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What Carbon Capture and Storage (CCS) is expected to?

Describing potential future of a CO₂ mitigation technological system in the Seine
Waterway Axis.

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Abstract

The «Seine Waterway Axis » is located along the Seine river from Le Havre to Paris. A high density of manufacturing and heavy industry characterizes the area's economic activities. Regarding ecological transition objectives both reducing industry sector CO₂ emissions and maintaining local employment are two majors challenges for local stakeholders of this spatial area. In 2010, the Seine Waterway Axis' energy production's sector gathers 32 % of the French total emissions of this sector. Carbon Capture and Storage (CCS) appears to be a relevant technology in such a context. In 2007/2008 the idea of using CCS grew in some of the Seine Waterway Axis' stakeholders mind. But since, only few industrial scale's projects came to reality. How consider the future of this technology in this spatial area? How carbon capture and storage could contribute to mitigate CO₂ emissions in the Seine Waterway Axis? In this paper we will answer these question in analysing both spatial dynamics of this territories and expectations lincec with CCS by various stakeholders of the Seine Waterway Axis.

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Keywords: Carbon Capture and Storage; technological expectations; Social studies of Science and Technology; Spatial Planning.

1. Introduction

The «Seine Waterway Axis » is located along the Seine River from Le Havre to Paris. A high density of manufacturing and heavy industry characterizes the economic activities of the area. Regarding ecological transition objectives of both reducing industry sector CO₂ emissions and maintaining local employment are two major challenges for local stakeholders of this spatial area [1]. In 2010, energy production's sector of the Seine Waterway Axis accounted 32 % of the French total emissions of this sector. Carbon Capture and Storage (CCS) appeared to be a relevant technology in such situation. In 2007/2008 the idea of using CCS grew in some of the Seine Waterway Axis' stakeholders mind. But since then, only a few projects at an industrial scale have been realized. How consider

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the future of this technology in this spatial area? How could carbon capture and storage contribute to mitigate CO₂ emissions in the Seine Waterway Axis?

In order to answer these questions we propose in this paper to analyse technological expectations [2], sociotechnical imaginaries regarding CCS and potential reception of this technological artifact by the Seine Waterway Axis populations. This cross analysis will enable us to describe the potential future of CCS in this territory. In this paper we will first detail the concepts and the methodology used. Then, we will focus on socio-spatial dynamics of this territory in regards of CO₂ emissions and spatial structure of the Seine river valley.

Afterwards we will expose the various technological expectations and imaginaries regarding CCS technology in the Seine Waterway Axis. Finally, we will discuss the potential hybridations between CCS technology and Seine Waterway Axis Dynamics.

2. Concepts & Methodology: what are technological expectations, sociotechnical imaginaries and relevant socio-spatial dynamics and how identify them?

According to Borup and al.[2] technological expectations are real-time representations of future technological situations and capabilities (p. 286). These social scientists argue that expectations and visions guide technological and scientific activities. In describing future technological situations expectations sketch pathway to set up a new technology and enable scientists to obtain support and funding from others key stakeholders. Regarding the implementation of Carbon, Capture and Storage in the Seine Waterway Axis, analyzing expectations seems relevant because this technology is still at the demonstration level and not commercially available. In this paper we will describe the evolution of expectations regarding CCS. However analyzing engineers and scientists expectations won't enable us to fully describe future of CCS on the Seine Waterway Axis.

As defined by Jasanoff and Kim [3] sociotechnical imaginaries will help us to understand local stakeholders' representations of the future of CCS in this territory. According to these researchers sociotechnical imaginaries are collectively held, institutionally stabilized and publicly performed visions of desirable futures reflected in a design of scientific and/or technological project [4]. In regard to our research, the concept of sociotechnical imaginaries will enable us to understand the visions of local stakeholders about Carbon Capture and Storage establishment. But how can we identify these expectations and sociotechnical imaginaries? According to Borup et al. [2] and Jasanoff et Kim [3,4] we choose to study textual material and interviews to analyse technological expectations and sociotechnical imaginaries. The concept of narrative will help us in our analysis of these textual materials. Here we used this concept as Social scientists of Science and Political Scientist defined it. According to Social Scientists of Science [5], the innovation process is guided by a collective narrative. Deuten and Rip show that the vision to attain enounced at the first steps of an innovation project gives it a global plot. Narratives constrained actors in defined roles and pathways to follow. According to the example given by Deuten and Rip about a chemical innovation, the initial story lead the project manager to a wrong way and the innovation faces problems. However, managers had difficulties to question the initial scenario and follow new options.

According to Political Scientists, narratives enable Political leaders to convince populations of the need of a new policy or a political change. As Radaelli [6] noted, policy narratives are shaped as causal stories which often described an unbearable actual situation and a serie of political actions to attain a future desirable one. In our research, we both focus on the scientists narratives related to Carbon Capture and Storage in the Seine Waterway Axis and local Stakeholders narratives regarding the future situation connect with this technological system.

Nevertheless, to describe the potential futures of carbon capture and storage in the Seine Waterway Axis we also need to focus on populations' potential reception of this technology. However understanding this potential reception without a real project in development remains difficult because populations' opinions on new technology are very moving. To identify some trends regarding opposition or support toward infrastructures we choose to analyse socio-spatial dynamics. This analysis will enable us to typify potential conflictual or supporting areas regarding CCS establishment. To understand and combine these various factors we sketch these elementary structures of the Seine Waterway Axis. This methodology refers the research of Brunet a french geographer [7]. According to him, these graphic models enable researchers to understand spatial dynamics of a territory.

Combing the understanding of technological expectations and sociotechnical imaginaries related to CCS in the Seine Waterway Axis with the analysis of socio-spatial dynamics could enable us to sketch potential futures for carbon capture and storage in the Seine waterway axis and consequently potential low carbon futures for this spatial area. In the following section we will first describe the socio-spatial dynamics of the Seine Waterway Axis.

3. Is the Seine Waterway Axis Territory relevant to establish CCS?

As mentioned in the introduction of this paper, since 2005 the stakeholders of the Seine Waterway Axis planned to use Carbon Capture and Storage as a technological option to mitigate CO₂ emissions of their territory. In this section we will sketch social and spatial dynamics relevant regarding CCS technology establishment. At first, we will focus on previous CCS project in France and on Land Use Conflict literature in order to identify relevant factors regarding CCS establishment. Then we could describe the Seine Waterway Axis Dynamics according to these factors.

3.1. Establish CCS technology in France: What scope of controversies about this technology?

In France, there are very few CCS full scale projects. The only full scale CCS demonstration is a project led by Total and located in Lacq industrial area, in South west of France. Although successfully established, it was strongly disputed. In their gas plant of Lacq industrial area Total would like to demonstrate a full scale CCS project in capturing CO₂ with an oxycombustion technology and storing it in a depleted gas reservoir located in Jurançon city about 30 km from the industrial area. However, the CO₂ storage location raised a local opposition. Jurançon is well known for its wine production and store CO₂ under vineyard was perceived by wine producers as a threat for the commercial image of their products [8]. In addition, they also thought that CO₂ storage could potentially change the soil chemical composition and consequently affect the taste of the wine. The inhabitants of Jurançon also perceived CO₂ geological storage as risky for health. Although these opponents had founded an association to contest this technological project, Total experienced CCS during three years.

This brief summary of the Lacq CCS project show that technological controversy could raise various opposition factors. Here, this example shows that health hazards and commercial image are two main opposition factors to CCS establishment in Lacq. According to the scientific literature such an observation is not surprising. Callon et al., [9] shows how a nuclear storage project raise the opposition of the chicken producers of the east of France, because this project stain the image of their product. According to Borraz [10] we could also add that CO₂ storage in Lacq raise opposition because Jurançon inhabitants were unfamiliar with this technological option. Borraz analyses for instance how the installation of a cell phone transmitting antenna in a suburban area lead to a controversy because inhabitants didn't know how to find a responsible of the project and relevant information to understand it. Consequently, they find information on the internet and opposed to these projects. As Borraz showed, these kinds of opposition regarding technological project were frequent in suburban area. According to him, most of the populations who live in suburban areas are more sensitives regarding pollutions or harmful activities moved from cities to suburban areas and threatening their living standards. In the contrary an other geographer, Subra [11], shows some spatial areas were more willing to settle such harmful infrastructures. According to him subsidies or employment associated to an infrastructure settlement could enhance its implantation in some spatial areas more characterize by loss of industrial activities and high rate of unemployment.

This brief summary of the Lacq CCS demonstration project and of the social science literature illustrate the wide scope of the controversy associated with the establishment of CCS but also show territorial areas where such projects raise more oppositions. Thanks to these material we could identify in the Seine Waterway Axis potential territorial areas more willing to support CCS establishment or conversely opposed to it. We describe more accurately this territory in the following subsection.

3.2. Capturing CO₂ in the Seine downstream to store it in Paris Region.

In order to understand if Carbon Capture and Storage is a relevant technological option to mitigate greenhouse gas in the Seine Waterway Axis, we first look which activities (Industry, Transportation, Housing, Agriculture or Service) emit more greenhouse gas in this territory. To identify these sectors we first analyse the Seine Waterway Axis Regional Energy and Climate masterplan which fixes mitigation objectives for each activity. These documents illustrate that the downstream of the Seine Waterway Axis is more concerned with industrial greenhouse gas emissions than the other parts of this territory. Then, we focus specifically on CO₂ emissions and we observe again that the downstream of the Seine Waterway Axis remained more concerned with CO₂ industrial emissions. The following map illustrates the clusters of industrial facilities suitable with CCS in the Seine Waterway Axis and spatial structure of this area.

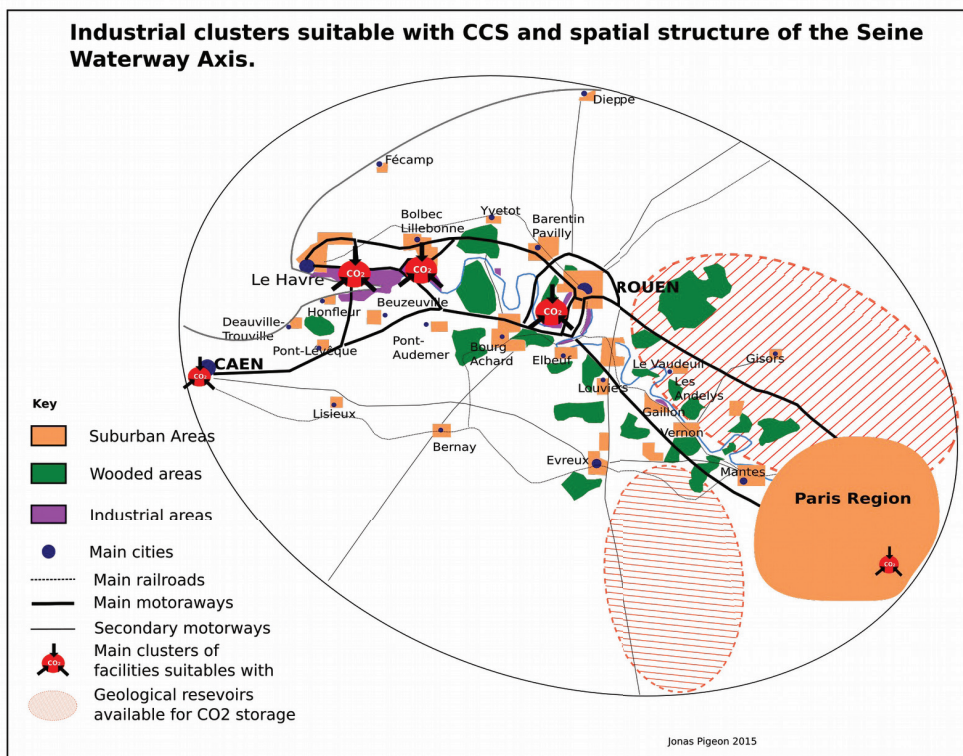


Fig.1. Industrial clusters suitable with CCS and spatial structure of the Seine Waterway Axis.

Here we easily notice that CO₂ industrial emissions gathered in two main clusters along the Seine waterway Axis: the bigger one, located in the Seine estuary and the other one in the Paris region.

Moreover the Seine Waterway Axis also counts geological reservoir suitable for CO₂ injection located in the Paris Basin. According to these data, establish Carbon Capture and Storage seems to be a relevant option to mitigate greenhouse gas in the Seine Waterway Axis territory. But, as described for the CCS project in Lacq, establish CCS in this territory could potentially raise opposition regarding local commercial image or a threat regarding living

standard in the suburban area. Thanks to theoretical works and the Lacq project analysis we choose to take into account preserved environmental areas and suburban areas as potentially opposed to a CCS establishment.

On the previous illustration we observe that CO₂ capture benefits essentially to the Seine downstream area and CO₂ storage only impact the Paris region. Consequently, such a project could be perceived as unfair because benefits and risk are dissociated. As Subra's [11] note since the 1980's in France spatial planning knew a great transformation. Until the 1980's the French State is the leader regarding spatial planning. It manage the establishment of big infrastructure as motorways or nuclear power without facing big opposition. The State's action was supported by most of the local political leaders and populations which perceived it as a progress. From the 1980's and the decentralisation of power process, spatial planning authority was transferred at regional and local levels. Therefore, local political representatives are looking for projects which benefit to their territory. Local political representatives would probably welcome Carbon Capture which enables to mitigate the greenhouse gas emissions of the existing industrial facilities in their area. Conversely CO₂ storage and its risks could raise oppositions because it may constrain other projects and because population could see it as a threat for health as Jurançon's inhabitants do. The previous drawing also shows that the upper part of the Seine Waterway Axis is characterised by suburban area. As described in the literature such areas are potentially more opposed to infrastructures project. The spatial planning department representatives we met during our research confirmed this statement. They affirmed that establishing a new infrastructure in this area (motorways, harbor infrastructure) or new housing projects is really difficult because populations want to preserved their living standard and does not bear anything that could damage it.

This information shows that if Carbon Capture and Storage could be relevant in the Seine Waterway Axis in regard of the level of CO₂ emissions of the industrial sector, establish CCS in this territory could face opposition especially regarding the CO₂ storage. To understand how the CCS establishment is considered by local stakeholders of the Seine Waterway Axis, we will describe narratives associated to this technology and their evolution since it appeared in local newspapers and stakeholders narratives in 2006 to 2015.

4 Carbon Capture and storage in the Seine waterway Axis: form Clean Coal to Industrial Ecology

In the Seine waterway Axis territory, Carbon Capture and Storage was first mentioned as greenhouse gas mitigation option in local newspapers in 2006-2007. In this section we will analyse narratives combined with CCS in a chronological way. We will first describe the various contexts of appearance of these narratives in various locations of the Seine Waterway Axis. Then, we will follow these narratives to observe their evolution.

4.1. CCS: A technology to develop commercially and a key technology in Clean Coal achievement

The local newspapers displayed two kinds of narratives regarding Carbon Capture and Storage Technology in the Seine Waterway Axis. From 2006 to 2008, local newspapers of Paris Region described CCS with a global scope. They first portayed humanity as addicted to fossil fuels but threatened by global warming consequences. According to the journalists, CCS could play a major role in decarbonizing part of fossil fuels CO₂ emissions.

In 2008 Paris region newspapers' articles focused on a CCS demonstration project planned by Veolia on its landfill site in Claye-Souilly located at west of Paris. This industrial site get value from waste treatment in producing methane and burning it to produce energy. To become a carbon neutral energy producer and to be a leader in the CCS development Veolia plans to demonstrate a full scale CCS project in the Claye-Souilly landfill because a geological reservoir suitable for CO₂ storage was available beneath the landfill. Therefore, capturing CO₂ from the energy production unit and storing it at the same place would be economic. Through this project, Veolia also aimed to reduce CCS economic cost from 30% reduction [12] . However, when it was publicly announced this project raised an opposition among local population. As told in a newspaper article on the 25th of June 2008 [13] local inhabitants expressed their concerns about CCS and their opposition to a new industrial project in an area where an international airport, quarry and landfill are already cause noise pollution. In addition an environmental association

led the opposition to this CCS project. Their blog gathers informations regarding CO₂ storage and its risks [14]. After few years this project remained unachieved because Veolia had not obtained funding from French government.

In the Seine Estuary, narratives linked CCS with Clean coal. During the summer of 2006, newspapers announced the establishment of two new coal power plants in Le Havre industrial area [15, 16]. These newspapers articles report the arguments of the proponents of these coal power plants projects justifying the choice of coal as energy at the beginning of the 21st century. According to these articles, although coal suffers from its image of polluting energy, using coal is still relevant regarding Oil & Gas growing economic cost and increasing scarcity. Moreover as shown in these newspapers, technological options available at the beginning of the 21st century make coal energy free from most of its pollutants. Available technology could indeed already trap Nitrogen and Sulphur oxide, and soon CO₂ could also be captured thanks to CCS.

After this public announcement, local environmental associations and green party regional representatives contested the establishment of two new coal power plants in the Seine Estuary area. They first expressed their mistrust in industrial authority in regards to the availability of Carbon Capture and in the ability of industrial stakeholders to develop quickly Clean coal plants. Moreover they denounced the lack of public debates regarding these two industrial projects. Because of the increasing scarcity oil & gas these local environmental associations would rather support green energy development than clean cofoal use [17].

This controversy regarding the two clean coal plants establishment in the Seine Estuary industrial area lasted almost two years. Two opposite narratives structured this controversy.

Firstly, proponents and opponents to Clean Coal both stated the oil & gas increasing scarcity and the growth of energy demand. They also agreed that using coal without clean coal technology would increase global warming. However, they disagreed on the way to deal with this issue. Proponents argue that clean coal is the economic way to solve energy demand issue without increasing global warming. On the contrary opponents considered that clean coal use would support the dependency of Societies to fossil fuels rather than enabling them to define a sustainable way to develop. Then they encourage renewable energy development.

The debate regarding the establishment of two new clean coal power plants ended because Carbon Capture and Storage technology wouldn't be quickly available. Proponents of these projects therefore abandoned them. After this event, Local stakeholders combined CCS with other territorial projects.

4.2. From Clean Coal to Carbon Free industrial Cluster

As clean coal interest declines in the Seine Estuary Local stakeholders planned to use Carbon Capture and Storage in order to decarbonise the Seine river valley industrial clusters. In order to establish a huge industrial CCS network, the Seine Waterway Axis stakeholders analyse the technical and economic feasibility of such a project through a research project named COCATE. As described in the first part of this paper, the Seine Waterway Axis both gathers Large CO₂ emitters and also geological reservoirs suitable for CO₂ storage. Scientist involved in the COCATE research project considered that pooling industrial flue gas to capture was a more economical way to decarbonise an industrial cluster. Carbon Capture Technology is expansive indeed and a huge quantity of energy is need to capture CO₂. Therefore only big industrial facilities could use this technology. Pool flue gas from various industrial sites in order to capture CO₂ emissions enables also to capture CO₂ from little industrial facilities and consequently decarbonise industrial area [18].

However, develop a huge industrial network remained difficult in Europe and consequently in the Seine River valley. In 2010 European Union launched a big funding program. The goal of this institution was to improve CCS technology in order to deploy it quickly at an industrial scale. To reach this objective European Union proposed to found eight full scale CCS demonstration projects with the New Entrant Reserve Fund. This fund corresponds to the 300 million allowances (rights to emit one tonne of carbon dioxide) in the New Entrants' Reserve of the European Emissions Trading Scheme². But in 2008 after the economic crisis, the price of a ton of CO₂ emitted decreased

² <http://www.ner300.com/> consulted the 29th september 2016.

dramatically in the European Emissions Trading Scheme whereas industries expected an increasing price. Consequently they were looking for technological options to reduce their CO₂ emissions. In this context, the first call of the NER 300 funding program ended without participants. All of them abandoned their CCS project regarding the decrease of CO₂ price on the European Emissions Trading Scheme [19]. We will explain now the consequences of the NER 300 failure on the development of CCS in the Seine Waterway Axis.

4.3. From CO₂ Storage to CO₂ re-use: Carbon, Capture and Storage a technological artifact which contributes to industrial Ecology?

The Seine Waterway Axis Stakeholders imagined CCS use in various ways. Although, most of them knew approximately, CCS they didn't considered it as already available. Describing now briefly their representations of CCS and then the conversion from CO₂ storage to CO₂ re-use.

In our interviews we observed that most of environmental associations representatives envisioned CCS as a technology which encourage fossil fuels use. Therefore, according to these stakeholders' views CCS wouldn't contribute to reduce CO₂ emissions of the territory, and development of Renewables Energy should be a priority. Conversely Local Political Representatives and administrations envisioned CCS as a technological system which could contribute to maintain the economic attractiveness of the Seine Waterway Axis territory. As described in the first part of this paper, the Seine Waterway Axis is an industrial area where environmental rules regarding were planned as more and more stringent. Therefore CCS could enable Local political representatives and administrations to reduce CO₂ emissions in the Seine Waterway Axis and maintain the economic attractiveness of the territory for the establishment of large CO₂ emitting industry. Moreover local Political representatives and administrations combined CCS use with other technological options already available and developed in the territory.

Most of the local political representatives and administration representatives we interviewed described their engagement in industrial ecology or circular economy initiatives. This representation of the future of the Seine Waterway Axis as a low carbon conurbation based on circular economy was initially proposed by an architecture team which was charged by the French government in 2008 to design the future of Paris region [20]. After this project this definition of the Seine river valley as a low carbon conurbation was broadly shared among various stakeholders. This shared visions of the establishment of a low carbon conurbation through industrial ecology in the Seine river valley as a desirable future constitute a sociotechnical imaginary.

Consequently they didn't considered CO₂ massive storage as a relevant option. They would rather look for CO₂ re-use options before geological storage. After 2013 and the NER 300 first call failure CO₂ re-use was a critical issue. We will describe now the CO₂ recycling options considered by the Seine Waterway Axis stakeholders.

The narratives analysed in our research showed two ways of CO₂ re-use. First, as we began to describe above, the Seine Waterway Axis local political representatives, economic representatives and administration representatives planned to combine CCS with Industrial Ecology. According to them, recycling CO₂ gives it an immediate economic value. The point of view of these stakeholders could be analysed with the reference to the research of Callon about economic market [21]. This sociologist showed that economic markets framed what is to take into account in the transaction. Actually, in the European Trading Scheme Contexte CO₂ emissions have a really low value. Therefore capturing CO₂ from flue gas and re-using it became relevant because it gives an immediate value to CO₂ in the local industrial ecology market. For instance, a waste management facility of the Seine Estuary industrial cluster plans to capture the emitted CO₂ to sell it to other facilities in the cluster which use CO₂ in their industrial process.

Then, some of the Seine Waterway Axis stakeholders planned to develop new economic activities linked with CO₂ re-use. They considered that CO₂ could easily replace some chemical solvents and proposed to explore this technological option [22]. Moreover, CO₂ capture and re-use enable the production of Carbon free Hydrogen and consequently the Hydrogen economy. For instance, in the Seine Waterway Axis, the industrial company Air Liquid developed a CO₂ capture process on an Hydrogen production unit. The CO₂ captured was then sold and re-use in food processing industry [23].

Finally, Carbon Capture and Re-use was also envisioned in combination with Renewable Energy. Electricity storage remains one major issue regarding wind or solar power. Currently, electricity storage of wind or solar power remained difficult. During an international conference which took place in Le Havre in March 2013 [24], some chemistry sector representatives proposed to convert CO₂ and wind or solar power electricity in Methanol through catalysis. Therefore, methanol produced from renewable and CO₂ could be used anytime and solar or wind power intermittency wouldn't be an issue anymore.

The various narratives described in this paper show an evolution regarding the representations of CCS for the Seine Waterway Axis Stakeholders. The following tables sum up these narratives for each stakeholder at various period and in different location.

Table 1. Narratives linked with CCS and their evolution in the Seine Waterway Axis.

Stakeholders	Time Period	2006 – 2009		2010 – 2015	
	Location	Seine downstream part	Seine upstream part	Seine downstream part	Seine upstream part
<i>Environment sector representatives</i>		Opposed to clean coal with CCS as a technological option in a context of global warming	An unproved technology potentially harmful for health.	Opposed to CCS which encourage fossil fuel use rather the development of renewable energy sources	
<i>Energy sector representatives</i>		Clean coal and CCS a critical technological system to face energy increasing energy demand and global warming			CO ₂ recycling as an option to take into account
<i>Chemistry sector representatives</i>				Carbon Capture a technology enabling CO ₂ chemistry, Carbon Capture to produce decarbonized hydrogen Carbon Capture a technology enabling energy storage of intermittent renewable energy sources	
<i>CCS developers</i>		CCS a technology soon commercially available	A technology to demonstrate to reduce its cost	CO ₂ recycling as an accepted technological option combined with Carbon Capture	
<i>Regional planning representatives</i>		An opportunity to decarbonize Industrial clusters in the Seine Waterway Axis		Carbon Capture as a part of industrial ecology	
<i>Scientists</i>		Prove the safety and the efficiency of CCS before developing it			
<i>Political representatives</i>		An opportunity to decarbonize Industrial clusters in the Seine Waterway Axis		Carbon Capture as a part of industrial ecology	

It shows clearly the persistence of the same narratives for the Ecological representatives or Energy sector representatives. However, it also shows the transformation of the narratives from Local Political representatives. They first envisioned CCS as an attractive technology for their territory and then considered it as part of industrial ecology. The evolution of the various narratives is also related to NER 300 failure and the inefficiency of European Trading Scheme.

5. Conclusions

In this paper we would show what was Carbon Capture and Storage is expected to in the Seine Waterway Axis. In describing the characteristics of this area we first showed that the CO₂ large emitters gathered in the Seine Estuary. However, although suitable CO₂ storage reservoirs were available in the upper part of the Axis this area which was less industrialised. In the Paris region the density of population was higher than in the other part of the Seine Waterway Axis. In addition, as we observed in our research, Paris region usually rejects polluting activities out of the region therefore store CO₂ in this area wouldn't be easy.

This paper also described the evolution of narratives linked to CCS by the Seine Waterway Axis Stakeholders. Firstly considered as technology enabling clean coal, the unavailability of CCS at a commercial scale and the inefficiency of European Trading Scheme, CCS was then envisioned as a technology which could contribute to Industrial Ecology, clean hydrogen production or Solar and wind power conversion. Finally, the stakeholders of the Seine Waterway Axis would rather develop Carbon Capture and CO₂ re-use because this technology could enable them to attain their goal: the establishment of a low carbon conurbation along the Seine River. This result show an hybridization between the technological expectations linked with CCS and the sociotechnical imaginary defended in the Seine Waterway Axis of the establishment through Industrial Ecology of a low carbon conurbation.

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