Socio-technical structuring of biogas in France

RA6.2 Intermediary report

François-Joseph DANIEL, Victor BAILLY

UMR GESTE ENGEES-IRSTEA

April 2015

Fonds Européen de Développement Régional (FEDER)
Europäischer Fonds für Regionale Entwicklung (EFRE)
Dépasser les frontières : projet après projet
Der Oberrhein wächst zusammen, mit jedem Projekt

Abstract

The rapid growth of the biogas sector is marked by the implementation of a real "social world" (Strauss, 1978) consisting of scientists, engineers, design departments, firms, public policies, and so on, at the origin of projects that may be complete or not, of knowledge that is shared to a greater or lesser degree, of common references, of successes and of failures. The French case shows that the biogas world is complex. While it is indeed structured in the form of socio-technical networks, it is also divided into sub-worlds, each with its own more or less cohesive actor networks, a singular approach to development issues, and a degree of technological and symbolic homogeneity.

Introduction

In the past few years biogas production clearly has become a key development issue in several respects[1]. Not only are biogas production plants considered as an alternative energy source that corresponds to national strategies to develop renewable energies; by recovering the organic waste of human activity to produce methane, these facilities also work towards the objective of developing a circular economy (concretized in France, for example, in the recent law on energy transition). Yet the development of this technology is by no means self-evident. As many studies on the subject have already shown, the emergence of biogas is linked to the following: contingent social organizations that structure the biomass supply and energy use locally (Bluemling, Mol, & Tu, 2013; Gold, 2012; Markard, Stadelmann, & Truffer, 2009; Mol, 2014)[2]; professional cultures that, in a given sector, may be more or less favourable to collective entrepreneurial action (Wirth, Markard, Truffer, & Rohracher, 2013); investment risks (Reise, Musshoff, Granoszewski, & Spiller, 2012); and the institutional and political dimensions which, in turn, shape the configuration of projects in the field (Carrosio, 2013). Some studies have moreover shown the socio-technical networks that support the socio-cognitive innovation dynamics in the field (Raven & Geels, 2010). The rapid growth of this sector is thus marked by the implementation of a real "social world" (Strauss, 1978) consisting of scientists, engineers, design departments, firms, public policies, and so on, at the origin of projects that may be complete or not, of knowledge that is shared to a greater or lesser degree, of common references, of successes and of failures. While these studies have provided insight on the structuring of this industry from an original angle, they have seldom explored the diversity of the socio-technical worlds inhabiting this entity. The French case shows that the biogas world is complex. While it is indeed structured in the form of socio-technical networks, it is also divided into sub-worlds, each with its own more or less cohesive actor networks, a singular approach to development issues, and a degree of technological and symbolic homogeneity. The aim of the present report is to describe the emergence of these worlds and thus to further our understanding of the socio-technical structuring of biogas[3].

[1] The authors would like to thank Liz Libbrecht who translated the original report into English.
[2] See also the report written under Task RA61 of the OUI-BIOMASSE project.
[3] The "socio-technical world" concept is inspired by the social worlds of Strauss (Strauss, 1978). It hasmore recently been developed by Rémi Barbier (2005).

Method: a qualitative approach

To understand the emergence of the socio-technical worlds of biogas, we first undertook exploratory research, based on available documentation on the subject. This initial research enabled us to familiarize ourselves with our research subject, particularly through its technical dimensions, regulatory context, public policies, historical components, and so on. From this preliminary step we developed a homogenous representation of the industry, in which we identified the different areas of application (Waste water treatment plant, industrial effluent, agricultural matter, organic waste). It also enabled us to discover the diversity of the actors revolving around biogas: project leaders and economic, political, administrative, institutional, scientific and technical actors. The second step consisted of semi-structured interviews with some of these actors, chosen for their heterogeneous profiles and diverse affiliations with different "sub-worlds". We then identified the "key actors" to meet, while leaving leeway enabling us to re-orientate the composition of the sample as the survey and the interviews progressed[4]. Interview guidelines were drawn up and were adapted to the type of actor interviewed[5]. The aim was to structure these interviews as little as possible so that the interviewees would talk about their activities and their perception of the biogas world, the biogas market, the development of the technology, the problems and obstacles encountered, and the challenges to meet.

Biogas production in the seventies and eighties

In France, interest in biogas as a source of energy production emerged in the 1940s and developed in the post-war years under the impetus of Ducellier and Isman's work[6]. These two pioneers of manure gas, both of whom taught at the *Ecole nationale d'agriculture* in Algiers, developed systems for small agricultural facilities to solve the energy supply problems experienced at the time in rural areas. Biogas produced from farm effluents could serve for domestic heating, lighting, and stoves. Various experiments based on this model were subsequently carried out, often by farmers themselves. However, with the advent of cheap

[4] See Annex xxx for the list of actors interviewed in each of the three countries.
[5] See Annex xxx for the interview guidelines.
[6] The account of the development of the biogas industry in France is largely inspired by Victor Bailly's Master's thesis (2014).

fuel in the 1950s and '60s, production by most of those facilities was ceased (Demuynck, 1987).

Following the oil crises of 1973 and 1979, public policy reflected renewed interest in the methanization of agriculture in most European countries, and a second wave of on-farm development of facilities ensued. At the time, only two plants from the fifties were still operational. From the early 1970s onwards, pioneer farmers set up what could be termed do-it-yourself digesters on their farms[7]. It was not until 1979 that a significant increase in the number of plants was noted (Graph xxx). The analysis of the emergence and geographical location of projects shows that behind the energy issue emerged a purely agricultural one. The first digesters appeared in regions where intensive livestock farming was common (primarily Brittany, Loire, Rhône, Alpes and Alsace) and where problems of nitrogen pollution of water emerged in catchment areas. According to a survey by the Commission of the European Communities, in 1987, on farmers' motivation for launching such projects, "on-farm biogas production [was] especially practised to produce energy or for energy production and depollution purposes" (Demuynck, 1987, 132). The agronomic benefits of the process concerned not only the installation of a pollution control technique, but also the improvement of manure as fertilizer and thereby savings on fertilizer. Alongside the development of agricultural biogas production from the late 1970s, the funding of research programmes highlighted a greater availability of fertilizing elements in digestate than in dung or liquid manure. Yet, at the time, government support for the industry remained focused mainly on energy benefits. This was evidenced in the key part that the *Agence Française pour la Maîtrise de l'Énergie* (AFME), the national energy agency, played in the development and monitoring of projects, and in the funding of research[8]. Energy production was devoted above all to domestic consumption in forms similar to those of the first wave of development in the 1950s (fuel for heating, cooking and farm machinery), and in the form of electricity, as biogas was mechanically transformed. Connecting up to the electrical network was neither a

[7] The EEC report of 1987, *Installations de biogaz en Europe*, identified three types of manufacturer: owners (often the farmers themselves), local artisans, and firms (manufacturers specialized in biogas plants). Often farmers built part of the facility themselves and delegated the rest to a local artisan or firm.

[8] In 1982 AFME had a large budget for biogas, to be allocated as follows: "1.4MF [Million Francs] for fundamental research, 3.7MF for on-farm digester projects, 2.5MF for pilot digester support, 1.3MF for socio-economic studies, and 2.1MF for a R&D programme". The *Agence Nationale pour la Valorisation de la Recherche* (ANVAR), the national agency for the promotion of research and technology transfer, provided 4MF in funding for research programmes. By comparison, the Ministry of Agriculture had only 1MF earmarked for pilot projects (Demuynck, 1987).

technological option nor a possibility encouraged by the public authorities and EDF (*Électricité de France* – the electricity utility, which had a monopoly)[9].

A fatal blow was struck to the second wave of development of agricultural biogas by the oil counter-crisis, which started in the early eighties and reached a peak in 1986 when the price of a barrel plummeted to ten dollars[10]. In addition to the lack of economic benefits of these projects, there were technical problems that complicated the exploitation of the equipment. As government measures were primarily ad hoc grants to get projects off the ground, they were insufficient to structure the industry lastingly and to ensure the development of more reliable facilities. Despite AFME's relatively large budget to support the start-up phase of projects, the socio-technical context at the time followed a rationale of experimentation without any strategy to develop a clearly-defined industry in the agricultural sector on a medium-term basis. AFME had barely started to build up expertise on the subject, based on feedback from experiments and its research programme, when it was compelled to cease its support for agricultural biogas and to cut off funds to farmers and research. Agricultural biogas, which had all the attributes of an alternative and renewable source of energy supply (decentralized system, independent producer, demand-centred approach, etc.), seemed somewhat picturesque compared to a French energy policy concentrated on heavy technology such as nuclear power. AFME, which was starting to structure its action to promote agricultural biogas production, was forced to cease its programmes and funding. As the entire industry was based on the agency's funding of projects, the few plant and parts manufacturers that had started to position themselves in this market had the rug pulled out from under their feet. They did not even have the time to adjust the innovation to the socio-technical circumstances, when all prospect of development of the industry evaporated. From 1987 onwards the plants all closed down and by 1994 not a single one remained in France (Graph xxx). During that period, AFME carried on promoting the potential benefits of agricultural biogas, but without the means to support the industry financially (GIDA, 1989).

Following the failure of the development of agricultural biogas, the energy issue disappeared. Anaerobic digestion was nevertheless developed, primarily in industry and waste water

[9] Only Denmark had favoured this option, with specific measures providing for feed-in tariff, from 1982. This enabled producers to sell their electricity at advantageous rates. As Danish electricity companies were legally obliged to buy electricity produced from biogas at a minimum rate equivalent to the operating cost of the facility, producers were able to derive substantial income and to make their equipment technically viable.

[10] In the first half of the eighties, the price of a barrel of crude oil oscillated between 30 and 40 dollars.

treatment plants, for pollution control and water purification. It was only from the 1990s onwards, with the increasing attention paid to climate change, that biogas recovered its legitimacy as a contribution to the French energy mix.

Climate issues and the re-legitimization of the biogas industry

Climate issues, which emerged in the late nineties, re-legitimized biogas production. These issues were first taken on board in the field of household waste, with the recovery of landfill gasses. The aim was no longer to develop a new anaerobic digestion process, since landfills inevitably produced methane and other polluting gases through the organic waste they contained. The technical challenge lay primarily in seeking solutions to capture these fumes, in order to limit the environmental pollution they caused. The first experiments in recovering landfill gasses were run in the 1970s in the USA, before gradually spreading to Europe in the 1980s (Couturier, 2009). They mainly concerned large landfills which produced significant quantities of electricity when they were equipped with combined heat and power systems. Almost all this electricity was then sold back to the grid[11]. These initiatives remained relatively marginal in France until the ministerial decree of 9 September 1997, which stipulated that landfills were legally compelled to take measures to capture and send biogas "preferably to a recovery plant or otherwise a flare". Compliance with these standards was however costly and, despite the regulations, biogas was not always recovered for electricity production. Without preferential rates for selling back the electricity, it was not always cost-effective for firms in the waste economy to install a combined heat and power system. Even with the introduction in 2002 of minimum feed-in tariffs, a majority of landfills carried on burning captured biogas rather than recovering it[12].

Notwithstanding landfill operators' still lukewarm enthusiasm for recovering biogas, the development of this industry did legitimize the role of biogas in the French energy mix. Against the backdrop of the changes announced (Rumpala, 2010), with public policies setting ambitious objectives for the production of renewable energy sources, the contribution of

[11] Unlike waste water treatment plants that used almost all the biogas as fuel for the process and for their premises, landfills did not have such energy needs and were geared towards energy recovery solutions for the electrical grid in the 1980s.

[12] In 2008, less than one third of the ISDND reported that they recovered the biogas captured, which accounted for close to 60% of the biogas produced (ERNST, 2010, 24-26).

landfill biogas was a godsend for the institutional stakeholders. The production of primary energy from biogas from the various industries represented a considerable energy source[13]. Moreover, the electricity sector had welcomed projects concerning the injection of electricity into the grid because they corresponded to EDF's standards. While agricultural biogas facilities' production was "negligible" when it came to the prospect of connecting them to the grid, landfills were seen as "interesting" energy sources. Apart from a convergence of technical and organizational rationales, the recovery of landfill biogas did not seem to constitute an "alternative" to nuclear power since its development potential was "by nature" limited to existing plants. The opening of this sector to biogas production was therefore unlikely to challenge France's energy choices. It was consequently materialized by the introduction, in 2002, of specific feed-in tariffs for biogas, designed primarily as an incentive for landfills to recover their biogas. This "fortuitous" contribution of biogas was moreover a lever of interessment (Callon, 1986) for promoters of biogas. A full-blown French industry gradually formed around this activity[14]. It was also under this impetus that in 1999 the *Association Technique Énergie Environnement* (ATEE) created the *Club Biogaz*, an inter-professional organization to collectively represent the industry's interests. The landfill biogas example was subsequently copied, as it showed other industries and waste water treatment plants possible routes for energy development (many biogas recovery projects were launched at the time, in existing plants in both industries and waste water treatment sectors). It paved the way for the development of two other (sub)industries that were, in turn, promising from a techno-scientific point of view: biogas production from household waste, and on-farm biogas production.

The difficult emergence of biogas from municipal waste

Biogas production from municipal waste was established from the early 2000s in France. This development was directly informed by circumstances in the world of waste recovery at the time. First, from the mid-2000s onwards, French and European public policy reflected the political will to promote the recovery of the organic part of household waste. European

[13] In 2008 more than 75 % of biogas produced in France was from landfills (ERNST, 2010, 25).

[14] "It was from this point that things really got going. […] The first feed-in tariff actually did […] give impetus to the recovery of landfill gas […]. So there was this first period that was actually not insignificant because that's when operators started to really start moving. Suppliers of generators, well until the early 2000s, you never heard about landfill gas. Well, biogas just wasn't spoken about. So it was actually landfill gas that allowed for the creation of the first biogas industry in France. Given that at waste water treatment plants, well the nineties were dead, virtually nothing was happening." (Expert).

legislation set the goal not only of limiting landfills to final waste as of 2002, but also of ranking the methods of processing it[15] (a measure taken in 2009, in the framework of the *Grenelle de l'Environnement*, a French national round table on the environment). Second, at local level the authorities' plans to set up incineration plants were being challenged more and more. As Rocher (2009) pointed out, "social protest, that we thought was targeted at landfills, shifted from burying to incineration"[16]. As it rapidly became essential to recover bio-waste, incineration was clearly not the ideal combustion method from a technical point of view, due to the humidity of the waste. Local authorities were compelled to find alternative methods, suited to the recovery of bio-waste. From 2007 this context, characterized by the injunction to recover waste, along with strong challenges to incineration, was a driver of many projects to produce biogas from household waste.

Most of these projects had the particularity of being equipped with mechanical-biological treatment (MBT) systems[17]. The local authorities were in favour of this process which separates the organic matter before it enters the digester and thereby avoids sorting at the source, by households, which at the time was perceived as something that would be difficult to implement. From a technical point of view, sorting at the source was really problematical for local authorities (new logistical management with a third rubbish bin; organic matter that is difficult to collect and transport; risks of bad odours), and the articulation with other modes of waste management proved to be very tricky. As waste treatment functions in a system of communicating vessels, it was necessary to be able to assess fairly precisely the efficiency of the selective collection of bio-waste, in order to be able to proportion the biogas plant and adjust the capacity of the other treatment equipment. From a financial point of view, this type of project implied specific costs for the establishment of separate waste collection and bio-waste processing plants. The operation could therefore prove to be politically hazardous, since additional effort would be required of households to sort their waste, in addition to a contribution (in the form of a tax or levy) to the public waste management service. From an organizational point of view, the distribution of competences among the town and the community of town authorities responsible for collecting waste, and those responsible for

[15] This new hierarchy of modes of treatment established the 3R principle (reduction-reuse-recycling): prevention, preparation for reuse, recovery of matter, recovery of energy, and, finally, elimination (in landfills).

[16] The Gilly-sur-Isère environmental disaster dealt the death blow to the image of incineration. The plant ceased operations in 2001 after tests that showed dioxin levels up to 750 times higher than the new European standard in force from 2000.

[17] Mechanical-biological sorting is a process that separates the organic matter from the rest of the waste. It is linked to a composting platform or a biogas plant that recovers the organic matter sorted by this process.

implementing waste treatment solutions on a larger scale, was potentially a problem. The service in charge of treatment did not always have the required decision-making power on the various modes of collection in the area it covered. Finally, from a social point of view, sometimes disconcerting feedback on the efficiency of selective collection of household packaging in urban areas made the local authorities' technicians sceptical about the amount of bio-waste that could actually be recovered[18]. The first experiments in French towns, in which households were required to sort the biodegradable part of their waste, tended to confirm their doubts about the level of enrolment of those users that could be reached. The first French biogas+ plants to have opted for selective collection to fuel their installation (Amiens in 1988 and Le Robert in 2005) experienced setbacks and ended up having to resort to MBT systems.

In view of these technical, financial, organizational and social constraints, MBT was seen as an integrated, turnkey solution that was easy to implement and to manage. The process became all the more credible from the 2000s, following the change of regulations on the compost produced after digestion. Until then, the difficulty of recovering this compost had been a very strong constraint in the development of MBT. The composts obtained could not have the status of a standardized product; they were still considered as waste and could therefore not be commercialized. In 2007 the compulsory application of the NFU 44-051 standard removed this constraint, thus giving such compost the status of a "product", provided that certain criteria were met concerning the amount of glass, plastics, heavy metals and other pollutants they contained. For the MBT process, this new standard symbolized the recognition of its capability to recycle matter in the form of compost, in addition to its energy recovery potential. Although the first French biogas plant for household waste was opened in Amiens in 1988, it was not until 2007 that the pace at which other plants were established really intensified. From a purely technological perspective this option rapidly appealed to local councillors. It enabled them to have a turnkey system for bio-waste management and especially energy production, without asking their constituents for an additional contribution. Projects were frequently supported or even presented by Green councillors, as in the case of the Amétyst plant in Montpellier, for instance. Finally, the partnerships formed to implement MBT concerned only some local councillors and technicians, as well as two rival firms in the market (Urbaser, via its subsidiary Valorga, a manufacturer-operator; and Vinci Environment, a manufacturer).

[18] In some urban areas the efficiency of selective collection was no more than 1% or 2% (Bailly, 2013).

Yet biogas, which was supposed to be an alternative to incineration, was in turn to become the subject of local controversies and to experience a slight downturn from 2012. The technical problems encountered when the plants started to operate (odours, fires, breakdowns, etc.) required additional work that incurred huge expenses and in some cases generated disputes between the various actors (contracting authority, manufacturer, operators). These disagreements concerned the responsibility of each of these actors in the problems encountered and the additional work to finance. The technical problems also caused intense odours that triggered local protest movements. Neighbourhood associations were formed, for instance in Montpellier and Saint Barthélémy d'Anjou. These associations denounced not only the nauseating odours but also the risks of explosions associated with the technological process, as well as the poor economic and environmental performance of the process. In addition to the mounting costs, largely financed by the tax payer, the local associations challenged the quality of the compost produced by the factory, and the possibilities of it actually being agronomically viable. Some resident associations that had emerged before the plants were built had managed to stall the project by going to court; for example the ARIVEM, situated in the town of Romainville near Paris. Faced with these different levels of controversy, the French government authorities failed to take a stand. Technical actors such as the ADEME were lukewarm about MBT[19] and recommended sorting by households, without having the means to launch a selective bio-waste collection policy on a national scale. Additionally, the public actors such as the Ministry of Ecology had already turned away from household waste, to focus instead on promoting the development of a more "agricultural" industry.

The development of agricultural biogas

In the 2000s the agricultural sector started to become highly active in biogas production. Projects were mounted for several reasons. First, the technological process was seen as a solution to nitrogen pollution. The problems of areas with a structural excess of nitrogen caused biogas to become a tool for treating livestock effluents, especially in Brittany. Moreover, feedback from experiences in the development of this sector in Germany and Denmark was a source of inspiration for French farmers. The German model, in particular, fuelled debate on the "French lag" regarding agricultural biogas. In the 2000s, French

[19] In a statement published in 2012, the ADEME acknowledged that the MBT process could contribute to the biodegradable waste fraction recovery objectives, but "urged the authorities to be particularly cautious when choosing this option" due to "limited and hardly convincing feedback on experiments" (ADEME, 2012).

livestock farmers, wanted to acquire biogas facilities to produce renewable energy from the animal effluent on their farms. While these first facilities were the product of small "home" experiments, the government's Climate Plan in 2004 really boosted agricultural biogas in France. By introducing the problem of reduction of methane emissions from manure storage, the Climate Plan put the agricultural sector on a par with industry and transport as regards greenhouse gases. It identified the storage of animal excrement as one of the main sources of greenhouse gases in agriculture, and recommended storage by "anaerobic means that reduce these emissions and allow for energy recovery from biogas and for the production of organic nitrogen to replace mineral fertilizers to some extent". While the problem was thus expressed in terms of climate, it also revived the energy and agricultural issues that were gradually to return to the centre of the techno-scientific promise. The introduction of new feed-in tariffs in 2006 – specifically designed to encourage agricultural projects[20] – was the first signal by the public authorities to this industry.

The industry's development nevertheless took a particular turn in France. First of all, the substrates fed into the digesters consisted mainly of organic waste (agricultural, industrial or from the catering industry) – as opposed to energy crops. The development of the French industry, from 2006 onwards, had initially taken place in the context of a food crisis and controversies over agro-fuels. The public authorities and the industry, to steer clear of controversy, had conveniently voiced their opposition to dedicated crops grown specially to feed digesters. While no regulations banned projects in which a biogas plant was run on maize silage, two measures were nevertheless taken to limit risks of excesses. First, the subsidization of projects by the ADEME and the Regional Councils was subject to certain conditions, notably a threshold for dedicated crops, ranging from 0 to 10 percent, depending on the region. Second, in addition to the basic feed-in tariffs, the incentive to use livestock effluent compensated for the poor methane yield of livestock effluent. The idea was to encourage project managers to opt for this type of substrate. Other relevant particularity of the French model of agricultural biogas development is that the agricultural substrates fed into digesters were richer in dry matter (dung) compared to those in Germany for example. Many French farms were still characterized by a mixed crop and livestock farming model, which produced

[20] The basic rate was between 13.37€c/kWh for facilities with power under or equal to 150 kW and 11.19€c/kWh for power greater than or equal to 2MW. Additionally, there was a financial incentive for treating livestock effluent, which could be as much as 2.6 €c/kWh for the smallest agricultural facilities (power under 150 kW) that treated at least 60% of the dung or liquid manure, as well as an incentive for energy efficiency, ranging from 0 to 4€c, depending on the facility's energy recovery rate.

semi-solid manure (*fumier*) as opposed to liquid manure (*lisier*). Yet, despite this particularity in the composition of substrates, technologies that processed liquid substrate were the main models developed. The French socio-technical network of manufacturers/developers was thus inspired by the technology developed in Northern Europe, which was better suited to more humid substrates.

The development of agricultural biogas production shows the diversity of facilities throughout France, in which two main models stand out. The first is a centralized model, corresponding to facilities whose substrates are collected more or less locally and are not only of agricultural origin. Local sources are also from the agri-food industry or large retailers. Some of these facilities are owned by farmers, and others by entrepreneurs from other sectors. The organic waste collected in France ensure that these facilities are profitable, first because the energetic potential of the sources is generally greater than that of farm residues, and second because they sometimes yields more revenue via the waste treatment license fees collected. Some of the facilities nevertheless have difficulty securing their biomass supply in a context of growing competition for the most energetic organic waste. As other industries have also started to take an interest in these sources[21], the waste recovery charges (*redevances de traitement*) that serve to balance these facilities' business plans tend to decline. The economic value of matter with a higher energetic potential tends to switch from negative to positive, and its status from waste to resource. Due to the difficulties peculiar to this centralized model of agricultural biogas, from 2011 onwards a second agricultural model, oriented more towards autonomous supplies, became more prevalent in national policies to support agricultural biogas. This model is characterized by smaller facilities, owned by farmers and supplied almost exclusively by agricultural biomass (livestock effluent, crop residues, and intermediate crops for energy). These smaller projects, considered to be less profitable[22], were supported more from 2011 after the energy feed-in tariff policy was revised. The Ministry of Ecology raised the feed-in tariffs and modified their structure so as to meet the objectives of the national plan to promote renewable energies. The objectives were to increase agriculture's contribution to French biogas production by increasing the feed-in tariffs and incentives for facilities of less than 500 kW. Under this new policy to support on-farm biogas production,

[21] For instance the biofuel industry for oils, the animal feed industry for recovery of animal by-products, and the German and Belgian biogas industries which have higher feed-in tariffs than those in France.
[22] An analysis of the profitability of agricultural showed the difficulties encountered by these projects on small farms (Couturier, 2013).

adopted in 2013 (known as the “energy biogas autonomy nitrogen” plan[23]), the French government set the goal of 1,000 on-farm biogas facilities by 2020. With these new orientations, the biogas market is resolutely geared towards smaller agricultural projects.

[23] *« Energie Méthanisation Autonomie Azote »*

References

ADEME. (2012). *Le Traitement Mécano-Biologique des ordures ménagères*: Les Avis de l'ADEME.

Bailly, V. (2013). *Redevance incitative et gestion des déchets ménagers en habitat social collectif. Le cas de la Communauté d'Agglomération du Grand-Besançon*: Mémoire de Master 2 en Sociologie de l'Université de Franche-Comté.

Bailly, V. (2014). *La méthanisation: d'une promesse technoscientifique à sa mise en filière*: Mémoire de Master 2 « Projets et sociologie de l'Aménagement, de l'Urbain et des Médiations de l'Environnement », Université de Strasbourg.

Barbier, R. (2005). Le monde du résidu. Pour une sociologie politique des objets. *Mémoire pour le diplôme d'habilitation à diriger des recherches en sociologie*.

Bluemling, B., Mol, A. P., & Tu, Q. (2013). The social organization of agricultural biogas production and use. *Energy policy, 63,* 10-17.

Callon, M. (1986). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St. Brieuc Bay. In J. Law (Ed.), *Power, Action and Befief: A New Sociology of Knowledge* (pp. 196-233). Londres, Boston and Henley: Routledge and Kegan Paul.

Carrosio, G. (2013). Energy production from biogas in the Italian countryside: policies and organizational models. *Energy policy, 63,* 3-9.

Couturier, C. (2009). Techniques de production d'électricité à partir de biogaz et de gaz de synthèse: Rapport-Solagro.

Couturier, C. (2013). Méthanisation agricole: quelle rentabilité selon les projets? *Sciences Eaux & Territoires, 12*(3), 72-77.

Demuynck, M. (1987). *Installations de biogaz en Europe*.

ERNST, Y. (2010). Étude de marché de la méthanisation et des valorisations du biogaz: ADEME et GrDF.

GIDA. (1989). *La méthanisation des fumiers. Guide pratique pour l'auto-construction*: AFME.

Gold, S. (2012). Governance for securing feedstock supply of biogas plants. *Journal on Chain and Network Science, 12*(1), 67-84.

Markard, J., Stadelmann, M., & Truffer, B. (2009). Prospective analysis of technological innovation systems: Identifying technological and organizational development options for biogas in Switzerland. *Research Policy, 38*(4), 655-667.

Mol, A. P. (2014). Bounded Biofuels? Sustainability of Global Biogas Developments. *Sociologia Ruralis, 54*(1), 1-20.

Raven, R., & Geels, F. (2010). Socio-cognitive evolution in niche development: comparative analysis of biogas development in Denmark and the Netherlands (1973–2004). *Technovation, 30*(2), 87-99.

Reise, C., Musshoff, O., Granoszewski, K., & Spiller, A. (2012). Which factors influence the expansion of bioenergy? An empirical study of the investment behaviours of German farmers. *Ecological Economics, 73*, 133-141.

Rocher, L. (2009). Les contradictions de la gestion intégrée des déchets urbains: l'incinération entre valorisation énergétique et refus social. *Flux*(4), 22-29.

Rumpala, Y. (2010). Recherche de voies de passage au «développement durable» et réflexivité institutionnelle. Retour sur les prétentions à la gestion d'une transition générale. *Revue française de socio-Economie*(2), 47-63.

Strauss, A. L. (1978). A social worlds perspective. *Studies in symbolic interaction, 1*, 119-128.

Wirth, S., Markard, J., Truffer, B., & Rohracher, H. (2013). Informal institutions matter: Professional culture and the development of biogas technology. *Environmental Innovation and Societal Transitions, 8*, 20-41.