Biogas production made easy

Reducing GHG emissions in cattle farming

Challenge-based innovation 2021

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This project has been developed in the framework of the Challenge-Based Innovation course of Fusion Point, a collaboration between Esade, IED, and UPC. In the CBI course, a challenge aligned with the UN Sustainable Development Goals is proposed to be worked on within multidisciplinary teams. Its methodology is based on systems thinking, design thinking, and futures thinking, which are terms that will be referred to in this dossier.

Research

Getting to know the problem

Greenhouse gases: an overview

The greenhouse effect was first discovered in 1856 by an American physicist named Eunice Foote. She realized the heat-trapping properties that carbon dioxide had by heating glass jars with water vapor, CO2 and air. How could Foote ever imagine that more than 160 years later greenhouse gases would be responsible for a worldwide climate crisis.

When we came to realize the repercussions that carbon dioxide has on the environment a lot of harm had already been done. Carbon dioxide levels are now 50% higher than when humanity began large-scale burning of fossil fuels during the industrial revolution.[1] We are learning the hard way how emissions released into the atmosphere are able to remain there for up to thousands of years, warming our planet more and more every day.

Greenhouse gas emissions are released when we burn fossil fuels, for example. Every time we drive to work, we take a flight to our dream holidays, we turn on the heater in winter or simply toggle our light switch. Fossil fuels are the most visible and main contributor to global warming and the one we have been more focused on for the last few years. Nevertheless, we should also consider chemical industrial processes and land use, which also play their part.

On top of that, we know that not only carbon dioxide is to blame for the rising temperatures, but also methane, nitrous oxide and many more often overlooked. Out of these, methane is the one we focused on. An assessment for the United Nations Environment Programme (UNEP)[2] states the following:

METHANE IS ALSO A POWERFUL GREENHOUSE GAS. OVER A 20-YEAR PERIOD, IT IS 80 TIMES MORE POTENT AT WARMING THAN CARBON DIOXIDE.

METHANE HAS ACCOUNTED FOR ROUGHLY 30 PER CENT OF GLOBAL WARMING SINCE PRE-INDUSTRIAL TIMES AND IS PROLIFERATING FASTER THAN AT ANY OTHER TIME SINCE

RECORD KEEPING BEGAN IN THE 1980S.

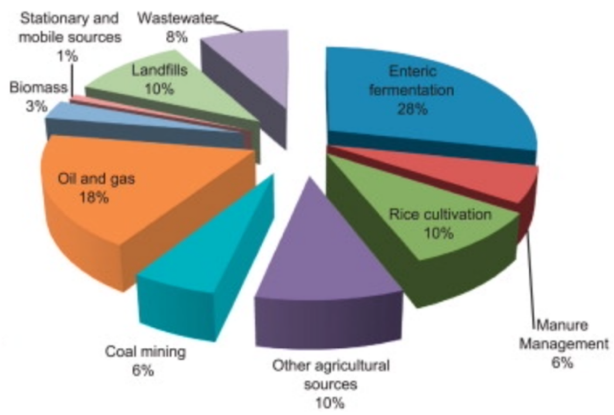
[1] https://www.weforum.org/agenda/2021/03/met-office-atmospheric-co2-industrial-levels-environment-climate-change/

[2] https://www.unep.org/news-and-stories/story/methane-emissions-are-driving-climate-change-heres-how-reduce-them

What's the big deal about methane?

Methane is one of the most harmful greenhouse gases and a major contributor to climate change. While it has a shorter lifetime in the atmosphere than CO_2, its global warming potential is bigger. Methane can stay in the atmosphere around 12 years, which is less than CO_2, which even though is part of the global carbon cycle some CO_2 can remain in the atmosphere for thousands of years.

Part of the methane emissions come from natural sources such as natural wetlands. Those emissions alone would not cause problems, as other natural processes and chemical reactions in the atmosphere help remove it and balance its levels. The human-made methane emissions are the troublesome ones. The CH_4 emissions coming from human activities represent 50-65% of the total.[3]



We can take a look at what are the main anthropogenic activities producing methane that is later on being emitted (Figure 1). The one that strikes us as the most problematic, and also bigger in proportion is enteric fermentation, accounting for up to a 28%. It is also worth noting manure management with a 6% of all global methane emissions.

Figure 1: Anthropogenic methane emissions by source in 2010.[4]

We can link both of these emissions, and many others, to farming. Enteric fermentation is performed by ruminants, such as cattle, sheep and deer. Out of those cattle is one of the pilar of farming worldwide. Dairy farming in particular, despite its local focus, is one of the largest global industries, with an estimated 270 million cows in the world.[5]

Dairy farming and GHG emissions

In western Europe, beef and especially dairy are the main protein sources produced, with more than 50% of the total, as stated in the Global Livestock Environmental Assessment Model by the UN.

This makes dairy farming a particularly interesting sector to focus on when we try to reduce emissions in Spain, or any other western Europe country.

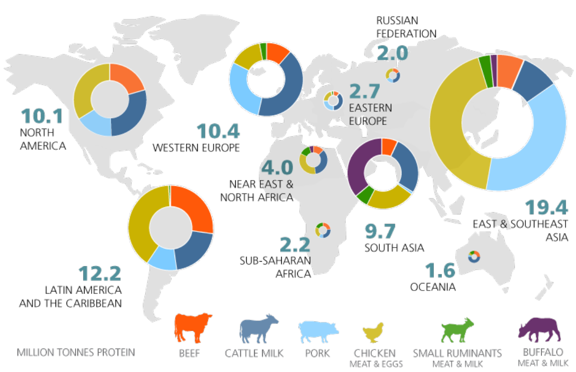


Figure 2: Regional protein production.[6]

[3] https://www.epa.gov/ghgemissions/overview-greenhouse-gases#CO2-references

[4] Rafiu O. Yusuf, Zainura Z. Noor, Ahmad H. Abba, Mohd Ariffin Abu Hassan, Mohd Fadhil Mohd Din, Methane emission by sectors: A comprehensive review of emission sources and mitigation methods, Renewable and Sustainable Energy Reviews. 2012.

[5] https://www.worldwildlife.org/industries/dairy

[6] https://www.fao.org/gleam/results/en/

This decision is not only backed up due to production volumes, if we take a look at emissions by species, beef and dairy cattle are again, by far, the biggest contributors.

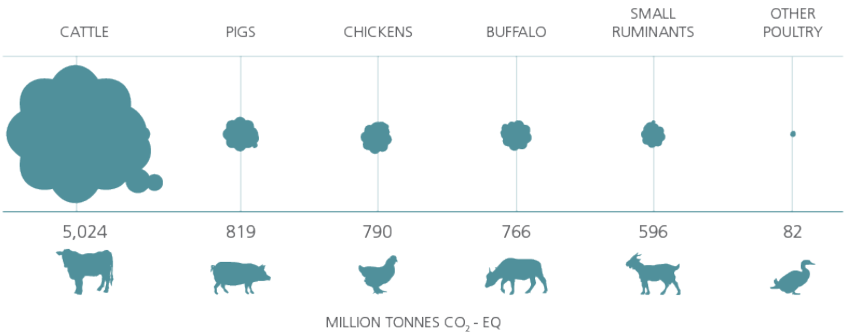


Figure 3: Global estimates of emissions by species.[7]

We can identify three main activities that produce greenhouse gas emissions in the dairy farming sector: feed production, enteric fermentation and manure management.

Feed production

This activity is mainly related to carbon dioxide emissions which come from:

- Expansion of feed crops and pastures into natural areas: As the production model has intensified so has the need of land to produce enough feed, getting to natural areas which were before involved in natural beneficial processes.
- Manufactures of fertilizers and pesticides: From this increase in feed production and as global warming effects arise the need for pesticides and fertilizers does too.
- Feed transportation and processing: In many cases it is cheaper for farmers to import feedstock from foreign countries, usually from South America, where crops like soy are produced in deforested areas.

Anaerobic fermentation

In ruminants, methane is produced mostly by enteric fermentation where microbes decompose and ferment plant materials, such as celluloses, fiber, starches, and sugars, in their digestive tract or rumen. Enteric methane is one by-product (along with carbon dioxide and hydrogen) of this digestive process and is expelled by the animal through burping.

While other by-products (acetate, propionate and butyrate) are absorbed by the animal and used as energy precursors to produce milk, meat and wool. Between 2 to 12% of a ruminant's energy intake is typically lost through the enteric fermentation process.[8]

[7] https://www.fao.org/gleam/results/en/

[8] https://www.fao.org/in-action/enteric-methane/background/what-is-enteric-methane/en/

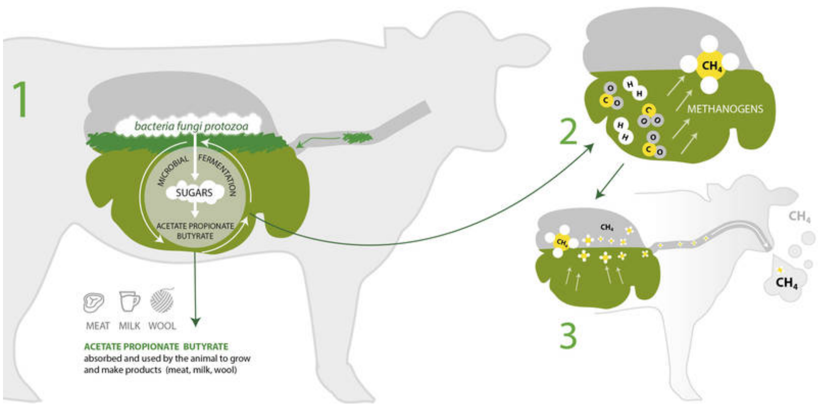


Figure 4: Enteric fermentation diagram.[8]

We have to bear in mind that an essential role is played by the way in which the animal's feeding is managed. For instance, the higher the portion of high-fiber ingredients in animal's diet is, the more enteric emissions are been produced. Currently, a lot work and research in finding the best way to reduce emissions suggest the possibility to modify animal's nutrition and therefore their digestion by using chemical and natural additives.

Manure management

Livestock urine and manure are significant sources of methane and nitrous oxide when broken down under anaerobic conditions. Anaerobic conditions often occur where manure is stored in large piles or settlement ponds to deal with waste from large numbers of animals managed in a confined area, as in dairy farms. Manure management has the greatest impact on the farm overall emissions, accounting for 60% of them.[9]

The manure management techniques that can be applied are closely related with the cattle diet and housing or pasture habits as they will determine the manure consistency and handling methods.

We can define three main strategies to deal with manure:

- Land spreading: The traditional way of disposing manure. Fertilizing crops with manure can bring undesired consequences such as increased ammonia emissions of soil nitrification. Before being spread, manure is usually piled which increases emissions.

Figure 5: Manure land spreading.

[9] A.C. VanderZaag, T.K. Flesch, R.L. Desjardins, H. Baldé, T. Wright, Measuring methane emissions from two dairy farms: Seasonal and manure-management effects, Agricultural and Forest Meteorology, 2014.

- Composting: By aerating manure piles anaerobic fermentation is reduced as well as the emissions produced by it. The use of compost also provides other greenhouse gas benefits, both directly through carbon sequestration and indirectly through improved soil health, reduced soil loss, increased water infiltration and storage, and reduction of other inputs.

Figure 6: Manure composting.

- Biogas production: With a biogas generation system, large volumes of manure are digested under low-oxygen conditions to produce biogas that is subsequently combusted to destroy methane and produce heat or electricity. The waste sludge is normally returned to the land as fertilizer, commonly after being separated into solid and liquid fractions.

Figure 7: Biogas production from manure.

Dairy farming in Spain

The dairy farming sector in Spain is not living its best time. Since society has realized the role of farming in climate change is has also blamed the farmers for the side effects of their job. While they just keep producing food in the same way their parents or even their grandparents did, they face a society who makes them responsible for that impact with little to no empathy. It is evident that the farming sector needs to understand their contribution to climate change, they need to be educated on how to do their job in a way that is the least harmful to the environment. Science and research are nowadays disconnected from the farmers reality, making them easier to deny their role in climate change and making nothing about it.

On top of that, the milk price paid to farmers in Spain is one of the lowest in Europe and it has been that way for several months now. The milk price paid to farmers only covers for 86% of the production costs, making farmers lose money.[10] Big milk distributors use it as an anchor product, selling it to consumers at low prices to make them visit the supermarkets in hopes that they buy other products. Because of this, the dairy industry has to keep its costs low and pressures farmers to buy their milk under cost, with no profit whatsoever. This has promoted the increase in size of the farming operations to try to increase profit by volume. In Catalonia, 31% of all livestock is gathered in 23 farms alone.[11] Because of this phenomenon small farms are disappearing, with more than 3 of every 10 farmers having lost their jobs since 2015.[10]

The government is already addressing the milk price matter with the last approved "Food Chain Law", that forbids a product to be sold under cost by any link in the food supply chain. In any case, we believe society should play an active role in this problem. While the dairy sector needs to be held accountable for its environmental impact, farmers also need public support to become educated on the topic and financial aids to implement sustainability initiatives in their farms.

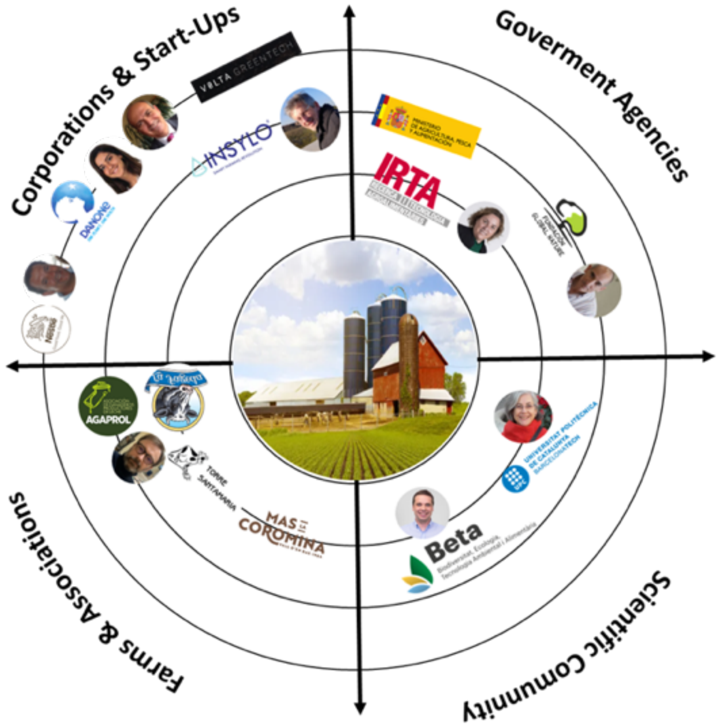
Figure 8: Number of dairy farmers in Spain from 2015.[10]

[10] https://agaprol.es/observatorio-agaprol/

[11] https://govern.cat/salapremsa//416509/consellera-jorda-anuncia-creacio-linstitut-llet-linia-financament-especifica-al-sector-lacticnotes-premsa

People and connections map

After trying to understand the situation of the dairy sector in Spain we mapped all the people and institutions involved, ending up with the following map.



Impact Gap Canvas

In order to obtain a deeper understanding of what is the problem to address and how it could be addressed, we developed an Impact Gap Canvas. This tool allows us to map the challenges related to our main problem statement, find what is being done and understand where the solutions are failing in order to develop a more aggressive and targeted stance.

As you may observe from the IGC below, we could see in many of the areas solutions already existed or presented problems we did not believe were the path forward. This understanding allowed us to take the route to a better solution as detailed in following segments of the dossier.

<table>
<tr><th>CHALLENGE MAPPING</th><th>IMPACT GAPS</th><th>SOLUTIONS MAPPING</th></tr>
<tr>
<td>

How do beef and dairy cows contribute to climate change?
4% of GHG comes from Dairy Farming globally. Cow's methane (x28 more heat than carbon dioxide).
Livestock agriculture is a source of methane, a powerful greenhouse gas.
Between 2005 and 2015 the Dairy industry increased its contribution by 18%.
A single cow releases around 250-500 liters of methane a day.
In Spain most dairy farmers do not produce their own feedstock.
Greenhouse gas cycles in agriculture.
Farmers have different view on their share tradition vs demands of reduction, could even be disbelief

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How to get precisely methane emissions data.
Additives are complicated to manage by farmers and are distrusted as a solution for health especially as they are expensive.
Manure processing solutions seem currently expensive especially the most impactful ones.
Complicated to balance protein needs in feeding vs carbon footprint of the crops.
How to deal with economic farmer's needs on a global crisis period.
Feedstock sourcing is difficult and highly impactful on the global footprint depending where it comes from.

</td>
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Now researchers are trying to breed them to burp less.
Energy use on farms.
Reducing greenhouse gas emissions through feeding dietary additives to milking cows.
Usage of manure for fertilizing: recycling cow manure to use as fertilizer.
Genetics of cow improving to produce more liters per cow and as such less methane per liter.
Mouth and breather methane capture on cows by start up.
Changes in the diet for cows are being tried to reduce carbon footprint of crops

</td>
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Primary research: interviews

To further expand the knowledge obtained through desk research, we reached to several experts and agents involved in the problem. After interviews with them, we extracted the following insights on the topic.

Maria Devant

Senior researcher on ruminant production at IRTA
(Institute of Agrifood Research and Technology in Catalonia)

Insights

- Current efforts targeted at reduction of emissions and nitrogen waste.
- High efficiency enteric fermentation through nutrition, little room for improvement in this matter except for new additives under research.
- Need to focus in manure management, bigger room for emissions reduction.
- Composting is being implemented in more farms, slowed down by investment costs.
- Difficulties for measuring methane emissions: high costs or low precision.
- Biogas currently difficult to implement, massive deployment costs.
- Intensive model not linked to less animal welfare.
- Young people required in the sector, increase in circularity.

David Frontela

Spokesperson for milk producers' association Agaprol
(Asociación de Ganaderos Productores de Leche in Spain)

Insights

- Producers are the weakest link in the supply chain compared to the dairy industry.
- Milk production has increased in the last years but still does not meet the country demands.
- Milk price remains low and almost stagnated for the last 2 years.
- Milk is used as an anchor product at supermarkets to incentivize sales.
- Intensive farms are required to meet the milk demand, Spain's territory would not allow relying solely in extensive farms.
- Sustainable initiatives are mostly motivated for regulations.
- Some big farms can afford composting or biogas, mostly experimental for now.
- Small farms need economical help to stay afloat.

Roser Romero

Agroalimentary and Biotechnological Engineer at UPC
(Universitat Politècnica de Catalunya in Catalonia)

Insights

- In Spain all milk is sold at different prices because of their quality, a base price is established and bonuses can be added if it meets certain properties.
- Regulation is very strict regarding concentration of antibiotics and other contaminants.
- In the dairy industry some sustainability initiatives have been taken.
- The farming model has shifted towards a more intensified one, getting better profits to make up for low milk prices.

Sergio Ponsá

Director of BETA Technological Center
(Technological Centre in Biodiversity, Ecology and Environmental and Food Technology in Catalonia)

Insights

- Increasing the farming sustainability goes from beginning to end: since feed production to the end product.
- In many cases feed production accounts for the majority of the impact.
- Enteric fermentation is difficult to mitigate although some improvements have been made through additives and diet modifications.
- Manure management is key in improving sustainability and increasing circularity.
- Retrieving elements such as nitrogen or phosphorous from manure is really interesting.
- Nowadays nutrition is being more targeted (to increase production efficiency) than manure management.
- Sustainability initiatives in the sector are either economically or legally motivated.
- There is room for innovation in decentralizing manure management.

Esteve Farrés

R&D engineer for Insylo
(IoT sylo management startup in Catalonia)

Insights

- Need to improve feed storage and logistics in farms.
- Data was the main barrier, how to predict deliveries and start producing when they did not know the farm stock precisely.
- Improving logistics and reducing transportation increases sustainability.
- Remote data obtention through IoT sensors and analytics.

Alicia Palmero
Sustainability junior at Danone

Insights

- Danone is publicly committed to reducing their CO2 emissions and are *BCorp* certified.
- Every decision needs to respond to climate and social crisis.
- Identified opportunities for methane reduction: soy, additives and biogas. Also increase in efficiency, nutrients recycling, etc.
- Rural depopulation also needs to be targeted along sustainability.

Pepe Yagüe
Milk Quality and Sustainability Manager at Danone

Insights

- Two types of contracts regarding milk price: indexed-based (most common) and cost-model (negotiating profit for 4-5 years, only for the best producers).
- Intensive and extensive farming can both be sustainable.
- Animal welfare is measured with the Welfare Quality Standard.
- Emissions per farm are calculated with the Cool Farm tool.
- Importance of farmer training in several topics, including animal welfare.
- Plant-based alternatives to dairy already account for 15% of Danone's business.
- Farmers want to contribute to sustainability but they are already struggling to pay the bills.

Pedro Ruiz
Environmental Sustainability Engineer at Nestlé

Insights

- A sustainability roadmap is key for every company nowadays.
- Three emission scopes can be defined: directly from facilities, from bought electricity and from the supply chain (in which farms account for more than 50% of the environmental impact).

Eduardo de Miguel
CEO of Foundation Global Nature

Insights

- Foundation Global Nature is focused on reducing the carbon footprint and promoting biodiversity in farms.
- Currently targeting extensive farming, cereal farming, vineyards, etc.
- Need to focus on targeting intensive farms, which nowadays account for 60% of the end products.
- Three main focus points: enteric fermentation, feeding and manure handling.
- Self-sufficient feeding is a challenge, 50% of the animal protein comes from imported soy. Need to recover local cultivation of protein.
- As consumers we need to use the power of choice to advocate for sustainable practices.

Primary research: visits

To get a deep understanding on the topic neither the desk research or the meetings with experts were enough, we felt we needed to get to know farmers first-hand. Not just to ask them about the sustainability of their farms but to hear their concerns, and how connected and aligned these are with the reduction of emissions.

After reaching out for visits we were rejected several times, mainly due to misgivings about our intentions. We mentioned the lack of public support farmers are facing and because of that, some of them did not want to face an interview at risk of getting a bad image. Either way, two farms were willing to speak to us and let us visit their facilities.

Granja Cal Rei
Vic, Catalonia, Spain
Intensive small size dairy farm

- 150 milking cows
- Manure disposal: Water cleaning, solid separation and land spreading.
- Selling milk through a local association of farmers.

This farm started in 1973 with just over a dozen animals for the Tañá family self-consumption. Nowadays it has around 150 milking cows and 55 hectares for producing cow feed.

After speaking with the owners, we could corroborate the struggle farmers are facing regarding milk price. That insecurity regarding profit that has been going on for around 2 years is making them reconsider every investment they want to make in their farm.

They have a project to upgrade their farm with new infrastructures, one of them to allow for manure composting. The family's new generations are the ones interested in this new project and are hoping to get UE funding for young farmers to carry it out. Regarding sustainability they say are heavily supervised to comply with regulations.

Overall, they are also worried about the loss of jobs in the countryside, the increase and uncertainty in the feed price and the low milk prices, which all cause a poor financial situation for farmers like them.



TORRE
SANTAMARIA

Granja Torre Santamaria
Lleida, Catalonia, Spain

Intensive big size dairy farm

- 2000 milking cows
- Manure disposal: Barn scraping, biogas production
- Selling the whole milk production directly to a big milk company.

Located in Vallfogona de Balaguer and also started as a family business, Granja Torre Santamaria gathers nowadays more than 2000 cows in their facilities. Their farming model is intensive, complying with the latest animal welfare certificates.

The farm produces around 50% of the feed they require, while they buy or import the rest.

They confirmed once again the struggle with milk price. In their case, being a big farm, they looked for ways to diversify their sources of income to not only rely on the milk profit.

Some years ago, they were pioneers in installing a small biogas plant that allowed for the farm electricity self-consumption. But it wasn't until 3 years ago when they considered building a biogas plant to process all the manure the cows generate. When the owners were looking for funding for the project, the COVID-19 pandemic struck and all the plans were stopped. After that they were contacted by a Swiss company interested in buying the biogas generated by the plant and at the end, they also provided the funding required.

Their biogas facilities are one of the firsts in Catalonia and in Spain. They incorporate an upgrading plant that allows for biogas to be purified and later on injected into the grid gas pipes. The project has only been working for some months, but an expansion project is already drafted that would allow the farm to process manure from farms nearby. While this manure processing technique is beyond interesting the whole cost of the infrastructures was about 4.5 million euros and requires a full-time technician for plant monitoring.



System map

The challenge we are facing is broad and as we have seen involves lots of different actors each with their one interests, relationships, problems, etc. The problems that we face in this context are complex and resolving one of them always impacts the rest. That is why systems thinking is a methodology we applied in our research. Systems thinking is a way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than by splitting it down into its parts.

As a visual way of representing the relationships and the system as a whole we developed the following system map.

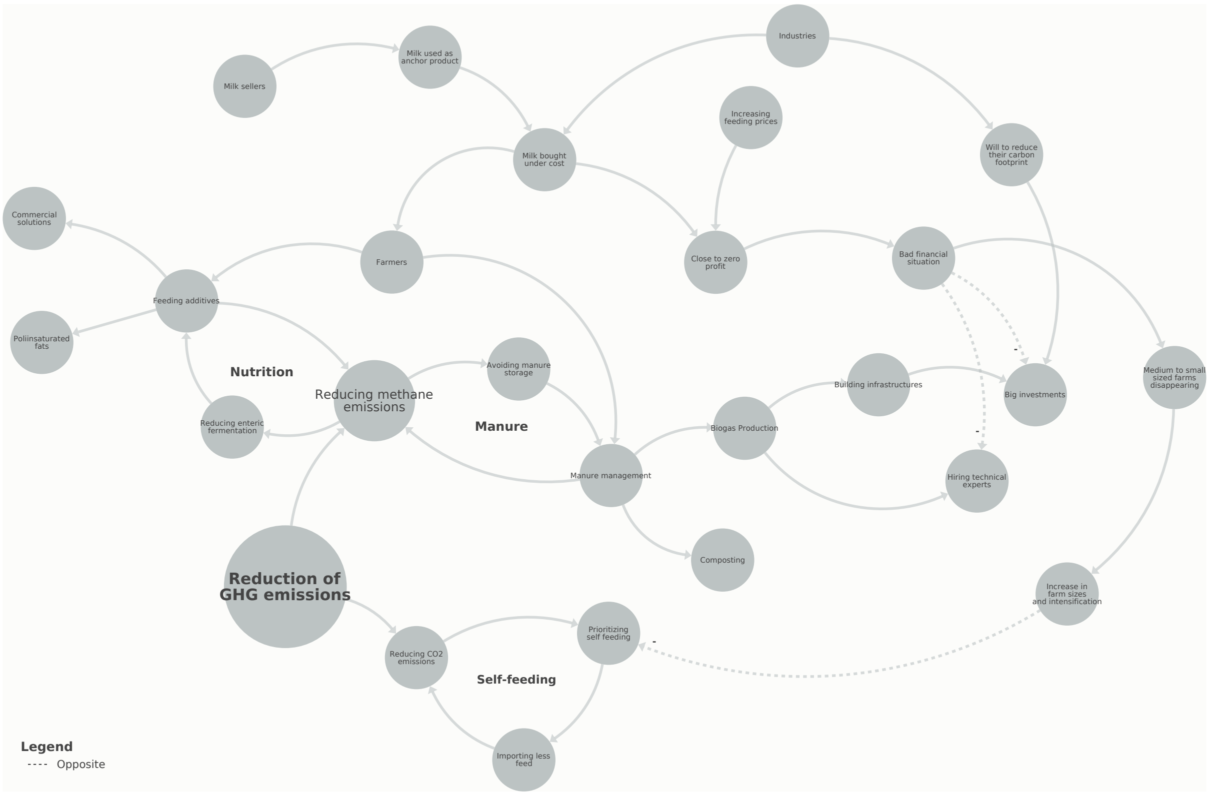


Figure 9: System map of the challenge.

Concept Development

Defining the problem and ideating a solution

Rephrasing the challenge

Following the course's design thinking methodology this represents the first step, which is empathizing with the challenge presented, to end up with a solution to it.

At this point we had what we considered to be a fair understanding of how a reduction of greenhouse gas emissions in cattle farming could be achieved or at least some current strategies to do so. And more importantly, we had knowledge of the connections, interactions and interests of most of the people involved in this problem.

This allowed us to rephrase the challenge:

"How can we bring a reduction of GHG emissions from dairy farms in a way which we don't damage their way of living (and income), which is vital for thousands of people and communities across Spain?"

From there we defined some possible paths to target this challenge.

Nutrition

- Explore chemical and natural additives that reduce methane emissions from cows' digestion. In this regard we investigated into algae-based additives, which propose a strong solution to be grown in self-contained installations.
- Prioritizing crops grown in the farm surroundings to decrease soy importing. A possible achievement would be a platform to put contacts farmer-to farmer and supplier to farmer opening it up and making more transparent the solution, as well as using available land to a better solution and supporting new business avenues.

Manure management

Working into creating a way to reduce cost and make more accessible the available technologies for the treatment of manure (mainly anaerobic digesters), as well as implementation for generating value for the operations (transforming to natural gas and energy) through usage of AI and other fundings or initiatives.

Transition to a new milk production model

Shaping a future in which milk production does not rely only on cattle but also on plant-based alternatives, lab-made synthetic milk, as well as extensive farming. So that we stop seeing cattle as only a food resource but as a living being.

Defining the problem

From the known possible strategies to target the challenge we rephrased and according to our research the next step was to define the problem that had the biggest impact on emissions coming from dairy farms.

Having manure management generated emissions account for 60% of the total and the need to increase the farmer's milk profit, the defined problem was:

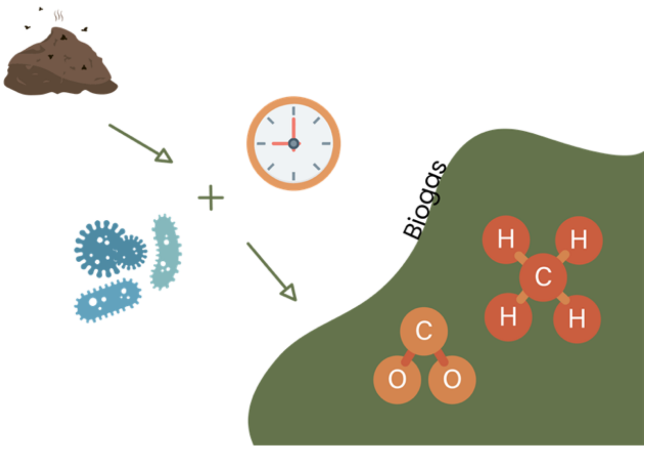
HOW TO MANAGE MANURE IN ORDER TO REDUCE METHANE EMISSIONS WHILE PROVIDING FARMERS WITH NEW INCOME SOURCES.

To tackle this issue, we found biogas production to be the most promising manure management technique, allowing the most drastic emission reduction of all alternatives. This was our first iteration on the design thinking process to reach a solution.

About biogas production

What is biogas?

Biogas is composed of methane at relatively high percentage (50 to 70%), carbon dioxide, hydrogen sulfide, water vapor and trace amounts of other gases. In order to produce it, we need a natural process described earlier, called anaerobic digestion (AD), in which bacteria break down organic matter in the absence of oxygen. We can use mostly biogas as cost-effective energy source and renewable natural gas to provide heat and generate electricity. Furthermore, with biogas we obtain 5x times less CO2 equivalent emissions from energy consumption, in other words, it is much more friendly to our planet.



Biogas production is particularly interesting applied to manure processing, allowing us to generate value from a residue that generates emissions. In the diagram below the inputs and outputs from the process are detailed. The impact of biogas production from manure is pretty much circular, supplying products that farmers need on a regular basis such as fertilizer, cow bedding or electricity.

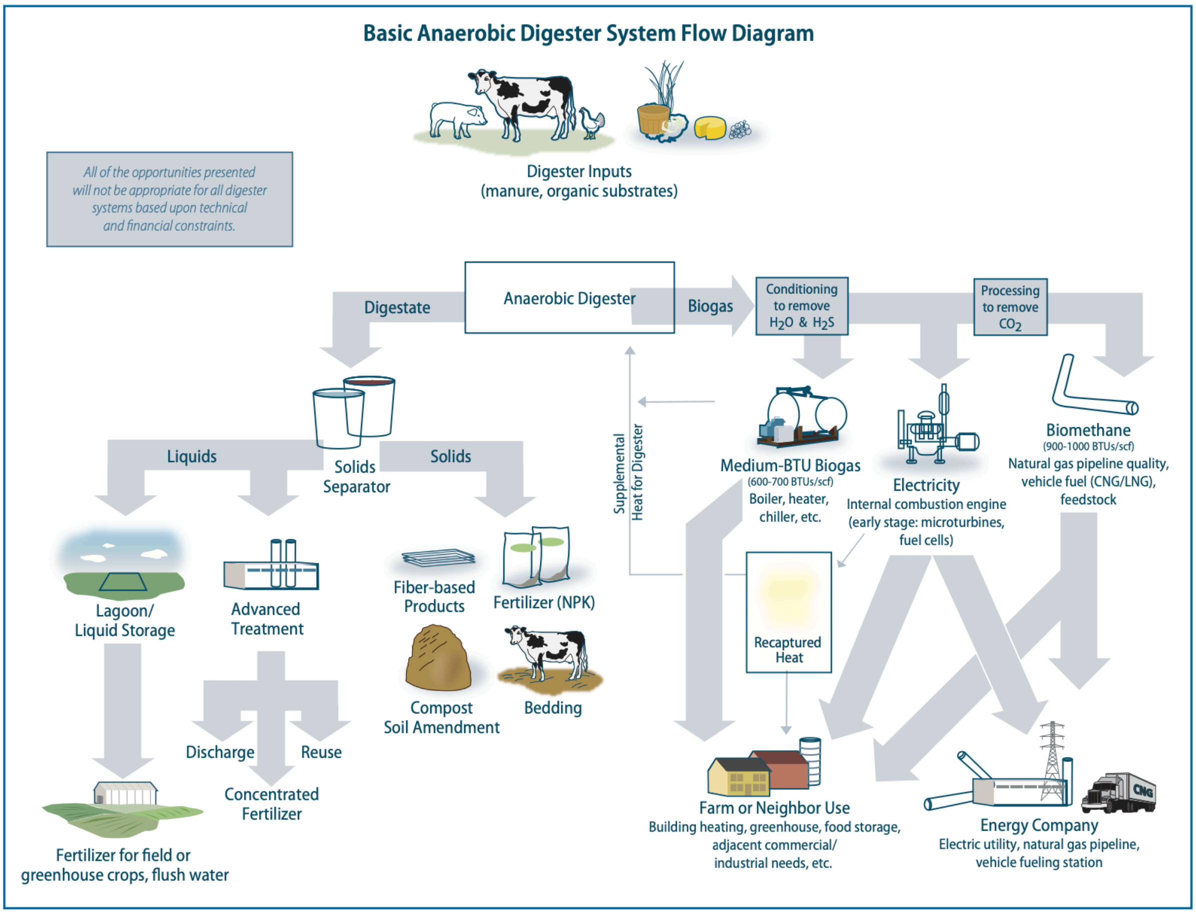


Figure 10: Diagram showing outputs of the biogas productive process.[12]

To further understand the process where biogas is produced, we find helpful explaining the following terms:

DIGESTER INPUTS

Anaerobic digestion is produced with any kind of organic matter but cow manure is particularly interesting because it already includes bacteria. To minimize the impact in emissions and increase the overall sustainability of the process it is desired to maximize the biogas production. To do that, other feedstock can be incorporated in the digester such as wastewater biosolids (e.g., municipal sewage sludge), food waste and other organics (e.g., fats, oils, crop residue).

DIGESTER

In the biogas plant reactor or so called biodigester is where anaerobic digestion (AD) for biogas production occurs. It is mainly a tank without oxygen where AD is established in different phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis.

Regarding digester design and size, there are different types depending largely on the technology used in the process and the properties of the manure fed into it.

[12] https://www.epa.gov/sites/default/files/2014-12/documents/recovering_value_from_waste.pdf

The three most common ones are:

- Covered lagoon digesters: sealed lagoon where manure just sits during retention time.
    - 30 to 45 days retention time.
    - For liquid manure, low in solids (0,5% to 2%).

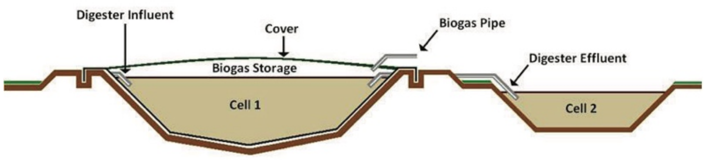


Figure 11: Schematic of a covered anaerobic lagoon digester.[13]

- Plug-flow digesters: long channels with rigid or flexible covers in which the manure flows along as a plug where the flow is constant through the digester.
    - Simple to operate.
    - 20 days retention time.
    - Low energy requirements (no stirring).
    - Semi-liquid manure (11% to 13% dry matter), scraped from the barn.

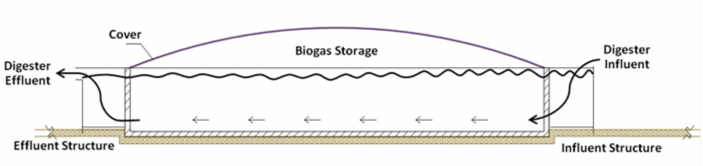


Figure 12: Schematic of a plug flow digester.[13]

- Complete mix digesters: Large enclosed heated tank with mixing system where fresh material is mixed with an active mass of microorganisms.
    - Bigger energy requirements (mixing needed).
    - 20 to 30 days retention time.
    - Lower dry matter content manure (4% to 12%) or diluted with water.

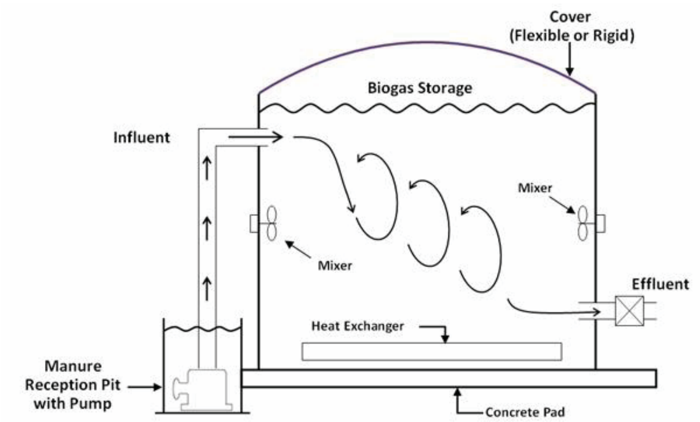


Figure 13: Schematic of a complete mix digester.[13]

[13] http://epa.gov/agstar/anaerobic/ad101/anaerobic- digesters.html

DIGESTATE

As part of the anaerobic digestion process a by-product called digestate is produced, that can be separated into liquid and solid portions. With appropriate treatment, both fractions useful coproducts and have many beneficial applications. For instance, solid portions can be used as animal bedding or organic-rich compost. Both liquid and solid portions have an important value and use in nutrient-rich fertilizers.

ELECTRICITY GENERATION

The most typical use case for biogas generated in farms is electricity generation with a cogenerator, that also provides heat. While it is obvious that energy can be used to power the farms facilities or neighboring houses, heat can be used to increase the digester temperature for optimal efficiency or to heat farm facilities and houses as well.

Worldwide and European biogas production

As we have been seeing in the past months, due to the international crisis caused by the conflict between Ukraine and Russia, natural gas dependency is a very relevant factor for the proper economic development and stability of a country, as so many realized by now. It is time to reconsider, now more than ever, the use of biogas as one of the main clean energy sources.

Nowadays, renewable gases production is worldwide low and it has high costs. Nevertheless, more biogas and biomethane is generated and with higher production volumes than low carbon hydrogen. Last year, the International Gas Union (IGU) after several studies and analysis, concluded that global biogas and biomethane production was equivalent of 1% of the global natural total gas production, and half of it came from European countries.

It is important to mention that most part of the biogas generated is often consumed by rural communities right next to the biogas plant, which cogenerates heat and energy. And little biomethane quantities are being injected into the grid, mainly in Denmark and German. This grid injection has regulations that demand an advanced biogas process called upgrading, through which carbon dioxide is decreased, obtaining then a higher biomethane purification. The infrastructure that allows for upgrading biogas requires in most cases big investments as its cost is high.

Biogas production in Spain

Spain has currently 6 biomethane plants in operation, one of which as mentioned before, we were able to visit, at Granja Torre Santamaria. It is the only biogas plant in Spain that has a livestock residue origin and also a grid injection point.

Name	Location	Grid Injection	Residue Origin	Production (Nm3/h)	Production (GWh/year)
Bens	A Coruña	Yes (distribution)	EDAR	100	8
Planta de Tratamiento de Biogás del Parque Tecnológico Valdemingómez	Madrid	Yes	Urban	2093	180
Planta Elena	Barcelona	Yes	Dump	140	12
Torre Santamaría	Balaguer	Yes	Organic-livestock	350	30
Unue	Burgos	Yes (distribution)	Food industry	300	26
Vilanant	Girona	No	Livestock	200	17

Table 14: Spain biomethane plants in operation by GASNAM source in 2022.[14]

There is an increasing number of biogas plants under construction throughout the peninsula. Over the past few years, being able to generate energy that can be consumed in a decentralized manner without depending on external agents, seems to be a sought-after future progress for many companies, including livestock's ones. However, big investments are needed allowing only farms with high capital to build industrial scale digesters and biogas plants. It implies also an added complexity and work when it comes to operate the plants, due to largely to the current trial and error method of production used.

FARMM: Our solution

As was described earlier, the defined problem within our challenge was the following:

HOW TO MANAGE MANURE IN ORDER TO REDUCE METHANE EMISSIONS WHILE PROVIDING FARMERS WITH NEW INCOME SOURCES.

After digging into biogas production as a possible solution to the problem, we identified infrastructure cost and the need of expertise to operate the facilities as the main pain points. To overcome them we would need a model that solves the economic aspect when it comes to implementing biogas facilities and, in addition, to be able to provide a good analysis and control of the biogas plant without hiring staff, in order to achieve great production efficiency while not increasing the farmer's workload.

14

https://www.google.com/maps/d/u/0/viewer?mid=1RjYh2lYt4cCsWjr1nvRDVxgS0WWpz0PS&ll=42.254360000000005%2C2.9046227000000036&z=8

Considering everything until this point, we propose the following solution:

A Decentralized and automated system that allows for biogas production in standard-sized farms as a subscription system

With the main characteristics of that system being the ones following:

ZERO Infrastructure cost

Our solution involves zero investment cost for the farmer, we will deliver the entire system from design, to permits and building the infrastructure. This will allow the main concern of our users to be resolved: **the initial capital investment to deploy the biodigester system.** By eliminating this problem adoption rate should only be limited by our funding capacity to build the systems.

Regarding the farm and its facilities, we aim to achieve a low construction cost by reusing current farm infrastructures. It implies that the existing facilities will not have to be destroyed, which would entail an economic and time expense, but rather we would adapt to the already existing ones, as far as possible. For instance, by building plug-flow digesters, which are easier to operate as we have seen before, and by making partial use of the farm current facilities, costs would be reduced considerably.

In order to support financially the solution, we will apply a two-tier financial compensation mechanism: A subscription fee and the selling of excess electricity produced to the grid, which will be detailed further in the document.

IoT, Sensors and Data

An IoT system for data gathering will be developed with a complete sensor solution that allows for real time analysis and data reporting on digester efficiency and biogas production state. Because anaerobic digestion process is a biological process and varies over time, with non-linear and highly complex system, what is called soft sensor based deep learning will be implemented.

As we will be creating general performance models from Ai as well the high prediction accuracy of the sensors, which would extract deep features and dynamic information, we will **avoid the current trial and error method** of control and optimization which can be observed in most biodigesters systems implemented in non-industrial dairy farms. All information captured by sensors including: monitoring temperature, flow rates, Gas level production, methane production, production parameters and highly important sustainability impact of the Biodigester; will be sent to our servers, which will analyze it and determine if some action has to be performed, **automatizing the action-decision making process** in order to achieve optimum levels of biogas production with minimal human effort.

It should be noted that as our solution is implemented in more farms-users, we will be able to analyze the information from different farms in a network effect allowing our algorithms to learn from each farm and create best practice models. In other words, the more data is gathered, the better and faster the system would evolve towards a future where both the farmer and our planet benefit. This data gathered can also be helpful for dairy companies to assess the sustainability of their supply chain.

SMART INTERVENTIONS

The farmer can easily check how the plant is going at any time through an online dashboard with real time data. The dashboard will provide him the necessary information to determine if a simple intervention is needed for optimal production. For instance, it would let the farmer know when the digester needs to be fed or emptied, and its amount. A technician intervention would be automatically scheduled, depending on that real time automated data analysis, either for routine maintenance purposes or in case an anomaly was detected. All of these decisions performed by AI models would allow for the facilities to always run smoothly without needing to hiring staff or requiring the farmer to be trained on biogas plants maintenance.

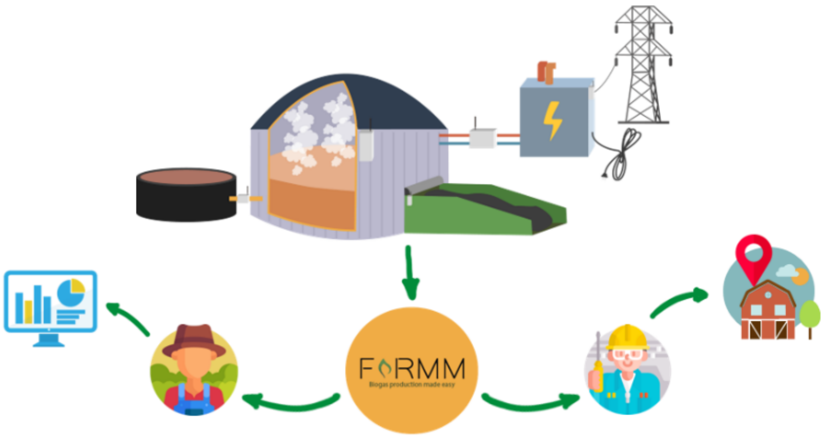


Figure 13: Scheme on how the system parts communicate (further explanation on video).

FARMER BENEFITS

One of the main profits that the farmer would experience is the **self-produced energy through biogas**. In addition, being self-sufficient in green energy brings the farmer closer to regulations in terms of sustainability, by reducing manure management costs and lowering gas emissions. Furthermore, the farmer obtains digestate which can be used or sold as a byproduct (e.g., fertilizer) and consequently it would imply **less dependency in external fertilizer** supplier companies.

As its noted in our solution, ZERO capital investment has been required from the farmer, so in order to finance the system a low subscription fee will be applied. This fee will be lower than 50% poof the electricity bill prior to biogas self-energy production creating **always immediate cash savings** to the dairy farm operations. In the Value Creation for Customer section of this dossier you can read a run of how much it would be and the cash savings.

ENERGY GRID INJECTION

FARMM's second source of revenue is the selling to the wholesale grid the excess energy produced by the Biodigester from the farmers biogas. At this point in time of the business model from year 7 onwards we will then share in a split 50%-50% the revenue generated with the farmer to give a secondary source of income and cash flow to his operations.

Validation

To validate our proposed solution to the identified problem, we contacted a researcher specialized in manure management, allowing us to verify the given assumptions and get some feedback on the actual implementation.

Belén Fernández

Researcher on Environmental Technologies specialized in anaerobic digestion at IRTA
(Institute of Agrifood Research and Technology in Catalonia)

Insights

- Centralized or decentralized models are respectively extended in different areas in Europe. Decentralized systems more extended in France.
- Information on what parameters to monitor and about the sensors to use.
- Mixing usually causes better biogas production efficiency, so it is always preferred.
- There are lots of possibilities for reusing digestate, ranging from fertilizer (without more processing) to generating bioplastics.
- Our idea looks viable to her, although a more thorough assessment would depend on the characteristics of each farm.

Circular Impact

Our objective is to create a circular impact in which our system model solution, farmers, and society at large interact and benefit each other in a sustainable way. We find it to be the best way to progress and adapt over time, as technology evolves, and new necessities are involved in the self-sufficient system.

Farms would be fully self-provided energy and all excess energy would be sold by us to the grid as they receive all our worry-free solution. Cleaner energy would be injected into the grid, being that our main economic source of income. Technical jobs would be created, as our important objective of making public and farms reconcile is achieved.

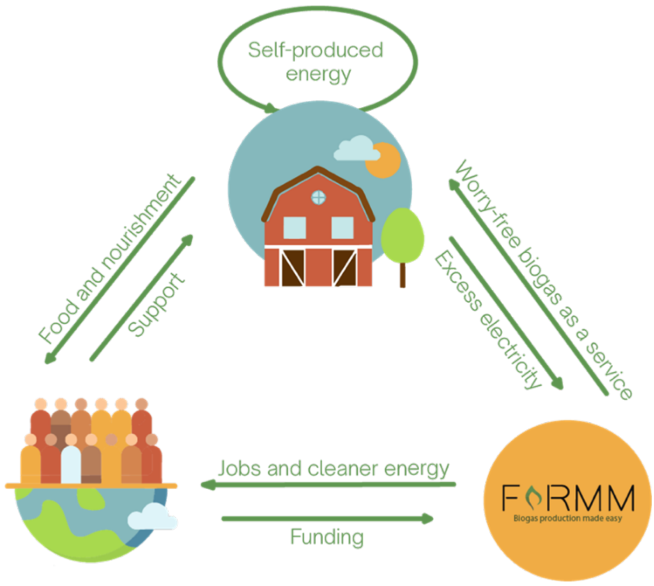


Figure 14: FARMM circular economy model.

Impact Model Canvas

In order to ensure our solution aligns with our understanding of the key insights obtained through our research, as well as to understand the deeper impact it can cause in society as a whole, we have elaborated an Impact Model Canvas (figure 15) in which we can observe in detail the needs and objective our solution has in order to create a real sustainable solution in concordance with FARMM circular economy model (figure 14).

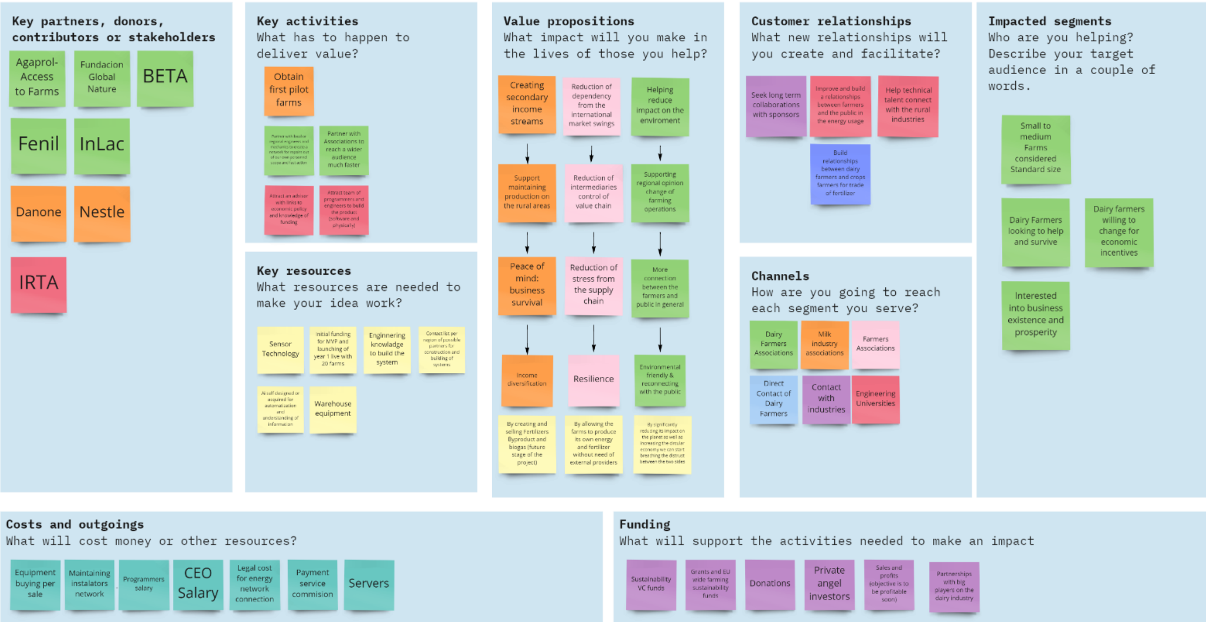
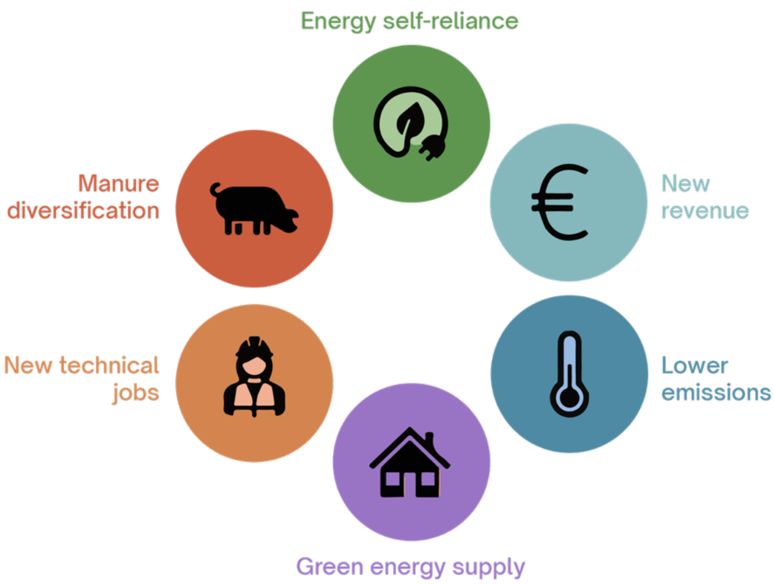


Figure 15: FARMM Impact Model Canvas.

Our vision of the future

The proposed solution model has the ability to shape its own elements depending on farm's needs and wishes. Furthermore, it can evolve over the years with great impact at all sustainable levels: economic, social and environmental. Some sustainable future targets are the following ones:



At this point, it is worth mentioning before the business case that our solution can be applied to approximately thirty-five hundreds standard sized farms in Spain which account for over 70% of all the dairy cows.

Energy self-reliance

It is essential that farmers stop being subjected to energy dependency, we help them providing complete grid independence with a green and much more sustainable energy source. It goes without saying that the farmer must be master of his own destiny and in order to achieve that, energy self-reliance helps a lot in terms of financial freedom. If fully deployed across the dairy farm industry we could ensure close to 100% energy independence in the sector.

Manure diversification

The diversity of organic matter that can be added to the digester, leads to new ways of manure diversification. The more manure a biogas plant has, the more biogas is produced. Therefore, a new stage to explore opens up. It might involve transport and distribution of manure, as well as the chance to use then manure from different animals and making the farmer grow at facility and economic level. As a result, FARMM could be easily applied not only to dairy farms but all livestock production including pigs. This expansion of our project to other segment of the economy, we estimate that could bring up to 7% of all the natural gas used in Spain.

New technical jobs

The biogas plant requires good maintenance policies and qualified technicians. In order to be able to maintain the network 100% operative, new technical jobs will be brought into the countryside in the building and maintenance phase of each digester. With regard to the maintenance and control of the servers where all data is gathered, it also requires a team of engineers and computer scientists. We would be helping then to generate new technical jobs for the rural areas. We estimate that more than hundred permanent technical jobs for our rural communities would be created.

Green energy supply

The excess of green energy generated that the farmer does not need for the farm operation is then injected into the grid. Taking into account the average energy consumption of a house in Spain, according to values provided by REE (Red Eléctrica de España), we calculate that we would power completely (heat and gas) over 70 thousand homes, which represent the entire city of Burgos in Spain.

Low emissions

Biogas production, as mentioned before, is one of the best ways to manage manure. We calculate that with biogas we obtain 5 times less CO2 equivalent emissions from energy consumption. With that been said, a drastic reduction of dairy farms emissions (mainly methane) to the environment would be performed.

New revenue

An increase in revenue sources is estimated and valued over 100 million euros per year in energy savings for the farmers. It was calculated by making and average of total dairy farms in Spain, which are between 11 and 13 thousand, and by estimating the farmer profits in the worst case.

Business Model

The Market

The Spanish market for farms is highly fragmented, ranging from dairy farms which only a couple dozen cows to the so called "Mega-Farms" containing thousands of cows (as we could call Granja Torre Santamaria one of our visited operations). In order to understand how the market (dairy Farms available) exist, we divided it into three segments:

- **Micro-farms:** These operations are limited in size and availability of funds, micro farms are what many in the public may idealize farms to be like, a farmer with thirty-forty cows and usually struggle financially greatly as cannot generate enough production to follow stricter and stricter regulations. In these segments we have included farms which own **below 100 dairy cows.**
- **Standard-Farms:** Operations which have an increased number of dairy cows, which permit them to reinvest on the farms itself and live of the operations for the owner's family (as well financially stronger to dream of passing down to next generation). These operations are struggling financially because of low milk price, however are more technical and professional ones, many appearing from consolidation of smaller failing micro-farms. The need of these operations is to be able to stabilize income, diversify sources of cash as well be able to comply with regulations to avoid further consolidation into mega-farms. In these segments we have included farms which own **between 100 to 500 dairy cows.**
- **Industrial Farms or "mega-farms":** Operations which are economically much stronger than smaller ones, able to create investment plans and follow through as well much more industrialize production as they can range into thousands of cows. These operations can re-invest on their own into more expensive and industrial level facilities, as well by volume of cows and efficiencies generated are able to weather lower price of milk and acquire failing farms. **Above 500 dairy cows.**

Total Market Size

We have estimated the total available market size based from the information contained by the Ministerio de Agricultura, Pesca y Alimentación latest report on the subject: Estructura del sector vacuno en España y la UE 2016-2020 in order to obtain as precise as possible information. Our estimations are contained in Table 2 below:

Total Available Dairy Farm Market Spain				
Market-Subdivision	**Quantity**	**% of dairy farms**	**Total Cows**	**% of dairy cows**
Micro-Farms	9146.00	69.9%	134550.00	16.6%
Standard Farms	3780.00	28.9%	552029.00	68.1%
Industrial Farms	160.00	1.2%	123909.00	15.3%
Total amount of Dairy Milk Farms (2020)	**13086.00**	**100%**	**810488.00**	**100.0%**

As it can be observed in Table 2, the Spanish dairy farm market is completely unbalanced with 1.2% or 160 industrial farms managing the same number of dairy cows as 69.9% (or 9146 micro-farms) farms. This aligns with what have been mentioned previously in our dossier by the consolidation of the sector into bigger farms.

However, we must notice that what it has been called the Standard size farm by our team remains with near 70% of all the dairy farms making it of high interest for our solution as well as a stop gap to avowing further consolidation into industrial farms.

Market Segmentation

In order to follow our ruling objective of our solution we must decide which of the market segments our solution will target. To do so we used three important aspects to make our decision:

1. Highest impact with the quickest deployment.
2. Economic viability.
3. Technological acceptability.

Using these three points as guidance and as provided by our concept in the dossier we have decided that the segment of the market to initially target will be the **standard size dairy farms.** Mainly due to them containing near 70% of the cows, making the highest impact in the environment and sustain our objective to support the reduction of farms consolidations into mega farms. But also, being the ones where it is most economically viable to do so, while resources for making it on their own are scarce as learned from our research.

Network effect to bring more people into the system by word of mouth and personal confirmations (highly important in the dairy farm business as personal trust is highly valued) is key to the initial deployment of our solution. As such possible locations to start must be determined with this goal in mind, we have separated the location of the farms by the main six regions and the rest, as can be seen in figure 16 below.

The main region to target is Galicia with over 1654 dairy farm operations, Castilla y Leon with 457 followed by other regions. However, it is clear that all six regions mentioned below will be the main focus of operations based on network effect and partner needs, and will be mentioned later for funding rounds.

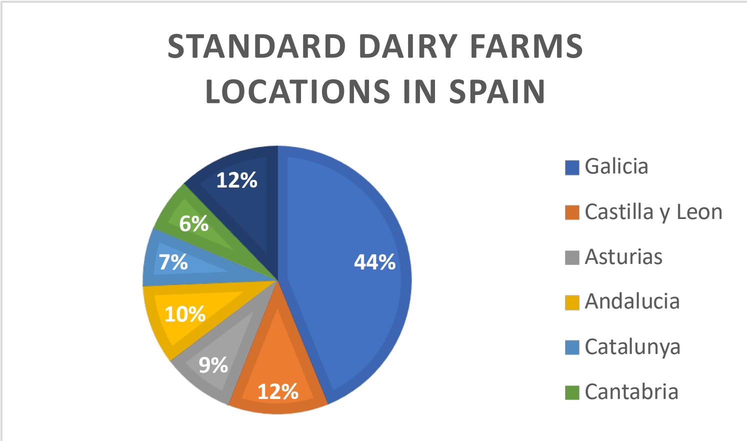


Figure 16: Location of Standard size dairy farms in Spain (estimated from the source)[15]

Market Value

In order to assess the economic impact and the financial viability of our solution itself we have assessed the estimated value of the total target market (standard size dairy farms) as its detailed in table 3 below:

Total Estimated Target Market Value			
Total Market Value Product		**Market Value Subscription**	
Average facilities value of our System	€ 140,000.00	Average monthly Subscription	€ 906.17
Target Market Size	3780.00	Average Yearly Subscription	€ 10,873.99
Total Estimated profit (20%)	€ 86,940,000.00	Total Subscription Market Size (monthly)	€ 3,425,322.60
Total Target Market Value (average)	**€ 529,200,000.00**	**Total Subscription Market Size (Yearly)**	**€ 41,103,682.20**

Table 3: Estimated Total target market value according to our calculations based on average size and income.

[15]https://www.mapa.gob.es/es/ganaderia/temas/produccion-y-mercados-ganaderos/estructurasectorvacunolechero2016-2020def_conue_tcm30-540399.pdf

Our market size value is divided into two which bear further explanation:

- **Facilities value:** This contemplates the average cost of the biodigester and infrastructure that will be deployed in an average size dairy farm of 200 dairy cows. It is important to notice we use an average cost, as infrastructure cost may vary farm to farm based on terrain, available reusable infrastructure, type of digester to use, manure characteristics, and other factors. Our solution is targeting an average profit of 20% of the value of the facilities, as this profit funds operations expansion as well as other costs of the company itself.
- **Subscription Value:** As it has been mentioned, in our solution model a subscription fee will be applied to the farms in order to cover for the cost of the facilities, as well as all the server and AI-Driven controls and production (including our maintenance crew and so on). This subscription is paid by the farmer instead of the usual electricity bill (the subscription is always below 50% of what he usually paid monthly for electricity to generate him savings).

As it can be observed in table 3 our subscription model will generate in the first life of the biodigesters (average of 20 years) near **€ 822,073,644.00** (at average subscription value) adding to the total possible market value of our facilities. We believe the complete **target market value** of our solution to reach over **1 Billion Euros** in the life value of our facilities.

Economic appeal and Validation

Value creation for the customer

Value Creation Average Farm User		
# of Cows the Farm has	200.00	
Biogas produced (m3) per day	80.00	
Dairy Farm Energy Generation (kWh per day)	560.00	
Savings		
Monthly Energy Savings	€	1,952.75
Monthly Fee	€	906.17
Total Monthly Savings	**€**	**1,046.58**
Yearly energy savings	€	23,433.00
Yearly energy Savings After subscription	€	12,559.01
Savings until year 7	€	87,913.10
YEAR 7 onwards		
Extra Revenues by energy selling per year	€	4,420.15
Lifetime value creation		
Energy Savings (20 years)	€	251,180.29
Extra revenue from energy selling from 7 year onwards	€	57,461.95
Total extra revenue generated for the Farm in lifetime cycle	**€**	**308,642.24**
Total investment by the dairy farm	**€**	**-**

Table 4: Estimated Total target market value according to our calculations based on average size and income.

Above it's a recreation on a dairy farm of 200 dairy cows (which we have estimated is our average user size), as it can be observed our solution brings **near € 90,000 in energy savings** after our fee to the farm in 7 years. On year 7, after we have recovered our investment on the infrastructure, the extra energy income generated by this farm (as it is sold to the grid) which we have been keeping 100% as detailed in our concept is shared with the farm in a ration of 50-50 creating an extra **€ 4,000 in new income** a year to the farmer.

With everything taken into account, our solution on its estimated lifetime cycle of 20 years, would have brought **over € 300,000 in value creation** from energy savings and extra cash income (everything is considered cash for the farmer as savings means less cash payments) which he can use for re-investing on the farm or simply extra cash to take home to his family, all at the cost of ZERO in investment and maintenance for himself creating a very strong case of installations.

Value creation FARMM

Value Creation Average Farm User for FARMM		
# of Cows the Farm has	200.00	
Biogas produced (m3) per day	80.00	
Dairy Farm Energy Generation (kWh per day)	560.00	
Value of the system	€	138,000.00
Revenue Generated		
Monthly excess energy selling (at average of 0.07 per kWh)	€	736.69
Yearly excess energy selling	€	8,840.30
Subscription fee monthly	€	906.17
Subscription fee Yerly	€	10,873.99
Total Monthly Revenue	€	1,642.86
Total Yearly Revenue	€	19,714.29
Total Revenue generated until year 7	€	138,000.00
YEAR 7 onwards		
Revenues by excess selling per year	€	4,420.15
Revenue from subscription fee yearly	€	10,873.99
Total Yearly Revenue	€	15,294.14
Lifetime value creation		
Excess energy selling revenue (20 years)	€	265,209.00
Subscription fee revenues (20 years)	€	217,479.71
Total revenue generated in lifetime cycle	**€**	**482,688.71**
Total infrastructure investment (average)	**€**	**115,000.00**

Table 5: Estimated Value creation for FARMM from an average user.

As table 5 above shows, an average user lifetime value for FARMM is near **€ 500,000** in a 20 years lifetime, creating a huge incentive for the system. As subscription revenues account for over **€ 10,000 a year** it creates a stable source of income for the organization and the expansion of the business. It is estimated that, on average, FARMM will recoup its initial investment on the infrastructure in 6 years adding up one extra year for its profit margin of the product itself, **a total of 7 years for product value recovery.**

If prices of wholesale energy to the grid increase in Spain, then the recovery and profits for the organization will surge upwards, with each cent representing an increase of near **€ 1,500.00 yearly** in extra revenue for FARMM.

Financial Information

3-Year Projections

P&L Future Projections			
	Forecast **Year 1**	Forecast **Year 2**	Forecast **Year 3**
(+) Revenue	€ 394,285.71	€ 1,182,857.14	€ 3,548,571.43
(-) Depreciation (facilities cost)	€ 115,000.00	€ 345,000.00	€ 1,035,000.00
(-) Other Costs	€ 9,600.00	€ 11,040.00	€ 13,440.00
Operating revenue	€ 269,685.71	€ 826,817.14	€ 2,500,131.43
General Admin Costs	€ 126,100.00	€ 352,300.00	€ 585,900.00
EBITA	€ 143,585.71	€ 474,517.14	€ 1,914,231.43
Taxes	€ 35,896.43	€ 118,629.29	€ 478,557.86
Net profit	**€ 107,689.29**	**€ 355,887.86**	**€ 1,435,673.57**

Table 6: Projection for 3 years based on investment rounds for new biodigesters construction.

Our team goal is to rapidly grow based on partner funding and later on VC funding to be able to quickly bring impact to the dairy farm sector. As table 6 shows the organization can be profitable from year one and will reinvest the profitability into the expansion of more users and facilities.

Our growth projections follow the following:

- **Year 1:** 20 biodigesters working and a small workforce of IT managers, developer and field engineer.
- **Year 2:** 60 biodigesters working with a fleet of 3 field engineers and expanding workforce of developers.
- **Year 3:** 180 biodigesters working with a workforce of 9 field engineers and over 10 developers working a stronger management force as well.

Our depreciation cost is the value of the facilities we are building depreciated at 20 years which is their lifetime, and our revenue is the combined of excess energy sold and subscription fees as seen in Table 5.

The strong showing of revenue and re-investable profits will allow a rapid expansion of funding and auto-investment to achieve the ultimate goal of all farms operator under the system to create the true impact of our solution.

Initial Investment Funding

Seed Financing Projections	
System cost for pilot MVP	€ 200,000.00
Salaries to be paid Previous to launch	€ 63,050.00
Costs of Information and consultants	€ 20,000.00
Funding for 6 months of salaries and operations	€ 63,050.00
Marketing Campaign and partners costs 6 months	€ 15,000.00
Biodigester facilities construction (fund estimated for 20 biodigesters)	€ 2,300,000.00
Total Seed Funding First year of operations	**€ 2,661,100.00**
Biodigester facilities construction (fund estimated for 40 biodigesters)	€ 4,600,000.00
Total Seed Funding second year of operations	**€ 4,600,000.00**
Biodigester facilities construction (fund estimated for 60 biodigesters)	€ 6,900,000.00
Total Financed funding (debt) for Third year of operations	**€ 6,900,000.00**

Table 7: Estimated seed funding needs for the project growth and targets.

In order to achieve the projections shown in table 6, we will need external seed funding for our organization. As its noted in Table 7, we will use the initial funding to create the first biodigester MVP and its accompanied AI – Driven systems, as well as the initial salary funding, including the cost of hiring external engineer consultants for our MVP.

It is essential to notice that, as we will work in a subscription system based on heavy investment, is very likely several funding rounds will need to be done or, to avoid dilution and external control and pressure, a special funding mechanism will be created to raise the needed capital investment.

There are two main avenues to raise the funding needed:

- **VC Funding/Impact VC funding:** The traditional way to pitch to venture capital funds. In order to raise the money, we would aim for Impact venture capital funds as they are more likely to invest in the view of the organization and its true goals and purposes.
- **Government funding:** Access to EU grants or Spanish government grants for sustainability and biogas production will be a way to reduce the need of seed funding and obtain the capital expenditures.
- **Partner Funding:** We believe we could go for the less common route of creating a joint venture or obtaining funding from a partner instead of a fund. The partner would be needed to be in the same alignment and most likely from the same industry (Dairy industry) in order to align with the goals and objective of both organizations.

Our goal and selected first choice is to obtain a partner, setting up a special funding mechanism with them for our launching operations. By using a partner, we can avoid venture capitalist dilution which would put at risk our purpose as an impact solution, ending up only in search of profits and IPOs. Secondly by partnering with a dairy industry organization, we would be accessing the already captive farm market of their suppliers of milk, reducing difficulties of entering the market, as well supporting the goals of such organization on the sustainable and responsible companies objectives.

Our first **chosen partner will be DANONE** to approach with our solution, view of the future and request for funding mechanism. We believe Danone is well placed to fund and support our initial farmer contact and expansion. They will also obtain from us support in order to achieve their sustainable goals as well as a profitable long term investment.

Implementation Timeline

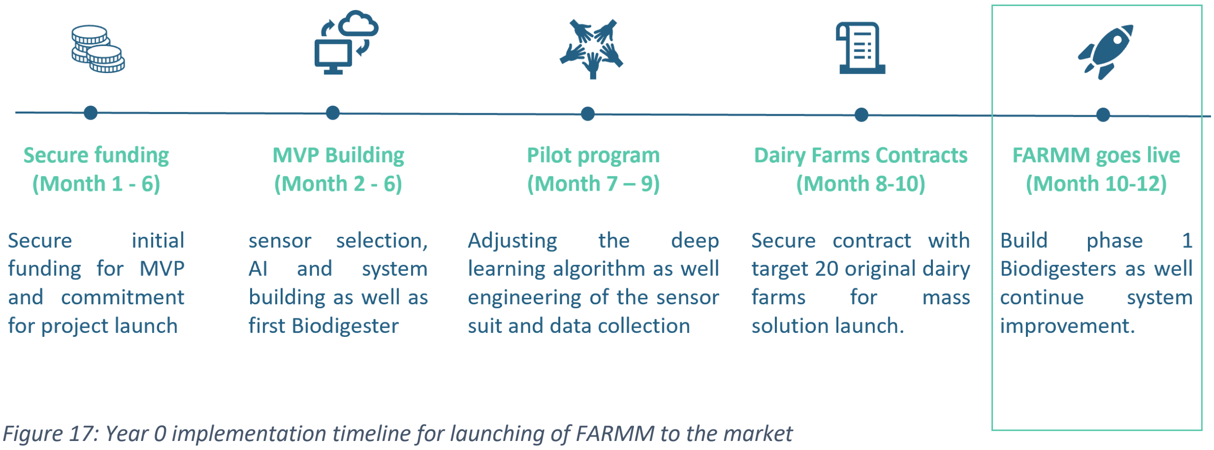


Figure 17: Year 0 implementation timeline for launching of FARMM to the market

FARMM timeline as it can be observed in Figure 17, encompasses 1 year pre-launch to generate all the developments, as well as securing the funding needed to achieve the projections (table 6) of 20 biodigesters operating in year one. Our objective would be to secure and build the 20 systems before year one launch to consider FARMM is going live, and then being able to meet up growth and expansion expectations.

Our initial models and AI systems will continuously be improved after launch in order to achieve maximum efficiency in energy production and minimum manual work by everyone involved.

In order to measure the success of the solution as well of the operations our suggested KPIs to keep tract at the start of the live will be:

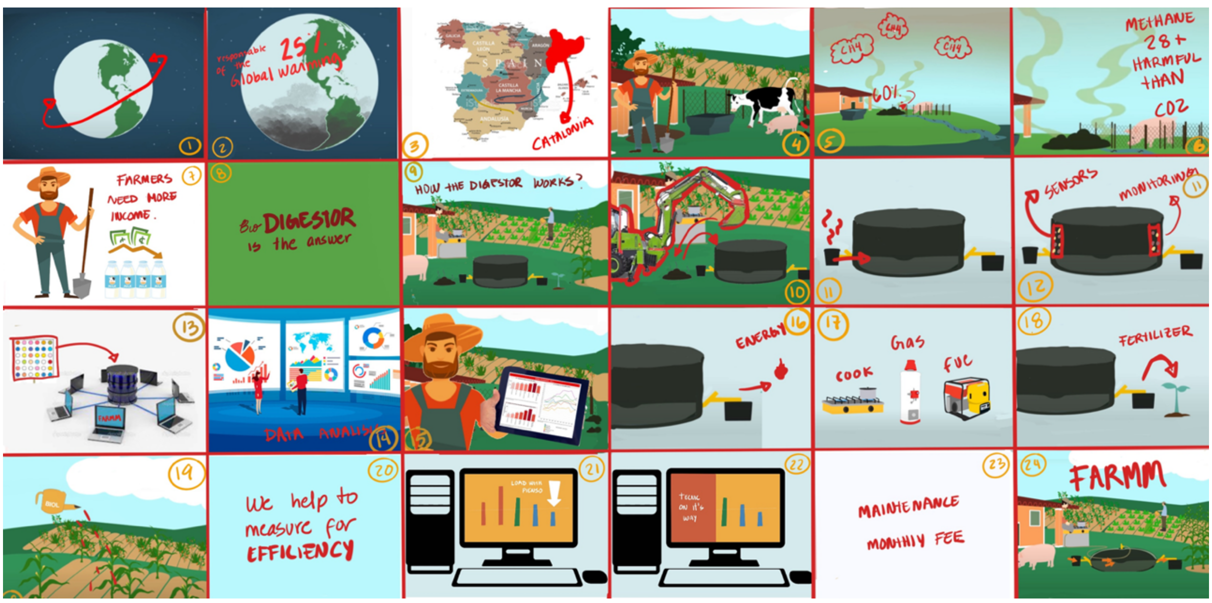
- Numbers of biodigesters fully functioning.
- Energy production vs objective production.
- Revenue from energy contracts.
- Number of dairy farm contracts in waiting list for new funding round and new requests.
- Increase in efficiency of biogas and energy production month-to-month.
- Automatic suggestions and technician visits done by the system.
- Farmers satisfaction with the system and its usage.
- Number of cows impacted by our system.
- Measurement of impact on the environment (meaning reduction of environmental damage).
- Number of farms that using our data have been able to certify their reduction of environmental damage.

Appendix

Prototype

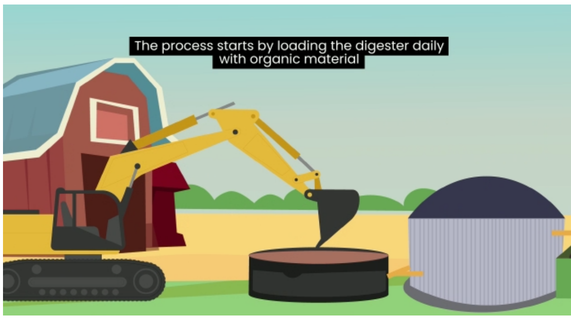
Storyboard

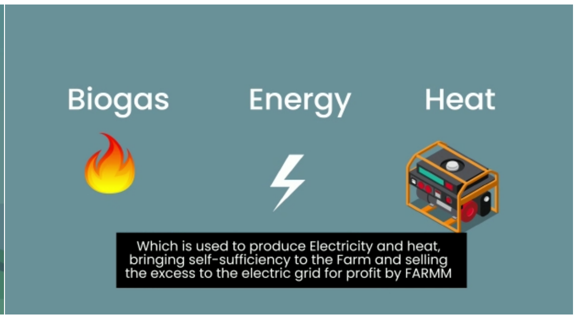
As the project involves many elements, it entails an added difficulty when it comes to explaining how it works. We decided that the best way to represent and communicate our idea was through a video. But in order to do so, we first needed to create a good graphic representation in sequence with all different concepts placed in an orderly and coherent manner for a good understanding of FARMM's operation and impact.

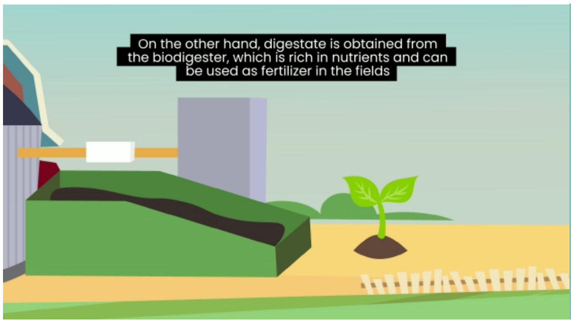


Video

Following the storyboard guidelines and to properly show how our system would work, we developed an animated video. Some screenshots of it can be found below:



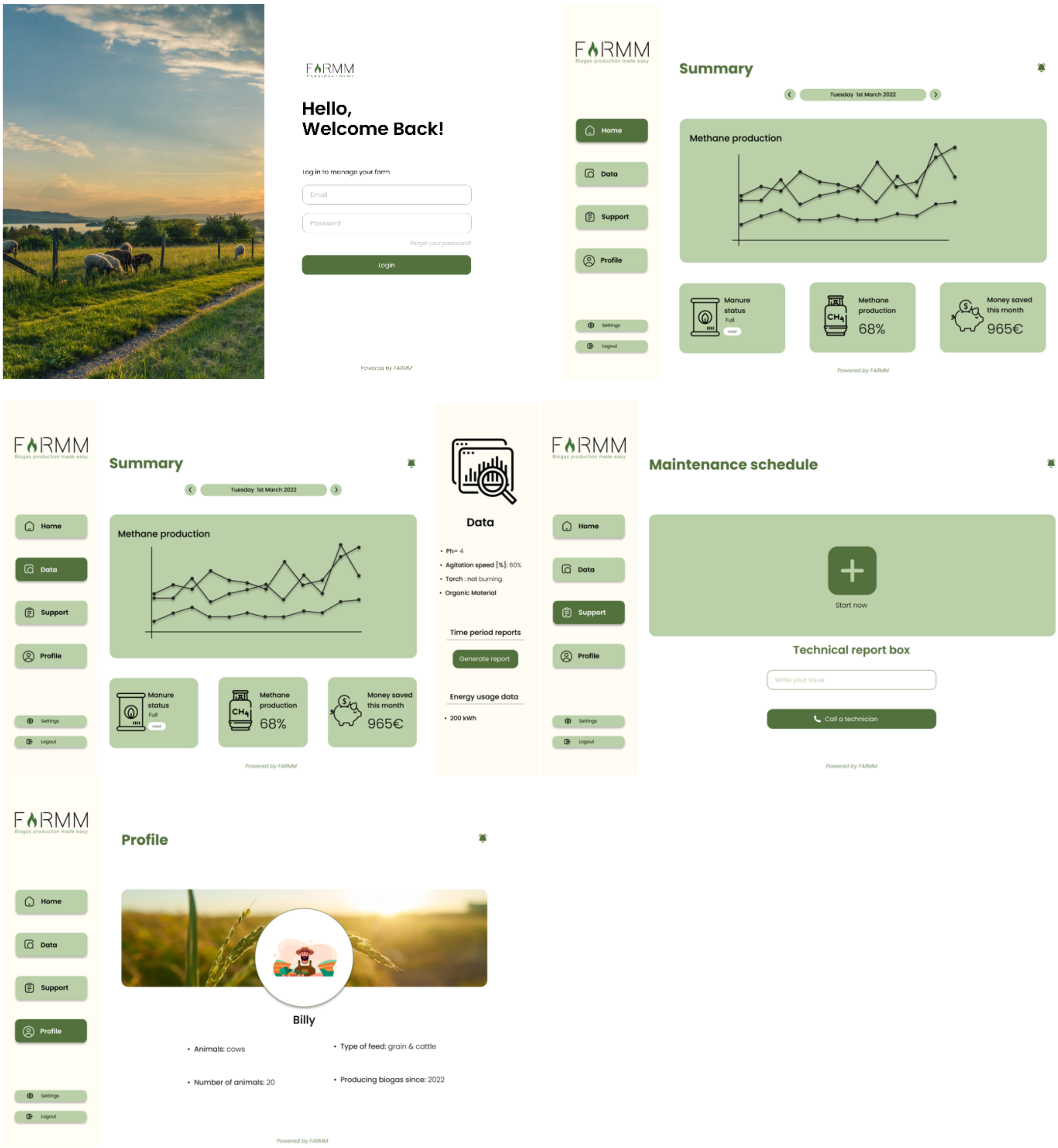




Farmer Dashboard

As part of our solution prototype, we designed the farmer dashboard, that would allow they to monitor the current or past state of the biogas plant, ask for support or see the needed actions to perform.

The interactive prototype can be explored in figma.com.



Our team

As the framework of our project implies, we are a multidisciplinary team. Here is a little about us:

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