GIS-based potential of French biomethane: Agricultural parcel register approach

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Abstract
Biomethane can be produced by anaerobic digestion of organic matter, today, mainly agricultural residues and intermediate crops. The production of these two could and will be estimated via a geographical information system, the French cropland plot register. This register gives us the crops and the field size, and therefore the plot production. By this we can have a finer granularity biogas prospect study, to verify prior studies such as the ADEME and Solagro study. Our estimate is substantially higher than theirs for unknown reasons.

Keywords: biomethane; GIS; parcels; France

While the fight against climate change is nowadays mainly about using newer and cleaner means of producing energy, as well as decarbonizing industry or transports, something else is important: the need to use everything we produce as much as possible. Agriculture is one example, currently some parts of grown crops are discarded, or used as fertilizers after putting them back in the soil. However, this way of discarding organic matter is not the most efficient. Anaerobic digestion of organic matter is one way of enhancing the energy efficiency of agriculture. [1]

Anaerobic digestion is a set of anaerobic digestion in 4 successive chemical steps. It is a way of turning The result being biogas and digestate, the former being a compound of methane, carbon dioxyde, water vapor and some other gases, the latter is the remaining organic matter left after the digestion, mainly used as a fertilizer. Digestate is a mean of reducing the carbon footprint of agriculture. [1] [9]

Biogas production could be a great way to reduce the associated pollution caused by agriculture, in two major ways: the first being the use of digestate, this digestate reducing the need of fertilizers needed,chemicals based fertilizers for modern productivist agriculture, detrimental to the environment by the rupture of the natural nitrogen cycle[13]. The second way of reducing the footprint is using the biomethane as a way to fuel modern agriculture. These ways being used along with more environmentally-friendly targets and practices that can be labeled under the BiogasDoneRight initiative[1]

In France, methane is well used, amounting to 418TWh[12] consumed in 2020. In January 2022, France made only close to 500MWh of biogas[12], thus amounting to roughly 6GWh in a year with this monthly production. All in all, biogas is still negligible in the natural gas market. However, many policies aim to improve this production, mainly by public feed-in tariffs, as such it is of use to know how much biogas France can theoretically produce.

There are many other ways to produce biomethane, via gasification and methanation, as well as power to gas. With the anaerobic digestion method, there are also other input materials, such as water treatment waste, household organic waste, and herbs[2]. However, in this study the main focus is on agricultural production of biogas. In this category there are three different input:

1. Agricultural residues : The inedible, unused parts of grown plants
2. CIMSE (French for Intermediary crop with multiple environmental use) : Crops used to resplenish soils, protect them, during the winter, or in summer on winter crops parcels. Only some crops can accomodate CIMSE.
3. Energy crops : Crops specifically grown with the aim of producing biogas, however it will not be covered in this study because of acceptability concerns that could hinder its development in the coming years.[5]

This study will evaluate how much residues and CIMSE are produced in France, and how much biogas it can then translate to. A study by ADEME, with the help of GRDF, Engie and Solagro, focusing on the gas production capabilities of France between 2010 and 2050[11]. Such approximates are important to know what place it will take in the energy transition. If only a small output can be achieved it will need to be balanced by other renewables.

Materials and methods

Geographical information system (GIS)

As prior studies has done approximates with the use of GIS[3], this study will aim to do so in the French territory. The French agricultural parcel register is found online, thus it can be used to have precise and comprehensive data on the crops grown in each and every regions. This data could be aggregated to give approximates of the biggest biomethane production possible in France. This study will only be conducted of metropolitan France with Corsica, excluding each and every overseas territory.

First off, using Python with geopandas, we can open French region-wide parcel data [14]. This data contains the following columns :

1. Parcel ID: Each parcel is listed here with a unique ID. As such, this column will be used as the index and key of the GIS
2. Surface : Parcel's area in hectares (10 000 m^2)
3. Code culture : the crop or the use of the parcel in general will be described by a 3-letter code. This code is described in the official documentation of the GIS[]
4. Culture group : For some crops only, code of the group of cultures
5. Geometry : Parcel's according polygon's coordinates under RGF93 projection (espg:2154)

A huge part of the data used in the computer program is made on the department level, with only some on the regional one. However, the RPG(short for "registre parcellaire géographique", french for geographical parcel register) can't be found on the departmental level, only on the regional or national level. The data is also exempt of any mention of departments, and as such, there is no way for any parcel to trace back its department. To resolve this, a GIS system featuring the geometry of French departments is necessary. The one found use another projection. Geopandas allows to change the projection, therefore, this GIS will be projected on the espg:2154 coordinates used by the RPG.

Agricultural data

Each parcel has a surface and a cultured crop but to give a production approximate we need median yields (in tons per hectares) of each crops. One of the main goal of this study is to verify the estimate of biomethane obtained by the anaerobic digestion of agricultural produce given by one of the leading study conducted by Solagro, Engie, GRDF and ADEME.

The data on yields is based on ADEME's study's data, with data on each crops featured, the main ones grown in France. The table used to know which crops can accommodate winter CIMSE or summer CIMSE, this table used along with median yields for two types respectively, also taken from this study. All the data is given on a departmental level, with some crops only being a region-wide or country-wide mean yield.[11]

For agricultural residues, there are many variables needed. First off, what percentage of the mass of the crop is counted as agricultural residue, and then, how much is really harvested and not left on the field, to leave some carbon for the soil to resplenish. This data is compiled on ADEME's study and used as is in this paper.[11]

Needed data also comprises BMP (biochemical methane potential), to know how much cubic meters of methane can be extracted from a ton of dry matter, according to each crop. To link the volumic output of biomethane to an energy one, we can use methane's calorific value.[11]

Study methodology

The data being sometimes given on a departmental level, it is needed to find a way to link each and every parcel to a department, however the RPG is on the regional level. Using the second GIS, corrected to the right projection plane, is useful. Geopandas contains the GeoSeries.within function used to know if any geometry shape lies within another, both projections being the same. Therefore for each and every region-wide RPG, the list of departments in this region is laid out, and for each of them, its geometry is used, and every parcel is tested to see if it lies in it. At the end, parcels are linked to the department it is into. However, with the sheer number of different plots in a region, it can be quite computer-intensive. For example, Normandy as about 500,000 different plots.

At this point, every parcel as a surface, a geometry, its use (be it a crop or not), and its department, mainly. With the information on yields, we can directly acquire the median production of the plot. With the data on residue percentage, we can know for each crop what is the expected production of agricultural residues. With the information on crop given and the median yield of CIMSE, we can have a median output of CIMSE grown here, these used completely as input for anaerobic digestion.

At this point, we have residues and CIMSE output given as ton of dry mass. With only the BMP we can then have the cubic meters of biomethane, and then an energy output with the calorific value.

To verify department-wide and region-wide amounts given by the original study by ADEME, we can also aggregate the theoretical energy output of each parcel in its according department, and each department to its region. Doing so will lend new approximates of the maximum theoretical energy output, considering that the dry matter is thoroughly collected and processed, with no loss.

Results

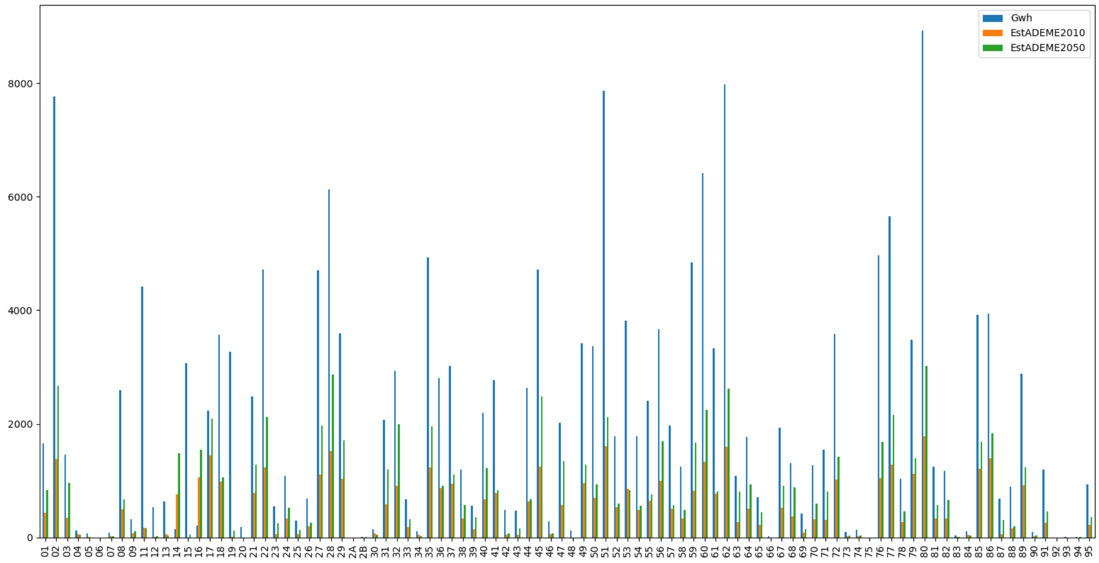

Figure 1: Each bar corresponds to a department with its code, for example 77 is the Seine-et-Marne department, the vertical axis is in GWh of biomethane energy, the blue bars being this study's results

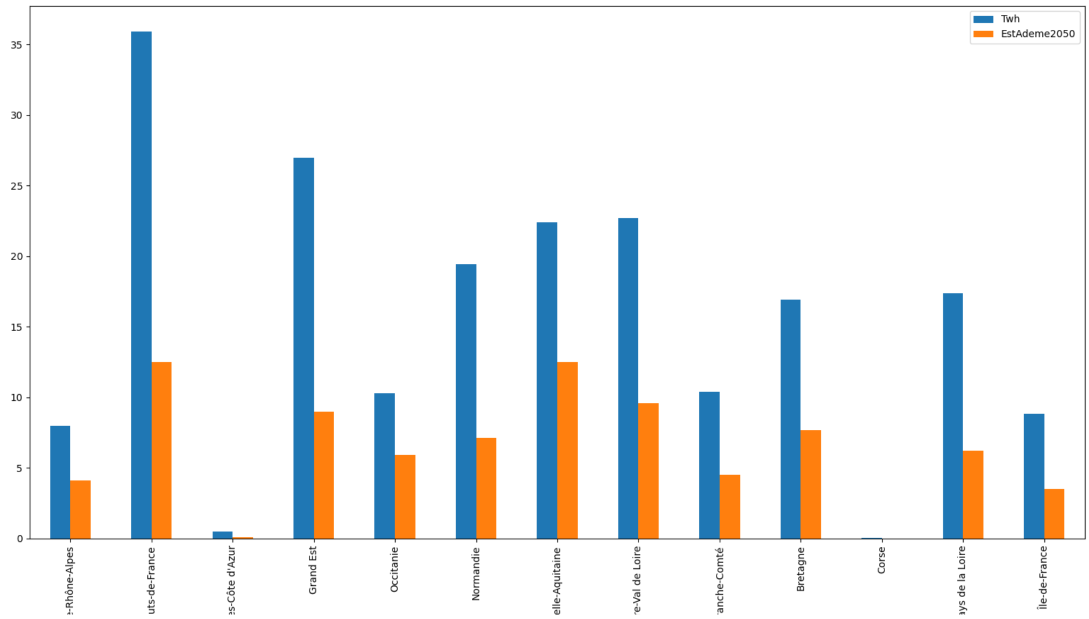

Figure 2: Each bar corresponds to a region with its name. Blue bar being this study's estimate and orange bar Ademe's 2050 estimates

Discussion

The results are on the same magnitude, but this study's are roughly three or four times higher. This difference is rather daunting. However, free from these considerations, it is to note that those approximates need to be understood. This is the maximum production of biogas by these organic matter input, and to get the most of this potential, France would need to not waste any matter, have all the infrastructure and reactors to process all inputs correctly, for biogas needs to be purified to be injected in the transport network.

As this production figure does not take into account extreme weather events, but these are going to be more and more common in the future, studies could be made to measure the climatic vulnerability of biogas production, even more so considering the first effects of climate change can already be seen in wheat yields in France [8]. Other way is to make new prospects up until 2050 following new agricultural and food habits scenario, with the example of the Afterres 2050 scenario by Solagro, which foresee a decrease in meat consumption[7], thus more space for crops. However, using an SIG would be complicated, since parcels are made to evolve according to the food production. Another possible way of improving this study is to optimize the placement of methanizers using our GIS based low-granularity approximates, which was done in prior studies[6]. This latter approach shall take into concern the acceptability of these projects, which is a huge detractor of the biogas technology[10]

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