the development of anaerobic digestion in France, our aim was to present a chronological narrative that traces the development of four anaerobic digestion projects. We focused on three pivotal phases—project initiation, securing of secondary resources, and plot selection—to structure our narratives.

- A. Project initiation: This parameter delves into the foundational aspects of project initiation, aiming to unravel the intricate processes that mark the inception and

evolution of each undertaking. By chronologically mapping the developmental journey from initiation to operationalization, this analysis provides valuable insights into the challenges and corresponding solutions encountered along this critical timeline.

Initiating Actors: The examination begins with an exploration of the primary actors who instigate anaerobic digestion projects. These initiators may span a spectrum of entities, including governmental bodies, private enterprises, or collaborative ventures. Understanding the diverse origins of these projects is crucial for delineating the landscape of actors involved.

Development and strategic Incentives: Understanding the incentives that drive the development of anaerobic digestion initiatives is crucial. Whether these incentives are economic, environmental, or aligned with broader sustainability goals, this aspect sheds light on the motivations behind project initiation.

- The analysis extends to explore whether the strategies adopted by different initiators result in discernible differences in project outcomes. This includes examining variations in technology adoption, operational models, and project scopes.
- Evaluating the interdependencies arising from chosen strategies and project objectives is paramount. This involves understanding how the pursuit of specific strategies by one initiator may impact or be synergetic with the goals of other project instigators.

Interactions Among Initiators and Governance: Investigating how these initiating actors interact is pivotal. This involves scrutinizing the collaborative efforts, potential conflicts, and synergies that emerge during the phases of project development.

- The analysis extends to identify key figures or entities that play a pivotal role in steering the project. Determining who holds the reins in decision-making processes and project direction is instrumental in understanding the power dynamics within the initiatives.
- A comprehensive examination of the financial structures supporting the anaerobic digestion projects is undertaken. This involves identifying the principal contributors, mechanisms for funding, and the overall financial architecture shaping the initiation and preliminary stages of the projects.

B. Securing secondary resources: The examination of input security scrutinizes the critical aspect of resource acquisition, gauging the stability, reliability, and sufficiency of inputs crucial to project functionality. This investigation is designed to shed light on

the multifaceted challenges associated with securing inputs, offering a nuanced understanding of the strategies employed to overcome potential hurdles.

Existence of Competencies: The initial facet explores the presence of competencies crucial for obtaining "quality materials." This includes identifying and cultivating the necessary skills, resources, and operational activities required for effective input securing from collection and transport to negotiation and purchasing. This critical dimension explores the organizational changes and instruments implemented to foster resource securing.

- Instruments and approaches: The examination distinguishes between scenarios where material utilization occurs spontaneously and instances where the establishment of specific mechanisms and instruments is necessary to facilitate input procurement. scrutinizing the pricing strategies adopted during the procurement phase and assessing the economic value generated through the entire process.
- Network Handling Resources: This facet investigates the nature of teams responsible for the valorization of several types of resources. Understanding the roles, expertise, and collaboration mechanisms within these teams provides insights into the efficiency of resource handling.

Modalities of exchanges: Investigating the types of exchanges between the anaerobic digestion plant and the suppliers of secondary resources. This investigation first highlights how the actors organize to reach agreements.

- This analysis aims to identify and describe the several types of modalities possible with suppliers of secondary resources. It also serves to present the specificities of each, as well as the challenges and benefits inherent to them.

C. Specific localization of the anaerobic digestion unit: The selection of a plot represents a pivotal decision-making juncture, influencing project dynamics significantly. This parameter explores the criteria, considerations, and challenges involved in the strategic selection of the project's physical location, elucidating how these decisions impact the project's overall success.

Geographic dimension:

- Impact on Resource Provision: The geographic location of the plot significantly influences the availability and accessibility of resources. This entails an examination

of how the selected plot affects the ease of resource provision, considering factors such as transportation and proximity to resource suppliers.

- Impact on Valorization Mode: The geographic location can also shape the mode of valorization. Understanding how the selected plot influences the chosen method of transforming resources provides insights into the operational dynamics of anaerobic digestion projects.

Social dimension: The social dimension encompasses the network of actors present in the chosen location, considering their involvement in project development and social acceptance. Evaluating the existing network provides insights into potential collaborations, community engagement, and the overall social landscape.

3.4 Limitation and validity of research

Several methodological limitations have emerged during this research. We note limitations due to the context of the research, as well as the sample of interviewees (3.4.1), the complexity of the problem investigated (3.4.2), and finally methodological limitations (3.4.3).

3.4.1 Context and sampling limitations

Firstly, the strategic nature of the activity under study posed challenges in data collection, leading to potential biases. Confidentiality constraints hindered the acquisition of certain documents, while concerns about confidentiality, stemming from my position within the two organizations, restricted access to some interviewees. Additionally, our sample exhibited bias towards stakeholders involved in anaerobic digestion projects, with limited representation from secondary resource suppliers. Engaging with farmers proved challenging due to their time constraints, although we mitigated this limitation by involving agricultural cooperatives. Similarly, interactions with agro-industrial entities were limited, possibly influenced by the sector's dynamic and regulated nature. Accessing government authorities proved difficult due to their demanding political schedules. Additionally, regarding the four selected projects, discrepancies were observed in the number and profiles of interviewees, as well as the availability and type of secondary data accessed. While detailed information such as meeting minutes and business plans were accessible for some projects, it was lacking for others. To address these gaps, efforts were made to supplement the available data with information obtained online.

Finally, this work could benefit from greater precision by observing a more extensive range of anaerobic digestion models in France and abroad. Other countries may not utilize the same technologies, nor the same secondary resources. They might have different regulatory frameworks or employ diverse options for valorizing byproducts of anaerobic digestion. Expanding the scope to include a broader range of anaerobic digestion models, both domestically and internationally, could enhance the precision and generalizability of our findings.

3.4.2 Complexity of case

Secondly, we observe a limitation due to the complexity of the case study in itself. From the very start of this thesis, we were faced with the scientific complexity of this case in understanding a biological and technical phenomenon. Indeed, the diversity of technical processes and sizes of projects as well as all the different administrative procedures to develop them and the evolving regulations made it challenging for us to fully understand the nuances in the different models possible.

Another limitation arises from the lack of detailed quantitative economic data on prices of secondary resources concerning the specific projects we investigated. However, we mitigated this limitation by consulting macroeconomic studies and reports, corroborating the intricate process involved to secure secondary resources.

3.4.3 Methodological limitations

Furthermore, the longitudinal nature of the projects under investigation necessitated retrospective reconstruction of their trajectories. All the projects investigated were lengthy and were already underway when we began our study. Therefore, we had to retrospectively reconstruct the project trajectory based on accounts from involved actors. However, it is important to acknowledge that this approach may present informants in a favorable light as it relies on potentially selective memories. To mitigate this limitation, we employed triangulation by contrasting accounts from different actors involved in each project, and cross-referencing interviews with document contents. This approach enhanced the rigor of our analysis and allowed us to consider multiple perspectives. The initial interpretations of the findings were evaluated through short reports and presentations with interviewees, which allowed for the validation of insights and the gathering of additional perspectives.

Summary of methodology

Objective: Investigate the complex process of securing secondary resources for circular business models within the context of anaerobic digestion projects.

This chapter aims to present the methodology implemented throughout this doctoral research. We adopted a qualitative approach to investigate the organization of actors to develop models pertaining to the circular economy in large companies, more specifically to theorize the specificities of the intricate process by which they secure secondary resources and to expand the literature on the circular economy.

Approach

- The study of the anaerobic digestion process is of significant interest as it encompasses several technical and biological tasks. These include the flow of secondary resources in terms of both quality and variable quantities, which can prove to be challenging to access, as well as the flow of by-products that can be valorized in several ways. Additionally, the process involves organizational challenges that must be overcome by various actors and is subject to influence by several public policies that pertain to different sectors simultaneously. Lastly, the process also has social challenges, including the acceptance of the process within its geographic territory. Effective collaboration among stakeholders and the strategic alignment of interests are crucial. Consequently, anaerobic digestion can yield valuable insights.
- We employed an exploratory methodology based on the epistemological constructivist pragmatic paradigm, generating questions as they were constructed throughout the study.
- The study utilized a comprehensive and longitudinal approach to investigate the factors that contribute to securing secondary resources and their importance in the implementation of circular business models.

Collection of data and triangulation

Primary data:

- Semi-structured interviews;

- Site visit;

Secondary data:

- Bibliography;
- Reports, studies, guides;
- Internal documents;
- Legislative and regulatory texts;
- Webinars and conferences;
- Newsletters, blogs, and websites.

Data processing

- Material classifications;
- Content and discourse analysis;
- Longitudinal description and narration through monographs

Limitations

- Context and sampling limitations: The strategic nature of the activity led to data collection challenges and potential biases. Discrepancies in interviewee profiles and data availability for selected projects. Lack of detailed economic data on secondary resources required reliance on macroeconomic studies for validation.
- Complexity of the case: Scientific complexity and diversity of technical processes, project sizes, and regulations made understanding models challenging.
- Methodological limitations: Longitudinal projects required retrospective reconstruction of trajectories. Bias mitigation through triangulation and validation with multiple perspectives.

Chapter 3. The analytical framework

This section aims to introduce the three analytical perspectives mobilized and build the theoretical framework that will guide our analysis in addressing our research question of how secondary resources are secured within circular economy business models.

To shed light on our research question, as detailed in chapter 2, we chose to study projects implementing circular economy models from their inception until their operation and analyze the processes by which secondary resources are secured. Having chosen the project as a level of analysis and having opted for a longitudinal approach to investigate these initiatives, to analyze our cases we have considered analytical perspectives not only focused on securing secondary resources but more broadly on circular business model implementation. Therefore, in our analysis of these projects, we chose literature that provides analytical perspectives that enable a better understanding of the dynamics at play in the implementation of circular economy initiatives. Hence, the concepts of governance (1), territory (2), and market emergence (3) will constitute the analytical framework of our study.

The first analytical perspective refers to **governance**. A significant body of work on the establishment of circular economy initiatives emphasizes the governance structures put in place to support these circular endeavors and their specificities (Arfaoui et al., 2022; Schultz et al., 2023). The shift from a linear to a circular economy presents governance challenges in managing inter-organizational and inter-sectoral flows, transcending conventional boundaries (Brown et al., 2021). Scholars increasingly recognize the pivotal role of governance in navigating the complexities of inter-organizational collaboration and sustainable transitions. This recognition prompts us to explore the role of governance in securing secondary resources and how various governance arrangements help tackle this issue.

The first section of this chapter provides an understanding of governance models in the circular economy, examining theoretical frameworks and practical insights from participant-governed networks to lead organization-governed structures, each characterized by distinct attributes and facing different tensions (Bridoux & Stoelhorst, 2022; Provan & Kenis, 2007). We examine governance arrangements emphasizing collaborative governance characteristics as well as the role of facilitators in orchestrating circular projects (Cramer, 2020).

A second analytical perspective we develop relates to **territory**. The reasons justifying the inclusion of the territorial dimension in this study are twofold. Firstly, numerous authors contend that providing solutions to environmental challenges necessitates recognizing the deep-rooted relationship individuals have with the territories they inhabit (Raulet-Croset, 2021). Each territory presents unique environmental and social challenges that must be taken into consideration when implementing circular projects. Consequently, the design and effectiveness of governance arrangements in circular projects are significantly influenced by the territorial context. Secondly, territories gain heightened importance in circular projects, where secondary resources vary depending on the territory. Technical and biological resources are not easily accessible to actors wishing to develop circular activities (Aggeri et al. 2023).

Thus, a second section explores the complex relationship between the circular economy and territory, addressing the ongoing debate regarding the territorial dimension's theoretical foundation and scope. It then clarifies the multifaceted perspectives of territory, highlighting its evolving definition (Detchenique et al., 2023; Régent et al., 2021). The section presents various conceptualizations of territory and practical case studies, and then elucidates the proximities leveraged by actors (Torre and Rallet, 2005; Bahers et al., 2017) and mechanisms of territorial anchoring (Bousquet, 2014; Régent et al. 2021) of circular projects.

Finally, we focus on **market emergence** as a third analytical perspective. Secondary resources condition the economics of circular business models (Linder and Williander, 2017). Scholars emphasize the importance of markets for secondary resources in overcoming feasibility challenges within circular economy projects (Beulque, 2019). However, when setting up new circular models, these markets may not exist. We mobilize the concept of 'market arrangements' (Callon, 2013), as it provides valuable insights into key processes and conditions enabling the emergence of markets.

Thus, the third section of our analytical framework provides a theoretical understanding of five processes of market arrangements. Specifically, we examine markets as social constructions. Finally, we provide some insights on the emergence of some secondary resource markets, emphasizing factors and devices favoring their emergence.

In sum, an analytical framework is proposed that highlights the interconnectedness of these perspectives, allowing for a comprehensive analysis of circular economy projects, specifically aiming to highlight the process of securing secondary resources.

1. First analytical perspective on governance

“The point I am trying to make is that governance is governance, management is management, and every organization must clearly distinguish between them if it wants the two to work in harmony to achieve the institution’s mission.” (Dayton, 1998)

The transformative shift from a linear to a circular economy poses governance challenges in managing inter-organizational and inter-sectoral flows and cutting across conventional boundaries. Scholars in the circular economy field have increasingly recognized the pivotal role of governance in navigating the complexities of inter-organizational collaboration and sustainable transitions (Arfaoui et al., 2022; Schultz et al., 2023). Indeed, the governance of environmental and social matters within the context of the circular economy represents a multifaceted landscape of inquiry that delves into the intricate interplays between actors, policies, and practices.

Through a holistic examination of governance in the circular economy, this section aims to (1.1) provide an understanding of governance models and practical insights discussed in the literature and their implications for sustainable development and circular transition processes. Theoretical models of governance offer foundational frameworks for understanding governance dynamics in circular economy models. We present (1.2) various governance forms, from participant-governed networks to lead organization-governed structures, each characterized by distinct attributes and tensions (Assens & Courie Lemeur, 2014; Provan & Kenis, 2007). Also, based on empirical findings, and practical insights, we (1.3) delineate the contours of effective governance within the circular economy context as discussed by authors. Collaborative governance emerges as a central theme, encompassing attributes such as independence, hierarchical flexibility, and collective decision-making (Brown, 2021; Arfaoui et al., 2022; Schultz et al., 2023). Finally, we highlight (1.4) the roles of various actors, intermediaries, and governance facilitators in driving circular transitions (Christensen, 2021; Cramer, 2020; Girard & Nocca, 2019; Trevisan et al., 2022). From municipalities to private companies or individuals, diverse profiles of governance facilitators emerge, each playing a pivotal role in orchestrating governance in circular economy contexts.

1.1 Governance of environmental matters

The circular and sustainable management literature has started to intertwine its research with the literature on governance. This integration is evident in studies examining contexts involving sustainable management (Bridoux & Stoelhorst, 2022; Cramer, 2022) and circular management (Schultz et al. 2023; Arfaoui et al. 2022). Indeed, many societal challenges, such as those related to sustainability, are too intricate to conform to the formal structures of governance (Cramer, 2022).

Scholars in the CE field have recognized the benefits of adopting a governance perspective to analyze mechanisms for managing inter-organizational collaboration (Schultz et al., 2021). Farooque et al. (2019) emphasized the pressing need for research on collaboration in circular economy contexts. Similarly, Fischer and Pascucci (2017) specifically call for investigations into the main challenge faced by firms engaged in the CE transition, i.e., how to arrange collaboration and business relations. Nevertheless, Schultz et al. (2023) assert that governance should be the keystone beyond stakeholder relationships. Even though, studies have thoroughly investigated how stakeholder collaborations can operate more effectively in meeting the challenges associated with the transition to a circular economy (Kanda et al., 2021), Schultz et al. (2023) argue that the effective realization of the circular economy demands thorough stakeholder collaboration guided by innovative governance, characterized by novel approaches to instill order, manage conflict, and achieve mutual benefits. Recognizing that the transition to a circular economy involves a shared interest among diverse stakeholders, not all of whom maintain direct mutual relationships, they argue that governance, rather than relationships alone, must become the keystone of stakeholder collaborations in this field. This perspective does not undermine the importance of relationships but underscores their critical embeddedness in governance structures necessary to harmonize stakeholder interests (Schultz et al., 2023). Indeed, the radical shift in perspective from a linear to a circular economy confronts challenges in the governance and management of inter-organizational and inter-sectoral material and energy flows (Korhonen et al., 2018). Also, the governance of CE endeavors remains challenging due to the necessity of cutting across sectoral, scalar, and administrative boundaries (Heurkens & Dąbrowski, 2020). Thus, authors address the lack of understanding of how to organize the governance of CE implementation departing from conventional linear approaches (Cramer, 2022).

The study of governance in CE spans different contexts, reflecting its multifaceted nature. These investigations include geographic considerations, including subterranean spaces and

cities (Christensen, 2021; Fratini et al., 2019; Girard & Nocca, 2019; Hámor-Vidó et al., 2021). Corporate contexts are also being explored, such as in construction projects (Brown et al., 2021), the pharmaceutical industry (Schultz et al., 2021) and specific sectors such as the agri-food industry (Poconi et al., 2021). Circular supply chain management, as studied by Schultz (2021), further illustrates the different contexts in which governance can be investigated. Governance configurations are also studied in the public sector, with a focus on municipalities (Christensen, 2021), revealing institutional barriers to CE transitions and highlighting the need for new rules governing the interactions between the actors involved (Fischer & Pascucci, 2017; Ghisellini et al., 2016; Heurkens & Dąbrowski, 2020). At the network and system level, researchers such as Cramer (2020) and Christensen (2021) examine governance dynamics, while investigations in urban regions (Cong & Thomsen, 2021; Obersteg et al., 2019), cities (Christensen, 2021; Cramer, 2022; Fratini et al., 2019; Girard & Nocca, 2019), and at regional scales (Heurkens & Dąbrowski, 2020) contribute to a comprehensive understanding. Finally, the legal aspects of governance in the subsurface space resources sector are explored (Hámor-Vidó, 2021), adding another layer to the complex web of CE governance considerations.

Investigations into governance processes in the context of the circular economy have revealed three main levels (Bulkeley & Kern, 2006; Obersteg et al., 2019). Firstly, multi-level governance considers the different scales involved in characterizing governance processes related to the shift of urban regions to a circular economy, ranging from local and regional to national and supranational, and the interactions between these levels. Secondly, cross-sectoral governance considers the involvement of different public sector divisions connected to circularity, such as waste management, spatial planning, environmental planning, and business development. Thirdly, multi-actor governance focuses on the participation of actors from public or private enterprises, research institutions, and civil society (NGOs, citizen initiatives).

Hence, the study of governance in the context of the circular economy is an area of literature that is rapidly gaining attention (Schultz et al., 2023). Research has primarily concentrated on the public sphere, which encompasses regional governance and regulatory frameworks, and the private sector, which investigates the operations and coordination of companies and other actors. Our study aims to contribute to the evolving landscape of private governance. The investigation centers on the dynamics of private governance mechanisms in orchestrating collaborative efforts to overcome the issue of securing secondary resources, leading to the implementation of circular economy business models.

1.2 Network governance models

Circular economy initiatives often rely on networks that involve various stakeholders working collaboratively and cooperatively (Moggi & Dameri, 2021; Zucchella & Previtali, 2019). The design of new circular business models is enhanced by the engagement of various actors in a network (Lewandowski, 2016). These networks play a pivotal role in integrating circularity into business models because they offer a systemic view of all the actors involved and consider their interrelations (Schultz et al., 2021, 2023).

Bridoux and Stoelhorst (2022), building on the works of Klein et al. (2019), define governance as an organizational framework that supports cooperation among actors and regulates their interactions, irrespective of whether they are situated within or outside the boundaries of a firm, by delineating authority over resource management⁷, monitoring and sanctioning to resolve conflicts of interests in favor of joint value creation, and determining how the value created jointly is distributed. Scholars have sought to describe possible forms of governance for networks. One such form is participant-governed networks, which are characterized by a decentralized structure in which network members govern themselves without a separate and unambiguous governing body. This form is characterized by a high degree of trust and a small number of participants (Assens & Courie Lemeur, 2014; Provan & Kenis, 2007). Another form is lead organization-governed networks, where a single organization acts as a highly centralized network broker. This model is characterized by centralized structures, moderate trust, a moderate number of participants, and moderate goal consensus (Assens & Courie Lemeur, 2014; Provan & Kenis, 2007). The network administrative organization (NAO) is a separate administrative entity that manages the network and is characterized by centralized structures, moderate trust, a moderate to large number of participants, and moderate to high goal consensus (Assens & Courie Lemeur, 2014; Provan & Kenis, 2007). In addition, polycentric governance involves reduced hierarchical control, regulated coordination, and specialized competence frameworks for each pole (Lehiany, 2013).

Provan and Kenis (2007) specifically analyzed the impact of governance on network effectiveness, addressing the tensions inherent to each governance form. Three basic tensions in network governance were identified. The first tension involves the trade-off between

⁷ Resource management refers to the accumulation, development, and allocation of assets or inputs that an organization uses to achieve its goals. Resources can include tangible assets like raw materials, equipment, and facilities, as well as intangible assets like human capital, intellectual property, and financial resources.

achieving efficiency in decision-making and ensuring all network participants have a voice. The second tension is the trade-off between maintaining stability and being adaptable to changing conditions. The third tension is the trade-off between maintaining legitimacy within the network and in the broader external environment.

Bridoux and Stoelhorst (2022), building on Provan and Kenis (2007), argue that the two alternative forms of governance—shared and lead governance—are a more appropriate and viable option for managing cooperation in the face of collective action problems while creating value among stakeholders. These alternatives challenge the traditional model characterized by centralized decision-making, where the firm and its managers make decisions independently in a dyadic firm-stakeholder relationship. They argue that shared or lead governance operates in a decentralized, bottom-up and collective manner, allowing stakeholders (including suppliers) to participate in governance decisions. The authors outline the characteristics of each form of governance, drawing on the design principles from the work of Ostrom (1990, 2000, 2010). Their analysis addresses questions about the decision-makers in governance relationships, the monitoring and sanctioning of non-compliance with governance rules, the nature of conflict resolution, and the methods used to fairly distribute jointly created value. Other dimensions are also assessed such as the role of managers, the creation of trust, the complexity of joint value creation activities, and the degree of dynamism in such activities. Similarly, Assens and Coléno (2023) investigate two cases describing the management of common goods. They conclude that the success of distributed and administered network strategies relied on two main conditions: cultural proximity among the actors, creating a climate of trust to facilitate collaboration and overcome rivalry challenges, and industrial proximity, meaning the presence of all actors within a limited geography to facilitate operational collaboration (Assens & Coléno, 2023).

1.3 Governance characteristics based on case studies

While numerous studies have presented theoretical models of governance conducive to the effective implementation of circular initiatives, this section explores the empirical realm of governance in the circular economy by providing insights drawn from real-world cases. Through a thorough examination of practical applications, we aim to unravel the complex tapestry of governance configurations within the circular economy. In particular, our focus shifts towards delineating the diverse types of actor configurations and their associated

attributes, providing a nuanced understanding grounded in the practical dynamics of circular governance.

Some authors have defined attributes for good governance based on an investigation of 14 cities considered circular (Girard & Nocca, 2019). Upon analyzing the cases, they defined the governance identified as collaborative, adaptative, experimental and reflexive. According to the authors, the circular city adopts collaborative governance that fosters a bottom-up cultural approach. Public bodies engage with various stakeholders—including citizens, businesses, and civil society—to address collective demands and uphold transparent, legitimate, and open governance practices. This collaborative model not only reduces barriers in implementing circular initiatives but also redistributes responsibilities, sharing risks, failures, and successes, encouraging a shift from individualistic thinking to a collective mindset. Circular governance is characterized as reflexive, signifying a shift in perspective guiding policies and planning. This approach moves beyond traditional institutional frameworks, adapting to environmental, social, and economic challenges through self-critical reflection and continuous feedback processes. This attribute is also identified by other authors defining governance in circular cities (Dagilienė et al., 2021; Heurkens & Dąbrowski, 2020). The third attribute incorporates an experimental dimension, embracing the risk of failure and emphasizing the logic of experimentation. It encourages learning from failures and integrating them into governance discussions. The final attribute is adaptive, prioritizing the satisfaction of human needs amid evolving behaviors, objectives, and socioeconomic and environmental contexts. Unlike static and technocratic models, this governance approach embraces dynamic changes, identifies obstacles to change, and develops remedies. To support the transition towards circularity, a review and strengthening of current institutional capital, legislative frameworks, and regulations are necessary. Governance tools can identify financial incentives for new business models, requiring strong *ex ante*, ongoing, and *ex post* evaluations.

Arfaoui et al. (2022) presented a model that highlights the importance of stakeholder participation, collaboration, and bottom-up governance in promoting the circular economy. To this end, they analyzed five anaerobic digestion projects in the French regions of Brittany and Normandy, focusing on the involvement of different stakeholders and the regulatory framework supporting the development of the circular economy. The proposed model of governance arrangements conducive to circular economy (CE) development includes key factors. First, all relevant local stakeholders should be involved in CE development, with an identifiable leader using a facilitative leadership style. Prioritizing stakeholders with technological expertise will ensure optimal use of available technologies. Second, effective

collaboration through frequent information sharing and self-organizing activities that facilitate cooperation between actors is crucial. Third, actors need to develop collective decision-making rules that allow for collaborative and bottom-up governance, while respecting constitutional rules such as the existing legal framework, and sectoral policies.

After investigating the case of the European chemicals and plastics industry, Schultz et al. (2023) identifies three modes of governance facilitating collaboration in circular economy. The first mode is company-centric governance, which focuses on optimizing daily business operations and dyadic stakeholder management, emphasizing sustainability as a means to profit. The second mode is collective-oriented governance, which has two varieties. Industry-oriented governance involves establishing long-term relationships within a specific industry setting to improve sustainability standards and practices at industry level. This requires governments to establish sustainability-oriented boundary conditions and NGOs to advocate for them. The second type is cross-industry-oriented governance, which emphasizes long-term relationships with partners beyond immediate industrial and sectoral boundaries. This requires the co-creation of innovative governance structures and highlights their crucial role in enabling and maintaining collaboration with diverse stakeholders.

Christensen (2021) conducted an analysis of two case studies that focused on Danish municipalities and local stakeholders to close the material loop for demolition materials and textile waste. To gain insight into circular economy governance, the author utilized a framework developed by Kern and Bulkeley (2006). This framework categorizes modes of governance for municipalities and provides a nuanced understanding of how different forms of governance, such as self-governance, governance by provision, governance by authority and governance by enabling, can support the transition to a circular economy. It was suggested that municipalities can play a key role in supporting and facilitating a transformation towards a CE. Cramer (2022) proposes a model based on the analysis of CE governance across sixteen different countries. The model underscores the significance of harmonizing the strengths of two governance forms to effectively implement CE initiatives: public governance, which represents the traditional governmental role in formulating and executing policies and regulations to address societal and environmental issues, and network governance, which entails a collaborative approach involving diverse actors such as government agencies, businesses, non-governmental organizations, and community groups. The model identifies key drivers for network governance, including strong leadership, active stakeholder involvement, and proactive corporate participation. Additionally, it highlights

drivers for public governance, such as clearly defined policy targets, regulatory instruments, public-private partnerships, and robust monitoring and evaluation mechanisms.

Brown et al. (2021) analyzed 22 cases of collaborative circular-oriented innovation. Upon investigating, the authors introduce a comprehensive process model for collaborative circular innovation, highlighting governance as a pivotal aspect within the three-step construction of a “collaborative architecture” for projects, which also includes partner alignment and definition of a value capture model. Partner alignment represents the collaborating partners aligning themselves around a shared purpose and vision for the project. The definition of a value capture model specifies how the collaboration will capture and distribute value, including considerations ranging from intellectual property rights to risk and reward management. Finally, the definition of structural and procedural governance mechanisms entails defining the governance framework for the collaboration, encompassing both formal rules articulated in authoritative documents and informal norms and values. The governance dimension is integral throughout, ensuring effective coordination and implementation of collaborative circular innovation.

In accordance, authors in the CE have sought to investigate theoretical governance modes. Trevisan et al. (2022) analyzed 24 publications and argued that governance supports coordination and the sharing of value between actors, which is crucial for the success of a circular ecosystem. The study highlights that governance in a circular ecosystem should be non-hierarchical and collaborative.

The following table 7 summarizes the characteristics of governance identified as being conducive to circular activities.

Table 7 Literature on governance characteristics

Governance characteristics	Description of characteristics	Authors and Years
Collaborative	<p><u>Collaboration among private business actors</u></p> <p>Stakeholder involvement and proactive corporate participation</p> <p>Local stakeholders</p> <p>Involves strong leadership</p> <p>Leader possesses technical expertise</p> <p>Self-organizing and non-hierarchical</p> <p>Long-term relationships across and beyond sector</p>	<p>Cramer, 2022</p> <p>Arfaoui et al., 2022</p> <p>Cramer, 2022</p> <p>Arfaoui et al., 2022</p> <p>Arfaoui et al., 2022;</p> <p>Trevisan et al., 2022</p> <p>Schultz et al., 2023</p>

	Collective decision-making rules, both authoritative, formal, and informal norms Information sharing Financial incentives	Arfaoui et al., 2022; Brown et al., 2021 Arfaoui et al., 2022 Girard & Nocca, 2019
	<u>Collaboration between private and public actors</u> Setting standards and boundaries Tax adjustments, subsidies, grants loans Policy targets, public private partnerships, monitoring and evaluating <u>Collaboration with citizens</u> Enhances transparency, addresses collective demands, and ensures legitimacy. Inclusion through environmental education, information campaigns	Shultz et al., 2023 Cong and Thomsen, 2021 Cramer, 2022 Girard & Nocca, 2019 Cong and Thomsen, 2021
Reflexive	Reflective governance involving continuous feedback processes, beyond traditional institutional frameworks, adapting to environmental, social, and economic challenges.	Girard & Nocca, 2019; Dagilienè et al., 2021; Heurkens & Dąbrowski, 2020
Experimental and Adaptive	Embraces dynamic changes, learns from failure, and adapts to social and environmental needs.	Girard & Nocca, 2019
Firm-centric	Optimizes daily business operations, conventional stakeholder management, profit driven.	Schultz et al., 2023

1.4 On the profiles of CE governance facilitators

In exploring governance in the circular economy, scholars consistently highlight the crucial role of a neutral intermediary (Cramer, 2020), variously referred to as an orchestrator (Hansen & Schmitt, 2021; Trevisan et al., 2022), promoter (Hansen & Schmitt, 2021), broker (Cramer, 2020), or territorial cyclifier (Gontard et al., 2018). Recognizing that both local government and market actors face constraints in individually governing the transition to a circular economy, intermediaries emerge as potentially influential actors in orchestrating transformative change processes (Cramer, 2020). These facilitators play a critical role in overcoming barriers, which is supported by research highlighting the need for intermediation

to address challenges such as interdependence and power relations, which are crucial for creating, delivering and capturing value within a circular ecosystem (Kanda et al., 2021).

Facilitators of CE Governance: Public actors, Companies, and Individuals

Empirical research on CE governance often focuses on the role of municipalities and cities, as highlighted by Dagilienė et al. (2021). The findings of Girard and Nocca (2019) and Christensen (2021) affirm that municipalities play diverse roles as facilitators in the governance of circular economy initiatives. Specifically, Christensen (2021) elucidates the multifaceted involvement of municipalities, encompassing the utilization of their own assets, ownership of utilities and waste companies, and the enforcement of rules or economic regulations. Furthermore, municipalities were observed to actively engage in facilitation, coordination, collaboration, and encouragement to foster circular economy practices.

In contrast, Trevisan et al. (2022) and Zucchella and Previtali (2018) argue that facilitators often take the form of private companies. They assume the crucial responsibility of establishing legitimacy for circular initiatives, thereby strengthening relations with stakeholders, fostering collaboration, facilitating project development, and promoting corporate sustainability. Additionally, Trevisan et al. (2022) observed that facilitators may need to restructure their business models to align with the objectives of the circular ecosystem.

On the other hand, other scholars argue that facilitators are individuals. Hansen and Schmitt (2021) focus on the concept of brokers, drawing from Fichter's definition (2009, p. 359), which characterizes brokers as "individuals who actively and intensively support the innovation process." Similarly, Cramer (2020) refers to specific individuals who assume the function of system orchestration in regions.

Furthermore, others have described these facilitators in the CE context as "joint stakeholders' platforms and other joint structures" (Gontard et al., 2018).

Their multifaceted roles

The roles of facilitators in CE governance are dynamic, evolving over time and contingent upon specific content and context considerations. Transition facilitators in a circular context orchestrate processes that demand flexibility, where precise planning of all actions may be impractical (Christensen, 2021; Cramer, 2020; Hansen & Schmitt, 2021). The facilitator's role involves a critical assessment of the ecosystem, which occurs at two key junctures: during ecosystem creation and after the ecosystem has been structured (Trevisan et al., 2022).

Beyond generic roles such as strengthening relations with stakeholders and enhancing establishment of collaboration (Christensen, 2021), the roles of facilitators in circular economy governance have been meticulously examined within specific contexts. Gontard et al. (2018) argue that facilitators for a bio-circular economy should connect stakeholders and material streams. Hansen and Schmitt (2021), for instance, delved into governance within the cradle-to-cradle innovation processes, identifying various roles that facilitators may play, such as possessing in-depth knowledge about the organization's innovation and facilitating its comprehension inside and outside. Cramer (2020), after analyzing six regions transitioning to a circular economy, identified five distinct roles undertaken by facilitators in the context of regional governance of circular activities. These roles include bringing together diverse stakeholders and coordinating their efforts; focusing on the needs and preferences of users to develop solutions aligned with citizens' requirements; and working within existing regulatory frameworks to promote change and innovation.

Both Cramer (2020) and Hansen and Schmitt (2021) highlight the importance of having an entrepreneurial mindset, the ability to inspire collaboration, and the capacity to think from a systemic perspective. They also emphasize the crucial role of networking across industries and facilitating collective action. Hansen and Schmitt (2020) highlight in particular the importance of managing trust while synchronizing and sharing sensitive information. In contrast, Cramer (2020) emphasizes the importance of acquiring information about the regional business landscape and political culture within a specific region.

In summary, numerous authors have delved into the roles of facilitators in circular economy projects either in their governance or through intermediary positions, recognizing their significance in enhancing transformative change processes. These facilitators can be manifested in various forms such as individuals, companies, and public actors, and can undertake diverse roles including orchestrating collaborative efforts, promoting innovation, and navigating regulatory frameworks.

These insights will serve as a foundation for comparing and investigating similar roles and profiles within the context of circular projects manipulating biological secondary resources.

1.5 Analytical framework to investigate governance forms in circular economy projects

In conclusion, the evolving landscape of CE scholarship has begun delving into the dynamics of functional governance (Arfaoui et al., 2022; Schultz et al., 2023). The circular economy often hinges on networks comprising diverse stakeholders collaborating to enhance the design of new circular business models (Moggi & Dameri, 2021; Zucchella & Previtali, 2019). Scholars have delineated successful governance forms for such networks, namely shared and lead governance (Bridoux and Stoelhorst, 2022). We aim to investigate the involvement of stakeholders, specifically suppliers, in governance structures.

Furthermore, building on the above insightful explorations on governance characteristics describing the organization of actors to facilitate the transition to a circular economy, this study elaborates on collaborative governance models (Arfaoui et al., 2022; Brown et al., 2021). We mainly build on the characteristics of collaborative governance between private business actors as well as between private and public actors (Table 7) to analyze our cases.

Finally, we look at the role of facilitators, more specifically public actors, in facilitating and orchestrating governance structure in these private circular networks (Cramer, 2020). The current discourse pays attention to local actors' organization in companies. The literature also sheds light on governance by institutional structures essential for translating CE principles into effective political action or the active role that local administrations can play in shaping this transition at a territorial level. We decided to focus our research on the latter to identify the role of these public facilitators as well as to describe their profiles in circular projects implemented at a local level. We will analyze their roles with regards to the territorial dimension of projects that we will present in the next subsection.

2. Second analytical perspective on the territorial dimension

“While space is a physical reality, a receptacle of juxtaposed actors, territory is an acquired quality, a social construct, a particularly “fragile” complex organization. Territory is the flip side of space. It is a connection before it is a border.” (Bonnemaison, 1995)⁸.

The second analytical perspective we chose relates to the notion of “Territory” and its conceptualizations. The inclusion of the territorial dimension in the analytical framework for the study has been motivated by two primary factors.

First, numerous authors invoke the concept of territory when addressing environmental and social management issues. Authors contend that providing solutions to environmental challenges requires recognizing the deep-rooted relationship individuals have with the territories they inhabit (Latour, 2017). Indeed, environmental matters can be considered as territorial because they appear in a specific context, precise localization, and require the involvement and interactions of local actors (Raulet-Croset, 2021). Integrating the local and territorial dimensions into project development becomes a key condition for achieving positive economic and social development (Maillefert & Robert, 2020). Consequently, the design and effectiveness of governance arrangements in circular projects are influenced significantly by the territorial context (Arfaoui et al. 2022). Thus, Christensen (2021) underscores the pivotal role of the local context in determining effective governance forms for circular economy transitions, stressing the need to tailor governance strategies according to the specific needs, resources, and stakeholders within an area. Furthermore, the significance of adopting an analytical perspective emphasizing the territory became evident during the examination of the anaerobic digestion projects under scrutiny in our study. The territorial dimension gains importance in such circular projects, where the secondary resources and the actors involved vary depending on the territory.

The second factor driving the inclusion of the territorial dimension is related to the ongoing debate regarding the spatial and territorial dimension of the circular economy.

⁸ Own translation of “Alors que l'espace est une réalité physique, un réceptacle d'acteurs qui se juxtaposent, le territoire est une qualité qui s'acquiert, un construit social, une organisation complexe particulièrement « fragile ». Le territoire est l'envers de l'espace. Il est un lien avant d'être une frontière”

Despite the inseparability of the circular economy from a geographic area due to the circulation of secondary resources on local or global levels, there is still no consensus on the territorial dimension's theoretical foundation and scope (Aggeri et al., 2023). This lack of consensus persists despite the crucial role the territorial dimension plays in ensuring the ecological and social transition of territories (Dermine-Brullot & Torre, 2020). The debate extends to whether circular activities extend beyond geographic isolation or remain predominantly localized and regional (Masi et al., 2017).

However, handling the concept of territory is challenging. Territory is a complex and multifaceted concept that has evolved over time (Paquot, 2011). In the neoclassical vision of the economy, territory is apprehended as a resource to exploit. In such a perspective, the territory is “a receptacle of activities”; it is considered a simple location endowed with factors of production (Asselineau, 2023). This understanding of territory as an exploitable resource is not unanimous. Indeed, many researchers, thinkers, and philosophers criticize this vision of the territory. Few works have succeeded in broadening the perspective of territory beyond the mere dimension of a simple location with factors of production (Asselineau, 2023). It can be understood as a geographic space appropriated and invested by individuals or social groups, possessing its own identity defined by geographic, political, economic, social, and cultural criteria.

We align with researchers broadening the concept of territory. In this section we first shed light on the current debate on the circular economy and territory (2.1). Then, (2.2) we present the analytical perspectives of territory in management literature. Although the research on strategic management of territories is recent, it has been instrumental in examining territorial perspectives (Albert-Cromarias et al., 2023; Régent et al., 2021). Strategic management literature offers analytical perspectives to comprehend the intricate approaches at play within a territory, emphasizing the importance of its resources and the diverse interests of its actors. Some authors have started to explore the territory's dynamics to understand how to implement sustainable projects, to identify the conditions for success, to organize collective action in a territory, and to create a competitive advantage (Maillefert & Robert, 2020; Raulet-Croset, 2021). Departing from the mere geographic and spatial dimension of territory, we present (2.3) the framework of proximities developed by Torre and Rallet (2005) supplemented by Bahers et al. (2007), which highlights relational interactions resulting from the environmental, political, and economic configurations of the territory. Finally, the section also presents (2.4) the approaches discussed in the literature for anchoring projects locally and their contributions to the development dynamics of a territory.

2.1 The debate on the spatial dimension of the circular economy

Links have been established between territory and strategic management, as well as between territory and environmental and social management. It is tempting to draw connections between territory and the circular economy. In his book “Prisoners of Geography,” Marshall (2016) presents a compelling argument about how geography acts as a crucial force in shaping the destinies of nations and their interactions on the global stage. Throughout the book, he discusses how geographic factors such as mountains, rivers, oceans, and natural resources have a significant impact on a nation’s development, power dynamics, geopolitical strategies, and human social development (Marshall, 2016). Similarly, geography and space have an impact on the development of circular activities. Indeed, in delimited spaces or specific areas of land, the supply and handling of valuable secondary resources that are easily accessible, pure, and that meet customer needs become a major challenge for all circular economy actors (Aggeri et al., 2023). In contrast to the linear model, these secondary resources are not easily available due to a lack of adequate infrastructures, optimized logistics, and organization.

Some authors argue that current developments driven by sustainability challenges are giving rise to circular activities relying on ecosystems anchored in a territory (Detchenique et al., 2023). Aggeri et al. (2023) introduce the concept of strong circularity, whereby the economy is integrated within local territories. They identify the local dimension as a key practical aspect in the success of operationalizing circular approaches within organizational and territorial management situations. Similarly, Bahers et al., (2017) and Durand et al., (2016), confirm that the territory is essential for applying the principles of the circular economy. This aligns with the conclusion that the effective deployment of CE policies occurs when considering a territorial network (Dermine-Brullot & Torre, 2020).

Nevertheless, a debate exists concerning the local and territorial dimension of the circular economy. Indeed, there remains an ongoing discussion regarding circular activities on whether they extend beyond geographic isolation (Masi et al., 2017) or remain predominantly localized and regional (Aarikka-Stenroos et al., 2022; De Angelis et al., 2018).

Authors are working on clarifying the localized character of the circular economy (Torre, 2022). In one study, authors noted that some waste is managed mainly locally (heavy, putrescible, or final waste) (Durand et al., 2016). This raises the question of the environmental

efficiency of the treatment methods adopted, which relates to this localized approach. Contrastingly, other waste with a high added value or hazardous waste will mainly be managed remotely on a global scale, to meet highly technological treatment processes and benefit from economies of scale. The correlation between the principle of proximity and that of the hierarchy of treatment methods can then be discussed.

Furthermore, Dermine-Brullot & Torre (2020) explore the place of space and the territorial dimension in CE processes, as well as their contribution to the sustainable development of territories. The authors examine the territorial roots of the major circular economy strategies defined by French public authorities, more specifically the ADEME, focusing on industrial and territorial ecology. They point out that the spatial dimension is often absent from responsible consumption and supply strategies, but that territorialized approaches can emerge thanks to initiatives such as “ressourceries,” run by local players. They argue that functional economy as well as industrial ecology are amongst the most local circular activities.

Alongside the short loops of repair, maintenance, and the economy of functionality, where short response times justify that these activities are locally organized, there are long loops, both for the recycling of certain materials that require mass volumes and processing in large industrial units (Aggeri et al., 2023). Indeed, some circular activities, such as the globalized market of second-hand smartphones, the recycling of metals, and the second-hand markets for certain high added-value products. There is a need to concentrate secondary resource flows towards large-scale processing and recycling units whose economic viability presupposes scaling up with long traveling distances to find outlets for these high added-value products. The local and territorial development dimension of the CE is in these cases totally absent.

Studies aiming to clarify the debate on spatial patterns on biological flows in the circular economy are burgeoning. Indeed, as mentioned in the previous chapter, the literature has not discussed biological streams as much (see chapter 1. Part 2.3). The management of biological resources exhibits notable discrepancies, with some being handled at local levels and others at a global scale. This divergence is influenced by multifaceted factors, as evidenced by recent scholarly work. Wohlfahrt et al. (2019) underscore the intricate spatial patterns inherent in biological flows spanning various scales, from local initiatives like collective heating systems or on-farm energy production plants that utilize locally sourced biomass to large-scale international biofuel production units that process biomass feedstocks from different regions to produce biofuels for a global market. Other authors highlight the escalating demand for bio-resources due to the promotion of the bioeconomy, which exerts globalized demands with projections indicate a doubling of global biomass demand by 2050 (Liobikiene et al., 2019).

However, localized constraints exist, particularly in regions like Europe where local biomass availability is limited. This is exemplified by the global trade of wood pellet imports into the EU, further underscoring the interplay between local demand and international supply (Wohlfahrt et al., 2019). Managing biomass flows necessitates the development of logistical infrastructures capable of accommodating diverse spatial frames and fluctuating production and consumption times (Wohlfahrt et al., 2019). The spatial management of biomass is further complicated by logistical challenges, such as the scattered distribution of biomass feedstock resources and the critical issue of biomass storage. Adapting local and global management to accommodate varying biomass feedstock characteristics, supplier strategies, and market dynamics is crucial for operational flexibility.

Finally, authors argue that uncertainties about the adequate integration of spatiality in sustainability approaches such as the circular economy, arise due to the schematic representation of sustainable development in terms of the three pillars (environmental, economic, and social) leaving little room for the spatial dimension (Dermine-Brulot & Torre, 2020). They advocate for the inclusion of the spatial dimension in CE discourses to address these uncertainties. Indeed, the authors argue in response to these uncertainties that including the spatial dimension could lead to better proposals for policies and practices related to the circular economy (Dermine-Brulot & Torre, 2020; Liobikiene et al., 2019; Wohlfahrt et al., 2019).

To contribute to the debate surrounding the circular economy and its local and territorial dimensions, it is crucial to clarify the conceptual and analytical framework surrounding the notion of "Territory" within management literature.

2.2 Analytical conceptualizations of territory

With the evolving perspective that portrays territory as a strategic variable (Torre, 2002), several authors have conducted a comprehensive review of definitions in strategic management to frame the ensuing discussions. For instance, Régent et al. (2021) highlight the existence of three perspectives: Territory as a provider of specific resources, territory as a symbolic and relational space, and finally, territory as an encompassing structure housing a set of resources and interrelated actors.

In the first conceptualization, territory is perceived as a geographic location with directly exploitable physical or economic characteristics. It is considered a space providing resources that can take various forms and be categorized into two types: generic resources and specific

resources. Specific resources allow territories to differentiate themselves and can be termed territorial under certain conditions. This approach emphasizes the differentiation of territories based on their specific resources and their capacity to valorize them. In the second conceptualization, territory is understood as an organized space shaped by the relationships forged among actors. It is perceived as a social construction where the connections between actors matter more than the location itself. Territory is studied in terms of actors and their interrelations, characterized as a socially delimited link endowed with constructed resources. This approach underscores the importance of relationships among actors in understanding territorial development. In the last conceptualization, territory is apprehended both as a physical space (the location) and as a set of relationships, symbols, and projects generated by actors (the link). It is considered an encompassing structure housing a set of resources and actors. This approach reconciles the two previous ones by highlighting the interaction between actors and the territory, emphasizing that actors and territory co-construct each other, mutually influencing one another. This conception underscores territorial governance and the combination of territorial dimensions (links and location) conducive to innovation.

The conceptualizations surrounding territory in strategic management expand beyond these perspectives. We identify an additional perspective explored by authors emphasizing the territory as a catalyst for innovation (Detchenique et al., 2023). In their article, they posit that innovation—particularly collective innovation—requires frequent interactions, face-to-face engagements, and fluid, interactive discussions. Beyond the physical interaction essential for innovation, it is also paramount to have a relational interaction to share values, coordination rules, and knowledge.

Accordingly, authors argue that these interactions are facilitated by the territory. Indeed, the territory benefits from what is known as geographic and cognitive proximity resulting from it (Torre & Rallet, 2005). Geographic proximity underscores the influence of the physical environment and spatial arrangements on economic interactions and coordination. It refers to the physical closeness or nearness of economic actors or activities in a specific geographic area. Organizations benefit from geographic proximity in various ways. This proximity manifests in different forms, such as easy access to local resources, frequent face-to-face interactions, rapid circulation of information and ideas, and the creation of local social and professional networks. Indeed, geographic proximity enables organizations to communicate more easily, collaborate more closely, and exchange knowledge, information, and resources more effectively due to physical proximity. By being close to each other, organizations can reduce transaction costs related to travel, logistics, and remote coordination. This can lead to

improved operational efficiency and cost savings. Finally, geographic proximity promotes the development of strong social and institutional relationships among local actors, which can enhance trust, cooperation, and solidarity within the local economic community. Geographic proximity can contribute to the success and development of companies in a local economic environment.

In contrast, Torre and Rallet (2005) underscore another type of proximity based on a relational dimension: Organized proximity refers to an organization's ability to facilitate interactions and coordination among its members, regardless of the physical distance separating them. It involves coordination and interaction mechanisms not confined by physical distance. It encompasses cognitive and social links, utilizing organizational structures, networks, and institutional arrangements to facilitate interactions and coordination over extended distances. Torre and Rallet (2005) argue that while geographic proximity fosters local interactions, it must be complemented and activated by organized proximity. Negative consequences such as pollution, noise, and conflicts among actors sharing the same space can result from geographic proximity. These externalities can harm the environment, quality of life, and social relations in the region, leading to tensions and conflicts among economic actors competing for limited resources or customers. Organized proximity plays a role in mitigating these negative aspects through the establishment of regulations, effective governance mechanisms and rules within organizations. It thus strengthens coordination and communication mechanisms to manage interactions with geographically close actors.

In conclusion, building upon the conceptualizations of these authors, territory is conceptualized as an encompassing structure housing a set of resources and interrelated actors and as a catalyst for innovation. These actors can leverage territorial proximities, which are either related to geographic or organized proximities, leading to the development of social and economic relationships.

2.3 Relational proximities and the circular economy

Several authors emphasize that circular models emerge by relying on networks and communities involving different actors who collaborate and cooperate on a specific territory (Moggi & Dameri, 2021; Zucchella & Previtali, 2019). The firm-centric viewpoint being insufficient, the adoption of a network logic is highlighted as a particularity of the effective implementation of circular models (Beulque, 2019; Micheaux, 2017). Moreover, the actors within a given territory who may engage in circular projects are not consistently uniform and

have diverse competencies (Ayrault, 2022; Aggeri et al. 2023), implicating various modes of network organization tailored to address distinct requirements (Provan and Kenis, 2007). In addition, in circular projects, resources are variable depending on the territory (Arfaoui et al., 2022) more specifically technical and biological resources are not easily accessible for actors wishing to develop circular activities (Aggeri et al. 2023). Scholars underscore the importance of cultivating precise and specialized competencies to handle the secondary resources essential for the functioning and sustainability of circular business models (Beulque, 2019; de Arroyabe et al., 2021; De los Rios & Charnley, 2017; Straub et al., 2023). Thus, it is argued that circular activities result in increased relational territorial interdependencies between actors manipulating resources available on a territory (Beulque, 2019).

Proximities that can be leveraged in relation to a territory do not only relate to a geographic proximity between actors, but also to an organized proximity that has been developed between actors cooperating on a territory. Building on Torre and Rallet (2005) and expanding relational proximities in the specific case of waste management, Bahers et al. (2017) differentiate environmental, politico-administrative, and socioeconomic proximities. The authors argue that these proximities are developed and leveraged when implementing local circular activities.

Environmental proximity considers the environmental impact of activities on a territory while respecting the local ecosystem and limiting transport and the exploitation of natural resources. Bahers et al. (2017) state that, in the context of waste management activity, analyzing environmental proximity consists of assessment methods such as the carbon footprint to minimize environmental impact. This approach aims to reduce the overall environmental footprint of waste by promoting treatment solutions that limit greenhouse gas emissions and ecosystem impacts. Hence, environmental proximity provides a crucial perspective for more sustainable and environmentally friendly waste management.

Politico-administrative proximity refers to the way in which public actors, such as local communities, inter-municipal associations, and urban communities, address environmental matters, taking into account socioeconomic development and local citizen interests. The actions of public actors are governed by regulations and competencies defined by legislation, directly influencing how they address waste management issues for instance by ensuring waste collection, transportation, or treatment solutions. Thus, politico-administrative proximity first entails the consideration of prevailing public policies and regulations within the territory and their appropriation by local public actors.

Finally, socioeconomic proximity involves considering the territory's social and economic development dynamics. It entails taking into consideration social and technical issues as well as the economies of scale linked to the circular activity to be implemented on a territory. Therefore, integrating socioeconomic proximity offers a relevant aspect to explore potential links between circular activities and local economic or social development.

By intersecting these additional dimensions of proximity, Bahers et al. (2017) seek to understand how actors can better appropriate the territorial issues of CE activities.

2.4 Territorial anchoring dynamics based on case studies

Another perspective emphasizes that actors can engage in a process of relating the activities they develop to the territory in order to facilitate and strengthen them. This is known as territorial anchoring. Bousquet (2014) defines territorial anchoring as *“the process and result of interactions between a company and its territory, based on the desire to collectively create specific and localized shared resources, enabling a company to remain in place for a long period”* (p. 20.)⁹. Régent et al. (2021) defines this anchoring as *“a unique process that can be assimilated to collective action, carried out by a set of actors of diverse nature and which aims to solve novel productive problems.”* In recent studies, there is a focus on the operational aspects and mechanisms addressing how organizations establish their presence in territories in response to environmental or social imperatives.

In this section, we identify mechanisms of territorial anchoring discussed by authors based on case studies. We present cases examining the mechanisms of territorial anchoring employed: (1) in the creative sector by individual entrepreneurs; (2) in collective action between the state and metropolises for air pollution management; (3) in three startups offering solutions for the collection and resale of used edible oils and fats, the installation of beehives on company premises, and the development of a digital platform for short-circuit food distribution; (4) in the education sector to develop a rural higher education institute; and (5) in a large company in the energy sector.

⁹ *Own translation of ‘ le processus et le résultat d’interactions entre une entreprise et son territoire, fondées sur la volonté de créer collectivement des ressources communes spécifiques et localisées, permettant une longue période de sédentarité d’une entreprise’*

The first case is analyzed by Loup and Leyronas (2021). They investigate the territorial anchoring of craft artisans in Pézenas, a small town in the southern part of France renowned for its rich cultural and artistic history, as well as significant architectural heritage. The authors aim to enhance our understanding of territorial anchoring from the perspective of artisans (Loup & Leyronas, 2021). They emphasize how they elucidated the mechanisms and dynamics by which these artisans anchor their activity in Pézenas. The authors examine the interactions between entrepreneurs and the territory, both individually and collectively, within a dynamic framework. They provide a comprehensive insight into the territorial anchoring of this craftsmanship by artisans in Pézenas, detailing how they establish firm territorial roots through a multifaceted approach. These artisans leverage the natural resources available within their territory—such as soil, wood, or stones—to create their distinctive works. They also draw on local techniques and know-how to produce unique and authentic products. To infuse their creations with inspiration from local stories, myths, and narratives, artisans weave a cultural tapestry that reflects the distinctive identity of the territory. Active engagement with local stakeholders such as craft industry coordinators, municipal advisors, and association leaders, is pivotal in their strategy. By doing so, artisans can enhance their business and broaden their networks within the community.

In the second case study on the improvement of air quality, authors underline the advantages of collaboration between stakeholders and “management chemin faisant” (on-the-fly management) as mechanisms favoring collective action in the public sector (Fiore & Hernandez, 2023). In fact, their case study highlights a state injunction. In concrete terms, it is the metropolises that are responsible for drawing up policies for their territory to implement and coordinate climate, air, and energy policies in response to the State’s demand. In this complex context, i.e., at territorial levels involving a high degree of interdependence between players, the authors argue the benefits of both types of management: collaborative and “chemin faisant.” Nevertheless, they also emphasize the role of the State, which remains ‘master of the game’ in orchestrating collective action across the whole territory.

Similarly, in a third research project, Maillefert and Robert (2020) looked at collective environmental organization by observing three private enterprises in the Hauts de France region. The main question was what factors contribute to the success of these sustainable business models, as well as the challenges or barriers that may prevent them from being effective and lasting in the area in which they are established. The researchers conclude that the ability to create a network of players in the area that encourages the hybridization of

resources, as well as the ability to institutionalize the value creation process, are essential to the success of these businesses.

The fourth case study represents an investigation on the implementation of a higher education institute in a rural area that responds to societal challenges. Asselineau (2023) manages to discern the conditions and mechanisms necessary for the success of this project associating firms and territories. In fact, this case study of the Institut Tramayes project shows that managing a sustainable and responsible regional dynamic appears possible if certain conditions are met: the intention to transform, through the active willingness and collaboration of private and public players to find and implement solutions, the expression of a shared vision, openness to a variety of partnerships, access to skills and resources, and finally a logic of openness, collaboration, and networking. More specifically, it stresses that this local cooperation can take the form on the one hand of material support (provision of premises or land), and on the other hand of local network exchange systems bringing players together.

The last case study explored how big energy companies are adjusting their strategies in response to the climate crisis (Daniélou, 2022). In this work, Danielou (2022) focuses on a multinational energy corporation dealing with the practical effects of climate change on its presence in different territories, particularly marked by its carbonized energy assets and infrastructure. As climate change makes these assets less suitable for the current environmental conditions, the company is reassessing its standing in these territories. Danielou's research investigates the specific mechanisms, "tactics" and methods the company is using to reposition and "re-anchor" its business strategically in response to the changing landscape driven by the need for decarbonization. He emphasizes the essential role played by business developers, acting like "brokers," in creating stability for the company in new locations that support its shift toward "anchoring" decarbonized initiatives. These intermediaries are crucial in establishing new relationships with territories and making sure the company's decarbonized energy assets are smoothly integrated. Danielou (2022) underscores their role in preparing a suitable territory, including transforming an unfamiliar landscape into a known one and convincing managers that it is the right fit. He highlights the semiotic work done by these business developers, using tools like reports and discourses to effectively translate abstract projects into practical realities for the company in new territories.

Table 8 summarizes the findings from the five case studies, illustrating diverse strategies employed by different entities to establish and maintain territorial connections as well as the outcomes.

Table 8 Mechanisms of territorial anchoring in five practical cases

Cases	Case 1 (Craft Artisans)	Case 2 (Air Pollution Management)	Case 3 (Startups)	Case 4 (Rural Higher Education Institute)	Case 5 (Large Energy Company)
Description	Craft production and artisanal work.	Air quality improvement initiatives.	Solutions for environmental sustainability.	Development of a rural higher education institute.	Energy sector operations and adjustments.
Primary focus	Individual entrepreneurs and their craft.	Collective action for public health benefits.	Innovative solutions for local environmental issues.	Collaborative local education initiatives.	Local corporate strategic response to global issue of climate change.
Primary territorial anchoring approach	Intensive engagement with local resources, techniques, and narratives.	Collaboration between local stakeholders and policy implementors.	Engaging with local resources and networks for sustainable business models.	Development of educational infrastructure and programs through shared vision, partnerships, and resource mobilization.	Integrating local business strategies in response to climate change.
Key local actors	Craft artisans, industry coordinators, municipal advisors, association leaders.	Public sector, organizations, metropolitan authorities.	Entrepreneurs, local players, environmental organizations.	Public and private partners, educational institutions, local communities.	Company executives, business developers, territorial stakeholders.
Outcome	Establishment of firm territorial roots for craft production.	Improved air quality and policy implementation locally.	Development of local sustainable business models and environmental solutions.	Establishment of a local educational infrastructure and community engagement.	Strategic local realignment and global decarbonization efforts.

All these cases demonstrate diverse mechanisms of territorial anchoring by leveraging resources and engaging with actors and networks within the territory. Nevertheless, there is a significant difference in outcomes between the cases focused on sustainability issues and the first case, which does not specifically address any environmental or social issues within the territory. In essence, all cases utilize mechanisms of territorial anchoring to engage with local resources and actors. However, the cases that focus on sustainability issues tend to have broader and more far-reaching impacts, which can improve the overall status and sustainability of the territory beyond the immediate operational activities of the organizations involved. In the cases of managing air pollution, offering environmental solutions, and developing rural education institutes, it is important to improve the operational activities of organizations while also contributing to the overall well-being and sustainability of the territory. However, in the first case, which involves craft artisans, the emphasis is primarily on improving the operational activity of individual entrepreneurs and their craft production. In line with these observations and beside the exploration of the mechanisms to embed circular projects locally, other authors have investigated the social and environmental contribution the circular economy makes to the territory. Indeed, many acknowledge the circular economy's advantages of boosting economic activities locally (Ellen MacArthur Foundation, 2013) and enhancing job creation within a territory (Torre, 2022).

2.5 Analytical framework to investigate territorial anchoring and proximities in circular economy projects

To conclude, the literature provides a solid theoretical foundation. This research recognizes that the territorial dimension, while often implied in theoretical approaches to the circular economy, is addressed differently as a determining factor for the success of these activities (Bahers et al., 2017). Our investigation will be based on the distinct perspectives of territory outlined in the preceding paragraphs conceptualizing territory as an encompassing structure housing a set of resources and interrelated actors and as a catalyst for innovation (Detchenique et al., 2023; Régent et al., 2021). Firstly, the research considers territory as housing interrelated actors and examines their relationships and interactions, with a particular focus on relational and interorganizational proximities. This conceptualization allows the exploration of circular models emerging through local networks and communities within territories. Secondly, the role of territory as a catalyst for innovation is explored, including its

innovative capacity and the implications on the development of the circular economy. Lastly, territory is viewed as an encompassing structure that houses a set of resources. The analysis aims to examine the impact of available resources on the development of circular initiatives. This perspective will contribute to ongoing discussions about the geographic and spatial scope of circular activities, with authors debating the significance of local versus global management of resources. It may provide valuable insights into the territorial dimension and help to mature the CE field (Kirchherr et al., 2023).

Finally, it appears that the issues of territorial anchoring dynamics naturally integrate into sustainable management approaches. The attention then shifts to the process of a company's territorial anchoring (Bousquet, 2014). We plan to further analyze local anaerobic digestion projects and how they leverage various types of proximities identified by Torre and Rallet (2005), namely geographic and organized proximities complemented by Bahers et al. (2017), namely environmental, politico-administrative and socioeconomic proximities. By describing how these proximities are unveiled in our case, we can better highlight the territorial issues of CE activities and how they relate to securing secondary biological resources. We will also specifically investigate the roles of territorial public actors and how they assist the development of local circular initiatives.

3. Third analytical perspective focusing on market emergence

“How does a market economy work? On the one hand, orthodox economists have long argued that market equilibrium depends on the automatic adjustment of supply and demand; on the other hand, heterodox economists (Williams, 1985; Arthur, 1989) but also historians (Chandlers, 1977; Tedlow, 1990) and sociologists (Prus, 1989) have tried to show that supply and demand are socially constructed (Granovetter and Swedber, 1992), and that managerial practice shapes the contours of the market.” – (Cochoy, 1998)

The supply and procurement of secondary resources condition the economics of circular business models (Linder and Williander, 2017). However, most often—unlike various raw materials—there is no preexisting market for these secondary resources. Authors are now acknowledging that the use of secondary resources may introduce new market segments to industries and create relationships between actors with no previous relationships: *“For example, production inputs are composed of used, recycled, or recaptured materials and often require the involvement of partners and experts who know about the benefits and limitations of such materials. The resulting demand for used or waste materials requires related logistics and could lead to the creation of new markets for secondary resources or an expansion of existing markets. In their most advanced form, the resulting resource flows and partnerships lead to symbiotic relationships that allow for multiple resource use, cascading and biorefining, continuous recycling, or even the emergence of industrial symbiosis networks based on spatial proximity (Chertow 2000; Ehrenfeld and Gertler 1997; EMF 2012).”* (Ludeke-Freund et al., 2018). The creation of a market has many positive socioeconomic repercussions (Garcia, 1986) that can compensate for the economic challenges circular business models face (Linder and Williander, 2017).

We align with researchers acknowledging the importance of social and management sciences for studying markets: *“When one agrees to place management sciences within economic reflection, economic sociology finds itself then very close to this 'science of organizational action', thus as collective reflection (Hatchuel, 2000), emphasizing the importance of the concrete work of market configuration. This link between sociology and economics through management sciences, sociology of organizations and sociology of science makes it possible to show the importance of marketing techniques on market transactions, that is to say the*

work of market professionals” (Steiner, 2007, pp. 37–38). Thus, following Fligstein and Calder (2015), we consider markets as “*socially constructed arenas where repeated exchanges occur between buyers and sellers under a set of formal rules and informal understandings governing relations among competitors, suppliers, and customers. These rules and understandings guide interactions, facilitate trade, define what products are produced, sometimes constitute the products themselves, and provide stability for buyers, sellers, and producers.*” (Fligstein & Calder, 2015, p. 1).

However, the process of emergence of these markets is rarely the subject of empirical studies (Toussaint, 2022). The literature seldom analyzes the processes by which markets for secondary resources emerge and does not analyze how they are made coherent and sustained over time (Beulque, 2019). Thus, we mobilize the notion of 'market arrangements' because this conceptual perspective proposed by Callon (2013) aims precisely to elucidate key determining processes in market emergence.

This section will detail (3.1) key processes leading to market arrangements, (3.2) the emergence of markets as social constructions and (3.3) specific case studies depicting the emergence process of markets for secondary resources.

3.1 Market arrangements

Callon (2013) critiques traditional market research that considers markets as interfaces. Scholars in the social and management sciences advocate for a deeper examination of market configurations and their effects (Callon, 2013; Steiner, 2007): “*Get closer to concrete markets, analyze the variety of their configurations and the effects they produce, with the aim of identifying the outlets that make it possible to act on this variety, such is the theoretical work of which I would like to show the possible lines of development. Yes, the task is immense. Of course, markets are everywhere. However, knowledge about them is still (too) scant*¹⁰” (Callon, 2013, p. 328). He highlights the need for a more comprehensive theoretical approach through the concept of the “*Agencement Marchand*” market arrangement. He argues that, unlike mere aggregations of transactions or institutional structures, this concept focuses on the organization and emergence of goods, sellers, and buyers within markets: “*Market arrangements do not simply structure, around already existing goods, the confrontation*

¹⁰ Own translation of “*Se rapprocher des marchés concrets, analyser la variété de leurs configurations et des effets qu'ils produisent, en ayant pour objectif d'identifier les prises qui permettent d'agir sur cette variété, tel est le travail théorique dont je souhaiterais montrer les lignes de développement possibles. Oui, la tâche est immense. Certes les marchés sont partout. Pourtant les connaissances à leur sujet sont encore (trop) maigres*”

between offers and demands whose genesis is not questioned. Their main responsibility is to organize the joint and progressive emergence of goods, their sellers and their buyers.” (Callon, 2013, p. 367). Callon (2013) outlines five key processes that contribute to market arrangements, which do not necessarily occur sequentially or in separate locations. Firstly, *“objectification of goods”* involves the transformation and qualification of goods. Secondly, *“the activation of calculative agencies”* refers to the collective valuation and qualification of goods by various actors involved in the market. Once goods are *“objectified,”* they need to be endowed with value for potential acquirers, necessitating a collaborative process of valuation involving diverse stakeholders such as researchers, engineers, marketers, and users. This collective effort through which they value and qualify the goods, spans numerous stages, including scenario planning, prototyping, business planning, and marketing strategies. Thirdly, *“the organization of merchant meetings,”* underscores the importance of identifying and studying points of interaction between goods and agents throughout the market process. For the first two processes to occur, meeting points for goods, sellers, and buyers are essential. Callon (2013) emphasizes the importance of studying and identifying these meeting places, from the initial stages of goods' preparation to the final evaluation of goods or services. Fourthly, *“merchant attachments”* represent the norms and regulations that sustain market arrangements, fostering trust among participants. In contexts characterized by uncertainty and variability, these attachments generate the trust necessary for the smooth progression of other market processes. Steiner (2007) discussed the links between quality and trust in the market of new and secondhand vehicles. He points out that *“Uncertainty about quality means that the price no longer plays its role of information (a higher price being the sign of better quality), but causes a phenomenon of adverse selection (...) the use of personal relationships is therefore increasing with uncertainty: the latter is the lowest for a new vehicle (due to the manufacturer's guarantee) and a professional seller (who wants to maintain his good reputation) and highest for a second-hand vehicle sold by an individual”* (Steiner, 2007, pp. 94–95). Thus, attachments can be useful on two dimensions: trust generated through interaction and trust facilitated by devices and procedures (e.g., norms, labels). Callon (2013) emphasizes the need for these relationships to be enduring and suggests that eco-design fosters more effective relationship management. Callon and Muniesa (2005) argue that to achieve the transaction through which the buyer and the seller will be quits, investments in the exploration of attachments and in their reconfiguration are needed (the more attachments, the more the market expands).

Lastly, “*price formulation*” involves the calculation and establishment of prices based on the preceding processes, rather than simple supply-demand dynamics: “*Prices also depend on social relations, those which make supply and demand exist in practical terms, but also those which give rise to the work of setting rates and prices*¹¹.” (Steiner, 2007, p. 74). This idea emphasizes the thinking that prices do not solely emerge from the interaction of supply and demand but are influenced by the qualification and transformation of goods. Specifically, they result from passivation, actions of calculative agencies, affect, and spatiotemporal attachments. The distributed calculative agencies play a crucial role in rendering goods calculable within the market context. In another study, authors investigate how the price of goods is calculated, emphasizing various methods for calculating values and reaching compromises (Callon & Muniesa, 2005). They argue that in financial markets, goods can be made calculable through pricing formulas that break down the value of complex products into various elementary components. This process simplifies the product into a formula that can be compared to other numbers, making it calculable and comparable. The establishment of a calculative space in which it can be connected and compared to a finite list of other products can be done through “metrological networks” such as quality labels, quality standards that measure and objectify certain properties. Authors have investigated how stakeholders price goods and services in the health sector (Rabeharisoa & Doganova, 2016, 2021). In his book, Steiner (2007) provides empirical examples of the social factors leading to the pricing of the Options Exchanges in the Chicago board (Mackenzie and Millo, 2003), the electric energy in the US (Yakubovich Granovetter and Mcguire 2005), the products in a large retail brand in France (Barrey 2006), and airplane tickets (Cross 1997 and Boyd 2007) (Steiner, 2007, pp. 87–92). He argues there is an “*economic engineering*” work involving “*a whole set of price workers*” involving relational networks of actors exchanging information and negotiating as well as technology and equipment to precisely measure quantity or volumes of goods exchanged.

But where do these market arrangements come from, and what is necessary to establish them?

¹¹ Own translation of “*Les prix eux aussi dépendent de relations sociales, celle qui font que l’offrent et la demande existent concrètement, mais aussi celles qui donnent lieu a un travail de fixation des tarifs et des prix.*”

3.2 The socioeconomic emergence of markets

Aspers, Bengtsson and Dobeson (2020) propose the concept of market fashioning, a process of shaping and emergence of markets. They identify three ideal types of market fashioning through mutual adjustment, organization, or fields, to which Toussaint (2022) adds the approach by creating new market categories. Authors have started investigating the conditions behind the successful emergence of markets. This line of research examines heterogeneous elements like rules, regulations, infrastructures, technical and calculative devices or discourses in shaping markets: *“The authors distinguish three types of practices that intervene in the shaping of markets: exchange practices related to the configuration of buyers, sellers, and the object of exchange (e.g., the introduction of self-service in retail, Kjellberg & Helgesson, 2007a); normalizing practices related to the formulation of rules, norms and standards for market behavior; and representational practices related to descriptions of markets (such as those produced by manufacturers and retailers in category review meetings; Azimont & Araujo, 2007).”* (Doganova & Karnøe, 2015, p. 23)

Other authors have taken an interest in the process of market emergence as a socioeconomic construction (Steiner, 2007). For instance, Flichy (2013) offers a socioeconomic analysis of how the Internet transitioned into a market. He observes that initially, the collaborative efforts of academics, government agencies, and private companies led to the development of Internet technology, primarily intended for information sharing rather than commercial purposes. However, it quickly evolved into a communication tool, serving non-market purposes. Subsequently, online communities emerged, facilitated by mediators promoting the technology in articles. Additionally, private sector involvement, facilitated the final connection to end-users. Consequently, various economic models emerged, including mass advertising, e-commerce, info mediation, and online commercial communities. Similarly, for Garcia (1986), the emergence of a “perfect market” is the result of a socioeconomic construction: *“the ‘perfect’ functioning of the market is due neither to mechanisms nor to an invisible hand restored by the application of the principles of ‘let it happen, let it go’¹²”* (Garcia, 1986, p. 13). She highlights the conditions and the process of emergence of the strawberry market. This market appears to be the result of the “continuous creation” and work of a certain number of agents; in particular, farmers and the economic advisor of the Chamber

¹² Own translation of *“le fonctionnement ‘parfait’ du marche n’est dû ni a des mécanismes, ni a une main invisible restaurée par l’application des principes du ‘laissez faire, laissez passe’”*

of Agriculture from the region who wanted to change the existing balance of power between strawberry producers and traders. The transactions in the market were prepared by extensive investment work at two levels. Monetary financing for the physical exchange area, the personnel, etc. and a collective “psychological” investment to create a collective identity for members and the conviction that it will work. In addition, the conducting of the sessions, construction of the market plan, and the language were all carefully thought out to create the right conditions for transactions and exchanges. The emergence of a market for strawberries had socioeconomic repercussions, notably price alignment, weakening the balance of power of brokers, increased exports, improvement of quality by sharing techniques between producers, creation of a quality label and regional notoriety, new strengthened links between producers, new sources of prestige through the creation of a board of directors for the “electronic auction market” (*marché au cadran*¹³). The table 9 below shows the process of social emergence of the two cases based on the market arrangements proposed by Callon (2013).

Processes of market emergence by Callon (2013)	Emergence of the strawberry market (Garcia, 1986)	Emergence of Internet as a market (Flichy, 2013)
Qualification	Preparation of strawberries for sale in Fontaines-en-Sologne. This includes actions such as picking the ripe strawberries, cleaning, sorting, and packaging them for market presentation.	In the case of the Internet market, passivation involves transforming the Internet from a tool for academic and research purposes into a commercial platform. This includes the development of user-friendly interfaces, e-commerce platforms, search engines, and the creation of digital content that can be bought and sold.
Qualitative agencies	Qualitative agencies are seen through the collaborative efforts of strawberry growers and market organizers—specifically the	It involves various stakeholders such as developers, entrepreneurs, investors, and users who contribute to the valuation of Internet-based services and products.

¹³ An electronic auction market ensures clarity of price setting, speed of sales and comparison with sales in other production areas. This kind of market developed from auction markets but its current sales system projects all the information necessary for sales onto a giant digital screen.

	<p>economic advisor of the Chamber of Agriculture—and potential buyers to establish the value of strawberries in Fontaines-en-Sologne. This involves discussions on quality, pricing strategies, and marketing efforts to attract buyers.</p>	<p>This includes the development of business models for online services, digital advertising, and e-commerce strategies, as well as the establishment of standards and metrics for online performance.</p>
Merchant meetings	<p>The organization of merchant meetings is evident in the case study through the establishment of the strawberry auction in Fontaines-en-Sologne in a former storage shed. After financial investment and renovation of the storage shed, it served as a meeting point for strawberry sellers and buyers, facilitating the exchange of goods and negotiation of prices.</p>	<p>It is facilitated through digital platforms that bring buyers and sellers together. This includes online marketplaces such as Amazon and eBay, social media platforms that connect businesses with consumers, and digital auction sites. These platforms serve as virtual meeting points where transactions occur, and goods and services are evaluated and exchanged.</p>
Merchant attachments	<p>Merchant attachments are demonstrated in the case study through the establishment of trust among strawberry sellers and buyers in Fontaines-en-Sologne. This trust is fostered through adherence to auction norms and regulations mainly proposed by the economic advisor, as well as enduring relationships between market participants. These attachments facilitate smooth market transactions and enhance trust among participants.</p>	<p>Regulations, trust-building mechanisms, and standards that ensure the reliability and security of online transactions. This includes the development of secure payment systems, privacy policies, user reviews and ratings, and regulatory frameworks governing online commerce.</p>
Price formulation	<p>Price formulation in the case study is influenced by various factors, including the quality of strawberries, market demand, and the negotiation process during the auction. Prices are</p>	<p>It is complex and influenced by multiple factors including the value-added services provided, the quality and uniqueness of digital products, the reputation of sellers, and market</p>

	not solely determined by supply and demand but are influenced by the collective valuation efforts of market participants and the quality of the strawberries presented for sale.	competition. Pricing models for online services often include subscription fees, pay-per-click advertising, and dynamic pricing strategies.
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Table 9 Market emergence of two case studies based on Callon (2013)

3.3 Empirical studies on the emergence of markets endowed with environmental qualities

Some research works have specifically analyzed environmental market emergence. Environmental markets “*organize the exchanges of goods with environmental qualities*” (Doganova & Laurent, 2019, p. 2). There are situations in which the emergence of a market for secondary resources is an operation that proved possible. For instance, in the case of plastic secondary resources, Micheaux (2019) depicts how private and public actors organized through the establishment of an assigned sector with extended producer responsibility to recover the waste, recondition, and resell plastics, thereby succeeding in creating a market for these plastics in France. Beulque’s (2019) detailed investigation relates how an automotive company managed to create markets for its secondary resources (copper, propylene, catalytic converter, and other reused parts). He emphasizes the phases of collection, preparation, cleaning, and transport of secondary resources, phases of negotiation skills and arguments to co-construct an offer and a demand with their customers and finally instruments such as specifications setting new quality lists of these secondary resources to estimate their value. Similarly, Hopkinson et al. (2018), related the strategy adopted by a manufacturing company in creating new markets for secondary resources (reused and remanufactured printers): “*Even so, as Colin Weaver, head of Ricoh UK Remanufacturing and involved with the U.K. operations since the mid-1990s, noted, ‘Looking back . . . reuse and remanufacture has never been an easy option for Ricoh UK and Europe. We had to develop a market, an infrastructure for reuse and a cultural acceptance that the on costs of reuse were less than the on costs of take, make, dispose, even in an environment where we did not have the evidence to support our claims’.*” (Hopkinson et al., 2018, p. 76). Through a longitudinal investigation, authors highlighted the strong marketing team and customer targeting as well as new standards in Europe on remanufacturing as a facilitator of the market’s adoption of reused and remanufactured printers.

However, there are other contexts where market emergence for secondary resources does not succeed, as Toussaint (2022) points out upon analyzing the case of space debris: “*At this stage, a space debris cleaning market does not exist yet, it seems difficult to envisage due to the various obstacles and uncertainties attached to it. In itself, space debris has no economic value and collecting it is very expensive. If its value exists, it is linked to the risk generated. However, we note that certain players, both public and private, are trying to implement strategies to shape this potential market. Some are particularly active, and place market creation as one of their main strategic objectives; others position themselves as participants; still others adopt a more wait-and-see stance. Market categorization is an issue for these players, and it fluctuates according to their strategies. The birth of the market depends in part on the development of regulation, the strategies for its development involve the development of the necessary technologies, under private but above all public financing, but also actions to raise awareness of the problem.*”

Table 10 summarizes the cases. In each case, the contributing factors to market emergence relate to the nature of the actors involved or the form of coordination between actors that is at work; the difference lies in the added value perceived by actors regarding the secondary resources exchanged.

Table 10 Summary of environmental market emergence cases

Case	Key actors involved	Factors favoring market emergence
Market for plastic waste	Private companies and Government	Organization through the establishment of an assigned sector with extended producer responsibility
Market for automotive components	Automobile company, customers	Phases of collection, preparation, cleaning, and transport of secondary resources. Negotiation skills and arguments to co-construct offer and demand. Instruments such as specifications setting new quality lists.
Market for reused and remanufactured printers	Manufacturing company, customers, European Standards	Development of market infrastructure for reuse. Strong marketing team and customer targeting. New standards in Europe on remanufacturing facilitating market adoption.
Market for space debris	Public and private players	Market creation efforts underway. Strategies involve technology development, financing, and

		awareness-raising.
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3.4 Analytical framework to investigate the market emergence of secondary resources in circular projects

In conclusion, the concept of market arrangements has investigative virtues because it allows the empirical study of market emergence to be engaged differently. Thus, the focus of our study will be on the organization dynamics of potential market emergence for biological secondary resources used in anaerobic digestion project development. We will base our investigation on the conceptualizations of Callon (2013). We will investigate the socioeconomic construction of a market for secondary resources by focusing our attention on the processes involved in making the goods exchanged both environmentally and economically valuable. For instance, we will investigate the *qualification process* to analyze how the actors evaluate and qualify the exchanged resources, *qualitative agencies* to explore the processes and devices used by actors to value secondary resources, and *merchant attachments* to explore how the relationship with suppliers is built and sustained through contracts and agreements. Ultimately, we will trace the processes through which actors find mutual grounds to appraise secondary resource exchanges during circular project development.

Conclusion of chapter 3

A comprehensive analytical framework

This section has introduced a comprehensive theoretical framework to examine how secondary resources are secured within circular economy business models. By presenting the concepts of governance, territory, and market emergence in circular projects, we aimed to gain insights from literature highlighting determinants, factors, and analytical perspectives crucial for understanding how secondary resources are secured. The focus on governance, territory, and market stems from the recognition of their significance in understanding the dynamics at play in the implementation of circular economy projects.

First, various governance forms that have been proven to be conducive to circular economy activities were examined. Effective governance is essential for successfully navigating the complexities of circular economy networks, particularly in managing inter-organizational and inter-sectoral flows. In this study, a collaborative governance approach (Brown et al., 2021; Schultz et al., 2023; Arfaoui et al., 2022) is adopted to examine the characteristics of governance modes (Provan and Kenis, 2007; Bridoux and Stoelhorst, 2022) in circular projects at the micro-level. This analysis seeks to investigate the impact of shared governance arrangements and the involvement of suppliers (Bridoux and Stoelhorst, 2022) on securing secondary resources in circular initiatives. Furthermore, we examine the role of public facilitators in governance structures implemented at a territorial level (Cramer, 2020).

Second, the territorial dimension is selected. We adopt a multifaceted perspective, conceptualizing territory as both a structure housing resources and actors, as well as a catalyst for innovation (Detchenique et al., 2023; Régent et al., 2021). This approach facilitates the exploration of circular models emerging through local networks, emphasizing the importance of territorial embeddedness. In this study we also mobilize the territorial proximities identified by Torre and Rallet (2005), namely geographic and organized proximities complemented by Bahers et al. (2017), namely environmental, politico-administrative and socioeconomic proximities. And finally, we examine the territorial anchoring dynamics as defined by Bousquet (2014) to analyze operational aspects and mechanisms by which the presence of organizations is related on a territory.

Lastly, market arrangements are explored. We adopt a social perspective on markets (Speiner, 2007; Flingestien and Calder 2015). Based on Callon (2013), this study investigates the framings and mechanisms leading to socioeconomic emergence of market for secondary resources. We specifically focus on actors' relationships, practices and devices used to find mutual agreements on the resources exchanged (Callon & Muniesa, 2005).

Thus, through the identification of the three dimensions we propose an analytical framework to investigate our research question “*How does governance, territorial proximities and premarket conditions support the process of establishing circular economy projects and securing secondary resources?*”

With this analysis framework outlined, our main research problem may be divided into three separate research questions (1) How can forms of governance and their specific characteristics contribute to securing secondary resources in CE projects? (2) To what extent and how do circular economy projects leverage territorial proximities in order to secure secondary resources? (3) In premarket conditions for secondary resources, what are the processes of market arrangements enabling agreements to be reached?

Chapter 4. Anaerobic digestion in France: Regulations, Processes, and Stakeholders

*“Science is beautiful when it makes
simple explanations of phenomena or
connections between different
observations.”*

–Stephen Hawking

This introductory section aims to describe the case of anaerobic digestion. This implicates the description of the technical process, mainly to explain how the secondary resources are used and highlight the complexities inherent in manipulating them. It appeared crucial to precede this description by a narrative of the development pattern of anaerobic digestion in France. This chapter will thus delve into the regulatory framework in France (1), the technical and biological processes involved (2), and finally present some of the key public actors driving and supporting its advancement (3).

Firstly, an exploration of the regulatory landscape provides insight into the foundation upon which anaerobic digestion initiatives have flourished. France's regulatory framework governing anaerobic digestion has undergone iterative developments aimed at fostering environmental sustainability and energy independence. By highlighting the evolution of regulations and laws pertinent to anaerobic digestion, this section illuminates the regulatory milestones that have shaped the landscape for anaerobic digestion projects. Moreover, it sheds light on the main models that have emerged within this regulatory framework, offering an overview of the diverse approaches adopted in anaerobic digestion projects across the country.

Secondly, a comprehensive understanding of anaerobic digestion necessitates an exploration of its technical and biological processes. The intricacies of anaerobic digestion, from selection

of secondary resources to the production of biogas and digestate, underscore the importance of a detailed examination of the process. By delineating the technical and biological aspects of anaerobic digestion, this section elucidates the mechanisms driving biogas production and emphasizes the use of various secondary resources in the processes. A description of the secondary resources possible provides clarity on their complex landscape, thereby laying the groundwork for a deeper comprehension of the process of securing them.

Lastly, the landscape of anaerobic digestion in France is shaped by a myriad of stakeholders, including public actors that play a pivotal role in supporting its development. By elucidating the roles of these key actors and examining how they have contributed to the advancement of anaerobic digestion initiatives, this section provides insights into the collaborative efforts driving the expansion of anaerobic digestion projects. Additionally, it explores how public actors have supported the development of specific types of anaerobic digestion models, thereby illustrating the dynamic interplay between policy, industry, and environmental objectives in shaping the anaerobic digestion landscape in France and the specific use of secondary resources.

1. The development pattern of anaerobic digestion models in France

“Madame Francois had a contract with the company which undertook the scavenging of the markets, and twice a week she carried off with her a load of leaves, forked up from the mass of refuse which littered the square. It made excellent manure. (...) Claude had quite a liking for manure, since it symbolizes the world and its life. The strippings and parings of the vegetables, the scourings of the markets, the refuse that fell from that colossal table, remained full of life, and returned to the spot where the vegetables had previously sprouted, to warm and nourish fresh generations of cabbages, turnips, and carrots. They rose again in fertile crops, and once more went to spread themselves out upon the market square. Paris rotted everything, and returned everything to the soil, which never wearied of repairing the ravages of death” – Emile Zola - Le ventre de Paris, 1873 ¹⁴.

Zola's citation serves as a poignant reminder that the concept of recycling organic waste for agricultural benefit is not a new phenomenon. This quote illustrates the age-old practice of utilizing biological resources, such as organic waste, for agricultural purposes in Paris. Madame Francois's contract with the scavenging company demonstrates the utilization of market refuse as excellent manure, highlighting the cyclical nature of organic matter returning to the soil to nourish new generations of crops. Zola's portrayal emphasizes the symbiotic relationship between urban waste and agricultural production, where organic waste is repurposed to enrich the soil and sustain agricultural productivity. This historical perspective resonates with the context of anaerobic digestion in France. While the utilization of biological resources for agricultural purposes has existed for centuries, the technological advancements and scaling up of anaerobic digestion projects in France began in the late 20th century, particularly around the 1980s. Anaerobic digestion represents a modern approach to harnessing the energy potential of organic waste, wherein biological resources are converted into biogas through anaerobic digestion processes.

The development of anaerobic digestion models in France has been influenced by a variety of factors, including the country's energy, agricultural, environmental, and waste management policies, as well as its national environmental objectives (Alaterre et al., 2015). This section aims to examine the historical development of different anaerobic digestion

¹⁴ <https://www.gutenberg.org/cache/epub/5744/pg5744-images.html>

models in France and to highlight the influence of various policies and objectives on the pursued models. Indeed, two specific models are currently prominent, with one experiencing a significant rise and attracting interest from actors in the field.

The narrative in this section is divided into three distinct periods. The first period, spanning from 1980 to 2010, marks the emergence of anaerobic digestion as an alternative for farmers affected by the oil crises, who sought alternatives to fossil fuels. This period witnessed the initial interest and experimentation with anaerobic digestion technology. The second period, from 2010 to 2019, is marked by the official assessment of biogas plants and their gradual rise in prominence. During this time, there was a notable increase in the implementation of biogas projects, accompanied by a growing recognition of their potential benefits in terms of waste management and renewable energy production. The third period, from 2019 to the present, marks the uptake of biomethane plants, signaling a shift towards more advanced and sustainable forms of anaerobic digestion technology. This period is characterized by an increased focus on biomethane production and its integration into existing energy systems, reflecting a broader commitment to decarbonization and renewable energy sources.

1.1 The timid start of anaerobic digestion from 1980 to 2010 in France

The first development of anaerobic digestion in France can be traced back to the 1940s and 1950s. These agricultural units on farms were set up to provide energy from agricultural waste and slurry produced by livestock farms not well provided for by the mains system. The objective was thus to supply energy to these small farms and treat part of the polluting matter they generated (Bautista Angeli, 2018). However, this development was halted by the marketing of low-cost petroleum products (Bailly, 2014). Nevertheless, the context of the oil crises in the 1970s revived the interest in this alternative solution to fossil fuels in many European countries (Raven & Geels, 2010). A second wave of agricultural digesters was thus built. Little by little, the installation of anaerobic digesters evolved and was no longer limited to farms. The treatment units then became larger to be able to receive more effluents and waste of various origins.

Norms issued in 2004 and 2006 regarding the composting of digestate helped structure the sector. By complying with the proposed standard, the digestate produced from biogas plants could become a product by statute and be transferred or sold in France. The financial context

was also more attractive with an investment aid by the French Agency for Ecological Transition in 2007 (ADEME—*Agence de la transition écologique* has been operating since 1992. It plays a pivotal role in advancing the ecological transition in France and assists in the accomplishment of national interests and strategies). The aim of this aid was to support project development through a waste fund. Specific digestate treatment equipment and anaerobic digestion projects with biogas recovery through cogeneration were eligible. Another fund was also proposed for anaerobic digestion projects with heat recovery, purification then injection into the natural gas network or NGV-type fuel recovery, and heat network projects resulting from cogeneration.

Moreover, the European Nitrates Directive¹⁵ initially came into force on December 12, 1991. Its aim was to protect water quality across Europe by reducing nitrates from agricultural sources that pollute ground and surface waters and by promoting the use of good farming practices, and it increased the regulatory digestate storage period from 4 to 6 months. Some farms did not have enough capacity on their land to store their effluent over a period of 6 months, so this directive incited them to consider anaerobic digestion as a solution. Instead of creating new areas of storage on agriculture lands, farmers valorized their effluent through anaerobic digestion.

In addition to the evolution of regulation and financial aid, a club was created to support the development of biogas in France. The Biogas Club was created on September 20, 1999, within the *Association Technique Energie Environnement* (ATEE, Technical Association for Energy and the Environment). ATEE promotes energy management based on technical foundations. It is a non-profit association under the French law of 1901, which defines this kind of association as an "*agreement by which two or more persons permanently pool their knowledge or their activity for a purpose other than that of sharing profits*"¹⁶ Currently, the Biogas Club gathers pioneers in the field, its members being the key stakeholders in the biogas and anaerobic digestion sectors. It brings together over 240 organizations¹⁷. The club encompasses a wide range of stakeholders involved in various aspects of anaerobic digestion and biogas production. This includes engineering firms

¹⁵ <https://rapportage.eaufrance.fr/directive-nitrates>

¹⁶ Translated from "*La convention par laquelle deux ou plusieurs personnes mettent en commun d'une façon permanente leurs connaissances ou leur activité dans un but autre que de partager des bénéfices*" - <https://www.associations.gouv.fr/liberte-associative.html>

¹⁷ https://atee.fr/system/files/2019-12/2018%2012%2020_biogaz_missions_listeadherentsv1_2.pdf

engaged in plant design and technical studies, companies specializing in anaerobic digestion unit design and development, organizations facilitating legal and financial aspects of anaerobic digestion projects, suppliers of biogas recovery technologies and purification equipment, operators of anaerobic digestion plants, industrial contractors, energy suppliers, local authorities managing waste treatment, cooperatives and farms involved in organic fertilizers, research and educational institutions, project support and promotion associations, and network operators connected to the French network. The Biogas Club is a nationally representative association in France and a founding member of the European Biogas Association (EBA). It facilitates interactions with public entities and facilitates the sharing of experiences and the expertise of its members. Indeed, the Biogas Club provides documents, reports, summaries, and recommendations to assist actors in the field on four aspects, described below. Additionally, information-sharing meetings are regularly organized on these topics:

1. **Legal Monitoring:** The club offers information on best contractual practices, with thematic fact sheets covering legal aspects related to inputs, technical installations, support mechanisms, digestate valorization, and taxation related to biogas production. The club compiles summaries, accompanied by a list of applicable regulations for project development. This includes Directive RED 2, ICPE (Classified Installations for Environmental Protection), and the Qualimetha label.
2. **Financing:** The club offers a counseling guide to raise awareness among project stakeholders about risk-taking processes, lessons learned, steps to secure bank financing, and useful contacts.
3. **Technical:** Information is available on project design and dimensions, with online tools available. Additionally, the club publishes a guide on connection procedures and steps to obtain an electricity purchase contract from biogas, detailing all the necessary steps and providing document templates. The club also provides information on biowaste, sludge, and other waste, including relevant official texts and decrees. It also presents studies on the availability of organic materials that can be digested in anaerobic digestion plants. Furthermore, the club hosts the National Technical Center for Biogas and Anaerobic digestion (CTBM, *Centre Technique national du Biogaz et de la Méthanisation*), which leads and coordinates a research and innovation network to provide the technical and human resources needed to support the development of anaerobic digestion. The CTBM facilitates working groups dedicated to improving the training level of anaerobic digestion facility personnel, to investigating CO₂

valorization opportunities, technical processes, and possibilities for commercialization, as well as a group committed to reducing fugitive methane emissions, finding ways to detect and remedy them.

4. Social: Studies are presented regarding the social aspects of projects to enhance acceptability and dialog.

1.2 A prevalent domination of biogas plants from 2010 to 2019

During the years 2010-2019, the anaerobic digestion sector began to get structured and professionalized (Alaterre et al., 2015). In 2010, only biogas entities were operated. The development of biogas plants has been prevalent (Figure 6). While both biogas and biomethane plants are based on the same technology of anaerobic digestion, there are some significant differences in their evolution in France.

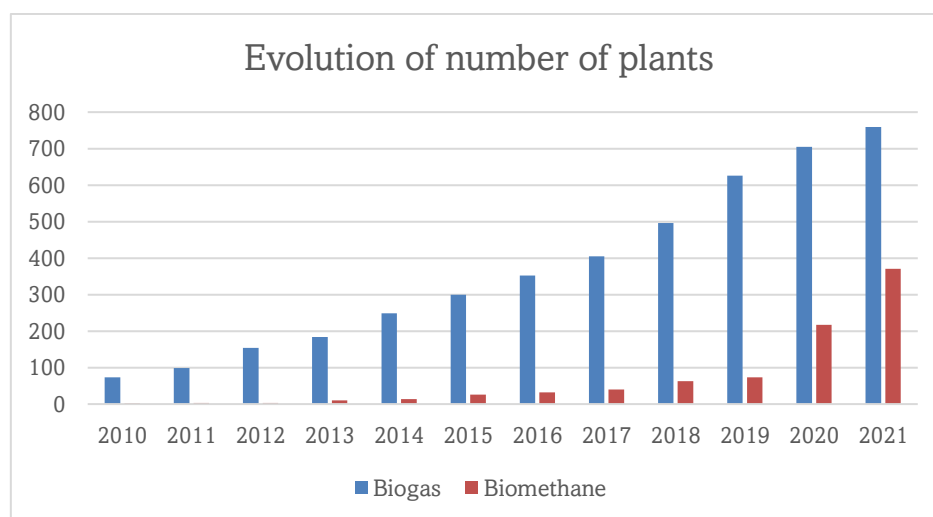


Figure 6 Evolution of biogas and biomethane plants - Adapted from ADEME 2022

Biogas plants have seen a dominant growth since their introduction in the late 1970s. Effectively, the purchase tariffs put in place in 2002 for electricity from biogas produced by anaerobic digestion supported the evolution of biogas plants in France. The purchase rates depend on the maximum electrical power installed, the installation and its energy efficiency. The interest was later strengthened in 2015 with preferential electricity purchasing tariffs for winning installations in government calls for tender implemented by the Energy Regulation Commission (CRE, *Commission de Régulation de l'Énergie*).

The regulatory framework was gradually reinforced with the creation in 2009 and 2010 of specific sections respectively devoted to anaerobic digestion and biogas recovery. They were

included in the nomenclature of environmentally-friendly classified installations (ICPE *Installations Classées pour la Protection de l'Environnement*) in the French Environmental Code. The purpose of the ICPE, filed with the prefectures and supervised by the DRIRE (Regional Directorate for Industry, Research, and the Environment), is to control and evaluate the anaerobic digestion facilities by studying their danger, impact, and risk to the environment. Other structuring decrees were issued in 2011 regarding the inputs allowed in anaerobic digestion¹⁸—describing their quality and quantity—and in 2016, limiting the proportion of dedicated crops to 15%¹⁹.

From a strategic point of view, in 2013 the Ministry of Agriculture and Food and the Ministry of Ecological and Inclusive Transition launched the EMAA Methane Energy and Nitrogen Autonomy Plan. The goal was to enhance nitrogen, and develop French anaerobic digestion models to generate additional income for farmers. The objective was to develop by 2020, 1,000 on-farm biogas plants in France, compared with 90 at the end of 2012. In this same year, the ADEME issued a comprehensive study of potential resources on the French territory that can be used in anaerobic digestion.

Additionally, in 2015, the government reinforced its interest in the sector through a National Low Carbon Strategy²⁰. This is France's roadmap for battling climate change introduced by the energy transition law for green growth. It includes specific guidelines designed to facilitate development of the anaerobic digestion sector and in particular calling for the development of agricultural anaerobic digestion valorizing livestock effluents, intermediate crops for energy purposes, and crop residues. They also call for a research and development focus on the technical processes, in particular on gas quality and the reduction of leaks, optimization of recovery and monitoring atmospheric emissions in relation to materials entering the facilities. The economic aspects to enhance cost control in projects are also an objective.

In keeping with this dynamic, in 2017 the ADEME issued a strategic roadmap²¹ produced by an expert panel consisting of large private companies, technical research centers, investors, Chambers of Agriculture, and associations of farmers and energy players. It presents the 2050

¹⁸ <https://www.legifrance.gouv.fr/loda/id/JORFTEXT000024833884/>

¹⁹ <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000032855125>

²⁰ <https://www.ecologie.gouv.fr/politiques-publiques/strategie-nationale-bas-carbone-snb#:~:text=Les%20pays%20d%C3%A9velopp%C3%A9s%20sont%20appel%C3%A9s,2050%20par%20rapport%20%C3%A0%201990%20.%20https://www.bulletin-officiel.developpement-durable.gouv.fr/notice?id=Bulletinofficiel-0028920&reqId=faef2125-4206-4405-a2eb-343cbf6fcd84&pos=15>

²¹ https://www.bioenergie-promotion.fr/wp-content/uploads/2017/09/methanisation_fr_2017-bd.pdf

vision of possible development and deduces the priority needs of research, development and innovation in the anaerobic digestion sector (ADEME, 2017). Among the needs stated were reinforcement of anaerobic digestion project planning and engineering, identification of sociological brakes and levers, development of new digital tools, analysis of economic risks, and proposals for new business models. Also, a national strategy for the mobilization of biomass²² followed shortly after, in 2018. This strategy sets out the conditions for increased and harmonious use of biomass resources, in line with the multi-annual energy programs and the national strategy for the bioeconomy.

Finally, in response to this dynamic, a strict framework was created in parallel in order to prevent the disorganized emergence of plants. For instance, in 2018, the RED II Directive²³ defines a series of sustainability and GHG emission criteria for anaerobic digestion plants. The RED II Directive is the main EU instrument dedicated to the promotion of energy produced from renewable sources with which French anaerobic digestion plants should comply.

1.3 The progressive takeover of biomethane plants starting in 2019

The first biomethane plants began operating in 2011, which corresponded to the favorable context of biomethane injection in France. In fact, the decree for biomethane purchase tariffs was issued on November 23, 2011. It set out the conditions for the purchase of biomethane injected into natural gas networks for a duration of 15 years (Grenelle 2 law adopted on July 12, 2010, as well as four decrees and four orders of November 2011²⁴).

Feed-in Tariff = Reference Tariff + Input premium + Connection to grid premium

Many amendments occurred to revise the feed-in tariff. In 2020, one of the changes entailed restricting access to the feed-in tariff to projects below 300 nm³/h²⁵. Larger projects became subject to call for bids. Also, a discount was applied if the project benefitted from ADEME aids. The latest amendment, in June 2023, reevaluated the feed-in tariff upwards, increasing

²² <https://www.ecologie.gouv.fr/sites/default/files/Strat%C3%A9gie%20Nationale%20de%20Mobilisation%20de%20la%20Biomasse.pdf>

²³ https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

²⁴ <https://www.legifrance.gouv.fr/loda/id/JORFTEXT000024833895>

²⁵ <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000042552351>

by around 15% for all sites producing less than 25 GWh/year²⁶. Among the modifications, this new tariff can be accessed by combining other supplementary investment aids (e.g., ADEME aids), provided that the project's internal rate of return before tax remains below 10% in nominal terms. These changes reflect the public authorities' desire to control the attractiveness and rapid development of the sector by adjusting the conditions favorable to the development of biomethane projects. More specifically, with the feed-in tariff they incentivize the valorization of a specific type of input.

The growth of the biomethane market in France can also be mainly explained by the goal set in 2015 by the French Act on Energy Transition for Green Growth (LTECV). France committed to ensuring that 10% of injections into the gas grid were of biomethane by 2030. However, the Pluriannual Energy Program²⁷ (PPE) published in 2019 later lowered the 2030 target to 7 - 10%.

Moreover, the implementation of the “right to inject”²⁸ in 2019 boosted interest in biomethane plants. It secured gas networks as an outlet for project developers by spreading over nearly 300 connection points throughout the territory. In 2022, as a result, the coverage by GRDF increased to 60% of connection costs, and the right to injection validated the establishment of cost-sharing rules when a new gas network benefitted from multiple biomethane producers. Guarantee-of-origin mechanisms were also set in motion in November 2020 to enhance the traceability of the biomethane injected for customers.

Furthermore, the increasing focus on reducing greenhouse gas emissions and transitioning to renewable energy sources has led to an increase in demand for biomethane as a sustainable alternative to fossil fuels, especially in the context of the ongoing Russo-Ukrainian war begun in 2021. Another factor contributing to the growth of the biomethane market in France is the increasing use of biomethane in the transportation sector, particularly in the form of compressed natural gas (CNG) and liquefied natural gas (LNG) for vehicles. This has been supported by the development of infrastructure such as biomethane refueling stations and the implementation of regulations to encourage the use of biomethane in the transport sector. The national policy framework for the development of alternative fuels (CANCA plan²⁹) aims to reach 140 stations by 2025. The AFGNV association, which promotes natural gas for

²⁶ <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000047670236>

²⁷ <https://www.ecologie.gouv.fr/sites/default/files/documents/20200422%20Synthe%CC%80se%20de%20la%20PPE.pdf>

²⁸ <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038702468>

²⁹ https://www.ecologie.gouv.fr/sites/default/files/Cadre_action_nationale_carburants_alternatifs_0.pdf

vehicles, has set a more ambitious objective of 300 CNG stations in 2025 (ENEA Consulting, 2017).

Furthermore, in 2020, public investment bank Bpifrance strengthened its support for anaerobic digestion project loans³⁰. It offers two loan options: the Agricultural Anaerobic digestion Loan, implemented in partnership with the Ministry of Agriculture, and the Anaerobic digestion Injection Loan, implemented in partnership with the ADEME. In addition, the Environmental Regulation (RE2020) defining the new energy and environmental regulations for the entire new construction sector in France was issued in 2020³¹. This regulation takes into account energy consumption in addition to carbon emissions, including those associated with the construction phase of new buildings. The RE2020 regulation in France could have several implications for biomethane, particularly regarding its use in new buildings. Indeed, biomethane, compared to other energy sources used in buildings, meets the carbon content thresholds required by this new regulation³².

Finally, in order to provide a framework for development and ensure good safety and construction rules for anaerobic digestion plants, ATEE developed the “Qualimetha” quality label in 2020. The objective of this certification is to make anaerobic digestion facilities more reliable by capitalizing on good design and construction practices. Three audit organizations are accredited: AFNOR, the French Association for Standardization; Bureau Veritas, and SGS France.

More recently, the latest French AGECE laws against waste and for a circular economy set ambitious objectives for the prevention and management of biowaste (i.e., biodegradable waste). It requires all professionals to sort biowaste, and local authorities in particular to provide biowaste collection solutions for private individuals. Anaerobic digestion has been identified as a solution to recover biowaste. Consequently, on March 4, 2023, a decree was published that created a specific section in the nomenclature of installations classified for the protection of the environment (ICPE 2783) relating to biowaste deconditioning³³ activities. It loosened the applicable regulatory thresholds, so deconditioning facilities for biowaste in

³⁰ <https://www.bpifrance.fr/catalogue-offres/pre-methanisation-ademe>

³¹ <https://rt-re-batiment.developpement-durable.gouv.fr/textes-de-la-re2020-en-version-consolidee-a617.html?lang=fr>

³² <https://www.grdf.fr/entreprises/grdf-et-vous-au-quotidien/dossiers-thematiques/residentiel/re2020/re2020-solutions-innovantes>

³³ *Biowaste from large producers, large and medium-sized supermarkets, etc. are disposed of in their packaging (plastic packaging, glass, rigid plastic, ceramics etc.). Therefore, a deconditioning step is necessary if biowaste is to be valorized in anaerobic digestion plants. “Deconditioning” designates the process by which a flow of packaged biowaste is purified as much as possible by separating the organic content of the containers from all non-fermentable materials*

anaerobic digestion plants with a capacity greater than 10 t/d will no longer be subject to authorization, for example.

Figure 7 provides an overview of the main French policies and funds that have supported anaerobic digestion in France from 1978 to 2023. It also presents the national objectives and strategic roadmaps that have been identified for developing the sector. Additionally, it briefly outlines the main EU actions in support of biomethane development.

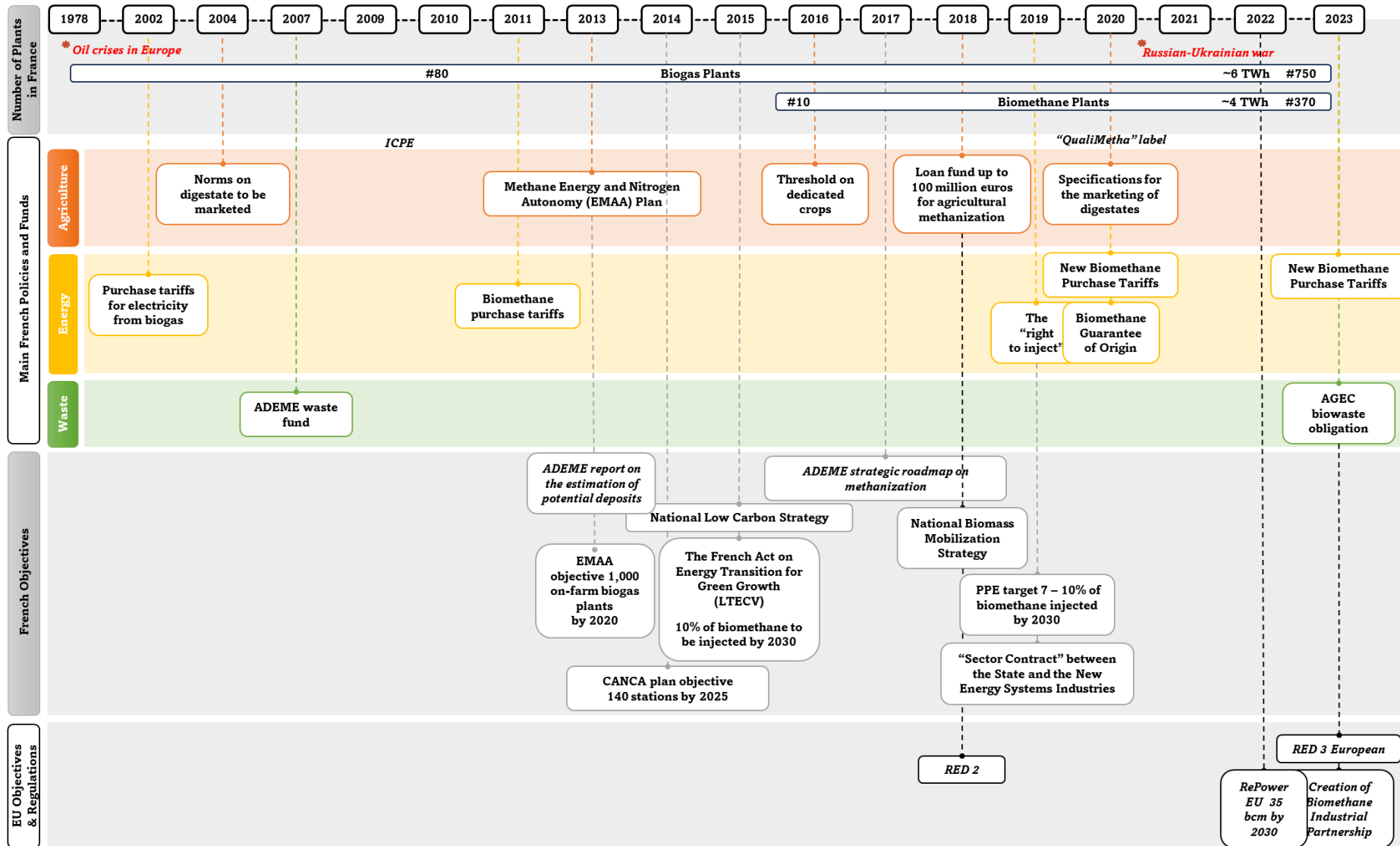


Figure 7 Timeline summarizing the development of biomethane entities with the main regulations, objectives, and standards in France and Europe

Since then, the biomethane sector has continued to grow in France. While Germany led the development of Europe's biomethane market for almost a decade from 2008 till 2016, France took the lead starting in 2017 (European Biogas Association, 2022). By early 2022, 371 biomethane plants were operational in France (ADEME). With a total capacity growing from less than 1 TWh in 2018 to 4 TWh in 2021 (European Biogas Association, 2022), the biomethane sector is growing more rapidly than that of biogas plants.

More precisely, as shown in Figure 8, on-farm biomethane plants are the prominent type registered in France in 2022. Their capacity is less than 125 Nm³/h. The frequency of this type of plant is followed by that of centralized anaerobic digestion plants, which have an average capacity of 260 Nm³/h.

Although numerous typologies have been proposed by professionals in the sector and academics (Berthe et al., 2020) we have chosen to adopt the classification proposed by the ADEME. This typology is characterized by its emphasis on the selection of secondary resources for the plant (the characteristics of these secondary resources will be further detailed in subsection 2.3).

- On-farm anaerobic digestion: The composition of the feedstock consists mainly of agricultural resources such as manure, slurry, crop residues and intermediate crops. This type of anaerobic digestion is mainly carried out by individual farmers or groups of farmers.
- Centralized anaerobic digestion: The feedstock for this type of anaerobic digestion includes a variety of resources that are co-digested within the same facility. These co-digestion units are commonly referred to as "territorial" or "multi-partner" units.
- Municipal waste anaerobic digestion: The feedstock consists mainly of biowaste from selective collection systems or residual municipal waste after extraction of the fermentable fraction.
- Industrial anaerobic digestion: The feedstock consists mainly of biowaste from agro-industrial activities. This type of anaerobic digestion is carried out by agro-industrial units as well as within the chemical or paper industry.
- Waste water treatment anaerobic digestion: This type of anaerobic digestion valorizes sludge from wastewater treatment plants.

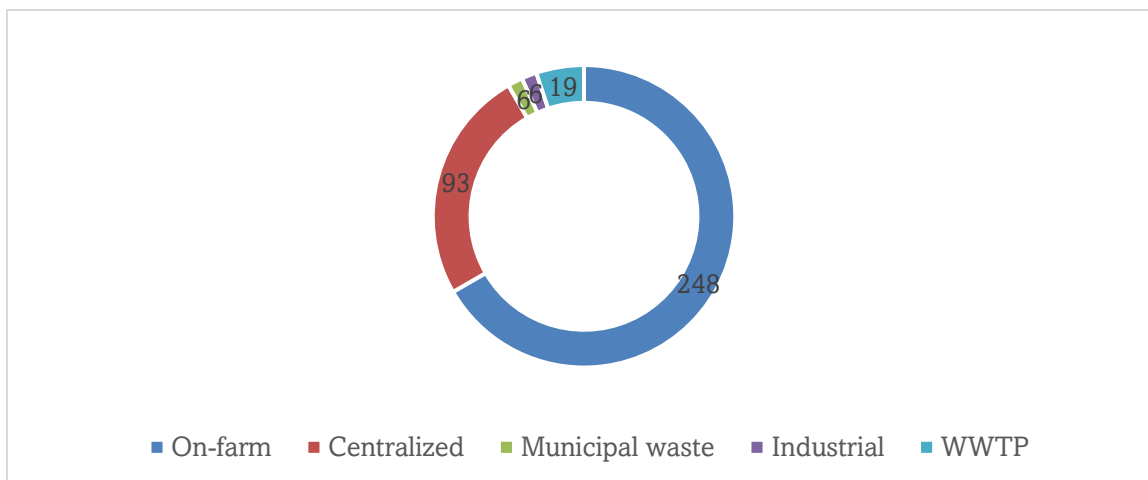


Figure 8 Number of biomethane plants per type of input in 2022

Moreover, we observed the gradual ascendance of biomethane models within France, with two distinct paradigms—on-farm and centralized—emerging as dominant. This prominence of specific models underscores the influence of national strategies in guiding anaerobic digestion development, further accentuated by external contextual factors. Nevertheless, While the "on-farm" type of anaerobic digestion was the first to develop and currently represents the largest number of units in France, the "centralized" type is growing rapidly. Notably, centralized anaerobic digestion has experienced a surge in prominence, garnering significant interest as it represents a major production capacity. Some authors believe that we are at a tipping point towards this type of centralized anaerobic digestion, which will become dominant.

The differences between these types of units also relate to the types of secondary resources mobilized. The ensuing section will focus our investigations on the characteristics of anaerobic digestion technologies.

2. The technical process of anaerobic digestion

While the term 'anaerobic digestion' may appear generic, a closer examination reveals the unique and tailored nature of plants, designed to suit specific resources. Indeed, there exists a core technology, but its adaptation is essential based on the particular conditions of each setting. Several technologies may be used to recreate the conditions of anaerobic digestion. A multitude of resources can be valorized in this process and various forms of output can be considered. From a technical and biological perspective, an anaerobic digestion plant is constructed by selecting options from these parameters.

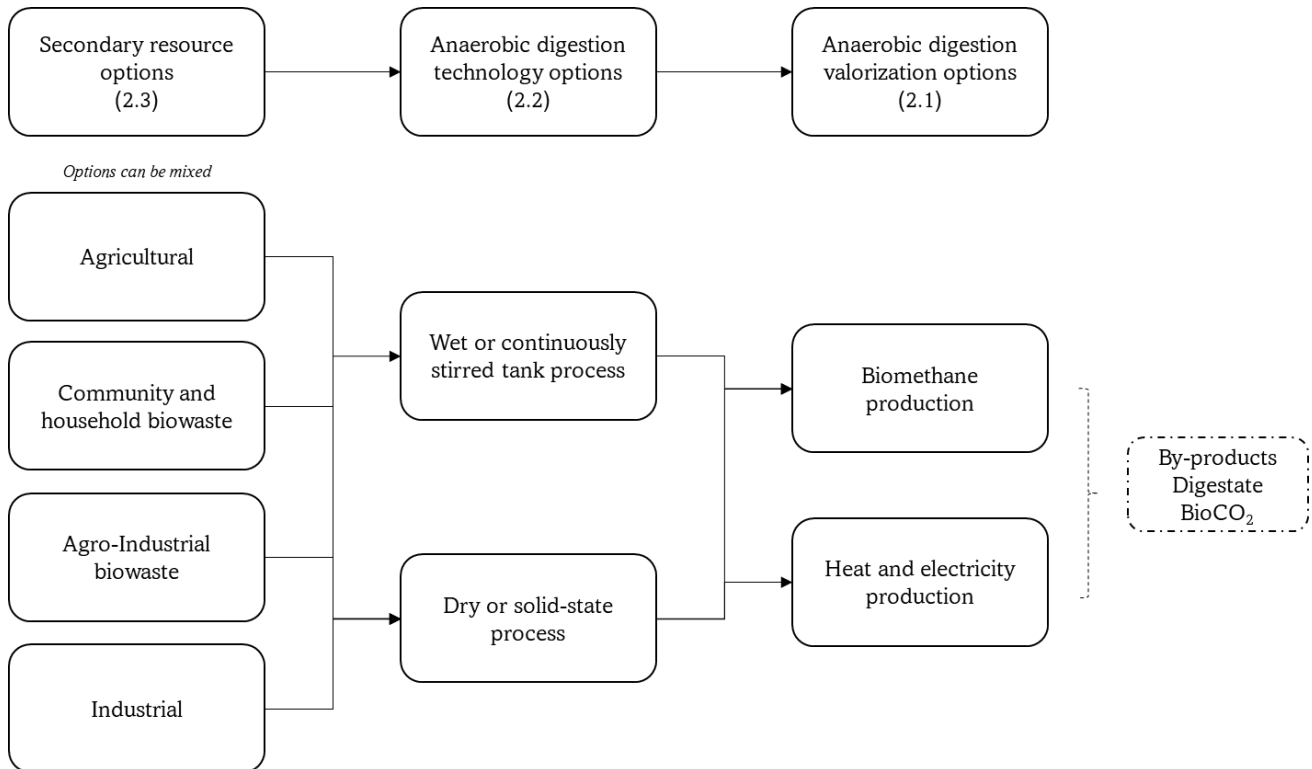


Figure 9 Options choose from when creating an anaerobic digestion plant

Different anaerobic digestion models can be developed by choosing between the options available for each parameter.

2.1 Diverse ways to valorize biogas to fit in a circular economy

Two pathways for biogas valorization are pursued within anaerobic digestion plants.

1. Purification to produce biomethane:

One route to valorize biogas involves its purification to produce biomethane. This involves a series of advanced separation and purification processes to remove impurities, particularly carbon dioxide and trace gases, from the biogas. The outcome of this purification step is biomethane, a highly purified form of methane that is nearly identical to natural gas in terms of quality and energy content. Several applications can then be considered. Biomethane can be directly injected into the natural gas grid. This integration with the existing gas infrastructure allows for the distribution of renewable natural gas. Biomethane can also be compressed and used as a vehicular fuel, commonly known as compressed natural gas (CNG).

2. Cogeneration to produce heat and electricity:

An alternative pathway for biogas valorization is cogeneration, a process that involves the simultaneous production of heat and electricity from the combustion of biogas. The heat generated through cogeneration can be used for various purposes, including space heating, industrial processes, or even for providing heat to local district heating networks. The electricity produced from biogas can be used to power the plant's operations or be fed into the grid to meet local or regional energy demands.

In both methods, microorganisms break down the organic matter (technical and biological process detailed in section 2.2), resulting in the production of biogas and byproducts, primarily digestate. Digestate is the solid or liquid material that remains after the biogas has been captured and removed. It is rich in organic matter (composition details are provided in section 2.3).

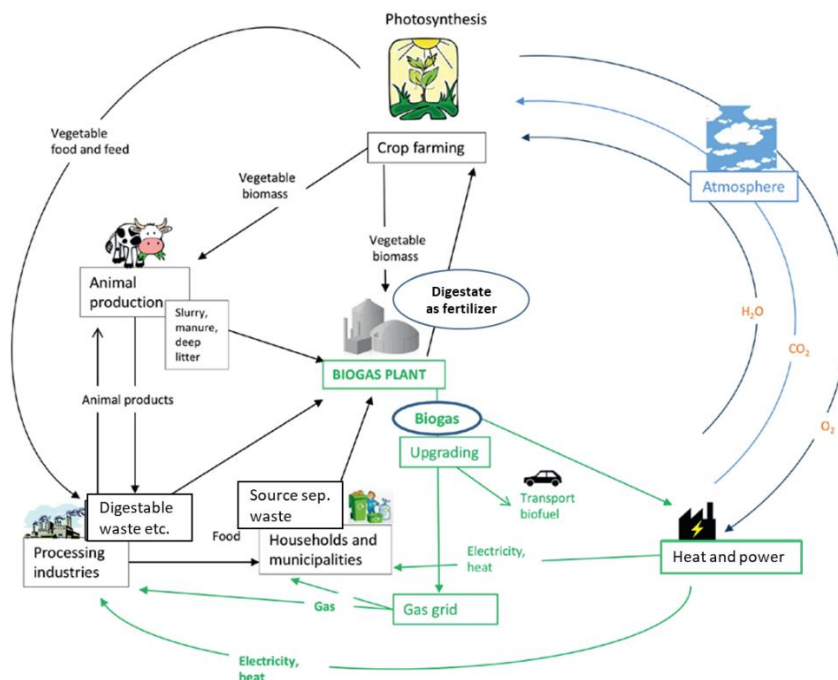


Figure 10 Example of circular flows in anaerobic digestion - Source: Al Seadi et al. 2018

2.2 A biological and technical process

Biogas is a mixture of methane and other gases, notably CO₂. It is saturated with water, composed of approximately 50% to 70% methane (CH₄), 20% to 50% carbon dioxide (CO₂), and some trace gases like ammonia (NH₃), nitrogen (N₂), or hydrogen sulfide (H₂S) (Bautista Angeli, 2018).

The process of anaerobic digestion mainly consists of three steps:

- Hydrolysis: hydrolytic and fermentative bacteria transform macromolecules and solid particles into volatile fatty acids (VFAs).
- Acidogenesis and acetogenesis: The compounds are then transformed within the cells of the fermenting micro-organisms to form organic acids (such as lactate), a substantial proportion of which are VFAs (such as acetic, propionic, and butyric acids). The bacteria then transform the compounds from the previous phase into acetate, hydrogen, and carbon dioxide.

- Methanogenesis: acetolactic bacteria use acetic acid to form carbon dioxide and methane ($\text{CH}_3\text{COOH} \rightarrow \text{CH}_4 + \text{CO}_2$) and hydrogenophilic bacteria reduce carbon dioxide with hydrogen to produce methane and water ($\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O}$).

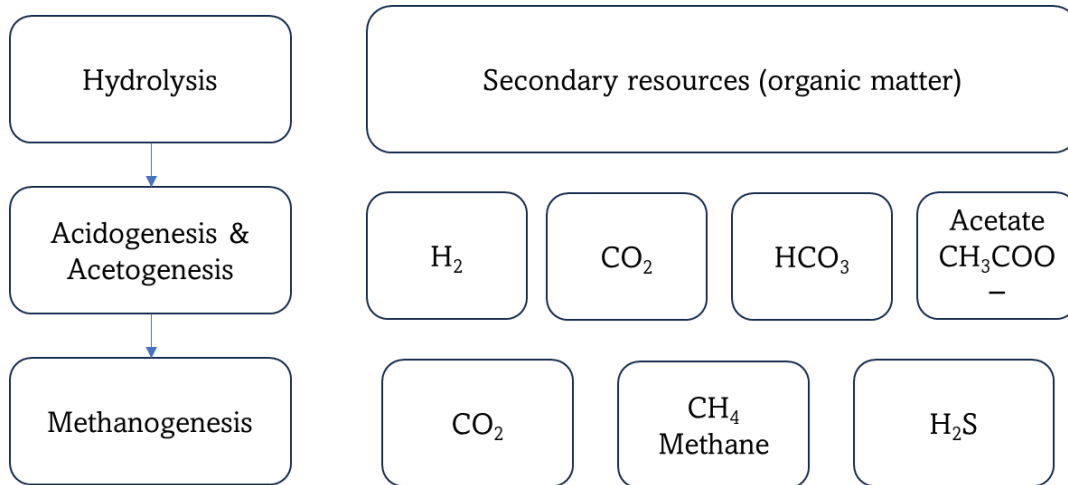


Figure 11 Simplified process of anaerobic digestion

There are different anaerobic digestion technologies, all of which require a digester to be heated, insulated, and airtight:

- The wet or continuously stirred tank process, where the dry matter content of the mixture is at most 20%. The process of digestion takes place in cylindrical tank digesters with a flexible and tight membrane on top. The mixture is pumped and stirred daily in the installation.
- The dry or solid-state process, where the dry matter content ranges between 20% and 40%. The digesters, in the form of silos, are installed in parallel. The substrates are not mixed or stirred. The digester is fed with the mixture sequentially at separate intervals.

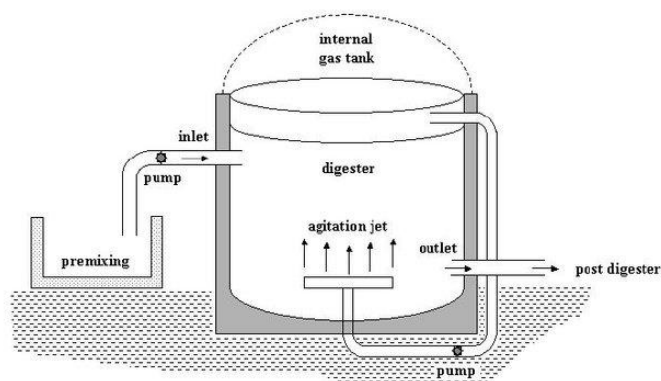


Figure 12 Wet process of anaerobic digestion - Source: Ploechl and Heiermann (2006)

Although there are some drawbacks associated with pre- and post-processing, such as heat loss, larger dimensions needed, and higher costs, it is worth noting that in France, the continuously stirred tank process is preferred due to its many operational benefits. It provides a uniform substrate, has a shorter residence time, better process control, medium solubility, and a clearer understanding of kinetics (Bautista Angeli, 2018).

Figure 13 displays an aerial view of the technical complexity of an anaerobic digestion plant.



Figure 13 Example of a biomethane plant in France - Source: Engie BiOZ

1: Weighbridge, 2: Wheel wash, 3: Office, 4: Resource reception building, 5: Liquid storage, 6: Digester 7: Post digester, 8: Phase separation building, 9: Digestate storage tanks, 10: Nitrogen treatment tanks, 11: Boiler, 12: Purification, 13: Gas flare, 14: GRTgaz injection station, 15: Biofilter air treatment, 16: Rainwater basin, 17: External storage slab, 18: Fire reserve, 19: Liquid digestate recovery tank

2.3 A diversity of secondary resources to be digested, subject to uncertainties and tensions

Prior to the biological and technical process, resources must be selected and introduced into the digesters. The resources utilized in anaerobic digestion constitute a portion of biomass resources. In France, biomass is defined by Article 19 of Law No. 2009-967³⁴ related to the implementation of the Grenelle Environment Program: "Biomass is the biodegradable fraction of products, waste, and residues from agriculture, including plant and animal substances from land and sea,

³⁴ https://www.legifrance.gouv.fr/jorf/article_jo/JORFARTI000020949597

forestry, and related industries, as well as the biodegradable fraction of industrial and household waste."

Diverse fermentable organic materials can be degraded by micro-organisms and bacteria during the anaerobic digestion process. These include:

- Agricultural resources: pig and cattle slurry, pig and cattle manure, poultry droppings, crop residues, intermediate crops
- Community and household resources: grass cuttings, roadside mowing waste, biowaste
- Agro-industrial resources: animal or vegetable fats, fruit, vegetables, biowaste
- Industrial resources: sludge from sewage treatment plants

	Resources	Methanogenic power (m ³ CH ₄ / t raw material) (Methasim 2010; Solagro, 2013)	Regulation on or restrictions to use in anaerobic digestion plants in France
Agricultural	Manure (solid) and slurry (liquid) ³⁵	5-150	NA
	Crop residues	50-300	NA
	Intermediate crops	100-300	NA
	Dedicated crops	100-300	Regulated, up to 15% allowed
Community	Biowaste	50-100	Technical treatment may be required
	Green waste	100-125	NA
Agro-industrial	Biowaste (excluding animal by-products ³⁶)	50-250	Technical treatment may be required
	Animal by-products waste (blood, fat, etc.)	50-450	Regulated, technical treatment required
Industrial	WWTP sludge and grease	50-250	NA

Table 11 Methanogenic power and regulations related to secondary resources

From a technical perspective, the choice of inputs, according to their methanogenic power, is essential to guarantee optimal performance of the anaerobic digestion unit. Methanogenic power refers to the ability of organic materials to produce methane gas. In the context of anaerobic

³⁵ "Manure" and "slurry" are two types of animal waste, but they differ in their form and composition. Manure refers to the solid excrement of animals, such as that of cows, horses, pigs, or poultry. Manure may contain organic materials such as dung, straw, litter, and food residues. Slurry is a liquid mixture of animal waste and water, often derived from intensive farming systems such as pig farms or dairy farms. Slurry may contain solid waste as well as urine and wash water. It is usually stored in storage pits or tanks.

³⁶ In France, animal by-products are commonly known by the acronym SPAN, for sous-produits animaux

digestion, methanogenic power refers to the potential of the resources to generate methane during the digestion process. Thus, the quality and quantity of resources play a critical role in the efficiency and effectiveness of the anaerobic digestion process. If the quality and quantity of the deposits is poor or inconsistent, the process can be disrupted, leading to lower biogas production, lower energy efficiency, and even the formation of toxic compounds. The methanogenic power of these different inputs, i.e., the quantity of methane that it can produce, differs. While high methanogenic power is favored, low-methanogenic resources are also essential in the final mixture as they help maintain an appropriate physico-chemical balance in the digester. Also, the choice of input impacts the nature of digestate. Indeed, after the anaerobic digestion process, the nutrient-rich organic material that remains contains plant nutrients such as nitrogen (N), potassium (K), and phosphorus (P). These nutrients play key roles in various aspects of plant development. Nitrogen is crucial for the formation of proteins, enzymes, and chlorophyll, which are essential for plant growth and photosynthesis. Phosphorus is involved in energy transfer within plants, root development, flowering, and fruit formation. Potassium helps regulate water movement within plants, improves stress tolerance, enhances disease resistance. The characteristics of digestates may vary depending on the operating conditions of anaerobic digestion and the resources digested in the process. Thus, depending on the nature of the mixture and its N, P and K content, the digestate can either be used as mineral fertilizer to be spread on agricultural lands, or used for energy valorization through combustion if it does not fit the requirements of non-toxicity (Kanda et al., 2021). If the resources contain toxic compounds such as chemicals or heavy metals, or harmful pathogenic bacteria that anaerobic digestion has not been able to reduce or eliminate, it may be necessary to consider another valorization pathway (Bautista Angeli, 2018).

In France, most types of secondary resources mobilized are agricultural (European Biogas Association, 2022). Indeed, in the eastern region of France, where the biomethane market is most developed (Figure 14), it is common for anaerobic digestion plants to utilize agricultural resources due to the regions' farming landscapes.

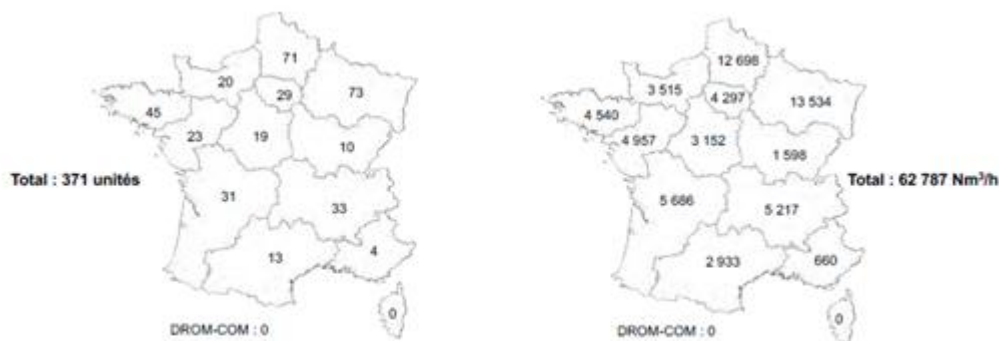


Figure 14 Number and capacity of biomethane plants per department – ADEME 2022

However, looking ahead to 2030 projections, the mobilization rates specific to anaerobic digestion present a complex scenario. Agricultural resources demonstrate relatively low mobilization rates (<15%), even though they constitute 90% of the overall resource available (Solagro, 2013). Despite the low mobilization rates, the potential mobilizable margin remains substantial. Non-agricultural resources, on the other hand, have moderate mobilization rates (20-40%) (Navigant, 2019; SIA Partners & GT Biogaz CSF, 2022). Also, the yearly variability in agricultural production, heavily relied upon in decarbonization strategies, could fluctuate significantly due to factors such as droughts and increasing extreme climatic events (Challet & Fourny, 2023). Specifically, the majority of exploitable biomass for biomethane production, comprising winter intermediate energy crops³⁷, crop residues, and grass, will be subject to this variability, which could result in fluctuations representing a 40% variability in total biogas production (Challet & Fourny, 2023). According to the EU agriculture outlook for 2023-2035, the decline in livestock farming, partially attributed to the shift towards more plant-based diets and awareness of their impact on climate change, is anticipated to have widespread effects across multiple sectors. Consequently, the availability of manure and slurry is expected to decrease, along with a decline in the availability of cereals intended for human consumption.

Also, as depicted in the table 12, biomass exploited for anaerobic digestion can serve various other purposes. Thus, its potential is strained due to competition in usage, even though energy

³⁷ These crops are commonly known in France by their acronym, CIVE (cultures intermédiaires à vocation énergétique)

mobilization is crucial (Courteau et al., 2016). Despite formulation of the National Strategy for Biomass Mobilization in 2018, coupled with the regional biomass plans (serving as a roadmap for the reasoned and balanced development of renewable energy production from biomass), numerous debates persist regarding the feasibility of achieving the low-carbon strategy goals with biomass. Indeed, external factors may impact the resources available for anaerobic digestion, such as alternative uses and climate change

Given the current challenges, agricultural biomass availability may not align with the long-term objectives set by the National Low Carbon Strategy (SNBC, *Stratégie Nationale Bas Carbone*). According to a 2021 France Stratégie study, current agricultural biomass mobilization for energy, at around 40 TWh, could theoretically reach a maximum potential of 120 TWh with additional resources. However, the SNBC projects a production potential of approximately 250 TWh, indicating that this target cannot be met solely with the identified additional resources (Mourjane & Fosse, 2021). The study conducted by the CSF working group has also confirmed that the current estimated resource needs from the food industry and biowaste closely align with or surpass the fraction anticipated to be mobilized by 2030 for anaerobic digestion. This could result in heightened competition for access to biowaste resources, leading to increased tensions in the anaerobic digestion sector.

There are also operational challenges in securing secondary resources while considering the optimal mixture configuration and quantity, harvesting time and frequency, transportation modes, together with delivery and storage conditions (Cerca et al. 2022). In fact, compared with fossil-based resources, anaerobic digestion deposits lack homogenization due to their diverse origins, fluctuations in availability and other seasonality factors (Paes et al. 2019).

While studies have been conducted to assess and project the potential accessible biomass and possible operational and market tensions, others have been designed to provide a more accurate vision of the biomass financial market (IEA, 2020; Ruiz et al., 2015; SIA Partners & GT Biogaz CSF, 2022). They all converge upon the conclusion that the anaerobic digestion sector also faces challenges in accurately gauging detailed market prices for inputs. There is significant heterogeneity in observed prices, both among major input categories and within the same

category. Geographic factors, even within the same region, contribute to the widening of price gaps for identical inputs. This uncertainty in market prices is accentuated due to competition (ENEA Consulting, 2017; ENGIE, 2021; Navigant, 2019; SIA Partners & GT Biogaz CSF, 2022). This may occur downstream, either among valorization pathways due to diverse resource types or among anaerobic digestion units themselves, particularly focusing on resources from agro-food industries. However, this phenomenon is currently less pronounced (SIA Partners & GT Biogaz CSF, 2022). Furthermore, upstream competition may occur, especially for agricultural resources like intermediate energy crops, whose cultivation demands a precise farming system so that they can be used for anaerobic digestion.

	Resources	Available net deposit in % from the 308 million tonnes of gross matter estimated for 2030 (Solagro 2013)	Estimate of the mobilization rate of the net available part dedicated to the anaerobic digestion sector (SIA Partners & GT Biogaz CSF, 2022)	Price range €/t raw material (SIA Partners & GT Biogaz CSF, 2022, IEA, 2020, Ruiz et al., 2015, Engie, 2021)	Other possible valorization (Agrosolutions, AGRESTE Primeur, 2010) ; SIA Partners & GT Biogaz CSF, 2022; AMORCE 2019)
Agricultural	Manure and slurry	57%	8%	5-90	Agronomic valorization: stored and spread
	Crop residues	12%	2%	5-50	Left on the ground Animal feed Composting Biofuel
	Intermediate crops for energy recovery	15%	13%	25-30	Alternative energy recovery
	Dedicated crops	6%	13%	25-30	Energy Recovery
Community	Biowaste	10%	19%	0-100	Composted and spread
	Green waste			0-10	Composted and spread
Agro-industrial	Biowaste (excluding animal by-products)		40%	0-270	Composted, stored, spread Incinerated with energy recovery Waste from starch

					manufacturing, and fruit and vegetable processing
	Animal by-product waste (blood, fat, etc.)				Incinerated with energy recovery
Industrial	WWTP sludge and grease		40%		Composted, stored, spread

Table 12 Detailed characteristics of secondary resources (available deposit, estimated mobilization rates, prices, and alternative valorizations)

In general, the mobilization of adequate resources for anaerobic digestion continues to be a challenge due to limited data, the variability in quantity and prices as well as the tensions surrounding it. We therefore note the complexity of the inputs (their characteristics, price, competition, estimation, etc.) and their impact on the technical processes chosen and the quality of the digestate. In view of this, associations and public bodies are working to produce technical summaries and reports to help stakeholders face up to the challenges posed by resources mobilized in anaerobic digestion.

3. Public actors supporting anaerobic digestion in France

This historical evolution of anaerobic digestion in France is marked by industrial structuring and the clustering of professionals to exchange on monitoring regulations and best practices. This can be related to the uncertainties and both operational and market tensions surrounding the complex and nuanced parameters involved in anaerobic digestion, more specifically regarding secondary resources. Indeed, we note the implication of prominent actors in shaping the trajectory of anaerobic digestion models in France, specifically on-farm and centralized models.

The ADEME has had a dual role to play in exerting pressure and raising awareness of public policies while also consolidating technical expertise and knowledge, as shown in Figure 15. Indeed, between 2011 and 2023, the agency published a total of 104 documents related to anaerobic digestion. Upon reviewing the abstracts and examining them closely, the reports were categorized by type. It is worth noting that approximately half of the published reports are assessments and evaluations, followed by qualitative descriptions based on comprehensive feedback of successful anaerobic digestion projects and practical guides.

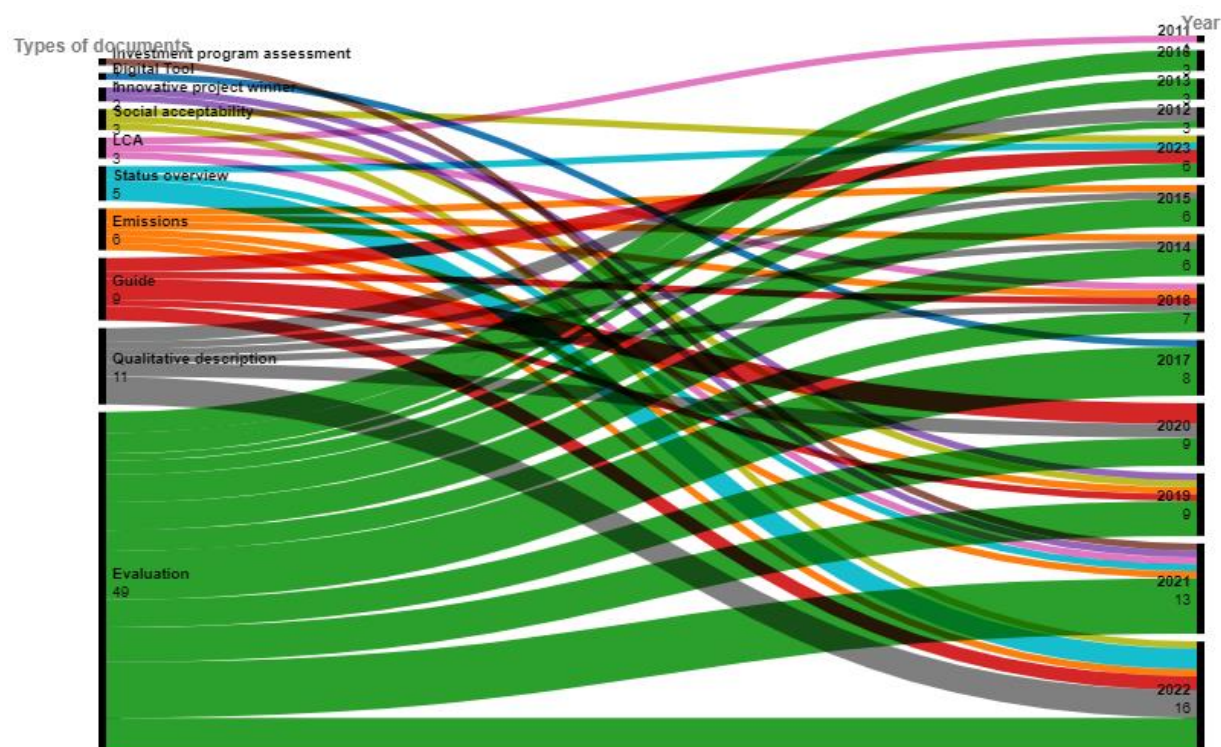


Figure 15 Types of documents published by the ADEME³⁸

The evaluation reports mainly assess the technical and/or economic aspect(s) of anaerobic digestion units, assess the potential of anaerobic digestion per region, report on agronomic aspects of digestate or inputs, and offer environmental assessments. The qualitative description reports include feedback of projects that have been operationally successful. They outline the technical and technological characteristics of the plant, the nature of inputs, the benefits in terms of production and employment, and the funding schemes. The practical guide reports simplify and explain administrative processes, such as document filing, and include financial tools and simulations to assist field actors in overcoming funding challenges. They also offer guides on biogas flow measurement and contracting to secure resources. Their qualitative descriptions typically follow a consistent pattern of case presentations. These presentations include an introduction to the context of unit development and a description of specific features such as size, input types, and valorization methods.

³⁸ A query was run using the keyword “Methanisation” in their online library on 10-23-2023. The list of documents with their abstract was extracted to Excel.

In 2019, the first *Contrat Stratégique de Filière* (Strategic Sector Contract) was signed between the state and representatives of the committee *Nouveaux Systèmes Energétiques*³⁹ (New Energy Systems), and subsequently renewed for 2021-2023. The founding members of the New Energy Systems are Engie, Total Energies, EDF and Schneider. It aims to promote decarbonization at a competitive cost. A biogas working group⁴⁰ was created within New Energy Systems. The principal goal of this working group is to elevate the industrialization and competitiveness of the biomethane sector. Comprising industry professionals, the working group actively contributes by providing methodologies, technical guides, standardization elements, solution/training catalogues, and addressing innovative aspects such as valorization of CO₂. The national recognition and expansive scope that biomethane now encompasses in France reflects the interest of major actors in the energy sector in developing centralized anaerobic digestion.

³⁹ New Energy Systems is one of the 19 Comités Stratégiques de Filière currently recognized. <https://www.conseil-national-industrie.gouv.fr/decouvrez-19-csf>

⁴⁰ <https://systemesenergetiques.org/groupe-de-travail/biogaz/>

Conclusion of chapter 4

This chapter served to situate anaerobic digestion in the national French context. The historical evolution of anaerobic digestion in France underscores the pivotal role of regulations in establishing a conducive environment for circular models in the energy sector. Regulatory frameworks, characterized by a balance of stringency to ensure safety and environmental protection and reasonable use of secondary resources, alongside incentives to encourage industry engagement, have been instrumental in shaping the trajectory of anaerobic digestion.

The structuring of anaerobic digestion models is not solely attributed to regulations but also to the contributions of public entities and their instruments, as well as associations. Anaerobic digestion is a technical complex process and faces challenges related to the securing of biological resources. Biological resources need to be of adequate quality and in sufficient quantity as they impact the performance of the plant as well as the quality of the resulting digestate.

We note the ADEME's impact in disseminating information, providing financial support, and lending technical project assistance. It has played a crucial role in guiding and facilitating anaerobic digestion initiatives, and helping actors navigate the complexities inherent in various models. Additionally, collaborative efforts facilitated by working groups, either through voluntary associations like the ATEE through their biogas club and their CTBM research center or state-led initiatives, have been instrumental in structuring the sector and fostering collective interest. Instruments such as the "*contrat stratégique de filière*" (CSF - strategic sector contract) serve as foundational documents outlining collaborative strategic initiatives within specific industries in France, indicative of concerted efforts to structure and advance anaerobic digestion. The launch of a working group and the signing of a CSF with the New Energy Systems committee represent significant strides in integrating biomethane into national strategic discussions and planning processes, underscoring the recognition of anaerobic digestion as a key component of France's energy transition agenda.

Finally, this chapter aimed to describe the case studied in our research and demonstrate its relevance to the research question. Indeed, given all these theoretical and empirical insights we argue that anaerobic digestion represents a suitable and new object for studying the question of circular economy implementation. More specifically, it shows that it can provide relevant insights into the issues of secondary resources regarding the challenges

of economic viability and the interdependence of actors. Indeed, in this chapter we were able to highlight how multifaceted influences can structure circular models, underscoring the concerted efforts of stakeholders in shaping circular initiatives.

In fact, anaerobic digestion projects are not only a technical and biological construct, but also a socially complex construct (Arfaoui et al., 2022). From its inception, development through to its operational phase, different actors come into play. An anaerobic digestion plant is constructed through specific economic and political relations as well as the involvement of actors from distinct categories (Lévy, 2003, p.908). It involves various relationships with local communities among which the plant is constructed, as well as legislators that enhance the development of projects through specific governmental support, incentive schemes and regulatory frameworks (Bourdin et al., 2020). It entails engaging with local providers of resources from various sectors, including waste management facilities, industrialists or public communities (Arfaoui et al., 2022). It also involves manipulating organic sources, crop residues, dedicated crops, and even energy crops, as well as livestock effluents. Anaerobic digestion is a mature technology and can be adapted to specific local conditions and contexts serving multiple societal functions (Kanda et al., 2021). It thus necessitates assessing the outputs and identifying the best utilization options, such as digestate, heat, electricity, or gas, which requires a specific engagement from different actors depending on the option chosen. In other energy projects—in the gas industry for instance, from drilling to domestic consumption—a limited number of economic agents are at play, most of whom are energy providers (Alaterre et al., 2015). This is not, however, the case in anaerobic digestion projects, where actors from different sectors are needed at various stages of the development.

Chapter 5. Securing secondary resources for anaerobic digestion projects in practice

Chapter 5.1 Selection of cases

This chapter aims to describe the processes involved in securing biological secondary resources, through narratives of anaerobic digestion project cases as mentioned in chapter 2 (section 3.3). First, before the project narratives, we deemed it important to provide contextual information to help readers situate the selected cases. The objective of this subsection is to set the stage for the narratives by delineating the strategies of three organizations with regard to anaerobic digestion as an additional activity, and elucidating the rationale behind our selection of the specific projects which are detailed in subsection 5.2.

Our doctoral research context, as mentioned in Chapter 2, facilitated our investigation into the development of anaerobic digestion within Engie and Veolia. This configuration also afforded us the opportunity to explore anaerobic digestion within an agricultural cooperative (EMC2). This subsection offers an overview of the emergence of anaerobic digestion projects within these distinct organizational settings: an agricultural cooperative (EMC2), an energy company (Engie) and a waste, water, and energy company (Veolia). Investigating these diverse sectors is pivotal to our study, as anaerobic digestion intersects with energy, waste, and agriculture (as detailed in chapter 3). We posited that investigating the interest of these three different sectors in the development of anaerobic digestion projects could offer valuable insights into the process of securing secondary resources.

Accessing three different organizations provided us with a multitude of anaerobic digestion projects to examine. We aligned our selection process with the strategic objectives and vision

of these organizations. Furthermore, we carefully considered criteria such as initiators, size, location of the project and quantity per type of secondary resources in our selection. This selection process ensured that our investigation into anaerobic digestion projects was thorough and reflective of the strategic goals of the organizations involved. We will present in the first two subsections the strategy regarding anaerobic digestion and then proceed by explaining how we selected projects, successively for Engie (1) and EMC2 (2), and then explain in a third subsection (3) why we decided not to select any project within Veolia.

1. Anaerobic digestion at an Energy Company

Our access to the energy company stemmed from the doctoral research context, as detailed in chapter 2 section 1.

On the one hand, we could directly contact the entities involved in biomethane activities. On the other hand, while being part of Engie Lab Crigen, we had access to teams working directly with entities responsible for developing biomethane plants, who agreed to put us in contact.

We seized the opportunity to contact actors in the company to investigate the motivations driving Engie to undertake anaerobic digestion projects. In the ensuing paragraphs, we elucidate the emergence of anaerobic digestion initiatives as well as the significance of the activity regarding Engie's strategy, followed by an explanation of our project selection criteria for a detailed narrative in Section 5.2.

“We decarbonize gas by producing green gas... It is not painting it green, but it's using a different gas. There are two different types: biogas, biomethane more specifically. It is mainly produced from waste which can be agricultural, agri-food or industrial. So, this biogas is the circular economy in energy. It is quite virtuous.”

–Catherine MacGregor (Chief Executive Officer of Engie) – Quotidien, June 12, 2023, TMC

1.1 Emergence of anaerobic digestion at Engie

Biogas as an interest in the trading of renewable gas from 2008

Engie was formed on July 22, 2008 through the merger of Gaz de France (GDF) and Suez. Gaz de France specialized in the purchase, transport, distribution, and marketing of fossil fuels. Suez designed solutions for managing services as a partner of local authorities, companies, and private individuals to meet essential needs in electricity, gas, energy services, water, and waste management. In July 2015, the corporate Group name changed from 'GDF Suez' to 'Engie'. The merger of Gaz de France and Suez in 2008 sparked the interest in producing biogas. In fact, Suez already had the skills and knowledge of valorizing biogas from waste and water treatment plants, whereas Gaz de France was a specialist in the gas field. Fueled by the authorization of the French State in 2011 to inject the gas produced by these plants into the gas network, the Group seized the opportunity to market biogas. It

decided to bring together and mobilize its internal capacities to sell natural gas. Therefore, it was through the prism of gas marketing that biogas started to fit Engie's strategy. They thus created the entity first known as Engie Biogaz.

“This is when it really entered the Group's vision. We said to ourselves: Biogas is a renewable gas, we sell gas, we will succeed in doing something with it. We will be successful in selling biogas.” – Former project manager, Engie BiOZ

Biogas as an interest in the production of renewable gas starting 2011

Engie soon realized that only marketing biomethane to their clients would potentially lead to missed opportunities to fully understand the biogas sector, along with the stakes involved. This prompted the Group to launch a separate entity, Engie BiOZ, dedicated to developing anaerobic digestion projects. Again, the company decided to capitalize on internal capacities developed within Cofely, another entity which operated biomass boilers.

“By remaining solely on the sale, we will lack an understanding of the sector and its challenges. To be a good trader, we have to go back a little in the chain and take an interest in production. It was then that it was decided to create a new entity, Engie BiOZ. Also, Cofely had a huge development in biomass boilers made to burn biomass. Engie said that operating an anaerobic digestion plant will look a bit like burning biomass to make electricity or heat”
– Former project manager, Engie BiOZ

Anaerobic digestion as a solution for the survival of gas networks from 2015

The viability of gas networks found itself in jeopardy. Indeed, poor forecasts of gas consumption in France were issued in 2015. These unfavorable trajectories were coupled with a strong political agenda favoring the electrification of the energy mix in France. In 2015, Engie Biogaz became “BiOZ”, a 100% subsidiary of the Engie Group. It depends on 50% pertaining to Storengy and 50% pertaining to Engie Green (itself in the company France Renewable). Now that this new entity had been created, the company wanted to push the development of anaerobic digestion internally and externally. In fact, they wanted to guarantee a steady volume of biomethane in the gas networks.

To consolidate and defend their strategy regarding biogas at the national level, which had a very all-electric vision, BiOZ proceeded in 2018 with the purchase of Biogas Plus, a provider of biogas technology, and an expert in the field of anaerobic digestion. In 2019, it purchased Vol-V Biomasse. The company was an independent regional leader in anaerobic digestion in France. It had ten sites in operation and several dozen in development. This drove the

acceleration of organic growth and alignment with Engie's objectives. Developing an anaerobic digestion project can take up to 6 years. By collaborating with VolV Biomasse, Engie accelerated the internal development of specific skills required in the field.

“The reason we produce biomethane is because the gas network is located almost everywhere in France. It is amortized because it is well maintained and old, and it is no longer used at 100%, so there is a capacity freely available over the network due to a decrease in natural gas consumption in France. So, to save our gas network we produce biomethane. It is of mutual benefit: The natural gas network depends on biomethane to survive, and biomethane depends on the viability of the natural gas network (...) For a while the network managers upheld the subject [ensuring gas network viability] from a strong lobbying point of view...but to reinforce this approach and to prove to the State that Engie was really doing things to keep it viable, BiOZ acquired VolV Biomasse” – General Director, Engie BiOZ

Anaerobic digestion as a solution for the decarbonization and acceleration of the energy transition starting in 2019

A second more recent move in the Group strengthened the place of anaerobic digestion in the company. The purpose or *'raison d'être'* of the Group as stated by the company is to accelerate the energy transition of Engie's customers in order to achieve carbon neutrality. It is one of the few companies in the energy sector that advocates sustainable development and formulates clear commitments and a strategic action plan on the issue (Renouard, 2021). Fueled by the energy crisis at the end of 2021 caused by the war in Ukraine, anaerobic digestion appears to be a solution for Engie to gain autonomy in gas production. Thus, anaerobic digestion is no longer just a solution to save the gas network. It clearly reflects the customer need for access to decarbonized gas and represents a significant business opportunity for Engie.

By the end of 2020, BiOZ had 21 sites in operation, 17 currently in service. Amongst these sites, 13 provided an injection of 245 GWh/year and 4 cogeneration for 65 GWh/year. Thus, an average production per plant of 22 GWh/year. In 2020, it produced 12% of the total biomethane production in France. Engie has set energy production objectives of 1 TWh in 2023 and 4 TWh in 2030. More recently, in 2023, Engie created a new, dedicated entity known as “Renewable Gases Europe” with the objectives to reach 10 TWh in Europe by 2030. Therefore, beyond the production of biomethane in France, Engie is looking to expand its anaerobic digestion activity and position itself in Europe. It aims to capitalize on the expertise developed at BiOZ to accelerate its development.

“Today in the Group bringing biomethane to our customers is a huge challenge. And to bring biomethane back to our customers we believe that it is essential to be a producer. The ambitions for the production of methane are more than reaffirmed in our strategy” – Storengy’s Strategy Advisor

Anaerobic digestion at the crossroads of multiple actors within Engie

While Engie's venture into anaerobic digestion originally stemmed from the necessity to ensure the survival of its gas activity and the resilience of its gas network, it has more recently been placed at the very core of their strategic decarbonizing activities. Throughout the progression of their interest in anaerobic digestion, we observed a shift in the nature of projects. Initially, Engie engaged in collaborative projects initiated by external actors, and then they independently developed initiatives spanning from small- to medium-sized plants. However, in recent times, they are focusing on establishing larger-scale plants across Europe to meet the goals of producing biomethane. Figure 16 summarizes this evolution over time. The increasing interest in anaerobic digestion is evidenced by their involvement in different entities focused on the same subject.

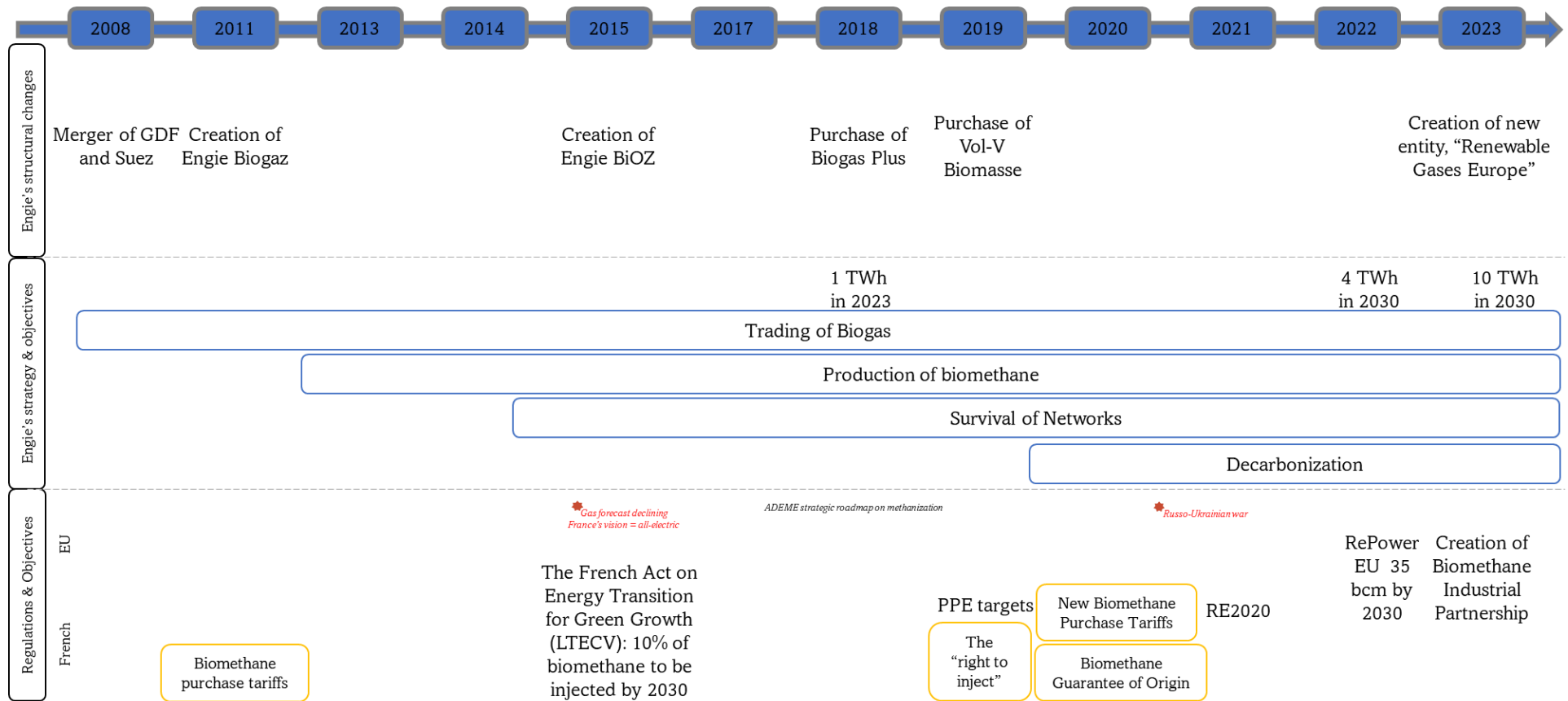


Figure 16 The evolution of Engie's biomethane strategy over time

To reach the biomethane production objectives for 2030, Engie leverages the expertise of multiple supporting actors. Internally, the company relies on the competencies and knowledge of its R&D entities (Biogaz Lab, Biomass & Waste, and Environment & Society Lab in the Research and Innovation Department). These entities provide valuable insights into the technical feasibility of projects, conduct societal studies, and perform environmental impact analyses. Such internal expertise allows Engie to ensure the viability and sustainability of its endeavors. Engie also collaborates with an internal consulting entity (Engie Impact) to further enhance its capabilities. These entities help in mapping potential markets, evaluating biomass potential, and providing valuable insights into various aspects of project development. Their expertise aids Engie in making informed decisions and identifying opportunities for growth. In addition to internal resources, Engie strategically acquired technical players to gain access to cutting-edge technologies and specialized expertise (Biogas Plus). This acquisition enables the company to stay at the forefront of innovation and effectively address complex challenges in the energy sector. Moreover, Engie acquired a local developer (Vol-V Biomasse) to bring operational entities and local exposure to the table, allowing Engie to establish a strong presence in specific regions. By leveraging the expertise of various actors both internally and externally, Engie BiOZ has strengthened its position in the biogas sector and now serves as a base for the expansion projected by Storengy. Figure 17 presents an overview of Engie's actors in the anaerobic digestion sector.

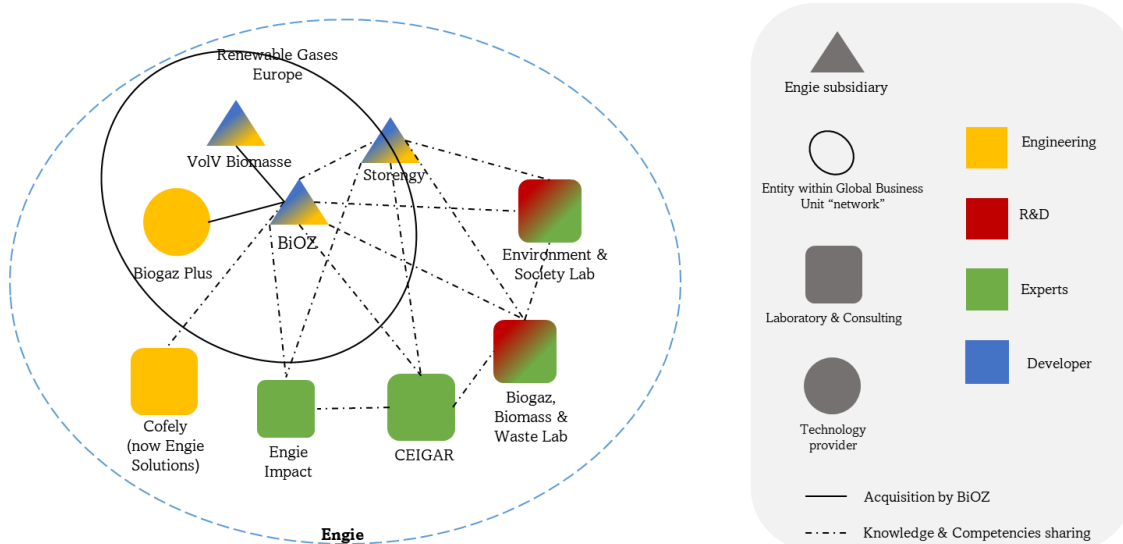


Figure 17 Engie's players in the anaerobic digestion sector

1.2 Selection of cases

To explore the development of anaerobic digestion projects within Engie, we conducted a comprehensive analysis of specific project cases. The selection of diverse cases aims to provide a multifaceted basis for understanding the complexities of anaerobic digestion projects in various contexts, reflecting the evolving and nuanced landscape of these projects' initiatives at Engie. It also aims to demonstrate how organizational engagement, geographic realities, and strategic decisions shape the projects.

As mentioned, the first criteria stem from opportunistic access, prioritizing those offering extensive opportunities for contacts with various actors and stakeholders involved in the projects. Nevertheless, the selection was also made in a way that represents Engie's strategic responses to industry dynamics and competition. Therefore, other criteria were based on various initiating actors, size of the plants and geographic location. Three cases were strategically chosen to illustrate Engie's trajectory and operationalization in anaerobic digestion projects: Methamoly, Caux Vallée de Seine, and Sibiom.

Methamoly was chosen because it is a project representing Engie's initial ventures into anaerobic digestion. It highlights the company's initial participation in a collaborative project with various stakeholders, where Engie was not the initiator. In contrast, in Caux Vallée de Seine project, Engie BiOZ independently manages an anaerobic digestion unit and its development, a model inherited from its acquisition of Vol-V Biomasse. This illustrates Engie's evolving role and competencies, developed to navigate the challenges of securing inputs. Finally, Sibiom (located in Belgium) was chosen first as a point of contrast with the French projects, demonstrating Engie's strategy to expand its operations internationally and to accelerate development through large-scale facilities. The international dimension offers a broader perspective on contextual factors that influence resource availability. The geographic diversity of the cases, located in various zones in France and Belgium, allows for an exploration of specificities within the same country and in contrast to another one.

The last project was also selected because it is a collaborative project, allowing a comparison with Methamoly's collaboration configuration. The addition of Sibiom, a larger plant under development by Storengy, compared with smaller plants such as Methamoly and Caux Vallée de Seine, allows for a valuable comparative analysis, shedding light on the dynamics, challenges involved, and resource management issues. This intentional variation in project size enhances the depth of the analysis. Furthermore, the cases were selected to reflect different rates of secondary resource utilization. For instance, Methamoly mobilizes 60% of

agricultural secondary resources, Caux Vallée de Seine strives for an equal distribution between agricultural and agro-industrial secondary resources, and finally, Sibiom opted for 80% of secondary resources from agro-industrial and industrial sources.

In conclusion, the selected cases demonstrate variations in the actors who initiate and participate in the projects, their organization, as well as the geographic locations, size of the plants, and secondary resources mobilized.

2. Anaerobic digestion at an Agricultural Cooperative

Our access to the agricultural cooperative EMC2 stemmed from opportunistic circumstances. While engaged with the CE team at Engie Lab Crigen, a project designed to evaluate various dimensions of anaerobic digestion plants, including circularity, was initiated and it was agreed that we would get involved. Unfortunately, the evaluation project was later abandoned.

Around the time of this abandoned project, it became apparent that exploring an anaerobic digestion project developed by a cooperative would offer complementary insights to our research, particularly regarding the perspectives of farmers on this technology, as well as supplementary information on the construction and organization of projects, and crucially, the process of securing secondary resource. Indeed, the key actors initiating anaerobic digestion projects as well as the motivations driving the adoption of anaerobic digestion are specific to the projects led by this cooperative. Moreover, EMC2 is located in the Grand Est region, the area with the highest concentration of anaerobic digestion entities in France (as detailed in Chapter 3, section 2.3). Additionally, it was ranked as the 4th largest cooperative in this region, and 30th among the top 65 agricultural cooperatives in terms of revenue in 2022⁴¹. These factors highlight EMC2's significant presence and influence in both the agricultural sector and the region, justifying our choice to investigate anaerobic digestion within this particular organization.

Recognizing these potential benefits to our research, we seized the opportunity to maintain contact with representatives involved in the initial project. Subsequently, we endeavored to investigate an agricultural cooperative's anaerobic digestion project with a focus on understanding how its secondary resources were secured.

In the ensuing paragraphs, we elucidate the motivations driving the cooperative to undertake anaerobic digestion projects, followed by an explanation of our project selection criteria for a detailed narrative in Section 5.2.

⁴¹ https://www.entreprises.coop/system/files/inline-files/CoopFR-Top100_2022_2.pdf

2.1 Emergence of anaerobic digestion at EMC2 - A series of stimuli

EMC2 is an agricultural cooperative in Lorraine, founded in 1988 from the merger of two cooperatives. It is a company created and governed by farmers. It covers 15 departments in the east and north-east of France. Its mission is to support farmers in their plant and animal production by offering them collection, supply, and advice solutions.

The emergence of anaerobic digestion at EMC2 unfolded gradually, driven by a series of stimuli spanning several years. *"It is singular because it (anaerobic digestion) was initially relatively distant from the cooperative's primary agricultural focus,"* explained the project manager of the first project. Discussions around energy-related topics, including anaerobic digestion, began around 2004 within the Agronomy and Environment Commission at cooperative level. The agronomy director, recalled the cooperative's early engagements with the subject, *"We first looked at this topic because, in both livestock and crop production, there were individual farmer projects or collective projects that were starting to be considered."* He also mentioned that, simultaneously, various actors—including large entities like Veolia—*"contacted EMC2 and sought to understand how to capture our agricultural biomass resources"*. The initiatives focused on cogeneration projects, driven by calls for tenders from the Commission de Régulation de l'Énergie (CRE), constituted a further stimulus. *"The first major collective projects we had to think about were related to CRE tenders. We studied local biomass such as straw and considered using it, either by burning it or gradually incorporating it into the anaerobic digestion,"* explained the agronomy director. However, the cooperative decided not to fully support these initiatives, choosing instead to individually assist farmers in crop production without delving into anaerobic digestion projects or developing their own entities. He concluded, *"So we looked at the maize varieties that could be methanogenic to support them in their plant production, but not to go further"*.

The cooperative's reluctance was primarily rooted in concerns about the core role of the cooperative. *"The decision was not to collectively develop our own plants as it's not the role of the cooperative"* emphasized the agronomy director. Also, the potential impacts on maize prices and profitability of anaerobic digestion projects at the time were major concerns mentioned by the project manager *"as far as cogeneration is concerned, according to our studies, it was quite difficult to come up with profitable projects."*

The cooperative's evolution towards anaerobic digestion was marked by a combination of other stimuli such as changes in economic factors, influencing the strategic decision to

explore collective projects, ultimately leading to the deployment of anaerobic digestion units within the cooperative's territory. Indeed around 2007, *“the price of fertilizers increased suddenly, and we felt it”* added the agronomy director. Another critical turning point occurred in 2010; marked changes in the economic landscape prompted a reevaluation of the cooperative's stance. Indeed, according to the project manager *“It was really the day when the injection projects became accessible that we looked at this more seriously at the cooperative level. Also, GRDF's willingness to help set up injection projects, so it certainly became more profitable financially. So, we said, well, we could benefit from looking into it, not individually, but to consider collective projects at the cooperative level.”* These mechanisms, state-funded connection cost payments, and regulatory frameworks all contributed to the economic viability of anaerobic digestion. The adoption of gas injection models was favored by the cooperative even though the integration of injected biogas into the distribution or transportation network introduces a constraint, requiring careful territorial planning to determine suitable unit locations. The choice of cogeneration was eliminated since it presents the notable challenge of needing a specific and predetermined heat client to purchase the generated heat. Given the context of rural territories, the availability of clients was relatively limited at the time. Therefore, injection plants emerged as a more economical and suitable choice for the cooperative.

Finally, the President of EMC2, also the Vice President of the Grand Est region responsible for energy, played a pivotal role in steering the cooperative toward anaerobic digestion. *“The president of the cooperative is relatively aware of what's going on in this domain,”* mentioned the director of operations. Therefore, the posture of EMC2 evolved and the desire to develop this activity was also reinforced by the fact that the cooperative hired specialized experts *“At that time, we went to ask a specialist in the subject of anaerobic digestion if he was interested in supporting us due to experience on a cooperative project”* recalled the agronomy director.

“What we wanted to do, in fact, was to make anaerobic digestion benefits available to farmers.”

–Operational Director at EMC2 (interview 10/27/2022)

2.2 Selection of cases

During our investigation of the projects at the cooperative we became aware that they had several potential projects, some abandoned mainly due to citizens' resistance and one that was operational at Landres. This was the first anaerobic digestion project launched by EMC. Our

decision was to select the first project developed, which proved to be successful. We decided to reject potential projects, because they would not provide insights into securing resources in the operational phase. The projects that were abandoned early in the development process due mainly to citizens' resistance did not align with the focus of our study, even if they would have been interesting.

After careful consideration, it appeared that examining the Landres case could provide useful insights to supplement the analysis of the other cases in our study. It offers a distinct perspective as it is solely driven by a collaborative entity of farmers and only mobilizes agricultural secondary resources. We focus on cultivating and expanding competencies within the cooperative and the specific governance mechanisms employed compared with an energy company. Furthermore, the Landres project allows a comparison because in terms of size, it is comparable to Methamoly.

3. Anaerobic digestion at a waste, water, and energy Company

Our access to Veolia also stemmed from the doctoral research context, as detailed in chapter 2 section 1.

However, the decision was made not to include a case study from Veolia. We encountered significant challenges in obtaining information necessary for our study, particularly concerning the project development process of centralized anaerobic digestion, despite conducting interviews. Veolia has historically positioned itself on anaerobic digestion at wastewater treatment plants. Even though the company has explored opportunities in developing centralized anaerobic digestion projects as categorized in chapter 3, the company further emphasized its priority in developing anaerobic digestion at WWTPs. This evolutive strategic context probably explains the difficulty encountered in gathering in-depth data on centralized anaerobic digestion projects. Despite the recognition of anaerobic digestion at WWTPs as a circular economy activity (Kiselev et al., 2019), we chose not to focus on this type of anaerobic digestion project in our study. Our research aims to explore CE projects characterized by secondary resources that are challenging to access and secure, necessitating robust collaboration among local stakeholders. Anaerobic digestion at WWTPs operates with several advantages that distinguish it from the types of projects we aim to study. Specifically, WWTPs benefit from a relatively consistent composition and volume of feedstock, with only minor variations due to daily and seasonal fluctuations in wastewater generation. This feedstock is collected through well-established sewer systems and transported via pipelines directly to the treatment plant (McCarty et al., 2011). This streamlined and predictable feedstock management contrasts sharply with the more complex logistics and variability associated with agricultural waste, community waste, and biowaste management (detailed in chapter 4). Figure 18 shows a simplified representation of biogas production at a WWTP. Raw wastewater, collected through the sewer systems, undergoes biological, physical, and chemical treatments to meet the requirements of treated water standards. During the wastewater treatment process, sewage sludge is produced. This sewage sludge is valorized through the anaerobic digestion process to produce biogas.

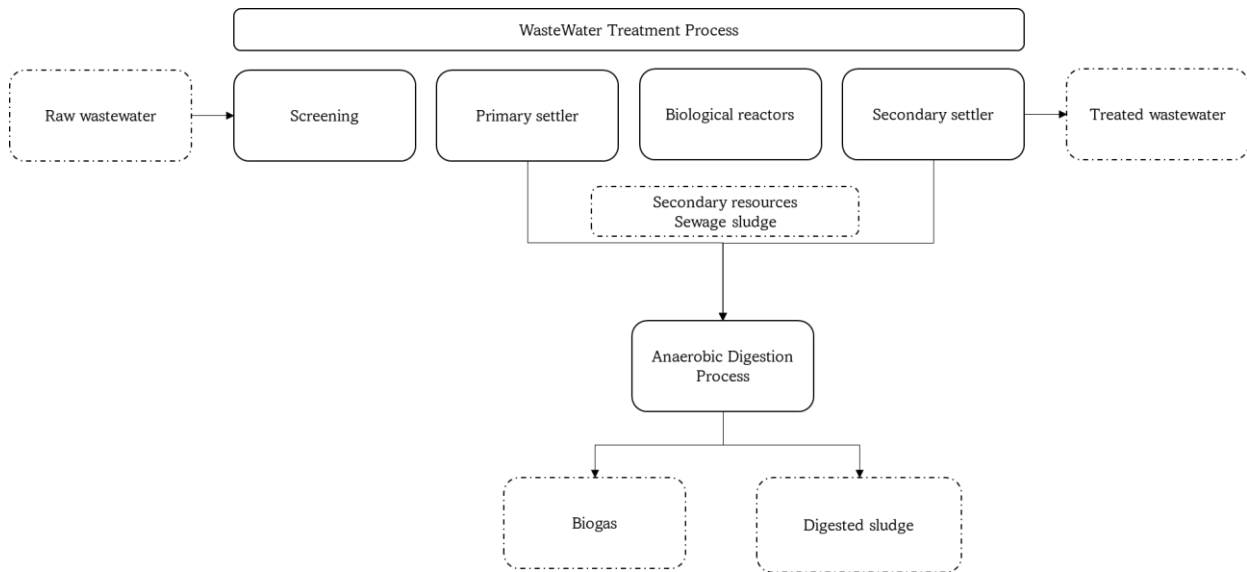


Figure 18 Simplified process of anaerobic digestion at WWTP - Source :adopted from (Gandiglio et al., 2019)

In subsequent paragraphs, we delve into the emergence of anaerobic digestion at Veolia, providing justifications for our choice.

Preference for anaerobic digestion at wastewater treatment plants

Veolia was created in 2003 as a result of a separation of Vivendi Environment from its parent organization, Vivendi Universal⁴². Vivendi Universal was formerly “*Compagnie Générale des Eaux*” and was largely focused on the water sector. In 1999, Vivendi Environment was created to address water (through its Vivendi Water division), energy services (through its *Compagnie Générale de Chauffage* division, later name Dalkia), transportation service (through *Compagnie Générale d'Entreprises automobiles*, later named Connex), waste management (through its Onyx environmental division, originally part of *Compagnie Générale d'Entreprises automobiles*).

Given its history in waste and water management, the anaerobic digestion of sludge from wastewater treatment plants is the most common and favored solution to produce biogas at Veolia. In this approach, the inputs used for biogas production mainly consist of sludge and various types of waste. Therefore, Veolia makes use of the available resources on the sites of their clients. Veolia operates over 1900 WWTPs, of which 41 produce biogas.

⁴² <https://www.veolia.com/en/veolia-group/who-are-we/our-history>

"We are going to position ourselves more on projects that I will describe as easy, which are the treatment of sludge from wastewater treatment plants. It is our natural profession. We have our natural customers. As soon as we leave this scope and anaerobic digestion including other stakeholders, we are leaving our comfort zone as it stands today."

– Director of the Organic Division (interview 01/20/2023)

Starting in 2018, an interest in centralized and on-farm anaerobic digestion

Veolia SEDE, a subsidiary of Veolia, adopted a Buyback strategy. Indeed, according to the Biological Treatment division manager, *"the easiest way to move fast and meet the CEO's objective is to buy."* The Operations and Development manager for the West region in France confirmed that Veolia SEDE has been exploring several takeover projects since 2018 as a means to diversify by acquiring existing anaerobic digestion units⁴³. To date, Veolia owns and exploits two centralized plants in France. Nevertheless, it supplies *organic* deposits to more than 250 centralized anaerobic digestion plants as mentioned by the Operations Manager of a biowaste sorting facility at *Veolia Recyclage et Valorisation des déchets* (RVD).

In 2021, Veolia established a task force to accompany the development of centralized anaerobic digestion in the Group, upon identifying it as a new market opportunity departing from the traditional anaerobic digestion at WWTPs. The task force projected that centralized anaerobic digestion would experience growth due to the AGEC regulation in France, which enforced the separate collection of household bio-waste by 2023. The objectives of the task force were shared during a webinar in December 2021. To enhance the Group's competitiveness in this activity, it was suggested that the methodology needed to be standardized, the offer tailored to the market, and the design be assured and guarantees offered. The task force identified centralized anaerobic digestion as a challenging aspect, with the manipulation of up to 40 unknown inputs (instead of the three sludge inputs well-known at Veolia) being identified as one of the challenges. The Group's interest in territorial centralized anaerobic digestion clearly demonstrates the potential for developing centralized anaerobic digestion by waste management companies.

Nevertheless, the development and operation of Veolia's own centralized plants remains timid. On the other hand, Veolia CEO Estelle Brachlianoff fervently emphasized the

⁴³ <https://www.innovation24.news/2023/07/05/sede-partenaire-privilegie-dans-la-reprise-de-sites-sas-meetha-vous-en-parle/>

significance of anaerobic digestion at WWTPs for Veolia during the Reflexions Conference on June 9, 2023, at the Polytechnique higher education establishment.

“So, if you equip all the wastewater treatment plants in France with an anaerobic digestion unit, 25% of the Russian gas we used to import into France could be replaced by biogas ... So, we are talking here about local energy, decentralized energy at a city or industrial park level, which can be a means of decarbonization thanks to what is basically a local source of energy. Biogas therefore ticks the box of course, being renewable.”

To further mark the strategy of anaerobic digestion at WWTPs, in 2022 Veolia announced⁴⁴ with Total Energies their objectives to co-invest in a portfolio of international projects with the ambition of producing up to 1.5 TWh per year of biomethane from Veolia’s WWTPs by 2025. Total Energies will market the produced biomethane.

To conclude, Veolia's journey in anaerobic digestion encompasses shifts in actor dynamics and changes in governance. We may observe significant illustrations of Veolia's evolving approach to this technology over time, with a historical and ongoing emphasis on anaerobic digestion at WWTPs.

⁴⁴ <https://www.veolia.com/sites/g/files/dvc4206/files/document/2023/04/veolia-rapport-integre-2022-2023.pdf>
<https://www.veolia.com/en/our-media/newsroom/press-releases/totalenergies-and-veolia-join-forces-accelerate-development-biomethane>

Conclusion of chapter 5.1

To conclude, we have chosen to investigate and compare anaerobic digestion within distinct organizational settings: an agricultural cooperative (EMC2) and an energy company (Engie) to gain insights into the process of securing secondary resources.

When looking specifically at the centralized model of anaerobic digestion, EMC2 had one operational project, while Engie had more than 20. We prioritized projects offering extensive opportunities for engagement with the various actors and stakeholders involved. We also purposefully selected the cases that allowed us to provide a thorough and detailed account of the process of securing secondary resources. We selected three projects at Engie, strategically chosen to illustrate Engie's trajectory and operationalization in anaerobic digestion projects as well as their involvement in the securing process—Methamoly and Caux Vallée de Seine in France, and Sibiom in Belgium—while ensuring variety in the actors involved, the size of plants, their location, and what secondary resources were mobilized. In the same perspective, we selected the first and only operational project at EMC2 at the time of this research.

As for Veolia, even though we observed that a company involved in the management of organic waste can be at the initiative of anaerobic digestion projects, we did not select any case. Indeed, we had little opportunity to reconstruct the historical development of projects in a way that accounts for the intricacies of the process of securing secondary resources.

Table 13 below presents a comprehensive overview of the cases that will be detailed through narratives in the subsequent section.

Table 13 Summary of cases and criteria for selection

Case	Actors initiating the project	Location	Size	Secondary resources	Status
Landres	Agricultural cooperative	France	Small	100% agricultural	Operational
Methamoly	Agriculture – Local public structure	France	Small	60% agricultural	Operational
Caux Vallée de Seine	Energy company – Local public structure	France	Medium	50% agricultural; 50% agro-industrial	Operational
Sibiom	Energy company – Local public structure	Belgium	Large	20% agricultural; 80% agro-industrial and industrial	Under development

5.2 Four project narratives

This section aims to describe the processes of securing biological secondary resources. To do so, it provides an overview of the emergence and development of four anaerobic digestion projects.

In the preceding section (5.1), we outlined the approach taken in the selection process for the four projects under scrutiny. This section will systematically introduce the projects: Landres, Methamoly, Caux Vallée de Seine, and finally Sibiom. We have strategically arranged the presentation, commencing with the projects situated in France before transitioning to the one in Belgium, and prioritizing operational projects in the initial discourse. Our ordering principle encompasses two dimensions: first, by project size, progressing from smaller to larger installations, and second, by the primary actors driving the initiatives—ranging from agricultural cooperatives of farmers with the EMC2 project, to combinations of farmers and public local actors, and finally, energy companies partnering with public local actors.

This chapter is subdivided into four sections, each dedicated to a specific project. Within each subsection, we delve into the narrative of project development provided by the key actors during interviews, supplemented by additional insights gleaned from sources such as documents provided by interviewees, newspapers, or local media.

For every project, a dedicated segment introduces the interviewees. An introduction to the interviewees is imperative to elucidate their roles within the project. Through structured interviews conducted with these individuals, their insights and expertise constitute the foundation of the forthcoming narratives. Each interviewee offers a distinct perspective and assumes specific responsibilities, thereby enriching our comprehension of project evolution. Accordingly, succinct profiles of the interviewees, accompanied by their respective job titles, will be provided. While the positions and functions accurately reflect real-world roles, all the names utilized herein are fictitious to maintain anonymity yet optimize clarity and coherence within the ensuing narratives. It is pertinent to acknowledge that verbatim excerpts are all translated from French. Also, in the narratives they do not uniformly represent all interviewees. Instead, selection prioritizes relevance, aiming to elucidate and enhance accessibility of the case narratives for readers. However, it is important to underscore that all

interviews, supplemented by external documentation, have significantly contributed to the construction of the narratives.

An exposition of the project's main characteristics is then provided. This encompasses technical specifications of the plant, including size and type, as well as pertinent geographic details. Additionally, financial and biological aspects are explored, highlighting the distinctive features of the projects—a summary of which is provided in Table 14. Furthermore, an overview of the project timeline is provided (Figures 19, 21, 22 and 23).

Each section proceeds with a detailed examination of the inception phases, elucidating how the project was initially conceptualized, the motivating factors, the key actors involved, and the overarching context.

Finally, we delve into the phases pertaining to secondary resource procurement, illuminating the approaches undertaken by actors in navigating challenges, along with the tactics and actions employed in securing necessary secondary resources.

The table below presents a comprehensive overview, summarizing key technical specifications, secondary resource types, timing considerations, financial aspects, and geographic contexts of the anaerobic digestion projects studied.

Table 14 General information on the four anaerobic digestion projects

Project	Size	Type	Substrates	Production of digestate (solid and liquid)	Agricultural resources	Biowaste resources	Investment (in millions of euros)	Subsidies (in euros)	Year of inception	Commissioning date	Status	Plot
Landres	14GWh/year	Injection into the grid – Feed-in tariff	24,000 T	24,000 T	18 farmers providing 100%		6.9	NA	2017	December 2021	Operational	France: Lorraine region – Business park – Owned by cooperative
Methamoly	12 GWh/year	Injection into the grid – Feed-in tariff	17,000 T	18,000 T	12 farmers providing 60% of substrates	Around 10 providing 40% of substrates	6,6	744,000	2011	March 2019	Operational	France: Auvergne-Rhône-Alpes region – Business park – Owned by SAS Methamoly
Caux Vallée de Seine	19GWh/year	Injection into the grid – Feed-in tariff	21,000 T	22,000 T	17 farmers providing 50% of substrates	Around 10 agro-industrial companies providing 50% of substrates	11.2	1,800,000	2010	February 2023	Operational	France: Normandy region – Industrial park – Purchased by Engie
Sibiom	100 GWh/year	Injection into the grid – Green certificates	150,000 T	120,000 T	20% of substrates	80% of substrates			2013		Under development	Belgium: Wallonia region – Industrial park

1. The Landres project

This narrative is based on the interviews and exchanges with Gabriel, Colin, Matteo, Samuel, and Michel.

Gabriel is the Operations Director at EMC2, *“I have been with the cooperative for 15 years. I am the director of operations here, so roughly speaking, my mission is to take care of everything related to the industrial operations, investment, and logistics, whether directly or indirectly. That is everything people need to function, so to speak, within this framework. Within this scope, I handle the deployment of anaerobic digestion units at the cooperative level. I am not alone, of course. We have Colin, who you probably met earlier, who’s central to the project.”*

Colin is the Project Manager at EMC2, *“I was previously an energy advisor in a Chamber of Agriculture. I joined the cooperative following Gabriel's request for my expertise in the energy sector, to take up the position of anaerobic digestion project manager and to supervise the Landres project.”*

Matteo is the Agronomy Director at EMC2, *“I have been here since 1999, for 24 years. I work on everything related to agronomy, regulations, and input traceability to support new projects. For example, the implementation of anaerobic digestion, and I am also involved in interfacing with a research center working on agronomy matters.”*

Samuel is the Regional Development Manager at EMC2, *“My job is to supervise the teams, the technicians on the ground who are in direct contact with members and farmers.”*

Michel is the Agricultural Technician at EMC2, *“I held the role of technician and directly supported farmers for 12 years in the cooperative, from 2007 to 2019. I provide agricultural support in terms of machinery, grain collection, and procurement in the development of the energy branch of the cooperative dealing with anaerobic digestion.”*

1.1 Main characteristics of the anaerobic digestion unit

The first project ever developed by EMC2 is located in Landres and the construction was completed in 10 months. The project required an investment of 6.9 million euros, with 76% of funds contributed by around thirty local funds from the Grand Est region. This initiative garnered the participation of 18 agricultural operations procuring 24,000 tons of agricultural inputs per year, resulting in the supply of biogas to 1,400 households. Additionally, the project yields an annual production of 24,000 tons of digestate, serving as a valuable soil fertilizer. According to Colin, *“They strategically designed the project with a capacity of less than 36,000 tons treated. The aim is to operate below the scrutiny of public inquiry zones. These sites fall outside the realm of requiring formal authorization and are subject only to registration.”*

Figure 19 below depicts the overall evolution of the project from its inception in 2017 till its official operation date in 2021. In 2017, the cooperative engaged in meetings to present the activity of anaerobic digestion to its farmers. The activity gained approval among a number of interested farmers in the cooperative in 2018. The following year saw the achievement of administrative procedures. The formal authorization requests were submitted in 2020, followed by a public hearing at the beginning of 2021. The public inquiry to authorize implementation of the plant was validated in July 2021, and construction on the designated site was completed by the end of the same year. December 4, 2021, marked the successful commissioning of the plant and commencement of operations.

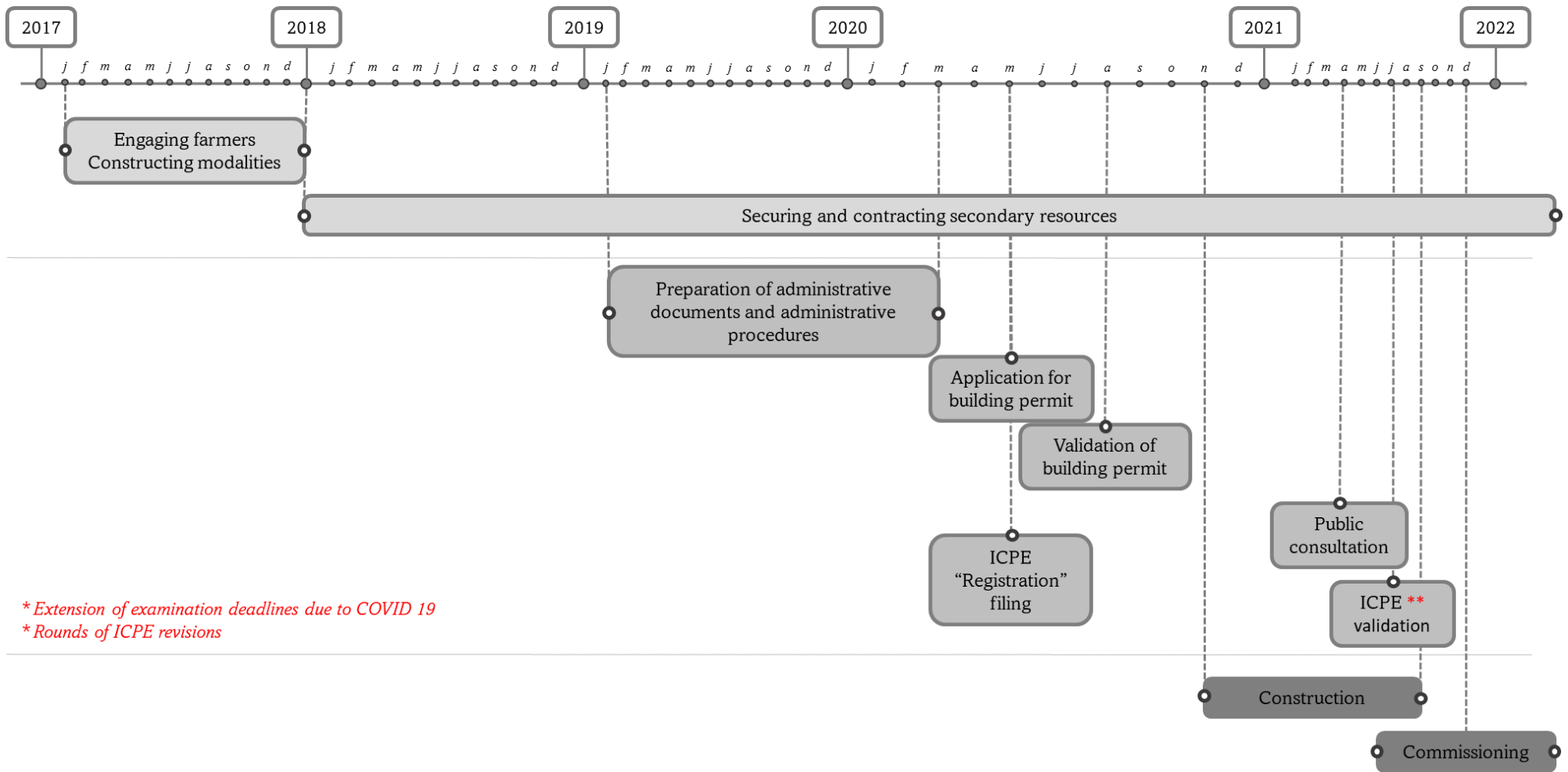


Figure 19 Timeline of the Landres case study

1.2 Project inception in 2017 – Proving the complementarity of anaerobic digestion as a solution for the cooperative

The decision to expand the cooperative's expertise and provide members with the opportunity to produce green energy through anaerobic digestion was driven by a commitment to developing collective projects while preserving both a cooperative dynamic and agricultural practices. As mentioned by Matteo, *"As a cooperative, we wanted to stay within our cooperative framework, avoiding the excesses seen in Germany. We remain in agriculture, with organizational synergy with the livestock sector and not in competition"*. Also, Gabriel reiterated that this *"stems from a commitment to serve the members."* And Samuel confirmed their will to help farmers in this initiative, *"While some farmers independently embraced anaerobic digestion, as a cooperative, we considered it our responsibility to assist those who may not have the means, inclination, or expertise to venture into the realm of energy. Our aim was to ensure farmers could still benefit from it."*

Once the decision was made to develop anaerobic digestion entities with injection, the cooperative had to construct clear arguments around their choice to pursue anaerobic digestion. They offered three compelling justifications, namely financial, agronomic, and regulatory compliance.

Firstly, the cooperative argued that the project would provide stable financial benefits for farmers, offering them a consistent, supplementary source of income. According to Matteo, *"For the farmer, it was a stable income supplement over time. We buy their inputs and sell them digestate under conditions that would not change during the contractual period, which is typically 10 or 15 years."*

As mentioned in chapter 3, agricultural resources for anaerobic digestion can include manure or slurry from farmers in the cooperative engaged in livestock farming, an activity primarily involving raising animals such as cows, sheep, pigs, poultry, or others destined for the production of meat, milk, or other animal-derived products. Agricultural resources for anaerobic digestion can also include crop residues, intermediate crops, and dedicated crops from cereal-producing farmers. The activity of a cereal farmer primarily involves cultivating grains such as wheat, corn, barley, rye, oats, or other grains, as well as growing forage crops for livestock. This activity entails preparing the ground, sowing seeds, maintaining crops, controlling diseases and pests, and harvesting the grains once they have reached maturity. Cereal farmers may also be involved in storing, marketing, and selling their cereal crops. The

cooperative, however, did not intend to shift the entire cereal-producing farmers' output toward anaerobic digestion. They restricted the use of crops for anaerobic digestion to a maximum of 20% of their utilized agricultural area.

The cooperative argued that the anaerobic digestion initiative would bring agronomic benefits to cereal-producing farmers. Matteo used his expertise in agronomy to construct these arguments.

Other than providing crop residues such as wheat straw, corn stalks, or other cereal residues, cereal farmers can participate in anaerobic digestion by considering crop rotations in several ways (Figure 20). Crop rotation is an agricultural practice whereby diverse types of crops are alternated on the same plot of land over seasons or years. This technique aims to improve soil health and fertility, increase crop yields, and reduce problems with diseases, pests, and weeds. For example, certain crops can enrich the soil with nitrogen, while others can prevent the accumulation of specific diseases or pests. A crop may leave beneficial residues in the soil to be used by the next crop, or a crop may have a beneficial effect on soil structure, thereby improving its ability to retain water and nutrients. Crop rotation can be geared towards serving anaerobic digestion. Farmers can introduce intermediate crops for energy recovery (widely known as 'CIVE' crops in France) between their main cereal crops. These intermediate crops are high-yield biomass crops such as sorghum, millet or miscanthus, which produce significant amounts of organic matter that can be used for anaerobic digestion. Farmers can also include forage crops in their crop rotations. Forage crops, such as clover or alfalfa, often produce abundant biomass that can be used as raw material for anaerobic digestion. Thus, Matteo was encouraging a rotation strategy that would bring benefits to each farmer's land while opening up opportunities for crops serving as inputs in anaerobic digestion plants. He confirmed, *"There is also the agronomic aspect. The idea is also to 'clean' the plots, and consider their production in a slightly different way in terms of rotation. The cooperative developed these units to provide farmers with a response in terms of weed and pest control. Our farmers faced resistance, especially with black-grass."*

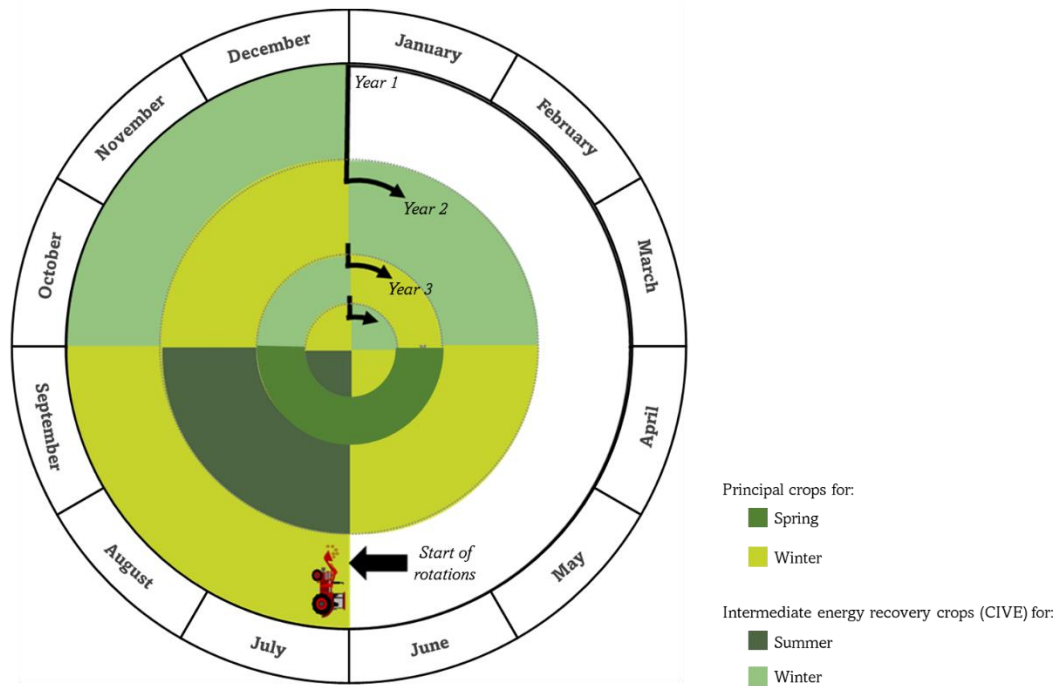


Figure 20 Example of possible rotation strategy for anaerobic digestion (adapted from info.metha.org)

Lastly, Matteo explained that the cooperative highlighted the regulatory advantages of their anaerobic digestion initiative to farmers engaged in livestock farming, "Obviously, it also allows them to address compliance, for example. Basically, they don't have all the logistical part related to the treatment of their effluent anymore. They do not need storage at their place; they bring the manure, or we pick it up gradually. They have no compliance constraints, and we store everything under shelter at our facility, and spread it over their fields with suitable tools." The cooperative's anaerobic digestion initiative relieved farmers of compliance burdens related to effluent treatment, providing a more efficient and compliant solution.

The coherent argumentation developed by the cooperative around these three pillars—financial stability, agronomic benefits, and regulatory alignment—convinced 18 farmers in the cooperative and in the region where they planned to implement the plant to join the project. This group of farmers was the foundation of the successful inception of the first anaerobic digestion project within the agricultural cooperative: the Landres anaerobic digestion plant.

1.3 Securing the inputs starting in 2018

1.3.1 Choosing inputs in accordance with cooperative values

The first crucial step in the development of the anaerobic digestion project at Landres involved selecting the inputs for the plant. This decision was driven by the cooperative's commitment to preserving its primary activity: farming. As emphasized by Colin, "*Farming activity in the cooperative generates the second highest revenue. We have a very important livestock activity. The idea was especially not to develop anaerobic digestion at the detriment of our other activities. We needed to avoid upsetting the balance of the group's activities. Livestock has a significant share, so anything that could harm livestock, we avoid.*" This decision aligned with the cooperative's values and its dedication to maintaining the integrity of its various activities.

An integral part of the cooperative's value system was the decision to exclude straw from the project. This decision stemmed from a deliberate choice not to influence the straw market negatively. As Matteo explained, "*We do not include straw; it has been one of the project's intentions not to incorporate straw precisely to avoid influencing the straw market. Ultimately, many farms today sell straw among farmers or even in neighboring countries, notably with Belgium, and as consumers of straw we did not want to drive up straw prices. So we don't use straw.*"

Another aspect of selecting inputs entailed considering the regional context. The cooperative chose cover crops resistant to climatic hazards or winter flooding. This decision was particularly relevant as the region faced significant challenges related to these weather events. As expressed by Michel, "*We chose cover crops; we encouraged farmers to plant diverse cover crops, meaning cover crops that are sown late in the season and harvested quite early in the spring, which are less affected by climatic hazards or winter floods because we are in areas heavily affected by these episodes.*"

The second step entailed the cooperative selecting suppliers for these inputs. An important principle guiding this process was to prioritize cooperative members' participation in the project. As outlined by Gabriel, "*We first check with family, and then we move on to first cousins, then distant cousins, and at some point, neighbors. If I find what I need among our members, we stop there.*" This approach demonstrated a commitment to involving and ensuring cooperative members benefit from the anaerobic digestion project.

1.3.2 The construction of rules and modalities of exchange between the plant and the farmers

The cooperative faced the complex task of developing the modalities and agreements for exchanges with the anaerobic digestion plant, since Landres was their first project. According to Gabriel, this phase presented significant challenges, *“We had a lot of complications before arriving at the model that we defend today.”* The cooperative, characterized by effective communication and links between operational staff and administrators, took considerable time to construct a model with rules and norms that aligned with the vision of all participants. As Gabriel also stated, *“The technical part was relatively under control; it wasn’t really an issue. What was difficult in the project is that we had to build the model for a collective plant with contractual rules.”*

To address this challenge, the cooperative created contracts and norms with farmers on matters for which they had few or no references. These included the quality and quantity of inputs, variability in production from year to year (impacted by climate change), logistics (delivery frequencies, handling delays), and non-compliance with the contract. Crafting these contracts proved to be complex, involving considerations such as managing the variability in production, delivery quantities, and input quality. Colin highlighted the difficulties: *“It’s not easy to create the right contract, to set the right sliders in the right places. These are what I call passion killers. That is, if you do not deliver the quantities specified in the contract, what happens? What if you deliver them late? What if it is not the right quality? All these things to think about are not simple. We needed to draw up a contract for materials for which we had few or no references.”*

To overcome these challenges, the cooperative employed a dual approach. On the one hand, they had a fixed biogas price and a specific gas network, providing stability and a reference point for economic calculations. This perspective allowed them to establish fixed terms for purchasing farmers' inputs and selling digestate for the duration of the gas contract, typically 10 to 15 years. Gabriel pointed, *“When we are on a GRT network, we are going to have to balance out around 250 Nm³ to be really profitable (...) we are going to need 35,000 tons on a GRT. And at least 25,000 for a GRD, so these are the figures we have in mind.”* Also, using instruments such as Excel spreadsheets, they ensured profitability through economies of scale, factoring in investments, connection costs to the network, and site installation expenses.

On the other hand, to define the economic worth of inputs, they collaborated with research institutions and engaged in trial platforms for comparison to characterize the methanogenic

power⁴⁵, their content in nitrogen (N), phosphorus (P), and potassium (K) and other parameters such as production costs. The cooperative had participated in projects⁴⁶ from 2012 till 2017 related to inputs. Then, in 2017⁴⁷, EMC2 specifically required a study on the feasibility of micro-anaerobic digestion. Matteo confirmed, “we worked with ENSAIA, the agronomy school laboratory in Nancy, and INRA. So, in fact, we worked on this beforehand to have an idea on the methanogenic and production potential for each type of input.” Based on these insights, the cooperative determined two types of modalities of exchanges.

Manure and slurry are exchanged, respectively, with solid digestate and liquid digestate ensuring an equivalent quantity of N, P, and K content and price. This exchange is based on the widespread practice among farmers of purchasing chemical fertilizers according to their NPK content⁴⁸. NPK fertilizers are formulated to provide these essential nutrients in balanced proportions to support plant growth and maximize crop yields. They are widely used in agriculture to supplement soil nutrient levels and ensure optimal plant nutrition. Through anaerobic digestion, digestate can replace chemical N, P, and K fertilizers. Gabriel provided an illustrative table (Table 15) to demonstrate how the price of liquid digestate was determined. By assessing the N, P, and K levels in a sample of liquid digestate from the anaerobic digestion process, an assimilation rate for each component was established to reflect the actual chemical absorption by the soil. This assimilation rate, multiplied by a predetermined price derived from research and market analysis, determines the total invoiced amount per ton of liquid digestate purchased by farmers, mirroring the total invoiced amount per ton of slurry purchased by the plant from the farmers.

Table 15 Example of price calculation for liquid digestate

	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Units (U) (measured)	4.76	2.34	4.57
Assimilation Rate (AR)	40%	70%	100%

⁴⁵ As explained in chapter 3, methanogenic potential refers to the ability of a substance or material to produce methane gas through a biological process known as methanogenesis. This occurs in anaerobic environments where certain microorganisms, called methanogens, break down organic matter in the absence of oxygen, producing methane as a metabolic by-product. Determining the methanogenic potential of organic materials is important for assessing their suitability for anaerobic digestion processes. The methanogenic potential is typically measured or estimated based on factors such as the chemical composition and biodegradability of the material, as well as the activity of methanogenic microorganisms present in the environment. A higher methanogenic power indicates that a given input is more efficient at producing methane gas, which is the desired end product of anaerobic digestion.

⁴⁶ <https://www.calameo.com/read/00226057543e826f71de8> ; <https://ecophytopic.fr/dephy/concevoir-son-systeme/projet-expe-ecophyto-lorrain>

⁴⁷ https://ensaia.univ-lorraine.fr/telechargements/projet_pro_methanisation.pdf ;

⁴⁸ As explained in chapter 3, NPK nutrients are beneficial for various aspects of crop development.

(fixed in contract)			
Unit Price (UP) (fixed in contract)	€0.65	€0.80	€0.50
Value € = U*UP*AR	€1.24	€1.31	€2.28
Total invoiced per ton	€4.83 €		

The pricing of crops was determined based on existing benchmarks for market, production costs, and methanogenic power. Matteo adds that *“setting prices is mainly in relation to what's already being done in normal times. There is a market, I would say, for buying silage maize for example. It is also in relation to the cost of production.”*

The cooperative also considered logistical plans in the modalities, envisioning four options for economic exchanges to accommodate different farmer preferences. Indeed, as explained by Samuel *“the solution depends on how the farmer sees things in his organization. Some farmers do not want us to bring it in because they do not have the time.”* These options included variations in responsibilities for silage, input delivery, digestate removal, and spreading. Through this intricate process, the cooperative successfully navigated the complexities of developing modalities and agreements of exchanges, laying a foundation for the anaerobic digestion project's sustainable and collaborative execution. They imagined four options of economic exchanges in their contracts according to different logistical plans.

- The farmer takes care of the silage, brings the inputs to the plant, where the inputs are valued. The farmer takes back the digestate and takes care of the spreading.
- The farmer takes care of the silage, brings the inputs to the plant, where the contribution is valued. The anaerobic digestion plant is responsible for the delivery and spreading of digestate.
- The anaerobic digestion unit takes care of the silage and delivery and valorizes the input. The farmer removes the digestate and takes care of the spreading.
- The anaerobic digestion unit takes care of the silage and delivery and valorizes the input. The anaerobic digestion plant is responsible for the delivery and spreading of digestate.

The legal aspect of the contracts tended to worry some farmers. It can scare them with the impression of having a debt for a certain period of time. As mentioned by Samuel *“It scares them to sign a contract in spite of everything. The impression of having a debt, being tied*

hand and foot for a certain length of time. It stresses them out to think that they are going to have to manage to deliver what they have committed to deliver. So, we make regular adjustments because the cooperative is there to find solutions for them, to maintain a somewhat flexible relationship. The document is more there to say, well, there are rules, so we should not exaggerate too much.”

To address farmers’ concerns about contractual commitments, the cooperative maintained flexibility in the contractual document to find solutions and foster a structured yet adaptable relationship. The contract outlined general rules to avoid exaggeration while incorporating mechanisms like substitution or averaging over years to reassure farmers and ensure a secure supply at the same time. According to Gabriel *“So our contract is flexible, but not too flexible, because we also need to secure supply in view of the investments we have made. So, what does our contract actually say? It says that if you commit to 100 tons, you can deliver between 90 and 110 tons. On the other hand, we have a tolerance of 10% over the year. What is important is the three-year average.”* If they have poor performance on their land, they can deliver another type of input according to a specified substitution plan. The table 16 below, shared by Matteo, depicts the proposal made for substitution of crops.

Table 16 Proposal for substitution based on methanogenic power

	Substitution crops				
	Maize	Sorghum	Grass	Intercrop/ Energy Crop	Sunflower
Lacking crops					
Maize		1.2 T	1.4 T	1.5 T	1.17 T
Sorghum	0.8 T		1.2 T	1.2 T	1 T
Grass	0.7 T	0.8 T		1.1 T	0.9 T
Intercrop/Energy Crop	0.65 T	0.8 T	0.9 T		0.8 T
Sunflower	0.78 T	1 T	1.1 T	1.2 T	

1.3.3 Engaging the farmers

Following the establishment of rules and modalities, the cooperative faced the challenge of ‘resistance’ as some farmers had to adapt to new practices regarding crop rotations and digestate spreading. Engaging members in this transformative process required extensive efforts, including multiple meetings and the provision of a dedicated technician for personalized follow-up.

Farmers exhibited a genuine difficulty in adapting to the change, often demonstrating what could be termed as resistance. According to Michel, *“They are accustomed to their routine of*

cultivating rapeseed, wheat, and barley, and spreading livestock effluents; they found it challenging to integrate the anaerobic digestion process into their existing farming practices. To address this, we invested significant time, spending at least 2 to 3 hours with each farmer, often multiple meetings to reassure them and explain how the integration would unfold. The initial challenge was intensified by the absence of a concrete unit to showcase during the project's inception". Farmers also questioned their participation in anaerobic digestion because of financial advantages to harvesting crops for feed. According to Michel, *"They're shocked with the price fluctuation; we heard farmers say they would have sold wheat rather than an intercrop for anaerobic digestion, and that they could have done better financially."* Thus, to overcome the potential reluctance of farmers to participate, the cooperative employed a long-term engagement strategy. By emphasizing the benefits over an extended period, they aimed to shift the focus from immediate concerns to the sustainable advantages of the anaerobic digestion project. Colin highlighted the need to encourage farmers to *"look at the long term"* during discussions.

To facilitate the engagement process, each farmer had an appointed agricultural technician. These technicians, well-versed with the farmers and their farms, played a crucial role in building trust and ensuring the success of the project. The key role of the technician was to advise farmers on their practices and follow up their yields. The quality of the relationship between farmers and their technicians became a pivotal factor in upholding contracts. Matteo observed that *"farmers were more likely to sign contracts when we showed up with the technician. There is a strong rapport and trust with him."* Also, regular meetings and a minimum of three scheduled appointments further facilitated the farmers' engagement at Landres. These sessions allowed detailed discussions on the inputs delivered, assessments of previous years, and plans for the upcoming year to ensure compliance with contractual obligations. According to Matteo *"Effective communication and planning, led by technicians like Michel, played a crucial role in coordinating activities and ensuring adherence to schedules."* This aspect of communication was deemed vital to aligning harvest and effluent delivery schedules successfully. In instances where farmers faced challenges in meeting their contractual commitments due to climatic or technical factors, the cooperative's technical support team intervened. Technicians specializing in plant production worked closely with farmers to strategize and overcome challenges, demonstrating the cooperative's commitment to supporting members in meeting their contractual obligations despite unforeseen circumstances. Finally, despite variations in how farmers approached the project, with some attempting to leverage the situation to their advantage in terms of planning, the unit in

Landres functioned effectively due to “good cohesion among members and the federating working style approach of the appointed technician,” as mentioned by Samuel.

1.3.4 Financially incentivizing the farmers

The cooperative’s approach involves farmers not only as contributors but also as partners. To become suppliers of inputs for the anaerobic digestion plant, each farmer is required to acquire social shares in the plant. In return, they benefit from profits in the form of dividends generated by the plant. The value of these shares varies based on the type and quantity of inputs they commit to providing. For example, for a provider of crops the social share is estimated at 15 euros per ton, whereas for the providers of manure (solid) it is evaluated at 7 euros per ton and slurry (liquid) is estimated at 3 euros per ton. Collectively, the social shares from farmers constitute 7 to 8 percent of the total investment required for the development of the anaerobic digestion plant. Gabriel showed his concerns regarding this configuration, “*Striking a balance and fair distribution of value was crucial, given that the entire cooperative membership, contributing around 10 million euros, was involved in constructing a unit that directly benefits approximately 20 local farmers. This raised the question of how to equitably distribute returns from a machine generating annual results of approximately €350,000 or €300,000, considering that 93% of the cooperative members had invested in the project, albeit with relatively modest returns.*”

Nevertheless, when it comes to decision-making, strategy, and overall entity management, the responsibility does not lie with the farmers even if they purchased shares. The main financial risks were borne by the cooperative. According to Gabriel “*The cooperative made the investment; the operation is also carried out by people from the cooperative. It is a process that runs 24 hours a day, 365 days a year, and we have to set up on-call duty, and so on. So, it is a bit labor-intensive. This has a rather negative impact on the business model. But it also means that the farmers do not have to worry about it.*” The farmers’ role is primarily that of suppliers, providing the necessary raw materials for the entity’s operation. This division ensures a clear distinction between the operational and strategic aspects of the project.

The challenge and ultimate goal were to ensure that farmers feel satisfied and continue their involvement in the project beyond the initial contractual period. To address this, Gabriel highlighted that “*the cooperative has implemented various incentives designed to reward commitment and foster long-term engagement.*” These incentives are structured around the duration of the contract, offering bonuses to participants. In the initial 0 to 7 years of the

contract, participants providing crops receive a bonus of €3 per ton of input. As the partnership progresses, those who remain committed for 10 years and beyond receive an increased bonus of €4 per ton of input at the 15-year mark. This tiered approach acknowledges and rewards the longevity of participation, aiming to create a framework for sustained collaboration.

In addition to these contract-based incentives, the cooperative has formulated plans to provide participants with a monetary reward if the biogas plant proves to be financially successful.

1.3.5 Securing new inputs starting in 2022

The cooperative faces uncertainty when it comes to project inputs. According to Matteo *“In practice, inputs never unfold exactly as planned on paper—it is impossible. Dealing with living organisms and unpredictable weather adds an extra layer of complexity. Despite meticulous planning and maximum security measures, the dynamics are constantly in flux. Unexpected shifts, like incorporating other materials instead of the initially intended ones, are not uncommon.”* The cooperative, however, has a “safety net” in place for emergencies—a substantial reserve, particularly in the form of cereal by-products in the cooperative silos. As Michel pointed out, this is *“a resource never accounted for. This reserve serves as a last-minute recourse, a hidden asset that provides a sense of security in times of crisis.”*

Additionally, the cooperative is open to exploring alternative opportunities. The cooperative’s forward-looking strategy involves a recognition that the integration of new inputs is crucial for the future of anaerobic digestion projects. As Samuel notes, *“We are almost convinced that we will never build another plant if we do not integrate biowaste: We have some intermunicipal communities that really need to take care of their canteen waste.”*

This expansion into new territory brings both positive and negative considerations. On the positive side, the inclusion of additional inputs offers enhanced acceptability. According to Colin, *“It becomes easier, in a sense, to articulate why the project is beneficial for the community at large, when offering a solution to its waste.”* However, there are also challenges associated with this expansion. As the cooperative explores these opportunities with municipal entities, there is a realization that additional waste streams may introduce contaminants into the digestate. This concern is acknowledged with statements from Michel like, *“It will inevitably include some pieces, some plastic that will end up in the fields.”* This recognition underscores the need for careful planning and waste management practices to mitigate potential environmental impacts. Also, exploration of these opportunities involves

navigating complexities, such as the need for waste hygiene and financial viability. As Matteo also expressed, *“So, we are looking into that, but we need to sanitize this waste. We haven’t yet found the project’s profitability.”* This acknowledgment reflects a realistic approach, recognizing that new ventures require careful evaluation, especially when addressing the complexities of waste management regulations and financial sustainability. The cooperative’s proactive engagement with communities and adaptability to changing regulatory landscapes demonstrate its commitment to sustainable practices and continuous innovation.

1.4 Specific localization of the anaerobic digestion plant

The decision to establish the anaerobic digestion plant in Landres was a meticulous process guided by the superposition of three critical geographic factors. The initial step in the site selection process involved examining the gas network plan. As Colin explains, *“At the beginning, the project was determined by the superposition of several maps, starting with the map of the gas network, which already clarified the terrain.”* This emphasis on the gas network plan was pivotal in identifying suitable locations for the anaerobic digestion plant, ensuring connectivity and efficiency. Another key aspect was the consideration of the locations of cooperative participants. The cooperative aimed to optimize the site’s proximity to its members. In the words of Samuel, *“we overlaid it with the map of our members. It was about finding a very concentrated source. If we have to travel 20 km, it doesn’t work economically.”* This strategy aimed to minimize transportation costs and establish a location that would be economically viable for cooperative members. Additionally, efforts were made to align the selected site with the cooperative’s existing infrastructure. Seeking to leverage an existing site was crucial. According to Colin, *“we tried as much as possible to cling to an existing site. This way, we control the land, which is much simpler. Having said all that, well, there aren’t many points left on the map!”* This approach not only simplified the process but also provided greater control over the land, streamlining the establishment of the anaerobic digestion plant.

Specifically, the unit in Landres stood out because the cooperative already owned the land. As Gabriel notes, *“The Landres unit was straightforward because, in the end, the cooperative owned the land. It’s a plot adjacent to the existing collection silo.”* This alignment with cooperative ownership and existing infrastructure made Landres a strategic and practical choice for the anaerobic digestion project.

In summary, the Landres anaerobic digestion project exemplifies the cooperative's commitment to sustainable agricultural practices and energy solutions. Spearheaded by individuals like Gabriel, Colin, Matteo, Samuel, and Michel, the project emerged as a result of the cooperative's ability to leverage its existing resources, expertise, and network to sustainably valorize secondary resources. The localization of the plant in Landres exemplifies the cooperative's strategic thinking and alignment with its goals to valorize local secondary resources. Leveraging existing infrastructure and considering geographic factors, the cooperative optimized the site selection process to minimize costs and maximize efficiency.

The meticulous planning and execution of the project, evident from the timeline spanning 2017 to 2021, underscore the cooperative's strategic approach to addressing key challenges and maximizing opportunities. Central to the success of the project was the cooperative's emphasis on farmers' engagement and collaboration. By offering clear incentives to farmers, the cooperative fostered a sense of ownership and commitment among participants. Moreover, the establishment of transparent tailored contractual agreements, robust communication channels and tailored follow-up by dedicated technicians facilitated smooth exchanges and ensured mutual benefit while securing secondary resources.

2. The Methamoly project

This narrative is based on the interviews and exchanges with Eloi, Fabienne, Anna, Carl, and Thibault.

Eloi is the President of SAS Methamoly, *"I am originally from Lorraine, the son of a teacher. When I was younger, I had the opportunity to work abroad, particularly in West Africa, North Africa, and South America. During these assignments abroad, I had the chance to discover the world of energy. I am not sure if it is a fortunate circumstance or the opposite. Nevertheless, it opened my eyes to the French energy model, particularly how we sourced our energy. So, everything starts from there; it left a profound mark on me at the age of 20. When I returned to France in 2003, I decided to start afresh, so to speak, by acquiring an agricultural property, even though I had no background in that field. It was driven by my convictions, values, and a desire to live a grounded life, after everything I had experienced before. It was a crisis of conscience. Consequently, once I established myself in agriculture, I began to contemplate energy-related issues, such as how to develop an alternative energy model and cease reliance on distant, costly, and, most notably, life-costly energy sources. I emphasize 'life-costly' because that is what struck me the most. Money is one thing, but the lives we sacrifice to source energy here are another, and it is something we can never fully grasp. It is challenging to convey this issue to the consumer here. So, everything stems from there, from a deeply personal perspective, of course. I also understood that to undertake alternative projects, they needed to be collective; we needed a diverse range of skills and expertise. It all began around 2010, when I started to conduct a precise assessment of the situation, the available resources, and the possibilities. What could we do in the Monts du Lyonnais region in terms of wind, solar, anaerobic digestion, hydraulic power, etc. Quite quickly, I realized, because it was a region that was quite advanced in these areas, that anaerobic digestion would be the way forward."*

Fabienne is the Administrative and Financial Director at Energie Partagée, *"I participated in the project as a representative voice of Energie Partagée. We are an organization dedicated to enabling citizens and local communities to reclaim energy-related issues and implement all the tools all along the chain so that citizens can develop, build, operate, and finance renewable energy projects in their area."*

Anna is a Former Project Manager at Engie, *“I worked at Engie for over 25 years, primarily in the gas sector where I played an expert role within the Group. I led and participated in the technical design of the entity, process selection, etc., and attended steering committee meetings for the Methamoly project.”*

Carl, a Sales and Development Engineer at Suez Organique: *“I am currently responsible for sustainable development at Suez Organique, a subsidiary of Suez specializing in returning organic matter to soil. I have known about Methamoly for a long time. I met Eloi at the inception of the project, around 2012 or 2013. At that time, before my current position, I was the commercial manager for the southeast region for Suez Organique, and I was physically close to the Methamoly site. I live nearby. I met Eloi because he was looking for local partners for his project.”*

Thibault, Director of the Community of Municipalities' Ecological Transition public service *“I am Thibault, the director of the Ecohabitat park, which is essentially the public service for Ecological Transition of the Monts du Lyonnais Community of Municipalities. I have been working in the Monts du Lyonnais since 2011. Historically, the Ecohabitat park was a resource center for building and eco-construction that opened in 2009 to assist building companies in navigating the new thermal regulations, etc. We have developed many services targeting municipalities, companies, and residents to aid them in energy efficiency and renewable energy production.”*

2.1 Main characteristics of the anaerobic digestion unit

Methamoly is an anaerobic digestion plant located at ZA Croix Chartier, 42140 Saint-Denis-sur-Coise. It utilizes approximately 17,000 tons of feedstock each year, including 60% derived from livestock effluents and 40% of biowaste. It is characterized by a power output of 125 Nm³/h and an annual production capacity of 12,000 MWh. It provides gas supply to around 1,500 households annually, contributing to the energy needs of local communities. This operation not only generates energy but also plays a crucial role in waste management. It required a budget of €6.5 million, financed mainly by Crédit Agricole. The rest includes €230,000 secured through citizen financing initiated by Energie Partagée. The subsidies, totaling €744,000, were allocated by the ADEME (€350,000) and Auvergne-Rhone-Alpes Region (€400,000).

Figure 21 below depicts the overall evolution of the project from its inception in 2011 till its official operating date in 2019. In 2011, the initiative kicked off with a comprehensive feasibility study on renewable energies conducted by the Community of Municipalities. The process gained visibility in 2013 with a public information meeting for farmers presenting the activity of anaerobic digestion. Simultaneously, a farmer named Eloi took the lead by federating farmers to endorse an anaerobic digestion project. Between 2014 and 2015, project management was officially initiated by creating two administrative structures—SAS Agri ENR for the farmers, and the anaerobic digestion entity, SAS Methamoly. 2016 saw the achievement of financial closure, marking the successful progression of the project through various crucial stages. The formal authorization requests were submitted in 2016, followed by a public hearing at the beginning of 2017. The public inquiry to authorize plant implementation was validated in March 2017. The project then saw its plans take tangible shape as construction commenced on the designated site by mid-2017. March 7, 2019, marked the successful commissioning and commencement of plant operations.

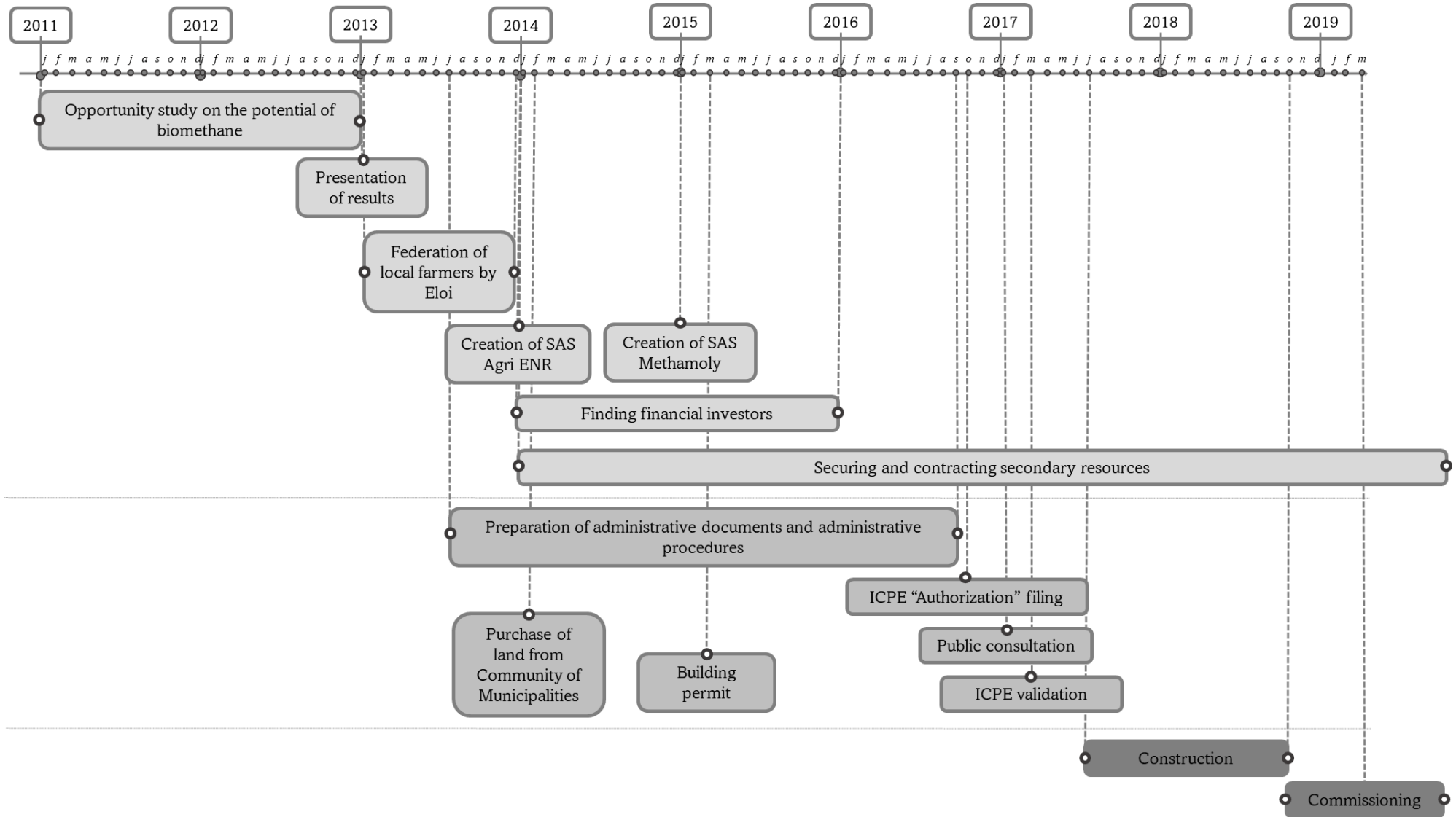


Figure 21 Timeline of the Methamoly case study

2.2 Project initiation in 2011: Alignment of two local actors' perspectives, a Farmer, and the Community of Municipalities.

2.2.1 From opportunity to feasibility study: 2011 to 2012

The Community of Municipalities created SIMOLY (*Syndicat Intercommunaire des Monts du Lyonnais*) in 1979. It brings together 34 municipalities between the Loire and the Rhône, creating a cross-border union that drives the municipalities of each department to work together. In 2011, SIMOLY initiated a TEPOS program⁴⁹ (*Territoires à Energie Positive*, positive energy territories), extending invitations to local participants to contribute towards the energy transition. This marked the beginning of discussions regarding the establishment of green energy in the region.

Supported by SIMOLY and the ADEME, an opportunity study was funded and conducted in the region to explore the potential of the establishment of a green energy facility. The technical expertise provided by the Chamber of Agriculture and Espace Info Energie played a crucial role in this phase. Within the framework of the territorial diagnosis conducted in 2012, conclusions were drawn regarding the choice of clean energy to be developed. Indeed, the region can be described as very rural and agricultural, with a significant presence of agri-food industries. The habitat density was considerable, effectively excluding wind energy as an option, as there was insufficient space between residences for installing wind turbines. Moreover, regulations stipulated a minimum distance of 500 meters, further supporting the decision to exclude wind energy. Solar energy presented a significant possibility, yet its production capacity fell short of the region's requirements, especially for its industries. Consequently, they swiftly turned their attention towards anaerobic digestion due to the area's agricultural history and potential. Thus, the configuration of the territory proved to be adequate for anaerobic digestion with the feedstock and land available.

⁴⁹ TEPOS is a network created in 2011. It is led by the Cler network for energy transition (*réseau Cler pour la transition énergétique*). The TEPOS program is based on three pillars: promoting energy sobriety, developing energy performance, and encouraging local production of renewable energies. Conducted locally, it reduces the energy bill for communities and residents. It promotes economic development and job creation in local energy production or energy management. It stimulates collective dynamics that bring meaning to citizens with the aim of responding to the challenges of global warming and resource depletion. <https://tepos.fr/le-reseau/>

2.2.2 Feasibility study presentation and farmer's enrollment from 2013 to 2014

In February 2013, SIMOLY organized a meeting to present the results of the feasibility study. They approached the farmers of the region, situated approximately halfway between Lyon and Saint-Étienne, encompassing hilly landscapes akin to low to medium mountains. All the farmers from the Monts du Lyonnais region were invited to the presentation. The objective was to present the results of the study and invite them to become part of the initiative. If willing, the farmers would receive support, training opportunities, visits to anaerobic digestion sites. Approximately 150 farmers attended the meeting.

Following the presentation, a group of farmers expressed their interest in embarking on an anaerobic digestion project. A group of local farmers created an association in 2013 under the name “Methamoly”. They aimed to investigate methods for utilizing their livestock effluent and for conducting a feasibility study to create an anaerobic digestion unit. The Community of Municipalities made available an advisor who had studied agronomic engineering, to provide technical support for the project. They received training and visited existing anaerobic digestion sites, which were not very numerous at the time. For some farmers, these visits provided examples of what not to do, because the plants did not comply with their vision of sustainable agriculture practices to be linked with anaerobic digestion projects.

Local farmers were led by Eloi. He instilled a collaborative dynamic in the project development as observed by Fabienne *“One of the farmers, Eloi, (...) very quickly encouraged a partnership approach by seeking out other actors beyond the community and the local authority which were already involved.”*

The group of farmers wanted to get more involved in the project and to influence the choices, as mentioned by Eloi: *“We're willing to lead this project, but we want to do it with other actors from the citizen energy sphere and with the local community, given the fact that we farmers alone wouldn't be able to make it work, yet we should still remain in control.”* From 2013 onwards, the group of farmers began to increase participation to include like-minded partners.

2.2.3 Reaching out to “like-minded” financial investors starting in 2014

The group of farmers wanted to take on board financial actors sharing their cooperative outlook. The total budget reached 6.5 million euros. Beside the bank loan from Credit

Agricole of 4.3 million euros, the group of farmers reached out to other financial contributors for funding during the development phase. They benefited from subsidies totaling €744,000 (ADEME granted them €350,000 and the Auvergne-Rhone-Alpes Region €400,000). They reached out to Energie Partagée, a clean energy investment company approved as a solidarity-based company of social utility (*Entreprise Solidaire d'Utilité Sociale*), which collected citizen investment through a crowdfunding operation that provided another €230,000. They also secured equity capital of 1.2 million euros. They invested 50% and the rest included local investors. This encompassed the contributions of SEM Soleil, a semi-public company (SEM: *société d'économie mixte*) that invests in renewable energy projects, and one of the oldest SEMs in France focused on renewable energies in the Loire department. Other investors included OSER, a regional fund for renewable energy development, which had been initiated by the Rhône-Alpes region, Unica Invest.

Engie also contributed to financing the project in equity funds. The desire to involve Engie was primarily related to its technical expertise, and its activities as an operator and buyer of biomethane. Engie is a major actor in the French gas market. The company's status as a specialist in gas was a crucial factor. Furthermore, at that time, there were not many anaerobic digestion projects, and more especially there were not many benchmarks, particularly none with this kind of collective governance. Also, there were not many insights yet into the technical functioning, and the few plants that were available were not necessarily positive. So, the project leaders needed assurance in making the right technical choices. According to Fabienne, "*Engie's presence in our set-up probably saved us from making technical mistakes.*" As a result, Engie participated in the initial financial investment. The company's involvement covered the entire site design and a commitment to the collective interest. Indeed, Fabienne reiterated, "*The interest on our behalf was both to potentially have a gas buyer, but also to have all this technical reference material from Engie.*" Initially, the group of farmers led by Eloi approached Enercoop, a cooperative energy supplier, because it was an electricity supplier that aligned with their cooperative dynamic and they wanted to explore the possibility of developing a gas offering. Enercoop was not successful in developing an offer that aligned with the interest of the group of farmers.

Simultaneously, Suez embarked on the project through local networking after an employee had informal discussions with Eloi. The objective was to leverage Suez's expertise in the biowaste sector. As mentioned by Carl, "*It's the internal network with colleagues at Suez that got me into the project. When I was talking to him, I heard that there was this project. So it was a colleague who acted as an intermediary.*" Suez had to evaluate its possible

involvement in the project, and end up collaborating with Engie under the joint venture of Engie Suez Methabio Development. According to Carl, *“for two years, we did not really know whether we wanted to acquire shares in the capital. But on the other hand, on the partnership aspect for supporting the biowaste inputs, and on the plan for the digestate, there was never any issue. It was more the financial part, what was in the capital, was it a good deal? I think we decided a little later on the subject to engage as a joint venture with Engie.”* It was a tough job to persuade his work superiors of the added value of this collaborative project. Indeed, he had to *“defend it internally because it was not a priority to join forces with other actors and be in the minority on a project and not have full power over the decisions (...) For me it was partnership that gives great satisfaction. Because it responds to local customer needs, it is first and foremost an intervention, another type of proximity, and that’s why it is interesting.”* Carl’s superiors were finally convinced by the project because they wanted to acquire notoriety in the activity and secure Suez’s presence.

The introduction of Engie and Suez, large capitalist enterprises primarily focused on profit-seeking, contrasts sharply with the cooperative ethos pursued initially by Eloi. Indeed, the involvement of grassroots actors with social and solidarity economy entities, formed a sort of 'like-minded' alliance aiming to develop a cooperative model of anaerobic digestion. Nevertheless, compromises had to be made. In this context, the 'like-mindedness' shared between social and solidarity economy enterprises and a capitalist multinational lies in *“their shared willingness to ensure the operational success of the project and thus contribute to the development of the territory,”* as mentioned by Anna.

2.2.4 Creation of SAS Methamoly in 2015 and SAS Agri ENR in 2014, federated by a local farmer

The involvement and commitment of farmers were decisive factors for the project. Indeed, the project started to materialize once the “Methamoly” association that gathered together farmers in 2013 was created under its leader, Eloi. He federated the farmers and united them within a new administrative structure—a simplified joint-stock company created in 2014 and known as SAS Agri ENR. This company was part of SAS Methamoly, whose administrative structuring was finalized in 2015.

The purpose behind uniting farmers in a separate structure within SAS Agri ENR was to incite them to manage their agricultural matters among themselves and to present a collective voice to SAS Methamoly, which manages the anaerobic digestion site. Even though the stakes

were significant and the interactions between anaerobic digestion and agricultural practices intense, actors did not want the SAS Methamoly to be hindered by disagreements regarding agricultural aspects. Indeed, according to Eloi, *“Farmers are not all aligned on the same issues all the time. They have farms that are different.”* SAS Methamoly agreed that farmers should reach a consensus about all decisions to take, and SAS Agri ENR would present a single opinion representing all the farmers.

Two of the farmers were particularly active among the dozen farmers the group counts, and divided the tasks among themselves. These two farmers particularly active in SAS Agri ENR were then offered partial employment by SAS Methamoly, having been detached from their farms and agricultural activities. This was part of the collective structure. During the establishment phase of the anaerobic digestion project, the two farmers were involved in farming through several joint farming groups (GAEC: *Groupement agricole d'exploitation en commun*) to alleviate the burden of farming activity. Throughout the project's development phase, they had weekly one-hour meetings, which was a substantial commitment for farmers. Currently, now that the plant is operating, one is responsible for agricultural aspects, including digestate and the link with farms, along with processes such as transportation. The other has taken on the role of site operations manager, which involves receiving goods, conducting technical inspections, feeding the digester, and ensuring emergency readiness.

Eloi insisted that all members, including farmers and investors, participate in every meeting. His approach was inclusive, aiming to involve everyone in the fundamental decisions of the project, such as selecting the manufacturer or deciding on techniques and technologies. This fostered a sense of collective decision-making, acknowledging that some individuals were more competent on certain subjects than others. This dynamic solidified the collective effort, as mentioned by Fabienne, *“He (Eloi) had this approach of saying that everyone must be involved in the fundamental decisions of the project (...) and even if we don't understand everything, we need to be involved in these discussions (...) That meant I had to concentrate on terms I didn't understand. In the end I got really annoyed doing all that stuff. But I do not regret it because I have learned many things, even though it is not really my cup of tea (...) Despite everything, it gave us the feeling of a collective decision and the knowledge that there were people who mastered certain subjects, others less. And that, in fact, forged the collective, and I find that very important.”*

Another crucial aspect that contributed to the lack of opposition to the project, *“although time-consuming and demanding, there was an extensive number of public meetings and engagement with local associations seeking answers,”* as pointed out by Fabienne. Eloi was

acutely aware of this and spent time discussing matters with both the project group and the residents. Carl also aligned with the importance of communication during the project development phase by mentioning that, “*the communication phase was very important for Methamoly and for ensuring a strong anchorage. And I think it is a good experience for us, as well as for the project’s acceptability.*”

2.2.5 The composition of SAS Methamoly

The company’s share capital is divided as follows: 50% of the shares are held by the farmers via SAS Agri ENR. Engie holds about 15%, securing a slightly larger share than all the other actors. Energie Partagée, SEM Soleil and OSER each hold approximately 12%.

Currently, a strategic committee meeting is held every three months to follow up on decisions such as equipping the building with photovoltaic roofing and determining acceptable materials based on distance criteria. All SAS Methamoly general assemblies are preceded by assemblies of the farmers, allowing them to form their own opinions and express a united voice.

Some elected officials in the region are in the waste syndicate and were part of SEM Soleil, which justifies their presence in the capital. For Engie, it is a matter of discussing strategic and operational decisions. As for Energie Partagée, their intention is to influence project decisions, whether they are technical choices or environmental decisions. Methamoly is committed to respecting the Energie Partagée anaerobic digestion charter. Energie Partagée intends to have a role in encouraging the development of practices by making its aid contingent upon the exemplary nature of anaerobic digestion projects, beyond the citizen and local aspects and the regulatory minimum. Energie Partagée lists a series of binding criteria regarding governance, agriculture, the environment, and energy to be followed by the anaerobic digestion entity. All criteria are laid out in a charter⁵⁰. When evaluating the agricultural inputs for the project, several standards come into play. Fabienne explained that “*we have criteria on the choice of inputs that we accept or do not accept because there are so many local issues at stake. We try not to collect biowaste, for example, from 1000 km away*”. One of these norms pertains to breeding practices, emphasizing the exclusion of both intensive and industrial models. Another important criterion focuses on the compatibility with organic farming. This does not require that all participating farmers must be engaged in

⁵⁰ <https://energie-partagee.org/wp-content/uploads/2017/04/Charte-Methanisation-Energie-Partagee.pdf>

organic farming, but rather that the inputs should permit the utilization of digestate on organic plots. Moreover, the application of the organic farming compatibility criterion could be flexible in cases where a well-founded territorial rationale and interest can be demonstrated, alongside considerations related to the type of waste being treated. An additional criterion pertains to the types of crops being cultivated, encompassing main crops for food or energy, intermediate crops such as CIVES and CIPAN, or accepted plant cover. Lastly, a practical criterion pertains to the digestate and its spreading, with an emphasis on feasibility and ease of application.

2.3 Securing the inputs starting in 2014

The Methamoly unit valorizes 17,000 tons of feedstock. The mixture of inputs is made up of 60% of livestock effluents, and 40% of biowaste.

2.3.1 Securing livestock effluent inputs

The livestock effluent procurement is overseen by the employees of SAS AgriENR. From an organizational point of view, Eloi, the project leader, manages everything related to this procurement. Specifically, he participates in proposing suitable contracts for input supply, as well as overseeing its general management. Another farmer is responsible for the logistics processes to ensure the links between the anaerobic digestion unit and all the farms supplying inputs. From a technical point of view, a third task includes checking on the quality of inputs. The site's operations manager, a farmer now employed by SAS Agri ENR, is responsible for this technical task. He sold his farm to become directly involved in the unit's management. His tasks mainly cover monitoring the quality of inputs. He supervises the reception of inputs and makes sure the technical inspections are properly conducted. Furthermore, he ensures that the digester is fed with the adequate quality and quantity of inputs. Finally, he oversees emergency readiness of inputs to mitigate missing or delayed deliveries. Having 12 farmers united in the SAS Agri ENR and investing financially in 50% of the capital of SAS Methamoly ensured that they provide the quantity of agricultural inputs required.

2.3.2 Securing biowaste inputs

Suez was assigned the task of identifying, securing and supplying the 40% of biowaste via the joint structure Engie Suez Methabio. Beyond its participation in the capital through the joint venture, Suez was involved for its expertise in the biowaste sector. Furthermore, the project

aligned with Suez's objectives to develop anaerobic digestion in the company, as mentioned by sales developer Carl *“our development strategy was to start engaging in anaerobic digestion facilities where we would be 100% owners, or we would financially invest in the facility, or we would supply biowaste. I was looking at the sites, or at least the projects in the area, and I presented my superiors with the projects that I thought had the best chance of going ahead. Methamoly was the right time for us to create this partnership. (...) It was the first site in which Suez participated as both a supplier of biowaste and a funder.”*

The securing of biowaste addresses both qualitative and quantitative issues. During the biowaste securing process, engineers develop an understanding of the quality of biowaste and its implications for anaerobic digestion system operations and the selection of appropriate technology. This requires a comprehensive analysis of the intricacies associated with biowaste quality and its direct impact on the quality of the resulting digestate, to be spread on farmers' land. The division in charge of organic solutions at Suez conducted tests to evaluate the agronomic viability of the biological mixture. Subsequently, engineers diligently navigated through the administrative procedures which allowed for the digestion of a particular category of inputs. Moreover, they developed and executed a thorough plan for spreading digestate, with continued monitoring to ensure compliance.

In addition to qualitative considerations, the sales developer was faced with the challenge of quantitatively assessing the available biowaste potential over an extended period. Carl focused on securing inputs through a detailed strategy. This task encompassed assessing the potential of internal clients within Suez's network in the region to supply their biowaste to Methamoly. According to him, *“A little before we started up, I canvassed the whole territory to find waste that was more likely to be digested in the project. I would say we did a bit of everything, we focused on the internal network, customers who were already with us, who we relocated, and then we started prospecting for new customers.”*

Simultaneously, efforts were made by Carl to attract external local clients to enhance input security and optimize a wider local approach for the solution already proposed to clients, i.e., composting. *“Some of our customers already with us were composting. We had a composting site not far away. There were a certain number of customers that we had never canvassed, because they had waste that was of less interest for composting.”*

He assessed offers such as composting that were already being proposed to these customers. He reached informed conclusions on whether to propose anaerobic digestion as an alternative offer for them based on *“a geographic criterion and criteria based on the methanogenic characteristics of the inputs. Analyses of the capacities enabled us to determine which inputs*

were of interest for anaerobic digestion. After that, we had to come up with a pricing strategy that met our expectations and those of our customers.”

Finally, he focused on presenting the local benefits of the solution proposed to his clients “*the local valorization of the resource, the circular economy, the production of biogas used nearby, and then the digestate returned to the soil, it’s true that these were arguments in favor of local processing.*”

2.3.3 Maintaining interest, adapting to market changes, and avoiding cannibalization

While securing the 17,000 tons of input, the teams encountered several challenges such as maintaining the interest of input providers, adapting to a change in the availability of inputs, and avoiding cannibalizing other valorization methods for biowaste. One of the greatest challenges to management of a conventional anaerobic digestion project, which takes years, was to keep input suppliers involved and interested. Due to the project taking an extensive amount of time—approximately 8 years between the initial inception of the project and the start of operations—negotiations with potential input providers proved difficult.

Some individuals with available input would insist on immediate action when the project was discussed during its development phases. But given the development timeline, treating the proposed feedstock was not feasible. Thus, discussions to finalize contracts revolved around elements that would not truly be operational for several years. The challenge thus lay in maintaining relationships with suppliers throughout this entire period. From an outsider’s perspective, it appeared as if nothing was happening. Consequently, people could easily assume that the project was not progressing. However, financial activities to secure funds and subsidies, as well as administrative tasks such as compiling documents and obtaining final approvals were going on behind the scenes. During the application authorization process, state services could take between six and nine months to examine documentation.

A significant part of Eloi’s work to secure inputs involved maintaining relationships through regular phone calls, providing updates, and ensuring that suppliers of resources sensed ongoing progress, even during months when it seemed stagnant. He recalls, “*The project took a very long time. We had discussions with potential providers of inputs who had their deposits available and were saying: “we can sign tomorrow morning; we’ll bring you the trucks.” But we were 3 years away from construction, so in fact it was a no go. So then they would say, “well sorry, but I’ll have found another solution by then.” So that was the difficulty; I think it*

is a time issue, because we have to discuss things and secure contracts that won't really be operational for another 3 years." In this perspective, to further underline the changing nature of secondary resources due to the extensive development period, Eloi confirmed, *"If we compare the list of inputs that we drew up at the very beginning, and the list of inputs that were actually incorporated into the digester the first time it operated, I don't think anything matched!"*

Another endeavor involved the establishment of partnerships when dealing with a complex input situation. Indeed, during the preliminary phases of prospecting, financial provisions were earmarked for the procurement of inputs, reflecting an early strategic orientation. However, the operational landscape experiences transformative evolutions over time. Methamoly could either be paid for the management and valorization of inputs or pay to have access to inputs, depending on the quality and the demand. For instance, initially it was considered that Methamoly would pay to have access to the biowaste of a sausage factory implemented in the region. However, it was discovered that the sausages were wrapped in plastic and metal rings, which would have to be extracted before incorporation in the digester. Consequently, negotiations concluded that the sausage plant would pay Methamoly to process and valorize this biowaste. This shift from inputs originally considered to incur costs to a valuable resource generating profit, added complexity to the project's financial management in addition to the technical management, as a suitable solution had to be found to remove the plastic and metal rings. According to Fabienne, *"It was difficult because a product that was considered a burden or economic cost suddenly became a valuable product, or vice versa."*

Finally, securing biowaste proved to be challenging for Suez's team on another level. On the one hand they had to deal with a changing market according to Carl: *"I know that when I was in charge of trade at Methamoly, we received a fee for all the materials we brought in (...) OK, but things have changed now. The market is changing, and materials are becoming more and more valuable."* Also, he had to avoid cannibalizing offers already proposed in the region for clients, *"because our clients were already offered the solution of composting with rates that had already been well negotiated for years. So, it was not necessarily easy to change everything."* Furthermore, he had difficulties in *"making long-term commitments with agro-industrial companies."* He also had to deal with competitive markets and prices. *"We're working on partnerships that need to be put in place quickly. And then the world of waste is a world of sharks. Well, like all industrial worlds to some extent, but particularly waste,*

because we have gone from a waste product that a priori costs money to a resource that is extremely expensive for some, especially those that have high methanogenic potential”

During the development of the project, the existence of another anaerobic digestion project in the region introduced the prospect of competition in supply. Ultimately, the other project encountered time delays, alleviating the concerns of market saturation in the waste-sourcing sphere. According to Carl *“these projects are too big. The fact of being associated with a group of farmers also brings security to the input mixture, it brings a base that is always there. It brings stability to the input mixture, technical stability, and economic stability too.”*

2.3.4 A novel solution for storing the digestate to optimize logistical issues

The project faced another major issue: avoiding noise from trucks transporting inputs to ensure acceptability among citizens. Indeed, the project had involved citizens since the very beginning. They quickly raised concerns about road transportation, with an emphasis on noise disturbance. Actors involved during the project development phases started brainstorming on ways to avoid noise. Fabienne recalls, *“Citizens said be careful with the road transport, don't let tractors or greedy lorries drive around, and as a result, it forced us to think that if we don't want trucks to drive empty, they must come back with something”*

An idea was proposed to avoid running empty tractors or trucks. This compelled them to find ways to avoid trucks driving empty after delivering inputs to the anaerobic digestion site. They had to leave the site filled. The solution proposed was to fill the trucks with digestate and organize a reverse logistical movement to deliver it to farms. In fact, the territory had the particular situation of having a significant number of farmers with manure pits stocking livestock effluents. Eventually these pits would no longer be of use due to the creation of the Methamoly anaerobic digestion site valorizing the livestock effluents. Consequently, for the reverse logistics to succeed in returning the digestate to the pits, a rehabilitation process was required. The team managed to obtain the necessary administrative authorizations to cover these pits and certify them to receive the digestate produced at the end of the anaerobic digestion cycle. Thus, instead of storing it on the anaerobic digestion site, the digestate would be stored on each farm. This concept also led to envision a transportation circuit for moving livestock effluents from the farms to the anaerobic digestion site and returning the digestate to the farms before being spread at the appropriate time in the seasonal cycle. A novelty in this

project was the storing of digestate in the pits on farms, creating a decentralized system of digestate management.

2.4 Specific localization of the anaerobic digestion unit: An expansion of the gas network in the territory

The geographic implementation of the project was greatly aided by the active involvement of the Community of Municipalities, on two levels.

First, they were actively engaged in the TEPOS program. Second, they put up for sale a community-owned plot in a business park, simplifying the project's localization. The selection criteria included considerations of the availability of a plot, proximity to farmers, and distance from residential areas. Thibault confirmed *“it is because it was available, it is a business park owned by the local authority. It was close to the farms. So, it was a good combination of factors.”* SAS Methamoly proceeded with the purchase of the land for the plant's implementation and conducted all the administrative procedures for the construction.

The project was designed to be located on the border of two departments. Consequently, actors encountered the challenges of complying with administrative procedures for both departments. Indeed, the farmers are situated in the Rhône department, while the anaerobic digestion site is located in the Loire department. As a result, they had to navigate the processes of both departments for the administrative authorizations to operate, especially regarding the installations classified for environmental protection (ICPE).

Also, Methamoly was designed to inject its biomethane production into the local gas network. Notably, in 2012, biomethane projects were relatively uncommon. Therefore, GRDF carried out specific works to enable the site to supply the territory more widely. According to Thibault, *“the community had to invest in connecting the plot to the gas network. There has been extensive collaboration with GRDF (Gaz Réseau Distribution France), which agreed to participate in the expansion of the network in the territory.”*

To conclude, the Methamoly project illustrates the development of a circular model driven by several local actors. It represents the intersection of public research initiatives on the potential of anaerobic digestion in the region in 2011 and the desire of a farmer to provide alternative solutions to the energy model. This case demonstrates the progressive and pioneering construction of a particular governance model in the energy domain witnessing

local actors, public entities, capitalist enterprises in the energy and waste sectors, and farmers gathered in a separate structure. Ultimately, it shows a resource securing process that proved to be quite smooth. The success of Methamoly can be ascribed to the seamless coordination and mutual trust throughout the actors' network. The leadership exhibited by Eloi and the confidence exhibited by the farming community played a pivotal role in steering the project towards materialization. Furthermore, the project reaped substantial benefits from the synergistic amalgamation of expertise provided by Suez and Engie, which imparted invaluable insights and resources pertinent to securing organic secondary resources and energy production, respectively.

3. The Caux Vallée de Seine project

This narrative is based on the interviews and exchanges with Amaury, Florian, Carmen, Marianne, and Elise.

Amaury is a Business Developer at Engie BiOZ, *"I am responsible for development in our territory, namely Normandy, Hauts-de-France, and Centre-Val de Loire. In my team, I supervise four project managers, each covering a designated area of the territory."*

Florian is a Procurement Officer at Engie BiOZ, *"I am Florian. For the past 4 years, I have been handling procurement of industrial organic materials for the biomethane plants in the Normandy and Hauts-de-France regions. I am based near Rouen."*

Carmen is a Logistics and Transport Manager at Engie BiOZ, *"I come from a pure road transport background with over 10 years of experience in the sector. Currently, I am responsible for transport and logistics at Engie BiOZ, and I took charge of this aspect in the Caux Vallée de Seine project."*

Marianne is an Agricultural Development Officer at Engie: *"So, I am Marianne, I have been an agricultural valorization engineer at Engie BiOZ for 4 years now. I am specifically in the operations team. We follow contracts, create new ones, and secure inputs for existing plants. We assist the project teams at the advanced stage of the project when they need help securing agricultural resources. In our team, we are separated into regional divisions. I cover the Normandy region, so it's essentially Normandy-Picardy and Île-de-France, and then there's Brittany, Vendée, and the central region."*

Elise is the Development Manager for the Circular Economy, Industrial Ecology & Energy Transition at a Territorial Development Agency. *"I have always been in the field of sustainable development. I have been working at Caux Vallée de Seine Agglo for 6 years. I engage in prospecting and project monitoring for industrial implantation projects with a focus on those related to the circular economy and decarbonization in our territory such as Caux Vallée de Seine."*

3.1 Main characteristics of the anaerobic digestion unit

The Caux Vallée de Seine entity is situated in the industrial park known as ZI Port Jerome, manifesting a dynamic nexus of industrial activities. Its operational framework encompasses the judicious utilization of up to 59 tons per day of feedstock, corresponding to an annual intake of 22,000 tons. Notably, this feedstock amalgamation boasts a balanced composition, being derived from both agricultural sources, accounting for 50% (comprising effluents and plant residues), and agro-industrial inputs, constituting the remaining 50%. Caux Vallée de Seine fosters symbiotic relationships with 17 partnering farmers and 10 agro-industrial entities.

It is characterized by a power output of 218 Nm³/h and an annual production capacity of 19 GWh. It supplies gas to around 1,700 households annually.

The realization of this project necessitated a financial commitment amounting to €11.213 million. Notably, a commendable proportion of €1.8 million was secured through FEDER.

Figure 22 below depicts the overall evolution of the project from its inception in 2010 till its official operating date in 2023. In 2010, a territorial assessment of the region found that anaerobic digestion constituted a sound solution to meet energy demands in a sustainable way. At the time, VOL-V Biomasse was chosen to develop the plant. In 2015, Engie BioZ took the lead on the project. 2016 and 2017 saw the identification and characterization of input material sources, to establish a robust foundation for subsequent stages. 2018 and 2019 witnessed the consolidation of exchanges with input suppliers. Subsequently, 2020 saw the strategic formulation of an expansive plan for digestate valorization, a feat facilitated through assistance from a specialized consultancy. Administrative processes spanned 2020 to 2021. The fruition of these preparatory phases culminated in the construction in August 2021 leading to the first cubic meter of biomethane being injected in February 2023.

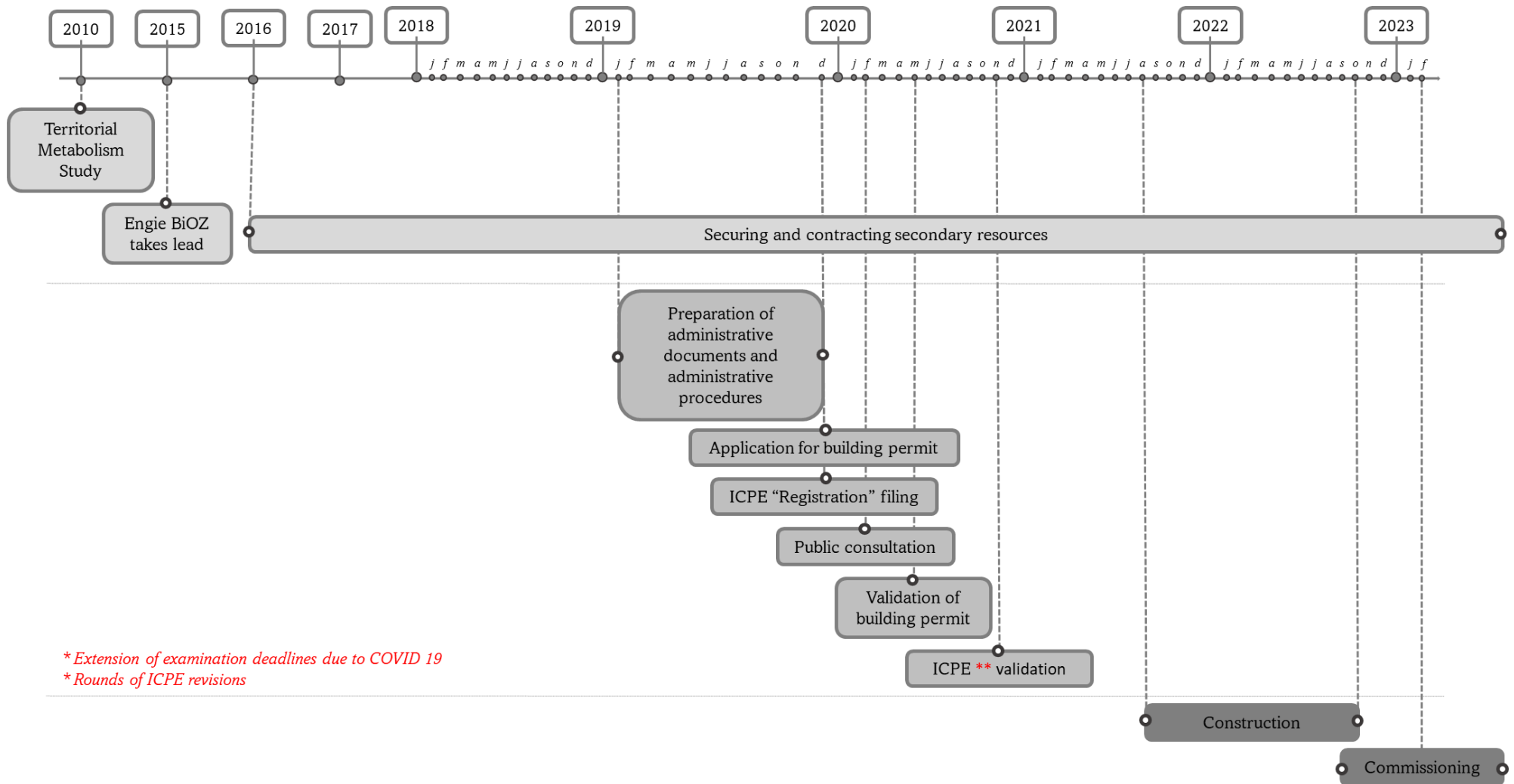


Figure 22 Timeline of the Caux Vallée de Seine case study

3.2 Project initiation in 2010: Anaerobic digestion, a solution identified in a study on “territorial metabolism”

The development of the entity spanned from its inception in 2010 till 2023. The project management was initially undertaken by VOL-V Biomasse, which was a well-known company in the region. The project was thus not developed by the same team and same business developer since it was first kicked off. *“The project is a bit special because it was Amaury who finished developing it, but before that it was someone else who left for new adventures,”* indicated Florian. In the following paragraphs we depict the evolution as told by the current team that took over the project since the others were not reachable within the period of this research. We supplemented information by archived data.

In 2008, the “Grenelle de l'Estuaire” showcased the potential of an industrial ecology approach for the region and the Estuaire de la Seine. In 2010, the *Association Ecologie Industrielle Estuaire* (AEIE - Industrial Ecology Estuary Association) was created. It brought together five regions on the Seine Estuary, including Caux Vallée de Seine, where the anaerobic digestion plant is located. When it was established, one of its key missions was the identification of industrial symbioses in Port-Jérôme⁵¹. In 2011, the association's industrial and territorial ecology initiative began, with the launch of two studies. The first was designed to evaluate the “territorial metabolism” of the regions by calculating material and energy flows. The second was an attempt to identify possible industrial symbioses. To meet part of the region’s demand for 22,409 GWh (in 2009), the study recommended developing wood energy, anaerobic digestion and wind power. The study estimated that 767,000 tons of unused slurry and manure, and 100,000 tons of biowaste could be fed into anaerobic digestion units.

3.3 Securing the inputs starting in 2016

Within the team developing the project, two specialized teams were in charge of constructing the relationship with farmers on the one hand and with the agro-industrial companies and collectivities on the other. The teams encompassed agronomic, commercial and transport expertise. We will depict the phase of securing inputs from the point of view of the current Engie team upon taking over the project in 2015.

⁵¹ <https://www.actu-environnement.com/ae/news/estuaire-seine-ecologie-industrielle-experimentation-oree-15506.php4>

3.3.1 Win-Win exchanges with the farmers?

The primary objective of the team interacting with farmers was to reach arrangements based on the balance of organic matter and adaptation to farmers' needs. Ultimately, the objective was to find agricultural land on which to spread the digestate, which is the by-product of anaerobic digestion. Marianne's task was to engage farmers in the project to lock in surfaces on their agricultural lands for the digestate to be spread over, and to secure agriculture inputs. Indeed, for this project, the development team had calculated approximately the required surface area needed for spreading the digestate. The objective was then to enroll farmers accordingly and ensure the project had access to the required lands to spread the digestate. Marianne recalls, *"We had 3,000 hectares of land-spreading plans for the digestate. We needed to think about the quantities of inputs that this could bring us. Simultaneously, we counted the number of farmers required to meet this objective."* The first phase consisted of a prospective approach, accompanied by a consultancy to help in the digestate-spreading plans, the identification of farmers and their requirements. She detailed the type of questions they tackled, *"What type of farmers are there in the area; are they going to be livestock breeders or more arable farmers? What are their practices and what are their needs? So, the first thing we had to do is assess the landscape."* During the first meeting in 2016, the team presented the project and its objectives to farmers. This included providing an overview of the project's scope and goals. Additionally, farmers' deposits were sampled to conduct a comprehensive assessment of their biological characteristics. This helped specify the methanogenic potential and accurately quantify availability on the land. She then pointed out that she dedicated one-on-one time to carefully listen and exchange with the identified farmers, *"I made an appointment with this consultancy and then we went to all the farmers individually, so we spent a good hour with each farmer (...) which allowed each one to tell us what they didn't want to tell us during the group meeting."*

Finally, Marianne and the sales team focused on the commercial aspects of the project. The terms of exchange were presented to the farmers, outlining the benefits and incentives they would receive by participating in the project. This included discussing financial considerations, such as compensation or substitution arrangements for deposits, as well as logistics support. Some involved non-monetary exchanges, such as bartering resources like manure and straw, due to farmers' reluctance to sign formal contracts, driven by concerns about climate fluctuations and other factors. Indeed, according to Amaury *"Farmers aren't*

necessarily happy to receive a bill from us because it generates sales that don't exist and therefore extinguishes other financial benefits they have.”

Also, an agricultural contractor who was part of a CUMA cooperative for using farming equipment (*Coopérative d'utilisation de matériel Agricole*) played a vital role in the plant's operations. This agricultural service he provided facilitated input management and digestate logistics. Engie paid the contractor to make the silage, deliver it on site, and then evacuate the digestate. The benefits of this approach were explained by Marianne, *“It saved us from having 17 farmers complaining to us and calling to ask when we are coming to pick the inputs up. So, this contractor puts it all in a big hangar then he manages the deliveries accordingly.”*

In certain instances, the farmers expressed reservations or declined the offered terms. Consequently, starting in 2018, the team initiated a negotiation phase to address these objections or reservations. For example, the two farmers supplying manure were keen to discuss logistics. They wished to avoid being reliant on the agricultural service provider, as they were unwilling to conform to a schedule. After joint deliberations, it was agreed that Engie would pay the farmers to undertake transportation themselves. Carmen clarified the flexibility in the configuration proposed, *“That was part of the negotiations with the farmers, as they wanted to do the transport as well. So these two farmers who were to provide us with manure asked if they could bring the inputs by themselves, so we said yes (...) it allows things to be done when they feel like it. On the other hand, depending on an agricultural service provider puts everything on a schedule and farmers hate schedules.”*

3.3.2 Added value: A turnkey solution to treat farmers' inputs

The main arguments presented to the farmers for non-monetary types of exchanges were related to agronomic, logistical and environmental benefits. The team stressed the advantages of digestate in terms of NPK (nitrogen, phosphorus, and potassium) supply compared with conventional chemical fertilizers or manure⁵². When digestate is applied at the right time, closer to the plant's needs, it is easier to valorize than manure. In terms of logistical benefits, Engie handles the manure storage and makes it easier for farmers to adhere to regulations regarding manure storage. Also, the team highlighted the fact that farmers can consider other

⁵² As explained in chapter 3, NPK nutrients are beneficial in various aspects of crop development and can be found in digestate depending on the resources introduced into the digester.

types of crop rotations on their land that can be both beneficial for their soils and digested in anaerobic digestion units (see the example of Figure 20). They also highlighted the beneficial logistical arrangements due to the fact that the agricultural service provider could manage all the deliveries from their land to the plants. And finally, they highlighted environmental benefits such as CO₂ emissions avoided. This task of convincing farmers was challenging, according to Marianne, *“That was the challenge of the first 2 years. We had to convince farmers that they had made the right choice in signing up with us.”* The goal was to find common ground and reach a mutually beneficial agreement that addressed the farmers' concerns while remaining aligned with the project's objectives. The subsequent meetings involved finalizing the agreement and securing the farmers' engagement. This included finalizing legal and contractual aspects, ensuring all parties were in agreement on project implementation, and addressing any remaining questions or concerns the farmers may have. The focus of the team was to build a strong contractual relationship and secure the farmers' commitment to secure their supply of deposits over a period of 10 years. In 2021, the farmers received letters from a competitor that offered to purchase all the inputs. According to Marianne, *“we knew what Total proposed to the farmers, because when they received the letters, they quickly showed them to us. So we know that Total decided to buy back their inputs. It certainly looked attractive at first. Except that the farmers had to buy the digestate and go and get it from the plant, which is 30-40 km from their land.”*

So apart from stressing the benefits of the all-inclusive offer, and the local and territorial value of the project, Amaury and Fabien also worked on maintaining strong relationships with farmers during the whole project development phase. Between 2019 and the completion of construction in 2023, they organized recurrent phone calls and visits to the site during construction to maintain farmers' interest and keep their inputs secured till operations started. As mentioned by Fabien, *“When there was progress on the site, we'd hold a meeting to tell them that there's progress, and then take them on a tour of the site, so that they too can feel very involved. It was of interest to them, it allowed them to feel involved in the project and to see that it is becoming reality, because that is often what is missing in project development, the fact that it is a concrete structure. Because for a while, there is necessarily no news because there is all the administrative part, the prefectural decrees, all that, and that time can be a bit long for farmers.”*

3.3.3 An uphill battle to negotiate exchanges with agro-industrial companies

While the team's efforts with the farmers focused on securing land and inputs through mutually beneficial arrangements, negotiating with agro-industrial companies presented a different set of challenges. Engie BiOZ has a dedicated team to identify potential agro-industrial supply due to the increased competition resulting from other recovery channels on the territory. The specialized team identified potential prospects. They identified current valorization methods for these inputs, if available. These inputs can be valorized locally through other recovery channels (such as incineration, composting or animal feed) or through other anaerobic digestion plants.

According to Carmen, the objective was to propose the most attractive financial solution through the terms of exchange. She pointed out, *“It's just that you have to fight a bit on the pricing side.”* Her team also had to tailor the propositions because, *“the customers either have their own fleet of vehicles and take care of the transport and bring us the material, or our transport cost is covered by the customer, it depends.”*

Even though industries *“seek to decarbonize, seek to have a good image”*, presenting the terms of exchange to one of the agro-industrial companies with starch biowaste proved to be *“a challenge (...) meaning that we spent at least 6 months on the contract (...)”*, as outlined by Amaury. On the one hand Engie wanted *“to secure a long-term tariff, to cap prices so that we have real visibility and don't explode costs.”* On the other hand, the industrial firms *“did not want to lock in a tariff for 3 years. They did not want to have something fixed for the long term,”* recalled Florian.

The business developers began negotiations in 2019 to reach an agreement that could suit both parties, knowing that the tariff was a key issue. After discussions, they obtained a concession from the agro-industrial company in that it was declared willing to commit for two or three years but with an evolutive price. At first the team thought that pricing would be a sticking point for them, but in the end, they managed to successfully navigate the issues and reach some agreements. Indeed, after several meetings *“the solution was finally found”*, according to Florian because they had previously discussed several factors such as cost of transportation, cost of energy, cost of raw materials, and legal aspects. The two parties agreed on an indexation formula that would be checked at the end of each year. For Amaury, this was a *“compromise to try to secure a longer-term contract and make some concessions on the tariff, but to put a ceiling on it so that we have real visibility and don't explode costs and then*

fall into something that wouldn't be profitable for us.” He remembered that the negotiations “were heated in the sense that there was the war in Ukraine, the market was changing, and so on. So we felt that other sectors, such as animal feed, were also competing with us for these materials going into anaerobic digestion.” The team gave in on the indexation formula, but they succeeded in negotiating a fixed cap that must not exceed 10% of the initial price each year.

Previously, agro-industrial companies paid for waste disposal services. However, the waste from some agro-industrial companies has now acquired monetary value. Currently, some of them seek short-term contracts with flexible prices based on demand and competition for their waste, whether inside or outside their sector (e.g., composting, incineration, animal feed). The team had to adapt its offer accordingly.

3.3.4 Added value: A mesh solution for a continuous service proposed to agro-industrial companies

Engie recognizes the critical need to provide uninterrupted services to industrial customers, especially when dealing with the treatment of biowaste throughout the year. This imperative involves addressing both technical issues and the need for regular maintenance, acknowledging that any downtime can significantly impact their customers' operations, as mentioned by Amaury *“Whatever the cost, the customer must have his service, his output solution. There are industries that are blocked, or the entire production line is blocked if the waste does not get out.”* Engie aims to assure its industrial partners that, in the event of a technical problem or maintenance issue at one site, alternatives are readily available. Florian highlighted, *“We have to prove to industry that we are capable of treating these materials all year round. We explain that, with the extensive network we have today, our arguments are valid. If, for example, Saint-Jean-De-Folleville needs maintenance, breaks down, or anything else happens, we have back-up solutions.”* Engie acknowledges that, even in the absence of technical issues, regular maintenance is an intrinsic part of any anaerobic digestion site's life cycle. By proposing a *“mesh network solution”*, Engie strategically positions itself to absorb the impact of site-specific closures or maintenance, ensuring a reliable and uninterrupted flow of services. Amaury argued that they were *“building an internal network by developing our own entities at Engie BiOZ and expanding the external network by relying on either plants in which we are involved, or plants that we know very well, which are partner competitors.”* On the one hand, this collaborative approach strengthens the commitment to ensuring the

continuity of service proposed to customers. This strategy, in essence, safeguards the lifeblood of industries, providing them with back-up solutions to navigate potential disruptions seamlessly. On the other hand, this proposition guarantees Engie BiOZ security of input flows for the plant's process.

Beyond the technical aspects, the mesh solution extends to logistical challenges. Engie BiOZ leverages local transport services to ensure the efficient movement of materials and resources. Carmen recognized that they *“do not possess an extensive fleet of trucks, drivers, or equipment; we collaborate with local transporters.”* She mentioned that this collaboration involves sub-contracting to these partners, who *“often have a deeper understanding of the local dynamics and logistics, ensuring a more streamlined and cost-effective approach.”*

However, logistical challenges persist, and Engie acknowledges the importance of partnering with reliable transporters. Carmen observed that these transporters *“want to have a good low-carbon image. And they think that anaerobic digestion is on the up, so for them, these are potential markets to conquer.”* This presents a challenge for her team to *“find partners who offer correct pricing and are genuinely motivated to work with us.”*

In essence, the *“meshing solution”* embodies Engie's commitment to ensuring continuous service delivery for the benefit of its industrial customers, but also to ensuring operational resilience, navigating the challenge posed by the competitive landscape of input valorization within the agro-industrial realm.

3.4 Specific localization of the anaerobic digestion unit

The effective implementation of the project's geographic aspects benefited significantly from the active engagement of local public actors in the ecological transition as well as compliance with several factors.

First, Port-Jérôme is an industrial area located in Saint-Jean-de-Folleville, a community part of Caux Seine Agglo. Historically, this area was an industrial port area focused on fossil fuels and marked by the presence of actors such as Exxon Mobil or Esso. However, it is currently actively engaged in an ecological and industrial approach and has been awarded the "Cit'ergie®" label ⁵³for its energy and climate policy quality management process.

⁵³Currently named "Label Climat Air Energie": <https://www.territoires-climat.ademe.fr/ressource/128-43>

As mentioned, the project concept originated with VOL-V Biomasse. Consequently, the project was not followed by the same business developers from start to finish. The new team in charge at Engie BiOZ had met with local public actors at the time of the takeover in 2015. Fabien recalled that *“they identified an interesting piece of land in the area. The municipality was in the process of launching decarbonized projects, so we were in line with this objective. What is more, they had a really important objective for their industrial zone: implementation of the circular economy. It was the perfect timing.”* Furthermore, the geographic implementation of the plant in an industrial park proved to be beneficial. Indeed, according to Carmen *“anaerobic digestion transport and noises are often a source of concern by local residents. Saint-Jean-de-Folleville is in the middle of an industrial area, so as far as I know, this hasn't been a problem in the area”*.

Beyond providing a plot of land, Caux Seine Agglo, through its economic development division also proved to be a facilitator in the project to enhance local acceptability as mentioned by Elise: *“For example, we invited local citizens to participate in consultation meetings and technical discussions. Also, local councilors informed people about the project through newsletters, gazettes, the local press, and at town hall meetings to make the project more acceptable.”* Her team also facilitated administrative procedures.

The Caux Vallée de Seine project, from its inception in 2010 to its operationalization in 2023, reflects a journey marked by challenging planning, proactive engagement, and adaptive problem-solving. Initially conceptualized as a response to studies assessing the "territorial metabolism" and identifying potential industrial symbioses in the region, the project gained momentum through strategic partnerships and the takeover by Engie BiOZ's team. The specific localization of the anaerobic digestion unit within the industrial park exemplifies the alignment of project objectives with local economic and ecological transition initiatives, while mitigating potential concerns related to transport and noise. One key to the project's success was the diligent effort to secure resources from both agricultural and agro-industrial sources. Through extensive negotiations and tailored value propositions, Engie BiOZ effectively navigated the complexities of engaging with farmers and agro-industrial companies. By emphasizing the agronomic, logistical, and environmental benefits of participation, the team fostered a sense of mutual benefit and long-term commitment among stakeholders. Crucially, the project's commitment to continuous service delivery and operational resilience underscores Engie BiOZ's dedication to meeting the needs of its agro-

industrial partners and maintaining the anaerobic digestion unit's viability. Through a meshing solution that combines technical expertise, logistical efficiency, and strategic partnerships, the project exemplifies a holistic approach to sustainable energy management.

4. The Sibiom project

This narrative is based on the interviews and exchanges with Noah, Felix, Oscar, and Orens.

Noah is a former Biomethane Strategy Advisor with Storengy Engie, *“I've been with the company for about 10 years. I initially worked on acquiring new ventures in the oil and gas sector, then served as a strategy manager for enhancing biomethane development in Europe within Storengy. Agricultural issues related to anaerobic digestion are topics I am familiar with; my father-in-law was a farmer, so when discussing it, I speak from experience.”*

Felix is the former Business Developer at Storengy Engie (in charge of Sibiom from 2021 to the end of 2022), *“I've been with Engie for over 15 years. Specifically, for the past 3 years, I have been working at Storengy, in the Strategy and Development department. I am a project director. Until earlier this year, I worked on geothermal projects within the group, and now I am focusing on biomethane projects. Currently, I am working on two particular projects: the Sibiom project in Belgium and the Poznan project in Poland. These are two projects at different maturity levels.”*

Oscar is a Senior Business Developer at Storengy Engie (in charge of Sibiom from late in 2022), *“Personally, I've spent 11 years working for Engie, mainly focusing on activities in Belgium. Over those years, I have held various positions, primarily in business development. For example, I have worked on wind projects and other types of services as well. I was perhaps already leaning towards operational activities due to the needs. Last December, I joined the team of Noah and Felix. At that time, Engie created a new entity called RGE, which incorporated all biomethane activities. From an organizational standpoint, it was not an easy transition, and some colleagues either did not want to move to RGE or were offered other positions like Felix and Noah. However, this reorganization didn't impact my role, and I continue to focus on developing biomethane projects in Belgium.”*

Orens is the Director of Energy and Sustainable Solutions at the Territorial Development Agency, *“I've been with IDETA for over 15 years, serving as the director of the Energy and Sustainable Solutions department. In my department, as the name suggests, we focus on developing renewable projects. The primary focus is on wind energy, and the second, which I*

oversee, is biomethane. I am involved in various biomethane projects in the region, including the one known as Sibiom."

4.1 Main characteristics of the anaerobic digestion unit

The Sibiom project is planned to be located in an industrial area of Leuze-en-Hainaut in Wallonia, Belgium. The project aims to capitalize on the abundance of locally-produced vegetation by transforming it into biomethane. It is designed to produce 100 GWh based on 150,000 t/year of inputs with 20% from agricultural sources and 80% of biowaste. The entity has not yet been built.

Figure 23 below depicts the overall evolution of the project since its launch in 2013. In 2014, a regional development agency wished to decarbonize its industrial park. Engie, with its subsidiary Electrabel, was a historic partner of the agency. In 2014, they created Sibiom (*Société Industrielle de BioMéthanisation*) in order to develop a plant producing biomethane. In 2015, a public consultation was organized to take into account local residents' reservations. 2016 and 2019 were characterized by administrative procedures and technical designs for the plant. The project is currently stalling. Since 2020, project management has evolved from Storengy's lead to RGE's (Figure 17). Furthermore, many problems have been unveiled during this period regarding the availability of green certificates and of pre-identified organic secondary resources. Additionally, digestate valorization is hindering the project's advancement.

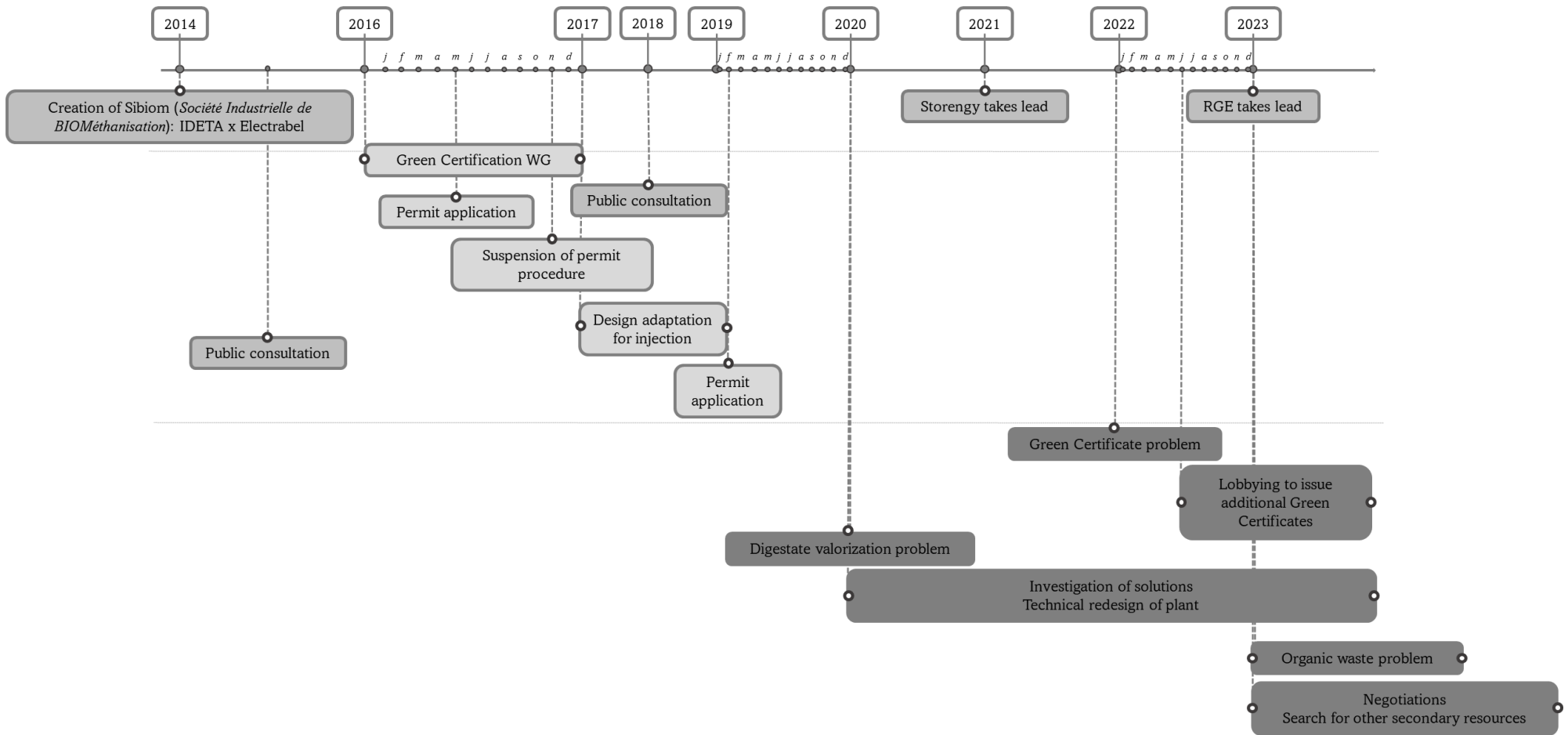


Figure 23 Timeline of the Sibiom case study

4.2 Project launch in 2013: Bringing together a local desire and energy expertise

The project originated from the vision of the IDETA territorial development agency, founded in 1991 to promote the economic expansion of Picardy Wallonia through the development of land for economic use and the development of business parks. The agency's involvement in infrastructure development, business support, and municipal services, with a diverse energy portfolio (gas, electricity, sustainable energy) prompted it to look into the biomethane solution. The objective was to contribute to the energy transition in Wallonia through green energy production and support for municipal energy and climate plans.

In 2013, recognizing the importance of green energy for business parks due to factors like heating needs, building considerations, and mobility requirements, IDETA decided to develop a biomethane plant. The aim was to produce green gas, assisting businesses in greening their processes and energy sourcing. According to Orens, the desire to develop an anaerobic digestion entity came from the realization that *“there was a significant consumption of gas and so the idea was to say we're going to try to implement a biomethane station in each of our business parks.”*

The agency approached Cofely, a subsidiary of Engie, and presented their biomethane project. The choice to include Engie was motivated by two reasons. First, in IDETA's approach to projects, collaboration with energy experts is crucial. The agency prefers partnering with energy actors because according to Orens they have *“energy knowledge and resources so we can tap into their expertise.”* Second, Noah pointed out that Engie was already involved in a wind project with IDETA. This led to the establishment of a co-development agreement with Engie's Belgian subsidiary, Electrabel, in 2014. They together created Sibiom, the project being handled by different entities within the company. Overall, Oscar (the current project manager) was annoyed that *“the project was handled by five or six different business developers (...) so we lost probably a lot of the information that had already been collected and work done. So that is the main issue in my opinion, it is difficult to see the logic and the project lost credibility both internally and externally.”* These changes were partially due to the organizational changes Engie has undergone. After Electrabel created the joint structure, it was then taken over by Storengy in 2021 before being finally handed over in 2023 to RGE, the new specialized entity in biomethane projects. Changing the entity in charge at Engie entailed a change in teams and the project manager. This constituted a major challenge in the project's management.

4.3 Constructing an adequate framework for biomethane injection – Green certification in 2016

In Belgium, energy matters are under the jurisdiction of regional authorities. Previous to 2016, Wallonia lacked a regulatory framework favorable to the injection of biomethane. Green certificates were made available for cogeneration projects. However, renewable energy projects were facing substantial implementation costs compared with conventional fossil fuels. This financial challenge prompted the need for a support mechanism, a mechanism that, “*at the time, lacked clarity,*” as pointed out by Orens.

In 2016, seizing the opportunity to fill this void, the regional authorities created a working group alongside biomethane project developers. The project team of Sibiom, alongside two other project teams, actively participated in co-constructing the mechanism with government services. Orens recalled, “*In the absence of a regulatory framework, we came up with somewhat innovative proposals. The framework was built in parallel with our project, so we were closely involved in defining the framework, since at the time it was practically the only project for injection into the grid.*” Even though some of their proposals were discarded, the participation of the Sibiom project team helped shape the current regulatory framework.

A single permit application was submitted in May 2016 by Sibiom. A technical modification was made to the project, involving a change in network from FLUXYS to ORES. This adjustment aimed to minimize energy costs associated with injection. In late 2016, Sibiom requested that the procedure be suspended so it could adapt its project and incorporate the possibility of injecting biomethane directly into the ORES distribution network. On February 28, 2019, a permit application was submitted with the purpose of injecting the produced gas into the distribution network.

4.4 A challenging project under development starting in 2019

Even though the project has benefited from public support for funding, development, administrative procedures, and even the provision of land, it currently faces development difficulties. As mentioned by Felix, “*Sibiom's strength is that we were able to sign long-term agreements that gave the project a great deal of stability over time. But that is also something we need to crystallize today. All the pillars of this project are very human, very local, and everything keeps changing right up to the last minute.*”

4.4.1 The problem of input availability in 2023

As the project progressed, market conditions shifted, and finding the rest of the required tons of annual input became increasingly challenging. To overcome the challenge, Engie relied on an external digital feedstock territorial mapping solution, Inex. According to Felix, *“Inex is a strategic digital tool for targeting regions, it's pretty easy to use.”* It aims to identify inputs to be valorized in circular activities. Initially it was developed for recycling industries to map and source potential materials. It developed a solution for the biogas sector that helps detect biowaste on the territory as well as giving detailed information about the producer, enabling market analysis and an overview of potential administrative regulations applicable to biowaste. The team also worked on prospecting among smaller agri-food industrial companies to secure the rest of the biowaste required.

Furthermore, in an effort to expand their operational capacity, they broadened their scope to include additional inputs. A waste collector, Dufour Group, was having its waste treated in Antwerp, and suggested becoming a partner in the project to treat and dispose of it closer to its collection center. Dufour Group is capable of addressing and managing smaller quantities efficiently. By forging partnerships with sources such as this, the project gained access to a valuable supplementary volume, predominantly sourced from professional activities. This encompassed diverse waste, including restaurant waste, unsold inventory, and production errors from various agri-food industrial entities. This expansion was particularly beneficial as it allowed the project to tap into a volume of waste that was decentralized and generated by smaller clients that the team could not otherwise reach. According to Oscar, *“Engie lacked the logistical capacity to engage with these smaller suppliers directly; they were beyond the reach of both ourselves and Engie. Dufour will be looking for small quantities from a number of its major customers, giving us a centralized additional volume.”*

Therefore, the team proceeded to form a partnership with Dufour. They negotiated 20% of capital shares in Sibiom and offered in return to provide the inputs for free. But as the project progressed, it appeared to Oscar—the current project manager at Engie—that Dufour would not be able to uphold this promise to provide the agreed upon feedstock for free. During recent meetings, they brought up the issue of pricing. According to Oscar *“Dufour started to ask for the transportation cost, the hygienization of the feedstock (...) In the beginning that was being offered free of charge, that kind of volume with that kind of quality for free. But now it is not free anymore. The quality is uncertain, and the volume is also uncertain. Dufour is not credible.”* The nature of the relationship with Engie has been undermined by Dufour's

position. In 2023, the current project manager was having doubts about Dufour's participation in the Sibiom project as it was motivated by a new factor: securing the winning bid in a call for tender for biowaste management in the region. Indeed, Oscar recalls that *“at that time, a call for tender was issued for waste collection. Dufour had filed an application but was not selected as a partner, so they lost the waste that they were promising us. Their promise was not backed up by any kind of sourcing on their side.”*

4.4.2 The problem of availability of Green Certificates starting in 2022

The team initially set an energy volume target. Then they estimated the volume required annually to reach the biomethane target production of 100 TWh. The first thing they did was to reach out to the Lutosa agri-food company (that belongs to the McCain Group) situated in the industrial park to understand its capacities. After analyzing the previous valorization deal the agri-food company had, the team was able to propose a competitive price. Indeed, according to Felix *“We negotiated a competitive contract with the nearby French fries factory that had significant biomass by-products valorized through biomethane, but in the Netherlands. So we were able to offer a more competitive price than our counterparts.”* The team was able to propose this more competitive price by eliminating transport costs. Therefore, the project secured a supply of approximately 50% of the volume from this local industrial company. Lutosa committed to supplying 80,000 tons of potato waste via a long-term contract. The agreement consisted of transforming 50,000 tons of potato waste enabling the production of biomethane for Lutosa's own use. The remaining 30,000 tons would be directly purchased by Engie from Lutosa for external distribution. The tolling agreement negotiated over a period of ten years with Lutosa presented a mutually beneficial arrangement for both parties. According to Felix the deal *“was very beneficial for us in terms of securing a supply, and for Lutosa too, as they could obtain green certificates through the project's biomethane supply.”*

However, by the time the two parties finalized their agreement, green certificates were no longer available. Since June 2022, the Engie project team has been lobbying the Walloon region to obtain additional green certificates.

4.4.3 The paradox of few agricultural ties and digestate valorization in 2019

In the initial stages of the project, between 2015 and 2016, consultations were conducted with local residents to address their concerns. The pre-established ratio of 80% of industrial waste and 20% of agricultural waste was challenged due to public resistance to the introduction of livestock effluents. According to Orens *“at the beginning, we could be honest, we had not necessarily limited the inputs from agriculture to leave ourselves as many possibilities as possible. But then we were really asked to limit this source due to odor issues.”* This further emphasized the need to limit agricultural contributions, leading to a first recalibration of the project design.

A paradox emerged as the project aimed to minimize its impact on the agricultural ecosystem while being intricately tied to it due to the coproduction of digestate that needs to be spread on farmland. Indeed, the project is expected to produce 120,000 T of digestate. By late 2019, the team realized it was struggling to valorize it. Orens confessed that *“Whether it is Engie or us, we are not really into the agricultural aspects, we work more on processes (...) It is this digestate element. We were a little bit surprised, or even astonished”*

The team is facing two fundamental issues concerning digestate valorization during the project's development. First, the anticipated ease of finding local farmers willing to accept digestate has not proven to be true. Despite the initial expectation of finding farmers within a fifteen-kilometer radius willing to accept digestate, securing agreements has proved difficult, leading to a shortage of suitable outlets for the 120,000 tons of annual digestate. Farmers either declined or requested compensation for taking the digestate. Indeed, according to Felix *“a study carried out by a local consultant in 2018 showed that within a radius of, I think, about fifteen kilometers around the project, there were farmers who would be willing to take on our digestate. But when we looked around, we could not find any takers for the digestate. Or else they were starting to be picky, saying that we were going to have to pay them for that.”*

Furthermore, the digestate expected from the plant will be mostly liquid. This represents another challenge in terms of storage and transportation.

Second, regulations on soil amendments further complicated the digestate disposal process. The region where the plant is expected to be located is heavily impregnated by soil improvers. To regulate agricultural amendments, the authorities specify limits per region. There are also specific rules regarding the spreading periods for digestate.

To address these challenges, the project team proposed multiple design recalibrations. First, insufficient storage capacity prompted the team to seek an alternative site for mass digestate storage. Second, the team is now exploring the option of drying the digestate, thus transforming it into a solid phase suitable for marketing to the agricultural sector. This approach not only aims to minimize storage volume requirements while streamlining logistical complexities, but also to increase its commercial value compared with the liquid phase. According to Felix “*The dried digestate, now in a solid state, could be efficiently sold to farmers at a competitive price ranging from 5 to 15 euros per ton compared with chemical fertilizers*”.

As a consequence of this last recalibration in the design, the current team under Oscar’s leadership began in 2023 to do some reverse engineering in order to reconstruct the project’s economic dimensions before proceeding with negotiations on inputs.

4.5 Composition of Sibiom’s shareholder capital

Sibiom’s current capital is shared between private and public actors. Engie holds 40% and Dufour 20%. As to public actors, IDETA holds 20%. More recently, CENEO joined the share capital by taking up 20% in 2022. CENEO is an intermunicipal actor that manages the interests of 57 towns and municipalities in Hainaut as well as 3 of the Hainaut regional development agencies⁵⁴ by acquiring holdings in the energy sector. In 2015, the 60 members of CENEO decided to focus the intermunicipal company's investment strategy on sustainable development. CENEO had already been active in the project’s development since 2021 and officially took a 20% stake on April 1, 2022.

4.6 Specific localization

The participation of a local public entity provided access to a suitable site for project implementation. The choice to select the industrial area of Leuze-en-Hainaut for the plant site was driven by three factors.

First, the land was available and was owned by IDETA, within its business parks. According to Orens at IDETA “*we have land available, so obviously that was one of our strengths in this project.*” Second, the plot was chosen given its unique attributes. In close proximity there is a significant agro-industrial presence, as well as two small industrial plants. This strategic

⁵⁴ IDETA (Intercommunale de développement économique des arrondissements de Tournai, d'Ath et de communes avoisinantes, IDEA (Intercommunale de Développement Économique et d'Aménagement du Cœur du Hainaut) , and IGRETEC (Intercommunale pour la gestion et la réalisation d'études techniques et économiques)

choice offered the dual benefit of a rich sourcing pool as well as close proximity. The third factor that Orens and his team took into consideration is that the plot of land is connected to the gas network. Thus, he argued “*it gave us the possibility of sourcing nearby with access to a gas network, which was our vision for regional development.*”

The vision for the plant’s development took shape, anchored in the principles of accessibility of land, accessibility to essential resources to be valorized in proximity to the plant, and accessibility to the gas network.

In conclusion, despite its origins and strategic partnerships, the Sibiom project has encountered significant hurdles along its journey from 2013, including organizational transitions, regulatory uncertainties, and logistical complexities in securing secondary resources and finding appropriate outlets for digestate. The project has undergone several organizational changes, transitioning between different entities within Engie, which has led to discontinuities and challenges in project management. Initially, the project faced challenges due to the lack of a favorable regulatory framework for biomethane injection in Wallonia. Despite securing agreements with industrial partners like Lutosa for biomethane supply, the unavailability of green certificates has impacted project advancement. Lobbying efforts with regional authorities have been initiated to address this issue. In addition, the project is facing difficulties in securing the required volume of organic inputs for biomethane production. Market conditions, changes in partnerships, and challenges with feedstock suppliers like Dufour Group have contributed to this issue. The project is struggling with the valorization of digestate, particularly due to difficulties in finding local farmers willing to accept it and regulatory complexities regarding its disposal. Efforts are underway to recalibrate the project’s design to address these challenges, including exploring options for drying digestate and marketing it to the agricultural sector. This paradoxical relationship between securing resources and the subsequent issue of digestate valorization underscores the critical challenges of the circular economy.

Chapter 6. Discussion

“Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house.”

– Henri Poincaré

In this discussion, we delve into the multifaceted landscape of circular projects based on biological secondary resources, with a focus on anaerobic digestion initiatives at the local level. Through our analysis of the four projects of anaerobic digestion emphasizing how actors organize and interact to secure local secondary resources for the development of circular business models, we uncover four key themes that shed light on the intricacies of these projects.

First, throughout our investigation, we emphasize a comprehensive three-phase process for securing secondary resources, underscoring the strategic approach adopted by stakeholders to ensure the long-term viability and success of local anaerobic digestion projects.

Second, our examination reveals the strategic yet challenging process of securing secondary resources in emerging markets. Through their efforts, stakeholders seek tools and instruments to define and qualify secondary resources then agree on contracts. They also develop tailored modalities of exchanges and rules aimed at securing secondary resources.

Third, we highlight the different territorial proximities. We discuss five crucial roles played by local public actors in supporting and facilitating local anaerobic digestion projects. Finally, we emphasize how the diverse pre-existing territorial proximities can be leveraged to enhance the territorial anchoring of projects.

Lastly, we analyze governance structures within anaerobic digestion projects, ranging from firm-centric to collaborative approaches involving secondary resource suppliers. We emphasize the significance of trust, communication, and partnerships in successfully securing secondary resources in shared governance. We also discuss the implications of involving resource suppliers in the governance structure.

1. The process for securing secondary resources

Biological secondary resources are not easily accessible to actors wishing to develop circular activities (Aggeri et al. 2023). Upon analyzing the four projects of anaerobic digestion, we offer (1) a detailed understanding of how organizations undertake the critical process of securing biological secondary resources by highlighting the three phases. We also discuss (2) the emergence of intermediary digital platforms emerging in the landscape of anaerobic digestion and the support they may bring throughout this process.

1.1 A three-phase process

Upon careful examination of the progress and chronological development of these projects, we have been able to clarify the approach taken to secure secondary resources. It is worth noting that although the projects use a similar technology for anaerobic digestion, each project has a unique trajectory. However, we could highlight that temporal phases in securing secondary resources are particularly crucial for framing the project across all cases, constituting a prominent challenge for actors developing circular business models. We consequently add to the literature on circular business model development (Geissdoerfer et al. 2017).

We specifically detail a three-phase process for securing secondary resources (Figure 24)

- Phase 1: Initial framing

During the framing stage, a macro assessment of available secondary resources is conducted. This initial approximation is based on the biomass potential study and results in preliminary volume approximations for plant sizing. Subsequently, this stage crystallizes the project, marking its technical characteristics and introducing irreversibility into the industrial process. For instance, in Methamoly and Caux Vallée de Seine projects, this initial macro assessment of the biomass potential was made by public local actors, providing an initial approximation prior to project development. While not explicitly conducted for the case of Sibiom, the project started based on the observation that sufficient biomass was available in the area where the plant would be constructed. Similarly, for the case of Landres, the project was initiated upon the observation that part of the cooperative's agricultural biomass could be valorized and bring additional benefits for the farmers. These macro assessments and

observations are further detailed by project initiators through volume approximations and market analysis to size the plant accordingly.

While no contractual commitment is finalized at this stage, this phase introduces irreversibility by defining the physical characteristics of the unit. Revisiting this initial framing can be a challenging task for the company, as it serves as the foundation for administrative documentation and initial business plans for financial institutions. As a result, this sets constraints that require the identification and securing of secondary resources that were approximately identified.

- Phase 2: Administrative procedures

This phase is the period necessary for thorough studies, administrative procedures, validations, and permits for construction processes. This phase is inherently inflexible and mostly outside the company's direct control, and can introduce several uncertainties that are hard to control.

This phase introduces a temporal gap that can be observed between the initial framing phase, which involves a technological decision-making process and the balancing of various secondary resources, and the third phase, which leads to the contractualization with suppliers of secondary resources.

- Phase 3: Contractualization of secondary resource supplies

During the third phase, the company engages in detailed contractualization. At this advanced stage of project development, contracts are established with secondary resource suppliers. The level of detail regarding input quality, regularity, and cost is significantly refined compared with the initial framing during phase 1. This is illustrated by the approach undertaken by the project manager in the Caux Vallée de Seine or Landres case studies, who crafted specific contracts with agro-industrial companies or farmers.

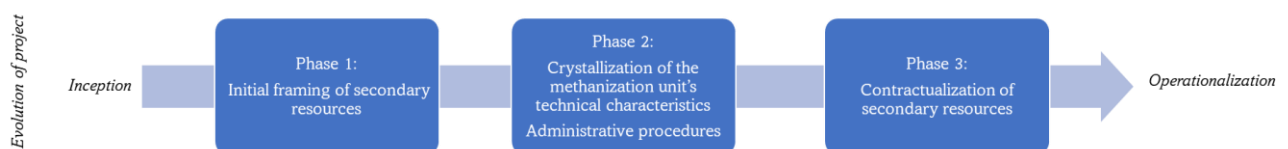


Figure 24 Three-phase process of securing secondary resources in circular projects

The pattern, illustrated in Figure 24, is distinctly specific to circular anaerobic digestion models, characterized by heightened uncertainty along the process and by an approximation of secondary resources during the critical early phases of project development.

In this research, we were able to highlight the intricate nature of timing in these circular projects. Navigating the timing between securing secondary resources and beginning operations presents a unique challenge in the development of anaerobic digestion projects. We underscore the complex dynamics involved in balancing the development timeline between the practicalities of securing feedstocks and the intricate interplay of administrative procedures in phase 2, such as dealing with the issue of project validation, obtaining Green Certificates, and finalizing technical issues related to digestate management, all of which introduce multiple factors of uncertainties to be tackled by the project development team. Finally, the success of the development of a circular anaerobic digestion project depends on the actors' ability to navigate these uncertainties and achieve the third phase, which is also not without challenges. The uncertainties arising during the second phase, beyond the control of project developers, introduce external changes that were not previously considered or anticipated, making it difficult to achieve the third phase successfully. These uncertainties relate to four different factors, that we were able to identify based on our investigation of case studies.

A first source of uncertainty relates to regulatory changes and developments. The growing emphasis on the circular economy in the professional sphere leads to constant changes in policies and regulations. This dynamic landscape complicates project planning and implementation, requiring constant adaptation to stay compliant and leverage new opportunities.

Secondly, the emergence of competition is another source of uncertainty. The same secondary resources targeted by circular projects may also be sought after by other activities that emerge during the second phase, including alternative anaerobic digestion methods or other solutions. This competition introduces a paradox where regulatory changes, while promoting circular activity, also intensify competition among actors developing circular models. For instance, regulations such as the AGECE law or calls for tenders can significantly impact the availability and accessibility of secondary resources, influencing project viability.

A third source of uncertainty is the robustness of commitment. Indeed, changes in the interest of stakeholders identified during the initial framing in committing beyond their primary occupation, presents a persistent challenge. The length of the second phase increases the risk of changes. Convincing them to participate in circular projects requires continuous engagement and incentive alignment. Farmers, in particular, are often reluctant to commit to initiatives beyond their primary occupation. A significant number of farmers may abandon the project due to its duration, perceived as too long. Similarly, it is crucial to maintain the

interest of agro-industrial companies in order to secure the quantity of resources identified during the initial framing. Agro-industrial suppliers, in particular, demand immediate solutions for their by-products, emphasizing the urgency of their needs.

The fourth source of uncertainty is the ability of farmers to comply with the changes required, such as alterations in crop rotations. Also, changes in their practices due to regulatory or climate change factors further complicate agriculture resource availability and quality.

In summary, the uncertainties that arise during the temporal gap of the second phase may hinder project development.

Another critical aspect that explains the difficulty in successfully achieving the third phase is the specificity of contracts applying to biological secondary resources. Project developers have to deal with different contract rationales.

On the one hand, drawing up contracts on the subject of agricultural resources is subject to the fear and reluctance of farmers. Very often, farmers are afraid of contracts because of the uncertainty of their production, which can be changed by common weather problems. Their reluctance can also be explained by their unfamiliarity with contracts as a business instrument. There is also the complication of pricing (discussed in detail in section 2). Finally, contractualization often involves negotiating the logistics of secondary resources, coupled with the option of digestate management. For all these reasons, contracts with farmers have to be based on a tailored approach. Their idiosyncrasy leads to complexity in the third phase of the process. Regardless of the temporal gap in the second phase, these difficulties persist whenever a contract needs to be drawn up with farmers.

On the other hand, the drafting of contracts with agro-industrialist companies follows a different rationale. Project developers have to deal with agro-industrialist companies that need immediate solutions to evacuate their biowaste. More specifically, they prefer proximity with anaerobic digestion units to reduce transport costs. Business developers must manage the short-term commitments of these actors, in contrast to farmers who engage for 10 to 15 years. This challenge is compounded by increased competition in the sector and considerable price volatility (discussed in more detail in section 2). For example, in the case of Caux Vallée de Seine, some agro-industrialist companies would not agree to contracts longer than three years, while others preferred to review contracts annually. The difficulty is therefore not in the act of contracting, as it is for farmers, but rather in the negotiation process to establish suitable contracts. In this case, the longer the temporal gap of the second phase, the more challenging it becomes to negotiate with agro-industrial companies, as they need immediate solutions for their biowaste.

1.2 The advent of digital platforms as mapping tools to connect providers and users of biological secondary resources

New instruments are being developed to address the challenges of securing secondary resources. Digital platforms have emerged as crucial tools in the process of securing secondary resources for anaerobic digestion projects. Our analysis revealed that these platforms are particularly useful during phase 1, where they assist actors in mapping potential sources of secondary resources, as platforms display possible sources of secondary resources. Indeed, upon analyzing our case studies, the Sibiom project mentioned the use of digital platforms during phase 1 to alleviate the challenges encountered when dealing with secondary resources in an unknown region. Indeed, Engie's expansion outside of France has benefited from the simplified identification of prospective opportunities and potential inputs in unfamiliar regions through the use of digital tools. Additionally, they play a significant role after phase 3, during the operational phase of the plant, by facilitating access to secondary resources, when there is an immediate or occasional purchase need due to a missing, incomplete, or non-compliant delivery by the original, contracted suppliers. The search for and identification of accessible resources must be constant, as they are both crucial for project development. They enable the stabilization of business proposals and help in the operationalization process, especially when unexpected scarcities arise due to uncertain input quality and quantity, together with increased competition in the sector (as highlighted in chapter 4). For instance, other cases, such as Caux Vallée de Seine, emphasized the use of digital platforms specifically for "spot purchases" during plant operation, after phase 3. These uses underscore the strategic engagement with digital platforms at the initial and operational stages of project development. However, these tools are not typically utilized during phases 2 and 3, as they do not contribute to maintaining relationships with suppliers, nor do they influence the negotiations and construction of contractual arrangements in phase 3.

The roles of digital tools and online platforms in assisting in the strategic mapping and identification of potential inputs have been discussed in the literature (Aggeri et al., 2023; Ciulli et al., 2020; Lewandowski, 2016). The literature has highlighted their roles in the context of technical resources (Blackburn et al., 2023; Radjou, 2021) and sometimes in the context of biological resources (Ciulli et al., 2020; Gontard et al., 2018). It is argued that these platforms are useful not only as virtual locations but also as connectors between secondary

resource producers and potential recipients, ultimately creating markets (Aggeri et al., 2023; Konietzko et al., 2019).

Thus, services and expertise offered by digital platforms, intermediaries, and biomass trading structures are significant assets in developing and structuring the anaerobic digestion sector. Organizations can access a burgeoning ‘spot market’ for secondary resources. Nevertheless, these platforms are still recent⁵⁵; the oldest has been available since 2015. Most of them enable negotiations between parties to fix prices or offer a price estimation service for secondary resource providers (based on factors presented in section 2). Others offer to draw up the procurement plan of secondary resources for anaerobic digestion plants. In France, in anticipation of possible economic and environmental obstacles, as well as increased competition in biomass-related activities due to the emergence of new platforms, the main marketplaces recently signed a charter of best practices⁵⁶ in 2022.

In conclusion, it is important to recognize that these digital platforms serve primarily as tools for mapping available secondary resources and connecting providers and potential customers rather than functioning as online marketplaces (Parker et al., 2016). Their recent emergence and inability to set prices further underscore the nascent nature of a secondary resources market for anaerobic digestion. While these platforms play a crucial role in facilitating resource identification and connection between producers and recipients, their evolving nature reflects a still emergent market for secondary resources.

⁵⁵ Examples of marketplaces: Margaron since 2015; Organix by Suez since 2017; Inex since 2017; Agricarbonne since 2018. D-carbone since 2018; ENIA since 2019; Valbenne by Total Energies since 2022

⁵⁶ The unification of these digital platforms to guarantee a stable organic resource supply for anaerobic digestion facilities, under the guidance of the New Energy Systems division of the industry's Strategic Committee, took place in March 2022.

2. Qualification of secondary resources, qualculative agencies and merchant attachments

In the context of anaerobic digestion and other sectors dependent on biological secondary resources, the nascent nature of the market creates significant challenges in determining resource prices. This uncertainty impacts the implementation of circular business models. Prices of biological secondary resources play a crucial role in the cost structure of biomethane business models, representing strategic assets essential for the viability of business models (Demil & Lecocq, 2010; Weppe et al., 2013).

The case studies analyzed illustrate the strategic and complex process of securing secondary resources for developing circular business models. The challenge is mirrored in the experiences of the organizations outlined in our case studies, where framing prices and negotiating resource trade exchanges occur on a case-by-case basis. When faced with such a challenging emerging market, organizations seek tools to *qualify* these resources. Our discussion highlights the work of *qualculative agencies* in relying on three key factors to qualify secondary resources. These factors play a crucial role in framing negotiations and agreeing on fair pricing rules.

Additionally, our analysis of the case studies highlights how project developers organize to create *merchant attachments*. They manage to create well-framed rules, exchanges and contracts, generating interactions with stakeholders who previously had no relationships. By instituting mechanisms for price framing and establishing adequate modalities of exchange, a value sharing between users and suppliers of secondary resources takes shape. Finally, our discussion emphasizes specific individual skills observed when negotiating and establishing the modalities of exchanges for secondary resources.

2.1 Qualification and Qualculative agencies: The reliance on parameters to define pricing rules

Upon analyzing the four case studies, we noted that actors developing anaerobic digestion projects face challenges in *qualifying* secondary resources. Feedstock quality can change significantly. Also, as depicted in Table 12 (chapter 4), feedstock prices vary considerably. In fact, several biomaterials injected into the plants were not subject to any commercial transactions or were subject to other transactions. Biological resources such as manure and straw were composted or left on the ground and had no economic value before the

establishment of anaerobic digestion projects. Others, like biowaste, were transformed through different pathways such as composting or incineration. With anaerobic digestion, these biological resources have acquired a new economic value (Table 12, chapter 4).

Confronted with challenging emerging market conditions, we can see in the four case studies how the developers rely on different parameters to surmount this challenge, qualify secondary resources and thus propose prices and argue their rationale. Indeed, actors in the biomethane sectors are striving to formalize contracts with secondary resource suppliers. The creation of mechanisms for defining secondary resource prices plays a central role. Indeed, developers of projects rely on tools to facilitate agreement on contracts and define their content, using estimates and measurable proxies. These proxies serve as a basis for arguing prices. Actors have developed expertise on establishing a contractual base by considering factors such as quality analysis, logistics and transportation costs.

2.1.1 Quality analysis: Methanogenic power and NPK content

The importance of knowledge in secondary resources, spanning chemical expertise, quality control, material analysis, composition, engineering excellence, and environmental engineering, has been extensively emphasized in the literature as fundamental for developing circular business models (Beulque, 2018; De los Rios & Charnley, 2017; De Arroyabe et al., 2021; Straub et al., 2023; De angelis et al. 2018). Our case studies further illustrate the importance of quality analysis and its impact on determining the purchasing prices of secondary resources. As shown in the case of Methamoly, a detailed analysis of secondary resources from an agro-industrial company revealed that the resources needed to go through a quality control process before they could be incorporated into the plant, thus impacting its purchasing price.

While most of the studies underscore the significance of material characterization from an operational product standpoint, our study offers insights into how characterizing secondary resources can help frame their purchasing price. Specifically, we emphasize that understanding the methanogenic potential of biological secondary resources not only helps identify their operational potential but also plays a crucial role in determining and agreeing upon a price. One key parameter utilized when framing resource prices is methanogenic power. In all cases, we note the involvement of specialist agronomic experts to conduct detailed sampling of provider inputs, enabling a comprehensive assessment of their biological characteristics.

The meticulous analysis of methanogenic characteristics is conducted by *Qualculative agencies* constituted by multiple actors such as independent agronomic laboratories (such as ENSAIA or INRA as illustrated in the Landres case), agronomic experts, engineers and researchers drawing up various reports and conducting studies. They provide business developers with valuable insights into the inherent energy potential of the resources, thereby informing pricing strategies and optimizing resource utilization. This method of analyzing the methanogenic power, pioneered by early actors in anaerobic digestion, is gradually becoming widespread. Even though closely correlated to the biogas sector, it demonstrates its potential for adoption in other sectors and industries seeking to define and agree on prices of biological secondary resources in emerging markets.

For specific resources like manure, alternative approaches to price construction involve evaluating the nitrogen (N), phosphorus (P), and potassium (K) content. Indeed, as mentioned in chapter 3, digestate obtained as a by-product can replace chemical fertilizers on farmland (Kanda et al., 2021). Chemical fertilizers⁵⁷, composed of N, P, and K, have fluctuating prices, leading to fluctuating estimation of the prices of N, P, and K in digestate. In the case studies on Landres, Caux Vallée de Seine and Methamoly, the use of digestate replaces the purchase of chemical fertilizers. Thus, digestate is exchanged for manure or slurry from farmers based on an equivalence in N, P, and K quantities. These metrics serve as a benchmark to ensure and agree on an equivalent return of digestate in terms of concentration content when bartering manure from the farmers for digestate from the plant, as exemplified in the cases of Caux Vallée de Seine or Methamoly. They also serve as price-setting rules, as seen in the case of Landres.

Finally, the current approach does not fully align with a comprehensive quality analysis; instead, it constitutes a considerably simplified approach, focusing narrowly on a limited set of identified parameters deemed significant. Primarily, the analysis prioritizes and selects few measurements, first taking into consideration NPK and methanogenic power as sources of value, and second identifying pollutants (e.g., presence of plastics, metals, etc.) as a source of costs. Consequently, the approach to quality assessment within these projects exhibits distinctive characteristics. A discernible disconnection persists between the quality assessments conducted by experts and the criteria ultimately retained within the contractual

⁵⁷ <https://www.indexbox.io/store/france-mixed-nitrogen-phosphorus-and-potassium-fertilizers-market-analysis-forecast-size-trends-and-insights/>

agreements and operational procedures. Nevertheless, this approach allows for the gradual establishment of standardized practices.

2.1.2 Transportation and logistics

The literature highlights the need to structure collection systems for circular business models (Beulque, 2019; Hopkinson et al., 2018; Straub et al., 2023). When analyzing our case studies, we specifically highlight that anaerobic digestion entities rely on a “capillary collection system” (Beulque, 2019) utilizing external local transportation services selected by experts (Kanda et al. 2021). A multitude of secondary resources are collected from diverse suppliers before being consolidated into more substantial volumes and processed at a storage platform operated at the biomethane entity level. If organic materials are stored in aerobic conditions—i.e., with oxygen—this can lead to biological degradation that reduces their methane-generating potential. Similarly, if environmental conditions such as temperature or humidity change, this can also affect the chemical composition of organic materials and thus their propensity to produce methane. Given the methanogenic power of biological secondary resources, the storage must be owned outright and adequately monitored.

Proposals on logistics and transportation of secondary resources are tailored to the needs of secondary resource suppliers. As depicted in the case of Caux de Vallée de Seine or Landres, organizations develop malleable logistical plan modalities, adapt their agreements, and propose different options that best suit the suppliers. Relying on local waste transport service providers to collect inputs appeared crucial. Acknowledging the absence of an extensive fleet of trucks, drivers, or equipment within the organizations, projects rely on local transport services to facilitate the efficient movement of materials and resources. For instance, in Caux Vallée de Seine, partnerships with local suppliers entail subcontracting to individuals or companies with a comprehensive understanding of local dynamics and logistics, thereby ensuring a more streamlined and cost-effective approach. However, the team faces the ongoing challenge of identifying partners offering competitive pricing and demonstrating genuine motivation to collaborate, in the face of increasing competition in the transportation of biological resources.

In a broader context, our case study analysis sheds light on challenges encountered by other circular business models relying on biological secondary resources. Specifically, we observe that the majority of resources in such models are dispersed in small quantities among numerous actors across the entire territory (Aggeri et al., 2023). Additionally, it is noteworthy

that companies developing circular models may face the obstacle of lacking an established collection system. Most importantly, the potency of these resources, particularly in terms of their methanogenic power, can vary depending on when the collection takes place and how they are stored. In summary, the spatial dispersion of biological resources and their dynamic methanogenic potential present significant hurdles for the development of biomethane projects.

These three parameters—NPK content, methanogenic power, and transportation logistics—represent a particular viewpoint, the perspective of the plant and project developers, the buyers of secondary resources.

In this context, there is no established market in the sense of buyers and sellers signaling their needs and offers, thus establishing a market price. Also, the uncertainties already stated in section 1, such as regulations and emergence of competing developments, constitute further challenges and add complexity for the emerging markets. Consequently, this situation leads to idiosyncratic stabilization of exchange modalities with each secondary resource provider. This unique dynamic underscores the complexity of circular economy implementation, highlighting the need for tailored strategies to effectively secure and purchase biological secondary resources and optimize the profitability of associated circular business models. Finally, this is a key task that we highlight, requiring dedicated assets and expertise for the project's planning and operationalization, to be further discussed in the following paragraphs.

2.2 Merchant attachments: Two types of contracts negotiated

Upon analyzing the case studies, we observe the gradual formalization of *attachments* that become stabilized for certain types (agricultural) and remain highly flexible for others (biowaste). It is worth noting that even within the same locality, the nature of exchanges may differ depending on the type of resources and actors involved. From the projects analyzed, we note two principal modalities and norms of exchange established around the anaerobic digestion entities: non-monetary and monetary exchanges.

2.2.1 Non-monetary exchanges

The first type involves non-monetary exchanges, such as bartering resources like manure, slurry, and straw. Due to farmers' reluctance to sign formal contracts, driven by

concerns about climate fluctuations, actors have reached a win-win agreement. This agreement ensures secured resources and the proper disposal of digestate, professionalizing exchanges in a barter system. This approach adds value for farmers, particularly considering the low methanogenic potential of their inputs and the need to secure digestate spreading for the plant. The contractualization with farmers focuses on creating fair, balanced, and stable agreements. This mechanism is particularly pertinent for farmers who are deeply rooted in their agricultural practices. Their engagement with the plant is not only a contractual exchange but a coherent and complementary extension of their existing agreements for the sale of other food products. Grounded in their agricultural pursuits, these farmers often navigate regulatory challenges—especially those related to manure—with a certain aversion to regulatory frameworks. They seek a harmonious balance between their traditional practices and the evolving regulatory landscape.

The negotiation and management of by-products such as digestate are critical aspects of anaerobic digestion models, mirroring the challenges encountered in securing secondary resources. Just as the acquisition of secondary resources poses challenges, negotiating with farmers for the uptake of by-products such as digestate is equally crucial yet challenging. This step, pivotal for the plant's success, is exemplified by the difficulties faced in evacuating and spreading digestate, as seen in the case of Sibiom. This highlights the interconnectedness of input and output management in circular projects and underscores the need for comprehensive strategies to address both aspects effectively. When examining the outputs of anaerobic digestion processes, we can classify them into two categories: industrial products like biomethane and CO₂, which typically have a stable and established market, and other by-products such as digestate, for which there is no pre-existing market. Unlike biomethane and CO₂, digestate lacks a structured market, presenting challenges similar to those encountered for the procurement of secondary resources. This dichotomy prompts critical questions regarding the management and valuation of by-products within circular economy frameworks, particularly concerning the development of efficient mechanisms for their uptake and utilization. Drawing from earlier discussions on the challenges of securing secondary resources and defining prices for them, it becomes evident that negotiating terms of exchange for by-products is a complex endeavor. Anaerobic digestion entities must navigate evolving market dynamics and tailor their strategies to effectively manage both inputs and outputs within the circular economy framework. While non-monetary exchanges are the most common to barter between manure and digestate, other configurations and strategies are

possible. This is exemplified in the case of Landres, where monetary exchanges occur to purchase manure from farmers and sell back digestate.

2.2.2 Monetary exchanges

The second type of exchange involves monetary transactions and typically concerns intermediate crops for energy recovery or dedicated crops, agro-industrial waste, and community biowaste. Intermediate and dedicated crops often have established prices⁵⁸ (for example wheat, corn, barley, rye, and oats). Monetary transactions are negotiated with farmers through long-term contracts. Other transactions, particularly concerning biowaste from the agro-industry sector, face instability and uncertainty due to evolving regulations and diverse utilization opportunities. Consequently, short-term contracts are common, reflecting the dynamic nature of exchanges. These contracts are adaptable to changing circumstances and regulations, allowing both parties to manage risks and seize emerging opportunities, as shown in the case study on Caux Vallée de Seine.

These secondary resources from agro-industrial companies demand contracts with renegotiation clauses for price adjustments and penalties for providers failing to meet agreed-upon quantity and quality standards, given their high methanogenic potential. Agro-industrial biowaste, which was previously a cost for industries in terms of disposal, can now be sold and thus holds monetary value. These actors seek short-term contracts with flexible prices based on demand and competition for their biowaste, both within and outside the sector (e.g., composting, incineration, animal feed). Short-term transactions with the highest bidders are favored over long-term contracts, prompting the proposal of price revision formulas considering factors such as inflation, material and labor costs, regulatory changes, and the geopolitical context, while also factoring in the methanogenic power of inputs.

By instituting mechanisms for price framing and establishing suitable modalities of exchange, value is shared between users and suppliers of secondary resources. We will further discuss value sharing in section 4.

In conclusion, our case studies reveal and shed light on how actors *qualify* secondary resources by relying on the work of *qualculative agencies* and how they develop *merchant*

⁵⁸ In France, the agricultural product producer price index (IPPAP) makes it possible to measure the evolution of prices received by farmers in return for the products they deliver.

attachments to define and agree on purchasing prices. It is evident that the pricing of secondary resources significantly impacts the overall profitability of circular business models (Linder and Williander, 2017). However, other uncertainties and parameters also influence the economic outcomes, including investment uncertainties, operational and capital expenditure, and regulatory factors.

One critical parameter affecting project economics is the local price of biomethane. Variations in biomethane purchasing mechanisms and prices can have a substantial impact. Depending on the country and its regulations, a plant may benefit from fixed feed-in tariffs or private purchase agreements, which greatly influence economic feasibility, as demonstrated in the Sibiom case compared with the French projects.

Schemes	France	Belgium
Production support mechanisms	National support through fixed feed-in tariffs over 15 years	Regional mechanisms; in Wallonia support takes the form of Green Certificates and guarantees of origin
Rules on inputs	Incentives to use specific agricultural residues Restriction on energy crops	Incentives to use specific agricultural residues There are no strict restrictions on the share of energy crops in the feedstock

Table 17 Biomethane production support, and rules on inputs in France and Belgium

The mechanisms in place where the plant is located affect the types of secondary resources used. Ultimately, the economic balance and profitability of the project remain paramount for business developers, influencing their negotiation strategies with suppliers of secondary resources. The negotiation and the different approaches leading to the construction of idiosyncratic agreements with each supplier as well as the pricing rules for secondary resources are critical actions that we have highlighted as essential for the successful implementation of circular business models. In the following paragraph, we highlight some skills developed by project developers to engage in these negotiations.

2.3 Skills related to price and contract negotiations

The market of secondary resources is an emerging and challenging one; actors strive to qualify secondary resources and engage in negotiations to find mutual ground for exchanges, as described in the cases. A lengthy pattern of meetings between project developers and providers of secondary resources occurs, sometimes spanning several months before all parties align. This negotiation process entails exploring various financial aspects, such as compensation or substitution arrangements for deposits, and offering adaptable logistical support and variable legal sanctions concerning the contract's violation. The objective is to establish a robust, binding agreement and secure the input providers' unwavering dedication to ensuring a continuous supply.

Persuasive and argumentative skills appear key to ensure effective communication of the benefits to suppliers—such as returning digestate to the land and avoiding having to comply with regulations on digestate management for farmers or, for agro-industrial companies, ensuring efficient treatment of biowaste in accordance with AGECE regulations. These benefits, presented by buyers of secondary resources, lead to the securing of favorable contracts and long-term stability of resource inputs.

Empathetic skills and acknowledgment of secondary resource contexts, specifically agricultural ones, appeared vital when considering the circumstances of farmer providers. As highlighted in the cases of Methamoly, Caux Vallée de Seine, and Landres, the buyers demonstrate empathy towards the climate and soil constraints faced by farmers that impact biological secondary resources. This empathetic approach underscores the importance of actively listening to and addressing the concerns and fears expressed by providers. Farmers exhibit genuine difficulty in adapting to new practices related to crop rotations and digestate spreading, often showing resistance to change. It is imperative to reassure them and provide comprehensive technical agronomic information to alleviate any apprehensions they may have. An agronomic technician played a crucial role in assisting farmers by holding multiple meetings as well as allocating time to individually advise farmers on their practices, following up on their yields, and strategizing to overcome challenges they may face on their land, as demonstrated in the case of Landres. Additionally, in the case of Methamoly, with Suez taking the lead, the agronomic expertise helped in developing modalities and evaluating the potential of biowaste.

Our research underscores the significance of competencies like legal negotiation or data analysis, showcasing their adaptability to changing contexts and their role in contributing to

securing secondary resources, coupled with specialized expertise in secondary resources such as agronomic expertise and the development of adequate capillary logistical arrangements as well as an ability to understand the agricultural context.

3. Territorial anchoring of local circular projects

Our analysis of anaerobic digestion projects builds on the proximity framework developed by Bahers et al. (2017) and portrays their manifestation at the national, regional, and local scales. At the regional and local scales, we discuss the significance of relational and politico-administrative proximities by identifying local public actors. More specifically, we examine their roles in facilitating circular projects acting as project initiators, network connectors, financial investors, plot providers, and administrative and technical assistants. Their involvement facilitates the development and implementation of circular initiatives. We analyze how a territory, through its regional and local public actors, can support the circular project and help anchor it.

3.1 The territorial proximities of anaerobic digestion plants

We will portray the various forms of proximity at different scales in order to provide insights into how actors navigate and leverage territorial dynamics to advance circular initiatives. Proximity at the national scale pertains to relationships and interactions between actors operating at the level of the entire country. Regional proximity focuses on connections and collaboration within a specific geographical region or administrative area. At the local scale, proximity involves interactions and interdependencies, often within a community or neighborhood. Our research extends the conceptual framework proposed by Bahers et al. (2017) by examining how proximities are manifested at different scales and how they influence the development and operation of anaerobic digestion entities.

- **National Scale Proximities**

At the national scale, politico-administrative proximity plays a pivotal role in shaping the regulatory landscape regarding secondary resources and in providing the necessary framework for the implementation of circular initiatives. In addition, national policies and regulations influence the viability and scalability of anaerobic digestion projects, emphasizing the importance of alignment between local and national objectives.

- **Regional Scale Proximities**

Upon analyzing these projects, we note that organized proximity at a regional level favors effective coordination, as illustrated by the implementation of Engie in specific regions where they aim to develop anaerobic digestion entities, contributing to the success of circular initiatives.

Furthermore, at the regional scale, our analysis reveals the significance of relational and politico-administrative proximities with public actors engaged in renewable energy or waste management initiatives. This proximity is crucial in shaping the regulatory environment and facilitating collaboration between stakeholders. Politico-administrative proximity can impact the development of circular initiatives beyond policy implementation.

- Local Scale Proximities

Zooming in to the local scale, we identify a multitude of proximities that underpin the anaerobic digestion entity settlement. Spatial proximity to secondary resources, such as agricultural resources and agro-industrial biowaste, enables efficient sourcing and minimizes transportation costs. Relational proximity with farmers and agro-industrial companies fosters collaboration, facilitating a steady supply of secondary resources for the anaerobic digestion process. Environmental proximity is crucial for optimizing transportation routes and minimizing the carbon footprint and the costs associated with biological secondary resource management. Additionally, socio-economic proximity underscores the interconnectedness between secondary resource management and local economic development, highlighting the potential of circular initiatives to stimulate economic growth and sustainability. Finally, politico-administrative proximity is also identified at this scale with public figures influencing and engaging closely with local communities.

In the following section we will further discuss the politico-administrative proximity at the regional and local scales. We will detail this proximity by focusing on public actors. Public actors can take on several roles that can help structure local circular projects. Their roles will be detailed in the following section.

3.2 Territorial public actors as facilitators of local circular business models

The investigated case studies involve numerous actors, including private companies, public organizations, project leaders, farmers, distributors, investors, local governments, and

associations, each with specific roles in implementing the circular model. However, it is important to note that successful implementation leverages the support of a specific type of actor. The projects studied have seen the significant involvement of regional and local public actors. This result is in line with studies investigating the role of public actors as facilitators of projects involving biological resources in particular (Gontard et al. 2018), projects in the circular economy in general (Cramer, 2020; Dagilienė et al., 2021; Girard and Nocca 2019; Christensen, 2021; Hansen and Schmitt, 2021), and local projects (Asselineau, 2023). In the four case studies, it became clear that public actors, spanning from the Regional Vice President or Community of Municipalities to regional development agencies or local financial structures, have played various types of roles. We will outline five roles identified based on these four case studies.

Role 1: Project initiator

In the Landres project, for instance, the President of EMC2—who also served as the Vice President of the Grand Est region responsible for energy—demonstrated significant influence in steering the cooperative towards anaerobic digestion initiatives, reflecting a strong commitment to the domain. Similarly, in the Methamoly project, we observe the active participation of various public entities—including the SIMOLY Community of Municipalities, and the Chamber of Agriculture—in initiating the study on the potential of anaerobic digestion in the region. In the context of Caux Vallée de Seine, entities such as Caux Seine Agglo, an agglomeration community in the departments of Seine-Maritime and the Normandy region, have also played a crucial role. Caux Seine Agglo launched the studies on the potential of anaerobic digestion. Finally, in the case of Sibiom, the IDETA territorial development agency, through its Energy and Sustainable Solutions Branch, sparked off the project by identifying the need to procure biogas for its industrial park. Thus, these public actors participated in launching these projects.

Role 2: Network connector

Also, one of the important strengths of the Community of Municipalities or municipal agglomeration community is their local networks, which include farmers, industries, agro-industrial companies, and local transportation. The anaerobic digestion project requires this local network to establish itself. These public facilitators entertain influential, trust-based relationships with this local network. They benefit from credibility and legitimacy among this

local network. This connector role is exemplified by the successful implementation of projects such as Methamoly and Caux Vallée de Seine, where SIMOLY and Caux Seine Agglo played a key role in connecting project developers with the local communities. Furthermore, as demonstrated by the Sibiom case in Wallonia, Engie was able to engage in the project due to its positive relationship with IDETA through a previous renewable project. This role of network connector can support project developers engaging with secondary resource providers, including farmers, industries, and waste management facilities, to secure the needed inputs.

It is worth noting that the strong ties between public facilitators and the local network of actors stem from their focus on territorial development and renewable energy policies. It is evident that the regions where the case studies were developed are committed to ecological and energy transition. The SIMOLY Community of Municipalities, Caux Seine Agglo, and IDETA are all engaged in various energy transition programs and initiatives. For instance, Caux Seine Agglo is associated with the *Association Ecologie Industrielle Estuaire*. Furthermore, Caux Seine Développement, its economic development agency, was even rewarded for its ecological engagement by winning a “Cit'ergie®” award for its energy and climate policy in the industrial area where the plant is located. IDETA has established ambitious goals for energy transition in Leuze-en-Hainaut. SIMOLY also showcases its involvement in ecological transition by partaking in the TEPOS initiative. Furthermore, these public actors cultivate trust and influential relationships with local communities, including farmers, industries, and transportation networks, to ensure social acceptance of circular projects. They leverage their credibility and legitimacy in the network to foster positive attitudes towards project implementation and enhance social acceptance.

Role 3: Financial investor

Different public actors contribute financially to the development of these initiatives. The ADEME played a role in both Methamoly and Caux Vallée de Seine by providing subsidies in the initial phases of the projects' development. Additionally, SEM Soleil and OSER exemplify the significance of public structures funding and driving forward public-private initiatives like Methamoly, with investments in its capital. IDETA also contributed to financial investment efforts by taking shares in the capital of Sibiom in the early stage of project development.

Role 4: Plot provider

The case studies also highlight the direct involvement of local public entities in the project development process. Collaboration with local actors, particularly in providing suitable tangible assets, have been identified. One of the roles identified from the case studies is the provision of a plot of land necessary for project development. This is illustrated by the Sibiom project, where the plot available in the industrial park was enhanced through the involvement of IDETA, the managing entity. IDETA contributed to land provision for the plant's implementation, reflecting its broader mission of serving the interests of its associated communities, businesses, and citizens in Wallonia. Similarly, the plot designated for Methamoly is associated with the SIMOLY Community of Municipalities. The company's interaction with local actors grants access to specific plots that may have otherwise been inaccessible. SIMOLY ultimately sold the land to ensure the project's actual implementation in the region. Also, the Ecological Transition public service Eco Parc contributed by overseeing the expansion of the gas network at the time to facilitate the site's connection. Caux Seine Agglo also contributed by selling its land, showcasing a collaborative approach to economic development.

Importantly, as seen in all projects, the identification of the site where the plant is to operate is a strategic decision by developers. The location of the plants in the case studies are diverse: the plant may be located in an industrial area, such as Caux de Vallée in the Port-Jérôme industrial port area or Sibiom in the Leuze-en-Hainaut industrial park, or they may be implemented in areas designated for business activities, as seen in the case of Methamoly. Ultimately, the plant location is determined by the nature of the biological secondary resources and the valorization output chosen. As noted by Aggeri et al. (2023), certain circular business models may be better suited for local markets, while others may require a globalized approach. Specifically, the scale of circular economy operations can vary depending on the nature of the secondary resources involved. Agricultural, agro-industrial, and community secondary resources may benefit from local valorization due to factors such as transportation costs, storage limitations, and the preservation of methanogenic characteristics. Therefore, it is important to consider developing locally embedded circular business models to address these common challenges and effectively leverage the potential of secondary resources. The different teams developing the projects demonstrated a careful and thoughtful approach (with some, for instance, using diverse geographic tools) to assess three crucial criteria that ensure the suitable location of the plant in the identified region.

The first criterion is access to injection networks specifically for biomethane entities. Reliable access is necessary for the injection and distribution of biomethane through an adequate infrastructure within a given territory. We notice in the case of Methamoly, “the adaptative characteristic of the territory” and the expansion of the gas network by GRDF to fulfill these criteria. The second criterion is the availability of inputs within a limited radius, typically 15-20 km. Proximity to providers of inputs not only minimizes transportation costs and ensures a steady supply, influencing the economic viability of the project, but also reduces the overall carbon footprint of the plant. Accordingly, the logistics available on the territory for transport and deposit delivery must be taken into consideration. Indeed, the selection of a plot has a considerable impact on the subsequent securing phases. For example, the decision to locate the Sibiom project in that specific industrial area bestowed a competitive advantage for securing the biowaste of Lutosa. The proximity of the expected plant resulted in more favorable pricing. Similarly, the location of Methamoly or Landres near farmland was an argument to convince farmers who granted access to their resources for anaerobic digestion. The third criterion is the availability of sufficient spreading surfaces for digestate. In the case of Sibiom, we observed challenges arising due to an underestimation of the surface area needed for spreading, and the assumption that it would be easy to find suitable outlets. Finally, the plot should be outside an environmentally protected zone and far enough from citizens to avoid disturbances. As illustrated by Caux Vallée de Seine, social acceptance was not an issue because it was located in an industrial park.

Role 5: Administrative and technical assistant

Public entities such as regional development agencies assist in navigating administrative procedures, obtaining permits, and coordinating regulatory compliance to facilitate the smooth implementation of circular projects. This is exemplified in the case of Caux Vallée de Seine, where Caux Seine Agglo offered administrative guidance, or in the case of Sibiom where IDETA’s technical expertise has contributed to the project’s development.

Table 18 summarizes the five roles public actors assume to facilitate circular economy projects.

Roles	Description
Project initiator	Public actors such as regional development agencies, the Community of Municipalities or of agglomerations, and community leaders play a

	crucial role in initiating projects by identifying the need for circular initiatives by conducting assessment studies on the region's potential and the availability of secondary resources. They are committed to promoting ecological and energy transition policies, driving the development of circular projects aligned with renewable energy goals and sustainability objectives.
Network connector	Facilitators such as the regional development agencies as well as the Community of Municipalities or of agglomerations cultivate trust and influential relationships with local networks to foster positive attitudes towards project implementation. They help connect project developers up to local actors such as farmers, industries, and waste management facilities, to secure the inputs necessary for circular processes and value chains.
Financial investor	Entities like regional development agencies, public-private funds, and government organizations contribute to the financial development of circular initiatives, providing crucial capital or subsidies for project implementation.
Plot provider	Local public entities, such as the Community of Municipalities and regional development agencies, play a vital role in providing suitable tangible assets, including plots of land, needed for project development and implementation.
Administrative and technical assistant	Public entities such as regional development agencies assist in navigating administrative procedures and offer technical guidance in project development.

Table 18 Roles of local public actors as CE facilitators

Furthermore, these case studies highlight the evolutive and dynamic role of territorial public actors during circular project implementation, specifically during the three-phase process that has been identified. The role of these facilitators during the project development process is highlighted by defining their role in the three phases of securing resources in the Figure 25 below.

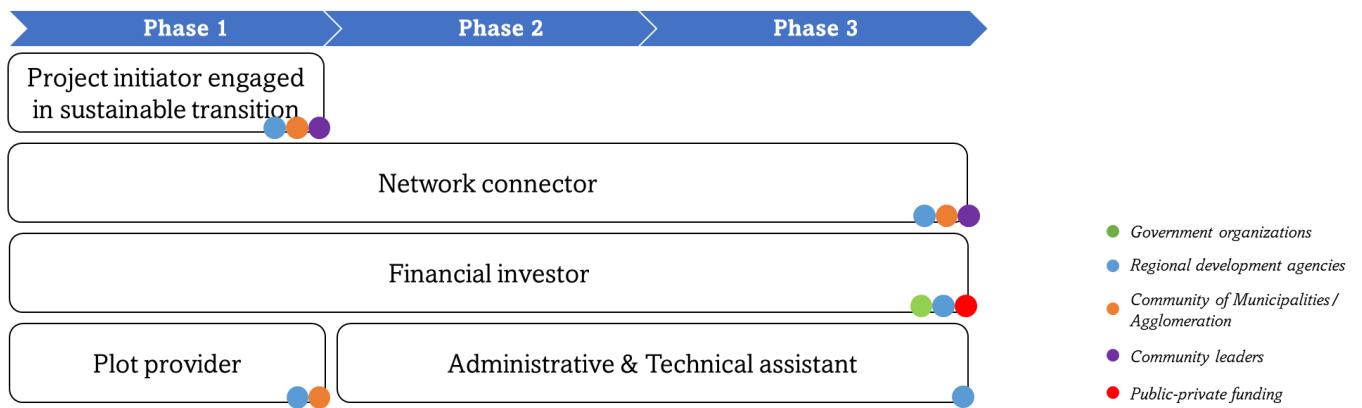


Figure 25 Overview of the roles fulfilled by public facilitators in implementing circular anaerobic digestion projects at the local level

To conclude, in the context of circular projects like anaerobic digestion, which necessitate the utilization of highly localized secondary resources, as opposed to other circular projects relying on secondary resources that may not be inherently local, it can be advantageous to leverage regional and local public actors to access the network. We highlight the specific need of organizations to identify strategic public actors such as the Community of Municipalities or regional development agencies and leverage their roles during the project's development. First, they can facilitate progress through their relational ties and networking with local actors based on trust and legitimacy. These roles, detailed in the previous section, include initiating projects, connecting the network of local actors and federating them as well as connecting providers of secondary resources. Second, they can propose to facilitate the development of circular projects through technical and administrative assistance, financial aid and finally the provision of land or assets.

With our case studies we shed light on another aspect of territorial anchoring as defined by Bousquet (2014). Indeed, the question could be expanded, not being limited to how is the circular project locally embedded and territorially anchored over a long period of time?, but also how does the local area support the circular project and help to structure it? Several territorial anchoring approaches have been discussed in the literature, with authors highlighting collaboration as conducive to this process (Ayrault, 2022; Fiore and Hernandez, 2023;), or active engagement with local stakeholders (Loup and Leyronas, 2021). In line with these studies, we argue that territorial anchoring takes place through the development of tailored relationships with regional and local public actors as a first anchoring point. Moving from a firm-centered perspective to a network logic, fostering collaborative relationships with local actors can facilitate the successful implementation of circular models. At the regional

level, the firm uses macro-relationship mapping skills to establish links within the territory. This initial engagement at the regional level leads to an understanding of the socio-geographic landscape of the area in which the company intends to operate the anaerobic digestion plant. From a social perspective, the first step in establishing a connection with the territory is to identify key local public stakeholders. Understanding their commitment and involvement in waste management, energy policy, and agricultural plans may facilitate the implementation of anaerobic digestion projects in the region.

However, it is worth mentioning that while public actors played crucial roles in facilitating various aspects of the circular projects we investigated, additional factors and processes such as contractualization (as outlined in the preceding section 2) are essential for a project's success. Serving as facilitators in networking for circular projects or in administrative processes does not guarantee the successful conclusion of the contractualization process outlined in the preceding section, which is a characteristic of phase 3.

4. Collaborative governance of local circular projects

In our investigation of these anaerobic digestion projects, we have unveiled distinctive types of governance structures. Our results are in line with Schultz et al. (2023) and Arfaoui et al. (2022), as we argue that different governance arrangements are conducive to the circular economy. These governance models offer valuable insights into the intricate dynamics shaping the initiatives of various stakeholders and their collaboration in the development and operation of anaerobic digestion projects. Our findings emphasize that a detailed understanding of collaborative governance and its impact on securing secondary resources is essential. Two types of governance are identified, each one involving different relationships with providers of secondary resources, and each one having its own advantages and disadvantages. The core of our findings underscores pivotal aspects of governance crucial for a successful implementation of projects in the anaerobic digestion domain. While Provan and Kenis (2007) underline three tensions in governance arrangements—ensuring efficiency in decision-making while ensuring all participants have a voice, maintaining stability while being adaptable to changes, and keeping legitimacy among the participants and the external environment—we highlight an additional type of tension specific to circular models: the tension between facilitating decision-making in governance arrangements and having shares in the capital of a structure on the one hand, and on the other hand ensuring a supply of secondary resources for the models. Indeed, we distinguish the different forms of governance arrangements in controlling resources and securing their adequate quantity and quality for the project to ensure its long-term economic viability.

4.1 Models of network governance

We discerned the existence of two governance models. On the one hand, there is a firm-centric model, exemplified by Caux Vallée de Seine, which involves private companies or organizations taking the initiative to launch a project on their own and laying down their own rules, without any suppliers of secondary resources participating in the plant's capital. On the other hand, there is a model where suppliers are involved, as exemplified by the Landres, Methamoly, and Sibiom projects: here, suppliers of secondary resources have shares in the plant's capital alongside the organization initiating the project. Three different configurations are possible.

4.1.1 The firm-centric model

The firm-centric model predominantly concentrates on optimizing daily business operations and engaging suppliers of secondary resources through effective, persuasive, and continuous stakeholder management (Schultz et al 2023). Within this framework, our analysis portrays how relations and rules are predominantly framed by one actor, notably observed in the initiation and management of a project such as Caux Vallée de Seine. These projects exemplify the centrality of actors, like Engie Bioz taking the lead in launching and overseeing anaerobic digestion initiatives. In this type of governance, the relationships and rules are mainly framed with reference to the intention of the actors initiating the project. Engie BioZ, acting as the project leader, brings technical expertise for the anaerobic digestion unit and access to the gas network. In this model, the involvement of suppliers of secondary resources, be they farmers or agro-industrial companies, is channeled through individually tailored contracts or barter. The absence of farmers or agro-industrial companies in the structure's capital underscores the company's intent to maintain control over both operational and strategic aspects of the project. The project manager's reliance on a well-known and popular farmer in the area proved to be crucial in getting others on board the project. The reliance on local federators known by the farmers, such as the CUMA, acts as a crucial link between farmers and Engie BioZ. While this firm-centric governance model places the financial risks and strategic decisions squarely on Engie, it aims to alleviate farmers of the operational and strategic burdens often associated with such projects. It nevertheless shows the fragility of the model with regards to securing secondary resources. The case highlights the challenges that project developers had to overcome while engaging suppliers of secondary resources and proposing modalities of exchange to farmers or agro-industrial companies.

4.1.2 The supplier-involved model

The supplier-involved governance model, a form of shared governance (Bridoux and Stoelhorst, 2022), is illustrated by the Landres, Methamoly, and Sibiom projects. In this type of governance, we observe novel collaborations that aim to secure secondary resources. Three configurations are possible, corresponding to diverse types of suppliers in the governance of the structure.

First comes the configuration where only suppliers of agricultural secondary resources are included, as is the case of the Landres project. While EMC2 took the lead in launching and overseeing the anaerobic digestion initiative, in this type of governance, the shareholders in

the plant primarily consist of farmers responsible for supplying the unit predominantly through long-term contracts. The farmers participating in the project are grouped under a separate administrative structure, have social shares in the anaerobic digestion plant, and receive financial incentives in the event of high profits. The relationships and rules are mainly framed by the intention of the project development team at EMC2, which initiated the project. While the team takes the lead in initiating and executing the anaerobic digestion venture, having the farmers involved in the capital alleviates the cooperative from the burden of worrying about secondary resources and operational failures, as they are invested and driven to make the plant succeed.

Second, the Sibiom project introduces a governance model characterized by the involvement of an industrial partner supplying biowaste resources to the plant. While Engie and IDETA are seen to take on the roles of project leaders, providing technical expertise for the anaerobic digestion unit and access to the gas network, an interesting aspect of this model involves the partnership of a waste collector/aggregator, namely Dufour. Dufour not only has a share of the capital in order to be involved in strategic decisions and for financial purposes, but most importantly to secure biowaste for the project. Collaboration in this project extends to another agro-industrial company through biomethane purchase agreements, highlighting a novel approach to secondary resource acquisition and utilization. This governance model facilitates the secure flow of input resources by contracting with an agro-industrial customer to decarbonize its activities, either by managing its food waste and converting it into biomethane or by involving it in the capital structure. However, farmers are not involved in the project in any of these ways, leading to digestate valorization issues.

The third governance arrangement identified is one that involves both agricultural suppliers and biowaste suppliers in the capital simultaneously, as illustrated by Methamoly, which emphasizes the importance of aligning different suppliers. The Methamoly project stands out for its involvement of suppliers providing multiple secondary resource inputs. On the one hand, farmers are represented in a separate administrative structure, giving them a collective voice in strategic decisions, and have long-term contracts. It is worth noting that the farmers supplying Methamoly were informed about the project and agreed to get on board via a separate structure before the final contracts were actually agreed upon. Their organization in a separate structure was seen as a means of mitigating uncertainty and fostering a cooperative spirit to ensure the project's success, which was maintained at a high level by their leader. This involvement added value to the project due to the constant communication with farmers assured by Eloi. He was responsible for providing updates on the progress of the project or

reasons for its stagnation, which helped maintain their involvement. On the other hand, the involvement of Suez, a waste company, in the capital secured access to a biowaste flow. Nevertheless, due to the multitude of actors engaged in the capital, efforts had to be made to ensure effective communication and decision-making, as reaching informed decisions took a long time.

Through our analysis of these case studies, we emphasize the significance of including local resource suppliers in governance structures. This aspect has received relatively little attention in the literature, with few discussions focusing on how to develop shared ownership and integrate suppliers into procurement planning (Cerca et al., 2022). While many authors emphasize collaborative approaches, their discussions often focus only on building strong relationships with suppliers (Hopkinson, 2018), establishing local collection systems (Beulque, 2018), and utilizing technologies such as the Internet of Things for resource mapping (Cerca et al., 2022; Gontard et al., 2018; Iakovou et al., 2010).

The involvement of suppliers is surely not the only factor ensuring success. As illustrated by the case studies, the participation of an energy company provides the technical expertise, the involvement of agricultural actors ensures support on the agronomic side, and the involvement of a waste manager offers expertise in navigating the complex landscape of biowaste. The four projects show that each actor brings different expertise to the project. Actors in the governance arrangements vary depending on the case. There is no specific number that is likely to be correct (Provan and Kenis, 2007). While authors in the circular economy stress the inclusion of all relevant stakeholders to make sure local circular business models are successful (Schultz et al. 2023; Arfaoui et al. 2022), we emphasize that the specific involvement of suppliers in the governance structure is crucial. The involvement of one type of supplier can entail the enrollment of others, thus granting access to additional secondary resources. Comparing Methamoly with Sibiom, the inclusion of farmers in the governance structure led to the proposal of a novel solution for digestate storage. In contrast, in Sibiom, actors encountered significant issues for valorizing digestate. We also argue that local public actors can participate in the governance structure, as is the case for both Methamoly and Sibiom, where they have shares in the structure's capital and participate in strategic decision-making. However, they can also act as facilitators without taking part in the structure's governance, yet still help advance the project, as illustrated by the other cases. Their roles have been detailed in section 3.2.

4.2 Attributes of collaborative governance

We observed that projects are initiated based on mutual trust and confidence that the anaerobic digestion entity will materialize. They align around a shared purpose and vision for the project (Brown et al. 2021) constructed at the level of the territory, focusing on its engagement in terms of local energy transition or waste management. The developers place trust in the promises made by local suppliers, while suppliers trust that an anaerobic digestion entity will be a viable solution for their secondary resource management or green energy procurement. However, trust is not necessarily present initially, as actors are from diverse sectors and have no previous relationships. In all cases, we only noted mutual agreement on a shared objective about the plant. This result contrasts with Assens and Coléno (2023), who argue that the success of shared governance stems from cultural proximity and pre-existing trust between the actors.

The interdependence between the plant and suppliers forms a strong bond, though the stakes are higher for developers when they are alone in the governance arrangement, as seen in the Caux Vallée de Seine project, and unlike the Landres, Methamoly or Sibiom projects where other suppliers are involved in the structure's capital. Indeed, the first mode requires higher argumentation and competitive pricing strategies to tackle the complex reticence of secondary resource suppliers to commit themselves, and thus ensure the project's success. In the other three case studies, including suppliers in the governance structure can facilitate the process of securing secondary resources. However, inclusion does not guarantee a secure access to these resources, as illustrated in the case of Sibiom with Dufour.

Also, we noticed that the governance structures of these projects are adaptative and open. As shown in the case studies of Methamoly and Sibiom, new local actors joined the structure during its development or even while operating. Governance structures may undergo changes along the way due to the project's duration, with some actors joining (e.g., Engie and Suez joining Methamoly, or first Dufour then Ceneo joining Sibiom). While Arfaoui et al. (2022) stress the importance of avoiding changes in actors, we argue that given the lengthy nature of projects and increasing regulatory changes, especially in the biowaste sector, incorporating such changes proved to be positive. This result is in line with Girard and Nocca (2019), who argued in favor of the adaptative characteristics of governance in the structure's economy, highlighting its ability to embrace dynamic change. We observed that the profiles of actors in the governance structure can influence the strategies and even the mix of secondary resources. For example, after a change in the governance structure, the composition of secondary

resources at Sibiom evolved to include biowaste, thus aligning with the core business of both Dufour and Suez. This demonstrates an ability to adapt to innovation and collaborate effectively.

To conclude, while governance models in anaerobic digestion projects vary, we can highlight the key specificities of a collaborative governance model that assures secure provision of resources. Firstly, such models entail forging strategic partnerships (as detailed in section 2) with suppliers of secondary resources, such as agricultural waste and biowaste, to ensure a reliable and consistent flow of feedstock orchestrated by a leading figure in the governance. These partnerships are underpinned by long-term contracts, providing stability and certainty to both parties involved, thus fostering an environment that is conducive to sustained collaboration. It is also worth noting that in many cases, participating in the governance of anaerobic digestion plants precedes the finalization of contracts, as evidenced in section 1. Moreover, the diversification of sourcing channels constitutes a fundamental aspect, mitigating reliance on any single supplier or type of resource and enhancing resilience to supply chain disruptions. Additionally, effective coordination across the entire resource supply chain is imperative, encompassing activities from collection and transportation to processing and delivery, thereby optimizing efficiency and accountability. Furthermore, incentivizing resource providers is integral to encouraging active participation and commitment to the project's success, whether through financial incentives or technical support. Constant communication and collaboration among project developers and providers of secondary resources, including regular meetings and feedback mechanisms, serve to address any emerging issues or concerns promptly. Together, these characteristics portray a robust collaborative governance framework tailored to ensure the secure and sustainable procurement of secondary resources for anaerobic digestion projects. Lastly, we align with Trevisan (2022), arguing that governance supports the sharing of value between actors. More specifically, we affirm that the sharing of value is not predetermined before projects are kicked off. Based on our analysis, we observe that value sharing occurs progressively through governance structuring and during the definition of modalities of exchanges and contracts with suppliers as highlighted in section 2.2

4.3 From Suppliers to partners: The Role of secondary resource providers in collaborative governance

The governance models previously presented facilitate the success of circular projects, but they do not ensure their completion. It has been observed that in the cases studied, there are quite different governance models, yet the plants are operating successfully. However, questioning governance arrangements in circular projects has shed light on the fact that in the circular economy, governance takes on another dimension. Conventionally, involving actors in governance serves to access capital, access profits for shareholders, and access company accounts to verify the distribution of value according to the rules. Analyzing these local circular projects reveals that shareholders play a role that is not merely overseeing the company's finances from afar. These supplier-involved models of governance challenge the conventional view that governance is separate from customers and suppliers (Bridoux & Stoelhorst, 2022; Raab & Kenis, 2009). In circular projects, given the nature of inputs and the nascent nature of the market, involving suppliers in the structure's capital can lead to the establishment of rules for drafting contracts and making adjustments in the event of stock shortages, thus leading to a secure input flow of secondary resources for the projects.

Indeed, it is intriguing to note that involving farmers in governance, as in Methamoly, facilitates the finding of solutions to valorize inputs and agree on prices. Similarly, involving the agro-industrial company Dufour in the governance of Sibiom stimulates and empowers them to find alternative input sources. In cases like Methamoly and Landres, where farmers participate in governance through separate administrative structures, this approach facilitates the establishment of long-term contracts and the implementation of exchange rules. It also ensures a distribution of financial gains for farmers. However, the simplicity and expediency of decision-making processes in cases like Landres may impede the incorporation of additional inputs, such as biowaste. Conversely, the involvement of multiple stakeholders—including farmers and the waste industry—in Methamoly enables the negotiation of tailored contracts for each farmer and stabilizes inputs from both agricultural and biowaste sectors. This multiplicity of actors, while enhancing inclusivity, may lengthen decision-making processes compared with more centralized approaches like EMC2. Contrasting examples such as Caux Vallée de Seine and Sibiom demonstrate that the involvement of suppliers in governance is not universally essential in circular projects. For instance, Sibiom's collaboration with Lutosa does not entail supplier participation in governance, yet ensures the stability of exchange agreements. Similarly, in Caux Vallée de Seine, agro-industrial entities are not formally included in governance structures. However, the project development team struggled initially to establish agreements on contractual arrangements.

Therefore, these cases reveal an additional facet of governance that extends beyond mere participation in the structure's capital in order to oversee its financial matters and participate in governance decisions (Bridoux and Stoelhorst, 2022). Indeed, it ensures a fair distribution of financial gains. Having suppliers of secondary resources in the governance structure is ultimately a way of ensuring a fair distribution of value between the input suppliers, particularly farmers, and the anaerobic digestion unit. What is more, the case studies reveal the roles of suppliers in governance arrangements, particularly in negotiating exchanges and facilitating innovative contracts to secure secondary resources. Consequently, scholarly investigation into governance sheds light on how involving particular suppliers in the governance mechanisms of CE projects serves as a driving force, streamlining operations and enhancing the efficacy of circular initiatives.

Chapter 7. Contributions, limitations, and future avenues of research

“To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.” – Albert Einstein

In this chapter we provide a summary of the results (1), before reviewing the various theoretical, methodological, and empirical contributions of this thesis (2) and concluding with a discussion on the limitations and future avenues of research (3).

1. Summary of results

This section summarizes the main findings of this research, which aimed to theorize the processes through which actors secure biological secondary resources within the context of circular business models. Indeed, our main research question was: *How does governance, territorial proximities and premarket conditions support the process of establishing circular economy projects and securing secondary resources?*

One crucial finding entails characterizing "secondary resources" and understanding their unique attributes. Another key outcome is the identification of a significant challenge for the implementation of these business models: the management of secondary resources, which critically influences their economic and operational viability. By exploring this issue through the lens of the case of anaerobic digestion, considered representative of such challenges, the study sheds light on the influence of regulations and public actors, elucidating their instrumental role in structuring circular activities and fostering their development. Furthermore, the thesis offers a processual description of projects from their inception, unveiling the diverse array of stakeholders involved and the evolutionary trajectories witnessed in each case. It outlines a comprehensive three-stage process for securing resources. The research unveils the presence of distinct governance attributes for collaboration with suppliers of secondary resources. Additionally, the thesis details relational proximities at a

micro scale by identifying the roles played by local public facilitators in the implementation of circular projects. It also elucidates the various strategies and instruments employed to address the challenges of a market for secondary biological resources. Figure 26 presents the three main pillars conducive to circular projects.

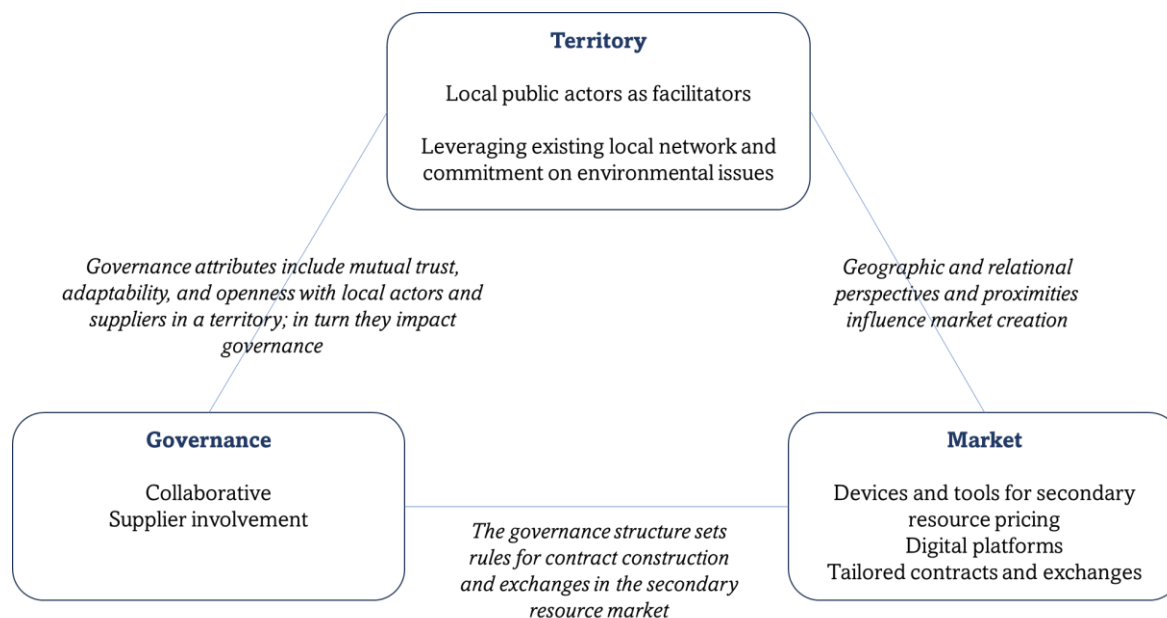


Figure 26 Three main pillars conducive to effective circular project implementation

By doing so we could answer our three main sub-questions.

1. How can forms of governance and their specific characteristics contribute to securing secondary resources in CE projects?

In examining the mechanisms and structures facilitating coordination within circular projects, a distinction arises between governance models involving secondary resource control, and strategic partnerships specifically with suppliers of secondary resources. Two primary governance models emerge: the firm-centric model and the supplier-involvement model, each with its own advantages and disadvantages. The former entails private companies taking the lead in project initiation and management without direct supplier involvement in the capital structure. Conversely, the supplier-involvement model involves resource suppliers acquiring shares in the project's capital, leading to various configurations based on the types of suppliers involved. By involving resource providers in the governance structure, circular projects challenge conventional views and establish new rules for contract construction, innovative exchanges and allow for the gradual construction of a value-sharing mechanism. This

highlights the significance of including local resource suppliers in governance structures, emphasizing the importance of strategic partnerships, diversification of resource sourcing channels, effective coordination across the supply chain, and constant communication and collaboration. Furthermore, we highlight attributes of collaborative governance structures, such as a collective shared vision of the objective of a circular project based on the territory's engagement in terms of ecological transition, and mutual trust between suppliers and the plant developers that is gradually constructed through lengthy negotiations, discussions and meetings. These models are also characterized by trust between developers and suppliers—built up throughout the project—adaptability, and openness, with governance structures evolving to incorporate new local actors and suppliers.

2. To what extent and how do circular economy projects leverage territorial proximities in order to secure secondary resources?

In examining the geographic and relational proximity-related factors of the territory, we have been able to reveal how actors engaging in circular activities can leverage these proximities to anchor their initiatives in the territory. Specifically, at the micro local level, we argue that leveraging relational and politico-administrative proximities allows actors in the circular economy to access specific local public actors to help them develop and implement projects. Indeed, these local public actors play five crucial roles in facilitating local circular projects. They can act as project initiators, network connectors, financial investors, plot providers or administrative and technical assistants. This highlights the importance of understanding the territorial context in which circular activities will develop and emphasizes the need for actors to build strong relationships with local public structures when developing local circular projects. Furthermore, we emphasize that these local public actors can fulfill their roles regardless of their inclusion in project governance.

3. In premarket conditions for secondary resources, what are the processes of market arrangements enabling agreements to be reached?

Challenges arise in securing secondary resources due to the emerging nature of markets, impacting circular business model viability. Upon examination, we were able to observe how *qualculative agencies* organized the framing of prices by relying on tailored tools and instruments to *qualify* secondary resource value. They rely on tools and proxies with key parameters like methanogenic power and NPK content to drive price discussions. Quality

analysis, involving methanogenic potential and chemical composition, informs pricing strategies. Agronomic experts play a critical role in assessing inputs, ensuring comprehensive biological evaluations that support fair pricing. Other parameters include the consideration of local capillary transportation in framing the exchanges with suppliers. Overall, these factors underscore the complexity of the emerging market of secondary biological resources and highlight the importance of tailored strategies to create *merchant attachments* to secure them. We detail the idiosyncratic modalities of exchange developed by actors, which encompass both non-monetary exchanges, such as bartering, and monetary exchanges through short-term and long-term contracts. Negotiation and empathy skills were crucial in securing fair agreements, allowing the gradual construction of value sharing with suppliers of secondary resources.

Description of results	Corresponding chapters	Corresponding discussion parts
Demonstration of the complexity of implementing the circular economy. Demonstration of the economic and operational challenges generated by secondary resources	Chapter 1: Introduction	1.1, 2.1 and 2.2
The role of public policies and public bodies, and their roles in structuring circular activities	Chapter 4: Anaerobic digestion in France: Regulations, processes, and stakeholders	3.1
The processual description of the 4 projects from their inception, with different players and developments in each case	Chapter 5.2: Developing circular anaerobic digestion models in practice	1.1
The 3-stage process of securing resources		1.1
Characterization of territorial governance modes and involvement in securing secondary resources The two modes of governance with attributes for collaboration		4

Qualification of the geographic and social proximities of a territory that facilitate circular project development		3.1
The roles of local and regional public facilitators involved in implementing circular projects		3.2
The different strategies and instruments used in an emerging market for secondary biological resources		1.2, 2.1, 2.2 and 2.3

Table 19 Summary of main results

2. Contributions

“It is my earnest desire that some of you should carry on this scientific work and keep for your ambition the determination to make a permanent contribution to science.” — Marie Curie

From the main results of the thesis, which have just been presented, various contributions emerge. These are theoretical (2.1), methodological (2.2), and managerial (2.3).

2.1 Theoretical Contributions

This doctoral work contributes primarily to the literature on the circular economy by shedding light on the intricacies involved in the development of circular activities (de Jesus & Mendonça, 2018; Guldmann, 2020; Kirchherr et al., 2018; Oghazi & Mostaghel, 2018). The process of establishing circular economy initiatives parallels an innovation process, characterized by iterative cycles and uncertainties (Linder & Williander, 2015). Our objective was to elucidate how actors navigate these complexities to establish and operationalize circular business models. Drawing upon the extensive emergent literature on the circular economy, we have identified a less-discussed process: the securing of secondary resources, particularly biological secondary resources. This process significantly impacts the economic viability and operational feasibility of circular business models. Through our analysis, we elucidate the challenges associated with accessing and securing biological secondary resources, including issues of availability, reliability, and quality. By highlighting the importance and key issues of securing secondary resources, especially in the context of biological resources, we have helped fill a gap in the existing literature. Thus, our theoretical framework addresses the limited understanding of the mechanisms and strategies involved in setting up circular economy initiatives, particularly in relation to securing resources. Consequently, our focus was directed towards theorizing the processes through which actors become organized to secure biological secondary resources within the context of circular business models. This theorization is deemed necessary to navigate the literature landscape, which often lacks comprehensive discussions on the establishment of circular business models

(Mentink, 2014; Geissdoerfer et al. 2017). Our theoretical contribution encompasses the portrayal of a three-phase process involved in establishing circular business models. This process involves the macro identification of resource availability, administrative and technical aspects, and finally the negotiation of resource access. By conceptualizing this process, we provide a structured framework for understanding the complexities inherent to the implementation of secondary resource securing strategies.

Next, this thesis has focused on three fields of literature to examine the process of securing secondary resources in circular projects: governance, territory, and market emergence. It aims to contribute to these fields from multiple perspectives.

Investigating the securing process from the governance angle, we highlight the various modes and attributes of actors' collaboration to secure resources necessary for their circular projects. We specifically detail shared governance (Bridoux and Stoeckhorst, 2022) and emphasize the crucial involvement of local suppliers. We argue that this type of governance can allow a fair value sharing with suppliers that is made possible through different configurations and the gradual construction of suitable contracts. Furthermore, while Provan and Kenis (2007) identify three tensions in governance arrangements, we highlight an additional tension specific to circular models: balancing decision-making facilitation and capital investment with ensuring the security of secondary resources. We also argue that these models rely on a shared vision and purpose around sustainability issues cultivated at the territorial level, and that trust between suppliers and plant developers is progressively constructed throughout the project and is not a prerequisite. To conclude, in studying circular economy governance, we respond to the call made by several authors (Fischer and Pascucci 2017, Brown et al. 2021; Schultz et al. 2023) to investigate how to arrange collaboration and business relations in the circular economy.

Second, analyzing the resource securing process through the lens of territory enriches the literature on this concept by relying on different analytical perspectives. Firstly, the research considers territory as housing interrelated actors and examines their relationships and interactions, with a particular focus on relational and interorganizational proximities. Understanding the dynamics of individuals' communities at various levels within a territory and their relation to the project directly impacts the success of these projects. Specifically, these works suggest the importance of a territory in establishing these local circular activities. This approach allows for the exploration of circular models that emerge through networks and

communities, highlighting the need for an approach relying on local networks within territories. Additionally, we extend the framework of Bahers et al. (2017) by examining how territorial proximities are manifested at different scales and influence the development and operation of circular projects. Through our case studies, we shed light on another aspect of territorial anchoring as defined by Bousquet (2014). Indeed, the question would not only be how the circular project is locally embedded and territorially anchored but rather how or in what way does the local area sustain the circular project and help structure it. Secondly, territory is viewed as an encompassing structure that houses a set of resources. The analysis aims to examine the impact of available resources on the development of circular initiatives. This clarifies the debate on the territorial dimension, which is often implied in theoretical approaches to the circular economy but addressed differently as a determining factor for the success of these activities. Also, by analyzing the territory as a social construction we could highlight some of the roles held locally, individually or at the organizational levels, on the territory, and upon which circular projects rely to secure adequate secondary resources and thus function effectively. For instance, roles held by the organization developing the plant when collaborating with suppliers, or by the technicians with their specific knowledge of local secondary biological resources, or the public actors involved. In so doing, we shed light on the importance of local public actors, whom we classify as facilitators in the emergence and implementation of these local projects. We provide clarifications on their profiles and roles, contributing to the existing literature (Cramer, 2020; Hansen and Schmitt, 2021; Christensen, 2021) and argue that the project can benefit from them without including them in the governance structure.

Finally, by analyzing the resource securing process through the lens of market arrangements, we were able to identify the challenges encountered by actors in qualifying secondary resources and their efforts to construct tailored exchanges and contracts with suppliers. By investigating the literature on market arrangements, we were also able to contribute to the description of three key processes in this emerging market. We highlight parameters used by actors to economically evaluate and qualify secondary resources exchanged. We also investigate the agreements they negotiate and the process applied. Furthermore, our theoretical framework underscores the importance of navigating the emerging market for biological resources. By theorizing the proxies and mechanisms employed by actors to overcome these challenges, we hope to contribute to the development of effective solutions for a market for biological resources within the CE context.

Literature	Description of Contributions
Circular economy and circular business models	Shedding light on the paradox of securing secondary resources. Enrichment of theories on BMC development by theorizing the three-stage process of securing secondary resources.
Governance	Proposal of a framework for understanding collaborative governance mechanisms and attributes in the circular economy. Identification of modes of governance involving suppliers of secondary resources
Territory	Broadening the definition of territory through 3 analytical perspectives. Analysis framework of proximities in the CE at 3 levels. Clarification of the local debate in the CE. Identification of the roles and profiles of regional and local public actors as facilitators in governance.
Market emergence	Highlighting the challenges of market emergence and the importance of a market for biological secondary resources. Description of the practices and devices used by actors in negotiating agreements to exchange these secondary resources

Table 20 Summary of main theoretical contributions

2.2. Methodological Contributions

This thesis also proposes methodological contributions at two levels.

Firstly, it contributes to the reflection on methodologies applicable for studying the development of the circular economy. It demonstrates the value of investigating the circular economy at the project level by adopting a qualitative and flexible approach based on longitudinal exploration and analysis. This approach has facilitated the understanding of the issues and challenges inherent in the empirical problem of securing secondary resources. Such an approach enabled us to comprehend the organization of a broad set of actors by highlighting the mechanisms over time and the key stakeholders involved in securing resources throughout the lengthy duration of projects. Additionally, we contribute to analytical frameworks proposed in the literature (Bocken and Geradts, 2020; Coffay and

Bocken 2023) by introducing a new framework lens to study and analyze circular projects, combining three dimensions: governance, territory, and market emergence.

Secondly, this thesis contributes to deepening the study of anaerobic digestion by proposing a novel approach. Most existing studies on anaerobic digestion projects have primarily focused on evaluating the performance of established systems against predefined quantitative objectives and on studying social acceptability, with limited investigations into the social processes leading to the establishment of anaerobic digestion plants. By positing that anaerobic digestion is not merely a technical construct, we contribute to and supplement research that proposes a social and managerial approach to studying anaerobic digestion (Alaterre et al., 2015; Niang, 2022; Bourdin and Nadou, 2020).

2.3. Managerial Contributions

As mentioned earlier in the preamble, the process of transitioning our economy to a circular model presents unique challenges. It is important to acknowledge that any attempt to address this question will inevitably fall short of perfection. While the responses presented in this thesis are not exhaustive or flawless, our aim remains to offer practical insights for policymakers, practitioners, and stakeholders engaged in circular economy initiatives and anaerobic digestion projects. In general, we hope to offer insights and data relevant to stakeholders, aiming to provide a comprehensive understanding of the problem of secondary resources to help stakeholders address it effectively. Additionally, we aim to offer recommendations for improving project planning, implementation, and governance of local circular projects based on our research findings.

Following the empirical investigation of the development of the anaerobic digestion sector and the four anaerobic digestion project case studies, this thesis hopes to have produced data that may interest stakeholders in the anaerobic digestion sector, particularly enriching a database on anaerobic digestion projects from their inception to operation. Given the fact that 20% to 30% of biogas projects are abandoned (Bourdin & Nadou, 2020), these data aim to enrich the body of knowledge available on the conditions for implementing circular anaerobic digestion projects at the local level. We help elucidate coordination challenges among stakeholders, which are among the factors contributing to failures.

First, this thesis aims to offer all actors intending to develop anaerobic digestion projects a synoptic view of the problem of securing secondary resources. By theorizing the securing process, we highlight the importance of preliminary studies on secondary resources in an area,

the idiosyncratic characterization of financial values, and the importance of managing suppliers of secondary resources during administrative validation as well as during plant operation. Furthermore, we shed light on the uncertainties and challenges arising during this process so that actors can anticipate them. Moreover, this thesis highlights various governance methods possible for circular anaerobic digestion projects and describes the relationships that bind the actors and their organization in detail as well as the involvement of suppliers in the process of securing secondary resources. Additionally, we characterize the relationship of these local projects with the territory in which they are anchored. By characterizing the territory as an encompassing structure housing a set of resources and interrelated actors, we enable developers of anaerobic digestion projects to understand how the territory can contribute to the implementation of these projects and which types of proximities need to be mobilized at different micro, meso, and macro scales. For example, we portray the profiles and roles that local public actors can play in these projects, enabling actors developing local projects to know who and when to mobilize these facilitators. Also, by analyzing the development of these projects, we underline some specific skills and expertise that foster their success. For instance, at the individual level, agricultural knowledge and project managers' adaptive empathy during the contracting for secondary resources, are crucial. Finally, we emphasize the importance of qualifying secondary resources in emerging markets by establishing agreed-on tools and using known factors (e.g., relying on proxies, development of methods to qualify secondary resources, use of digital platforms to identify spot resources) as well as the agreements negotiated.

Furthermore, the analysis of the four anaerobic digestion case studies can also serve as a source of inspiration for stakeholders involved in other local circular projects using biological secondary resources. This analysis allows for the differentiation between components of local circular business models and 'business as usual'. By highlighting the implications this has for development, it becomes apparent that in a linear business model, the focus lies on the extraction of natural primary resources, whereas in local circular business models, the emphasis shifts to utilizing secondary resources available within territories. Consequently, circular business models face challenges such as limited deposits of secondary resources dispersed across territories and subject to fluctuations, with variable and unpredictable quantities and qualities. Moreover, while key resource suppliers in linear business models operate within a known typology, those involved in local circular business models exhibit a more varied profile, leading to idiosyncratic contracts with fluctuating prices due to the

absence of a market for all types of biological secondary resources. Additionally, transportation methods differ, with business-as-usual relying on conventional means while local ones prioritize local and environmentally conscious transport options. However, this shift can result in NIMBY ('not in my backyard') issues due to noise and odor nuisances, with significant costs associated with collection and massification remaining a concern. Finally, stakeholders in circular business models encompass both public and private entities, often with a local focus, necessitating specific governance features tailored to accommodate the varied interests and actors involved.

3. Limitations and avenues for future research

“One contribution scientists can and should make is to be clear and explicit about the limits of scientific understanding, a matter that is particularly important in societies where people are trained to defer to alleged experts.”

— Noam Chomsky

This thesis has opened up new theoretical and methodological avenues for studying the implementation of local circular projects, specifically the process of securing secondary resources in anaerobic digestion projects. Further research is needed to test, refine, improve, complement, or refute our hypotheses. To that end, we will present three limitations we have observed in our research work and the future research directions we perceive.

3.1 Dynamics of the biological secondary resource market

The thesis focused on analyzing a process of securing secondary resources that emerged as a crucial and challenging step for the implementation of circular projects, impacting their financial and operational viability. This process of securing biological resources is relatively recent and expected to evolve. Indeed, a challenge arises from the fact that the market for biological secondary resources is emerging in the case of anaerobic digestion. However, the thesis could not concentrate on the additional effects that having a market could have on the process of securing resources. Will structuring facilitate the securing process for actors, or conversely, will having a well-structured market hinder the established dynamics between actors to negotiate tailored contracts with suitable, negotiated prices? The research could thus be based on and expand the work of Toussaint (2022) linking the role of markets as a political management tool for environmental issues in the context of space debris.

3.2 Limitations and validation prospects of hypothesized resource securing processes

“It’s fundamental, the sinews of war in anaerobic digestion today are clearly these secondary resources. That’s why we want to move fast and hard!” – Strategy Advisor

The hypotheses formulated in this thesis were developed abductively over the course of three years of doctoral research (Chapter 2, Section 2.1 Exploratory Approach). The issue of securing secondary resources and the theoretical hypotheses regarding governance, territory, and market emergence that arose from our research work need to be further tested in different circular projects.

One may wonder if the issue of securing secondary resources is particular to the case of anaerobic digestion or if actors face it in other empirical situations. It would be necessary to analyze the securing process longitudinally, as we did, to see if the same stages emerge or if other scenarios arise.

In this regard, one may question whether the various governance modes distinguished and observed during the analysis of the resource securing process are observable in other empirical cases of anaerobic digestion, or more broadly in biogas plants, or even in other projects using these types of resources. The organization of actors could thus be subject to verification. By investigating the role of stakeholder engagement in shaping territorial dynamics in other empirical cases, we could verify how various stakeholders—including local communities, businesses, and governmental bodies—interact and collaborate to develop other circular economy projects at the local level. We could also analyze how regions leverage their unique secondary resources and economic strengths to position themselves as hubs for circular innovation and development, beyond the roles that we identified. Furthermore, the categorization of facilitators could be generalized and expanded. Are the profiles and roles of facilitators the same in other anaerobic digestion projects or even in other case studies? Do they intervene at similar times of the securing process and in the same ways?

3.3 Exploration of alternative cases and territorial variations

We have shown that the case of anaerobic digestion is well-suited for studying the securing of secondary resources for the implementation of circular projects. However, this

case remains specific and particular as it is highly local and territorial. As indicated, there is a debate on the territoriality of the circular economy. Continuing this research could involve analyzing a new case, varying the specificities of secondary resources, for example, biological and non-local or technical and local. For instance, we could explore the case of the CO₂ emitted by the anaerobic digestion plant, which can be considered as secondary resources for other activities (e.g., greenhouse heating, dry ice, carbonated drinks in the food industry, slaughterhouses, mineralization). Additionally, we could explore the reuse of technical equipment in companies through a digital platform involving non-local and non-territorial management of these secondary resources. An exploration of these two cases of secondary resources, through a first series of interviews, has already been initiated during this doctoral work. Thus, future objectives for broadening the study of this issue of securing secondary resources could be to revisit the proposals laid out in this thesis concerning governance modes while studying territorial variation and the associated markets.

This research was qualitative in nature, aiming to investigate how actors secure secondary resources within circular economy models. It did not intend to quantitatively evaluate the circularity of anaerobic digestion plants. Therefore, we did not explore the environmental impacts of the process. Instead, we simply argue that it is a crucial vector in the circular energy transition. Its development should include careful biomass and land mobilization. Furthermore, while our study treats anaerobic digestion as a social construction, it fundamentally remains a complex industrial process. Numerous technical challenges and risks are inherent in anaerobic digestion, as evidenced by the occurrence of accidents in the sector. This underscores the need for continuous improvement and risk reduction strategies to enhance the safety and efficiency of anaerobic digestion processes.

Annex

Table 21 List of interventions to validate research

Dates	Type of presentation	Support	Main Purposes	Validity
17/09/2021	PhD student day – Engie Lab Crigen	PPT	Knowledge Transfer Discussion of work by colleagues	External
14/09/2021	Webinar Sustainable and Circular Business Models – Engie Research	PPT	Knowledge transfer	External
02/02/2023	Work restitution day of the program funding the thesis – Engie Research	PPT	Knowledge Transfer Discussion of work by colleagues	Internal
23/02/2023	Biweekly meeting -Engie Lab Crigen, Lab Environment and Society	PPT	Knowledge Transfer Discussion of work by colleagues	Internal
18/04/2023	« Journée portes ouverte » - Engie Lab Crigen Lab, Environnement and Society	Poster	Knowledge Transfer Discussion of work by colleagues	External
16/02/2023	Working Group on Circular Business Models – Comite 21 and Veolia	PPT	Knowledge Transfer	External
12/10/2022	Campus Veolia - MISE	PPT	Knowledge Transfer	
21/04/2021 11/05/2021 08/06/2021 25/06/2021 01/04/2022 08/04/2022 25/04/2022 06/05/2022 08/06/2022 17/06/2022 30/06/2022 18/07/2022 06/09/2022 13/09/2022 20/10/2022 21/12/2022 15/12/2022 27/01/2023 22/02/2023 21/03/2023 17/05/2023 23/10/2023	Steering committee Engie Lab Crigen, Veolia, CRG	PPT	Knowledge Transfer Discussion of work by Thesis industrial supervisors	Internal

21/09/2022 17/07/2023	Steering committee Engie, Veolia, CRG	PPT – Annual Report	Knowledge Transfer Discussion of work by Thesis industrial partners	Internal
19/05/2021	Doctoral seminar at Institut Interdisciplinaire de l'Innovation i3	PPT	Discussion of work by fellow researchers and doctoral students	External
10/09/2021 10/10/2022 15/05/2023	Thesis Seminars at CRG	PPT and report	Discussion of work by fellow researchers and doctoral students	External
19/10/2023	Mini Thesis Defense	PPT and report	Discussion of work by fellow researchers	External
05/07/2021	Summer School Innovation and Management at Institut Interdisciplinaire de l'Innovation i3	Poster	Discussion of work by fellow researchers and doctoral students	External
02/06/2022	Association International de Management Stratégique (AIMS) conference - Track : Orchestrer et valoriser les ressources pour de nouveaux BM face aux grands défis sociétaux et environnementaux	PPT and publication “ <i>Exploring circular activities and business models in the energy sector to answer the grand challenge</i> ”	Discussion of work by fellow researchers and doctoral students	External
08/06/2022	Association Information et Management (AIM) Conference - Track : RSE et post-RSE	PPT and publication “ <i>Specificities and development process of a digital platform serving a sharing economy in the energy sector</i> ”	Discussion of work by fellow researchers and doctoral students	External
09/07/2022	European Group for Organizational Studies (EGOS) conference - Track : Valuation and critique in the “Good economy”	PPT and publication “ <i>Exploring circular activities and business models in the energy sector to answer the grand challenge</i> ”	Discussion of work by fellow researchers and doctoral students	External
13/07/2022	R&D Management - Track : Innovation and digitalization towards sustainability leadership	PPT and publication: “ <i>Specificities and development process of a digital platform serving a sharing economy in the energy sector</i> ”	Discussion of work by fellow researchers and doctoral students	External

07/12/2023	ISTEC (Ecole Supérieure de Commerce et Marketing) Conference : Economie circulaire et nouveaux modèles d'affaires : quels enjeux pour l'innovation et la transformation des organisations ?	PPT and publication "How does the local dimension change a company's business model ? The case of local energy systems"	Discussion of work by fellow researchers and doctoral students	External
14-02-2022 and 14-02-2023	Sustainable and Circular Business Model Course (Science Technology and Management (STEEM) Master)	PPT (1 session of 3 hours)	Knowledge transfer	External
17-02-2023 → 28-04-2023	Business Models and Business Plan Master Course (Transport et développement durable (TraDD) Master)	PPT (7 sessions of 4 hour)	Knowledge transfer	External
10/03/2023	Course Circular Economy (Projet Innovation Conception Master)	PPT (1 session of 1:30 hour)	Knowledge transfer	External

Table 22 Sources of primary data (interviews and conferences)

Sources of Primary data (interviews and conferences)	Description	Processing and use
Interviews with experts in the circular economy	Semi-structured interviews of actors in France. Face to face, visioconference or by telephone, with or without registration, live note taking and detailed reports	Discourse analysis. Confrontation of interviews. Basis for searching secondary sources (reports, websites, organization charts, contacts, etc.). Use for understanding the issues, descriptions, regulations.. Used in chapter: 1
Interview with actors from anaerobic digestion sector	Semi-structured interviews of actors in France and Europe involved in Anaerobic digestion. Face to face, visioconference or by telephone, with or without registration, live note taking and detailed reports	Discourse analysis. Confrontation of interviews. Ranking by actors and project. Basis for searching secondary sources (reports, websites, organization charts, contacts, etc.). Use for understanding the issues, descriptions, identification of models, regulations, comparisons. Verbatim. Used in chapters: 4 and 5
Interviews with actors of digital market place	Semi-structured interviews of actors in France involved in projects of digital market place in B2B. Face to face, visioconference or by telephone, with or without registration, live note taking and detailed reports	Discourse analysis. Confrontation of interviews. Ranking by projects. Basis for searching secondary sources (reports, websites, organization charts, contacts, etc.). Use for understanding the issues, descriptions, identification of models, comparisons. Verbatim.

Interviews and note taking during conferences	-39	Meeting stakeholders and making contacts. Confrontation of points of view. Identification of innovative projects. Used in chapters:4 and 5
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Table 23 Sources of primary data (participations and observations)

Sources of Primary data (Participations and Observations)	Description	Processing and use
Participation to Record study on Distribution of value among circular value chain	Drafting the initial proposal to be submitted from Engie. Elaborating the final call for research project. Selecting the team to conduct the research. Participating in Kick off meeting and follow up meetings. Final report March 2024	Data exploitation Quantitative and qualitative for understanding the social and environmental impacts of anaerobic digestion projects on the value chain. Used in chapter : 4
Participation in Colloquim "Imaginaires et pratiques de l'économie circulaire"	Subjects on the origins of the concept, how it is appropriated by different actors, main issue of the concept and critiques. Different perspectives (historical, philosophical, geopolitical, sociological, managerial, economic. Best practices and case studies, their challenges, and their relationships to technological innovation. Drafting of reflection paper with the 3 other doctoral students participating in the colloquim.	Meeting stakeholders and making contacts. Confrontation of points of view on circular economy. Construction of critical perception of circular economy. Used in chapters : 1 and 3
Participation in Multifaceted Performance and Sustainable Development workshop day at Veolia	Participation in Workshop 29-06-2022 at Cite fertile for the Multifaceted Performance and Sustainable Development	Confrontation of points of view on circular economy Used in chapters : 1 and 2
Participatiton aux construction des feuilles de routes EC Engie	Proposition of projects and topics to be tackled by the Team - Evaluation and assessment of their strategic alignment to Engie and to the team's expertise	Confrontation of points of view on circular economy Used in chapters : 1 and 2
Participation in the Young Professionnal Network	Conference organized by young employees at Engie. Subjects on the ecological transition in the energy sector. Overview of circular activities in the company.	Confrontation of points of view on circular economy. Identification of projects. Meeting stakeholders and making new contacts Useful for the understanding of circular economy challenges and

		strategies in the company Used in chapters : 1 and 2
Participation in project Circular Economy Indicators at Engie	Conducting bibliographic analysis on topic (mostly indicators discussed in academic articles). Evaluation of relevant indicators in the energy sector. Conducting interviews with key stakeholders to assess relevance of framework developed.	Data exploitation Quantitative and qualitative for understanding the circularity levels of companies Used in chapters : 1 and 2
Participation in project Circular Economy Indicators at Veolia	Conducting bibliographic analysis on topic (mostly indicators developed by organizations) Evaluation of relevant indicators in the energy, waste and water sector. Selecting most adequate set of indicator	data exploitation Quantitative and qualitative for understanding the circularity levels of company Used in chapters : 1 and 2
Position paper Circular Economy at Veolia	Support in drafting the paper addressed to the strategic department of Veolia on the relevance of the circular economy topic and the necessity to broaden the scope beyond plastic recycling	Confrontation of points of view on circular economy Useful for the understanding of circular economy challenges and strategies in the company Used in chapters : 1 and 2
Participation in Anvie Workshop "Rien ne se perd, tout se transforme : l'économie circulaire, socle du « monde d'après » ?" on the 14 october, 5 november and 24 november 2020	3 sessions on the topics of consumption of resources, value creation for customers, the role of innovation in the transition	Confrontation of points of view on circular economy. Identification of projects. Meeting stakeholders and making new contacts Useful for the understanding of circular economy challenges and strategies of other companies Used in chapter : 1
Participation in "Fresque de l'économie Circulaire" (during Colloquim "Imaginaires et pratiques de l'économie circulaire" and at Engie Lab Crigen)	Collaborative workshop to understand the challenges of transforming our linear production-consumption system	Meeting stakeholders and making contacts. Confrontation of points of view on circular economy. Construction of critical perception of circular economy. Used in chapter : 1

Table 24 Sources of secondary data

Sources of Secondary data	Description	Processing and use
Academic bibliography	Zotero data base	Categorization by themes and topics Used in chapters: 1, 3 and 6

Annual companies' report	Engie and Veolia : 16 documents	Longitudinal processing. Confrontation with circular economy development and origins. Used in chapters: 4 and 5
Study, reports, information document, guides and best practices on the circular economy	From actors in France (ADEME, France Strategie, Circul'R, Association Francaise des Entreprises Privees, Institut National de l'Economie Circulaire) or abroad (Ellen Mac Arthur foundation, McKinsey, Deloitte, Circularity Gap Report, OCDE, European Commission, WBCSD, World Economic Forum) - 25+	Database of projects and best practices, assessment of circularity, comparisons, confrontation of data, etc. Used in chapters: 1, 2 and 3
Study, reports, information document, guides, and best practices on the anaerobic digestion sectors in France	From actors in France (ATEE, ENEA, ADEME, France Strategie, GRDF, Comite de Filiere Strategique) or abroad (EBA, OFATE) - 25+	Database of projects and best practices, technical and economic assessment, comparisons, confrontation of data, etc. Used in chapters : 4 and 5
Confidential documents at Engie	Access to Biogas Community of Practice: data base of internal documents - 20+	Project database, comparisons, data confrontation, etc. Used in chapters : 5
Legislative and regulatory texts on anaerobic digestion	European Directives, Articles on Code of Environmental, Law and Regulations	Longitudinal study to trace regulatory evolution and its influence. Processing in Excel Sheet Used in chapter : 4 and 5
Blogs site internets		Confrontation of points of view. Identification of new contacts Used in chapters : 4 and 5
Videos	Description of anaerobic digestion entities - Interview with stakeholders	Discourse analysis. Confrontation of interviews. Ranking by actors and project. Identification of new contacts Used in chapters: 4 and 5

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Title : Overcoming the challenges of securing secondary resources in circular economy projects: The case of anaerobic digestion

Keywords : circular economy; secondary resources; governance; territory; market arrangements; anaerobic digestion

Abstract: The challenges associated with securing secondary resources present a significant obstacle to the economic viability and operational feasibility of circular economy models, given their specific characteristics such as variability in quality and quantity, as well as the local dispersion of deposits held by different actors. This thesis explores the territorial organization of actors to address this empirical issue of securing secondary resources, which has been very little studied.

To address this question, the research focuses on the case of territorial anaerobic digestion (AD). This case was chosen due to its integration of circular economy principles, the competition and regulatory complexities surrounding the use of biological resources, and the socially complex, multi-actor processes involved in implementing such projects. The methodology is comprehensive, relying on 70 semi-structured interviews, observation complemented by secondary data. We opted for a longitudinal investigation into the development of four territorial AD projects. The analysis of these projects is based on an analytical framework we developed, grounded in three perspectives: governance, territory, and market emergence. These perspectives allow a better understanding of the dynamics involved in implementing circular economy initiatives.

Analysis of the four case studies from these three perspectives highlights several findings. First, we identify a three-phase process for securing secondary resources, emphasizing the strategic approaches adopted by stakeholders to ensure the viability of AD projects. Second, we address the challenges of securing resources in emerging markets, where stakeholders develop tools and exchange modalities to define resource prices and secure supplies. Third, we highlight the importance of territorial proximities in local circular projects, discussing the dynamic role of public actors as facilitators. Finally, we analyze governance structures within AD projects, ranging from firm-centric models to collaborative approaches involving resource suppliers.

This thesis mainly contributes to the literature on the circular economy by providing a strategic vision of the process of securing secondary resources in circular projects. The thesis also has managerial implications by offering insights into the governance mechanisms, territorial dynamics, and market arrangements that underpin successful circular economy initiatives.

Titre : Surmonter les défis de la sécurisation des ressources secondaires dans les projets d'économie circulaire : Le cas de la méthanisation

Mots clés : économie circulaire ; ressources secondaires ; gouvernance collaborative ; territoire ; arrangements de marché ; méthanisation

Résumé : Les défis liés à la sécurisation des ressources secondaires représentent une difficulté majeure pour la viabilité économique et la faisabilité opérationnelle des modèles d'économie circulaire, compte tenu de leurs caractéristiques spécifiques telles que la variabilité de qualité et de quantité, ainsi que la dispersion locale des gisements détenus par différents acteurs. Cette thèse s'interroge sur l'organisation des acteurs pour faire face à ce problème empirique de sécurisation des ressources secondaires, très peu étudié.

Pour répondre à cette question, notre recherche menée se concentre sur le cas de la méthanisation. Ce cas a été choisi en raison de son intégration des principes de l'économie circulaire, de la concurrence et des complexités réglementaires entourant l'utilisation des ressources biologiques, ainsi que des processus multi-acteurs socialement complexes impliqués dans la mise en œuvre de ce type de projet. La méthodologie est comprehensive s'appuyant sur 70 entretiens semi-directifs, de l'observation et des données secondaires. Nous avons retenu une étude longitudinale du développement de quatre projets de méthanisation. Nous avons développé un cadre analytique articulant trois perspectives théoriques portant sur la gouvernance, le territoire et l'émergence de marché. Il permet de mieux comprendre les dynamiques en jeu dans la mise en œuvre d'initiatives d'économie circulaire et la sécurisation des ressources secondaires.

Nous mettons en avant plusieurs résultats. Premièrement, nous identifions un processus en trois phases pour sécuriser les ressources secondaires, et soulignons les approches stratégiques adoptées par les parties prenantes pour assurer la viabilité des projets de méthanisation. Deuxièmement, nous montrons comment, en vue de la sécurisation des ressources secondaires, les parties prenantes développent des outils et des modalités d'échange pour définir les prix des ressources et sécuriser les approvisionnements, alors que les marchés pour ces ressources n'existent pas. Troisièmement, nous soulignons des proximités territoriales dans les projets circulaires, en discutant différents rôles des acteurs publics qui les favorisent. Enfin, nous analysons les structures de gouvernance des projets de méthanisation, et différencions des modèles centrés sur l'entreprise et des approches collaboratives impliquant les fournisseurs de ressources.

Cette thèse contribue à une meilleure compréhension des défis des projets d'économie circulaire en apportant une vision stratégique du processus de sécurisation des ressources secondaires. Elle montre aussi comment l'articulation des différentes perspectives théoriques constitue un cadre théorique éclairant pour ces projets.