Systemic approach of collective biogas plants on a territory using Geographic Information Systems (GIS) to move towards an environmental assessment

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Abstract

Implementing an anaerobic digestion (AD) unit on a territory can help meet several needs, since the AD process provides a solution for organic waste treatment, but also for GHG emissions reduction, renewable energy production or nutrient recovery. When environmental balance is set particularly through Life Cycle Assessment (LCA), the assessment should be based on the function fulfilled by the AD system, and the alternatives studied should reflect the actual opportunities of the implementation area. In this context, this study aims to develop a systemic spatial analysis of opportunities to develop biogas systems within any specific territory thanks to Geographic Information Systems (GIS). The production of biowaste, the agricultural practices and the outlets for energy recovery were studied through this framework for two contrasting territories. GIS treatments results showed AD schemes that differed depending on the features of territories. This work is a relevant previous step to LCA of collective AD plants.

Introduction

Anaerobic digestion of organic residues has been developing in France those past few years. Public policies have set up incentives to encourage this development, as the process could help meet the European “three 20 targets” by 2020: to reduce emissions of greenhouse gases by 20%, to increase energy efficiency to save 20% of EU energy consumption and to reach 20% of renewable energy in the total energy consumption in the EU. As the main arguments for the deployment of biogas units are connected to environmental concerns, there is a need to quantitatively asses the actual effects to the environment of implementing such AD plants. Among the environmental assessment tools, the Life Cycle Assessment (LCA) methodology is a standardized tool from which environmental aspects and impacts of a system are identified and quantified throughout its life cycle.

When LCA of a system is performed, the methodology has to be based upon the function fulfilled by the system. Two major elements of the LCA come out of this function: the functional unit – unit qualifying and quantifying the service delivered by the system and providing a reference to which the inputs and outputs can be related – and the alternatives to be compared with. When the process studied fulfills several functions that cannot be studied apart, the LCA practitioner choses a function to be the main one and the co-functions are then taken into account thanks to an allocation procedure [5].

When it comes to biogas systems, defining the major function can be difficult, since AD process is multifunctional. Such a unit can meet the need to handle organic waste, which origins are varied: manure, residues from food production, organic fraction of municipal waste *etc.*, and often require being co-digested in order to increase the cost-effectiveness of the project. The biogas produced by degradation of these waste constitutes a source of renewable energy with several options for recovering this energy, since it can be converted into electricity and/or heat, used as fuel in adapted vehicles, or injected into the natural gas grid. For the digestate – remaining residue outcoming the process – direct landspreading can be practised, but it can also be post-treated in order to concentrate the nutrients (N and P mainly). This second option offers the possibility to increase locally the efficiency of nutrients or to export such a fertilizer out of the territory.

Because of those multiple functions fulfilled by a biogas system, the opportunity to implement a collective AD unit within a territory depends on the stakeholders needs, and the AD scenarios must match the local constraints. The aim of this study is to develop a systemic approach of AD implementation schemes thanks to GIS. This conceptual framework will help define the matching AD schemes by taking local features into account and consequently the proper function of the system, prior to an environmental assessment through LCA.

Material and Methods

The feasibility of such a conceptual framework has been tested on two contrasting French territories: the Coglais (35, Ille et Vilaine) and the CARENE (44, Loire-Atlantique), both being district planning authorities. The Coglais is a rural 170 km² wide territory located in Brittany; its activities are mostly agricultural. The CARENE territory has a width of 320 km² and sites on the Loire River estuary; its activities are mostly industrial and littoral. The systemic study of both territories was based on spatial analysis of agricultural practices, energy demand and waste management. The GIS treatments were performed with the software Arcgis 10®.

Waste management: The bioresources of interest for AD purpose are varied. For this study, the resources from agriculture (manure, crop residues), from industries (agro-food, supermarkets) and from local communities (sewage sludge, canteens waste) were selected. Field investigations were conducted, combined with a methodology developed in previous work [3] in order to geo-locate the type, the amount and the potential energy content of each bioresource.

Agriculture: As the digestate resulting from an AD process contains a lot of nutrients (NPK), it can be spread as substitution of chemical fertilizers [2], [4]. For this purpose, the surface of arable and grassland that are available on the territories were estimated, in order to verify that the nutrient recovery will not exceed the soil capacity. National statistical data on farming provided the number of cattle, pigs and poultry per municipality. Using a nitrogen excretion rate for each animal category and cross-checking those data with the total surface of available lands for spreading, it was possible to calculate the N pressure.

Energy recovery: In France, the biogas is generally recovered through production of electricity and heat. Utilizing the surplus heat is then of major importance regarding the whole energy and environmental balance of the AD unit [6], [7], [8]. When the implementation of a collective biogas unit is planned, the outlets for recovering the heat are multiple: farms, agro-food industries or public establishments like swimming pools, schools … Those outlets must be located nearby the AD plant – so as to minimize the heat losses – and the heat requirement must not vary over seasons – to ensure that the energy from biogas that is produced continuously can be used any period of the year. So, the existing plants or other installations that could use the excess heat were geo-located and this inventory was cross checked with a land availability map to identify possible AD candidate sites. Buffer zones were defined around the inventoried points, as the outlet for heat recovery should not site further than 600 m away from the AD plant.

Results and discussion

The methodology described above was applied to both territories. Results are contrasted on the three fields of study.

Waste management: The organic material available on a territory reflects its economic activities (Table 1). The Coglais resources mainly come from agriculture: livestock manure and crop residues stand for 95% of the total feedstock energy content. The agro-industrial effluents only represent 3% but their energetic contribution could be significant on a specific location.

Table 1. Contribution of each bioresource type to the whole feedstock (% of total biomethane potential)

	Coglais	CARENE
Livestock manure	67 %	23 %
Crop residues	28 %	-
Biowaste from agro-food industries and supermarkets	4 %	22 %
Biowaste from canteens	-	2 %
Sludge from sewage treatment	1 %	53 %

In contrast, the CARENE energetic feedstock mainly consists in residues from food-production industries and supermarkets (48%) with a high energetic dry matter content, sludge from sewage treatment plant (28%) and food waste from schools and hospitals (10%). Since the 1st of January 2012, industrials producing more than 120 tons of biowaste a year are obliged to treat their biowaste thanks to a biological process such as anaerobic digestion or composting, supermarkets and agro-food-industry are highly concerned by collective AD unit projects.

Agriculture: Intensive farming activity is a typical feature of the Coglais territory, resulting in considerable quantity of manure being spread on agricultural soils. Figure 1 shows the amount of nitrogen coming from livestock per hectare of available land for spreading. In 7 out of the 11 municipalities, this ratio is over the regulatory limitation of 170 kg N/ha. This result points out the need to export a part of the produced nitrogen out of the territory. This can be facilitated thanks to anaerobic digestion of the manure supplemented by post-treatment of digestate.

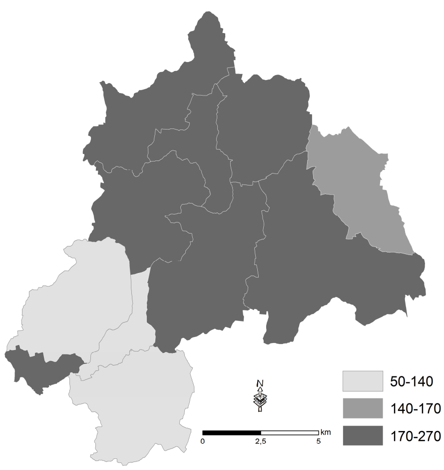

Figure 1. Amount of N produced per surface unit (kg N/ha) for the municipalities of the Coglais territory

Farming activities are marginal on the CARENE territory. Photo-interpretation of satellite images combined with field investigations led us to include only two medium-sized farms for the calculation of the N produced. The amount of N produced by local livestock is low enough to be spread on the CARENE crop lands – which is 1200 ha wide with compliance to regulation. An additional N input resulting from digestate spreading is therefore possible.

Energy demand: Figure 2 shows the location of heat consumers on the CARENE territory and the candidate sites for biogas unit implementation. Two mains locations were identified for energy recovery providing heat for a retirement home and a swimming pool simultaneously.
Results from Coglais territory pointed out a need to export a part of the N produced out of the territory. In case of implementing an AD plant, the digestate would therefore be post-treated using concentration process, which requires an important energy input [1]. All of the excess heat would then be used by this process.

Conclusion and perspectives

The systemic spatial analysis conducted revealed that an AD unit would be useful to handle stakes that differ from a territory to another. The CARENE stakeholders need to treat their organic waste and have the opportunity to produce a local renewable energy, while the Coglais stakeholders need to export the excess amount of nitrogen from manure. The developed framework is a preliminary step to Life Cycle Assessment: it makes it possible to define a functional unit fitting the local stakes and to design relevant AD schemes. In addition, the results of the GIS treatments will provide site-specific data for the Inventory step of the LCA.
In further work, the model could be made more complete, for example by calculating the phosphor pressure, or studying other biogas recovery pathways, especially injection into the natural gas grid.

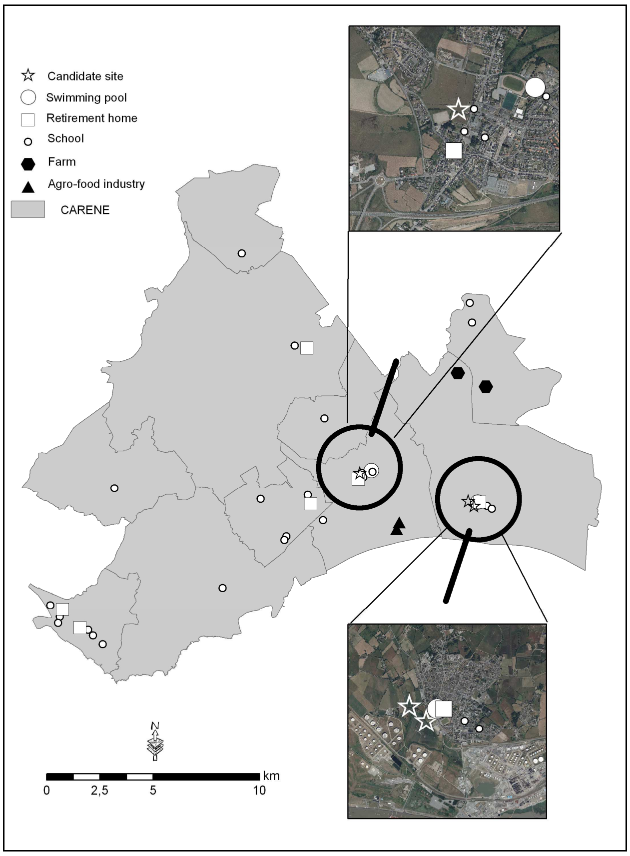

Figure 2. Outlets for heat recovery within the CARENE territory and candidate sites for biogas plant

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