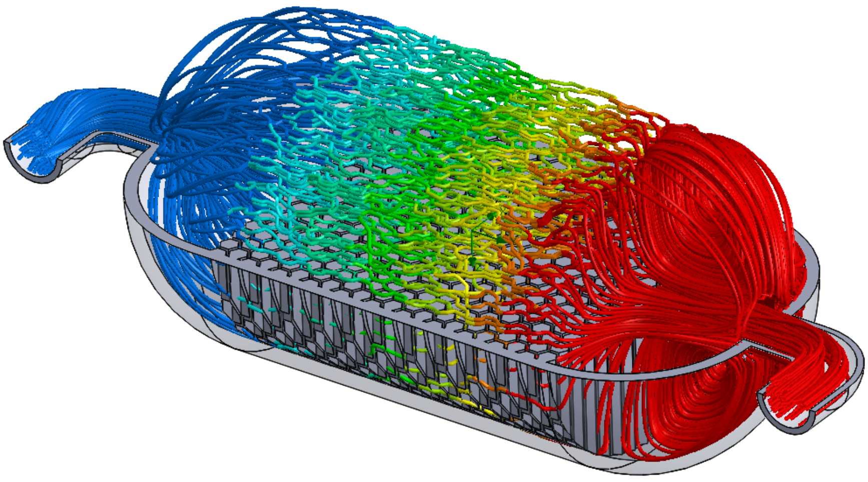
Reduction of methane emission from livestock

Innovation and Entrepreneurship



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Chapter 1

Reflection

The following report provides a general overview and summary of our journey working with radical innovation, while implementing our engineering knowledge and external expertise along the way. It reflects upon each influential step; from establishing a proper focus and exploring different ideation techniques to horizontal development and vertical thinking. A challenging process, which we believe resulted in a *novel concept*.

1.1 Establishing the team

In order to establish a proper working ground, start the focusing phase and the teamwork we first had to become an actual team. To achieve this status, we discussed and implemented two key aspects, which are often considered fundamental when any group of diverse people begin collaborating. These step are also associated with the *forming phase* in Tuckman's stages of group development [18].

1. First, we set a common goal. Without a concrete formulated goal established we could not become a team. We agreed that each team member was allowed to have their own personal ambition, but that the ambition of the team was to produce something great and novel, so that a high grade was possible for all members.

2. Next, we all signed a document stating what we agreed upon in 1) as well as how and when we worked with the handout-assignments in the future. This aspect ensured that every team member was being held accountable for their effort and that everyone was willing to put time aside to work with innovation as a unit, even though at times it could be difficult and confusing.

By establishing this foundation, we became a team which made the focusing phase more fluent and agile: we were all aboard the same boat on the same mission. Additionally, this was crucial for helping us go through the trials in the *storming phase* and into the *norming phase*. However, in some aspect we still considered ourselves a group of people; allowing each other to utilize our diversity and individual engineering expertise in the future process of creating something novel.

1.2 Focusing

As a generally overlooked area in agriculture we choose to explore the bi-products within this sector. To pinpoint a problem area, latent need or challenge we first created a *fishbone-diagram* exploring what was "closed", referring to solved areas, and what was "open", i.e unsolved areas or challenges. The items which was placed on the "open" side of the diagram would be potentially valuable *valleys* to explore. Of all the possibilities, we found methane emission to be the most lucrative valley to explore and develop a product for - in terms of both environmental and financial prospects. Additionally, another important aspect of choosing this particular focus was because every member was *intrinsically motivated* by it, given that this type of motivation has been documented to be paramount when working with creativity in the early stages [3].

To identify the real opportunities and which components and actors to target within the "methane system" the *9-windows diagram* from TRIZ was constructed (see Appendix B, section B.3.1). This helped us identify the most important aspect of the system, i.e: what components to target (technology) and which actors to approach (government, experts and consumers).

1.3 Challenging the situation & implementing knowledge

After the preliminary focus has been established, our approach to the innovation task and *stage room* changed. With only our insufficient knowledge about this area, we would never discover a latent need, let alone create a novel solution in the time span of the course. Therefore, we tried to adopt **i.** the *CIS Framework* and **ii.** the concept of *open innovation* to accelerate the process.

- Using the principles of lateral focus from the CIS-model, we interviewed a farmer who owns a medium-to-large scale farm with cows in the north of Jutland. Talking to him and experiencing the surroundings, we gained a lot of *tacit knowledge* regarding agricultural practices and mechanisms. Furthermore, we believe that we located a *latent* need, given the fact that he knew how much the environment affected the overall productivity and economics in agriculture, but not that his own cows contributed a considerable amount to the global warming effect via their methane emission. He and other farmers would benefit from a device which could eliminate the methane, thus avoiding future consequences.

- Utilizing our possibilities within the academic environment, we reached out to various experts and researchers. This was done to gather in-depth knowledge about methane as a substance and implement state-of-the-art technologies in our solutions. Amongst others, we consulted Li Rong from Aarhus University, who as a fluid dynamic expert and researcher in agricultural ventilation helped us in exploring trends and approaches in that area. The concept of open innovation was implemented as a *longitudinal approach*, which meant we also consulted experts through the following ideation phase.

The process of converging to a well-defined focus while investigating possibilities at the crime-scene and bringing in external knowledge resulted in a great starting point for the following *ideation phase*. We were now in the right mindset to come up with different inputs and ideas.

1.4 Ideation

The approach for the ideation phase was heavily influenced by the work done in the exploration and focusing phase. Looking back, we used a combination of a problem-solving and disruptive approach. The general industry does not see methane as a serious problem at the moment, so we were in reality inventing a solution before the problem.

1.4.1 Getting past *everyday creativity* and beyond

After having established a proper focus and stage setting, the team was ready to start the ideation phase and thus began the *diverging* from our initial starting point. Following the principles of guest lecturer Søren Hansen, we began the *fluency process* by using the classical "brainstorming" technique to empty our brains of every idea and thought regarding the collection, removal or usage of methane in agriculture. This procedure was central to get beyond the most common ideas, which could be characterized as *everyday creativity.*

From here on out we used an incremental approach, starting with the easiest idea generation techniques and gradually working our way towards the more radical methods, aiming for inputs characterized by "*beyond creativity*" or "*Big C creativity*" [5].

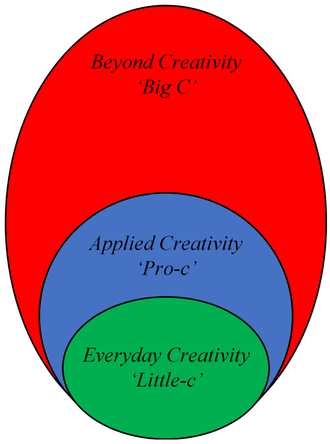


Figure 1.1: Creativity categories

We generated inputs from random words and pictures, which at first seemingly was not connected to our area. Then we moved on to *analogy techniques* investigating how other industries, but also nature itself, dealt with similar problems. Finally, we used techniques in the area of assumptions and provocation. Playing with wild and unrealistic scenarios and exaggerating certain aspects of the problems, e.g: What if livestock was not allowed to release methane at all? If the methane emissions are problem for the atmosphere could we change the atmosphere instead of methane?

1.4.2 Idea management and development

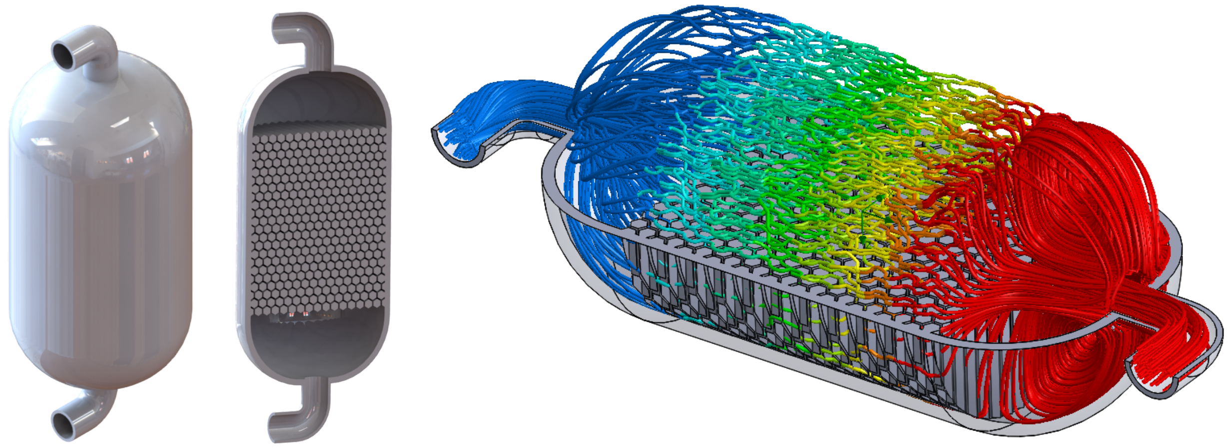
Utilizing Rosetta: The techniques resulted in a vast amount of inputs which we needed to handle in a structured way. For that reason, we decided to use 'Rosetta' for managing all the inputs, (see Appendix C.2). The inputs were added to Rosetta with a short description for each and then sorted into the colour-box [10]. Common and ordinary ideas that were feasible and easy to implement were marked as green ideas. Original and innovative ideas, which could be breakthrough ideas but harder to implement at present time, was marked as a blue ideas. Finally, the most radical ideas - ideas for the future was marked red.

Playstorming and moving horizontal: The inputs were challenged and developed through a longitudinal and horizontal process, where we continuously searched for insight and played with the ideas while consulting external experts. This resulted in additional ideas being generated. However, due to the knowledge gap and the limited time the conversation was characterized by a mix of instruction and consulting. There is no doubt that a more equal coaching-like debate between us and the experts would have been more beneficial regarding the gathering of knowledge.

1.5 The result and invention

The team worked with several ideas including bio-catalyzers inside cows and boxes with artificial atmospheres, postponing the final decision as far as we found comfortable. However, two weeks before the pitch the final invention was decided to be a *methane filtering reactor*. This idea had sprung out using the proposed blending technique from Søren Hansens lecture, taking a car-analogy (filter) and blending it with nature (bacteria in termite mounds). We chose this idea because we believe that the potential product belong to the *blue ocean strategy:* we could create a new market in the agricultural sector for efficient removal of methane from barns without harming the cows [12]. The technology is radical and the product is (as of now!) novel.

The invention itself is a reactor application, designed for ventilation systems which removes methane as it passes through. The reactor consists of a catalyst core made out of a zeolite-structure. On this hexagonal structure, methanotrophic bacteria cultured from termite mounds are applied, see Appendix A. The zeolite captures the nonpolar methane molecules on its active sides and the methanotrophs consume and convert the methane.



(a) Reactor (b) Cross-section (c) 3D flow

Figure 1.2: (a) The design, (b) Cross-section revealing the hexagonal zeolite structure
(c) Simulation of airflow showcasing the reduction of the methane concentration (red to blue)

A novelty search was conducted to investigate whether or not a patent application was a possibility [11]. The strategy employed consisted of talking to various experts, searching databases; including Google Patent, Patentscope and Espacenet. Based upon this analysis, no evidence was found that our invention exists in advance, and it was thus possible to make a patent, see Appendix D.1. The three demands of our patent are:

1) A reactor works by a biochemical process, **whereas** this reactor works by filtering a methane-containing air stream using a bacterium; *Methanotrophs*, which consumes in their metabolism.

2) A reactor usually consists of a packed bed, **whereas** this design consists of *zeolite surface* with cultivated methanotrophs.

3) A reactor interior consists of different designs, **whereas** this design consists of a honeycomb structure.

Chapter 2

Considerations

2.1 IPR-possibilities

With every innovation, it is important to establish the intellectual property rights (IPRs). This ensures protection of the design and functionality, so potential violations can be prevented and/or rightfully treated. IPRs were originally created to inspire and encourage the creation of new designs and discoveries by giving specific rights to creators (usually for a specific amount of time) [4].

Regarding our invention, there are 3 possible IPRs applied:

Patent: The combination of the Zeolite carrier infused with Methanotroph bacteria culture is a novel idea, which based on our novelty search was never created before. This gives us a great potential for possible future patenting. The patent then can be leased as a part of a collaboration process with other already existing ventilation companies. The implementation of bacteria as a filtrating agent also seems to be a novel concept, based on our novelty search, therefore it could also be patented.
Industrial design: In our creation, we implement the Zeolite in a honeycomb structure inside the reactors. This application of Zeolite is a new method in ventilation, since usually Zeolite is used as a coating of elements.

Figure 2.1: GHG neutral marking

Trademark: As a way to encourage farmers and companies to use our product in their ventilation systems, we wish to create a new product marking, which would tell the consumers that the producer is participating in methane-emission reduction. Considering the growing interest amongst consumers to buy ecologically-friendly products, this implies a possible growth in revenue, see Figure 2.1.

At a pitch-expo the group presented the invention for a group of five experts. Our invention received very positive feedback and the majority of them though our applied technology was radical. Additionally, three out of the five experts recommended us to conduct an extended novelty search and pursue the patent.

2.2 Business opportunities

The future of the invention holds different business opportunities. For maturing the final product, a lot of additional research is required. To ensure the maximum financial benefit from the research and the patent, an entrepreneurial company would be favorable. Production wise we can go two ways:

1) The created patent(s) can be leased for already existing ventilation manufacturers, thus creating a collaboration. This route can be interpreted as a "safe" way of marketing our inventions, since we wouldn't have to establish a new company and plan the production line from the very beginning.

2) Or, we can go the more daring way, pursuing a more entrepreneurial approach by producing the whole ventilation system ourselves, including the regular parts and the methane-filtering reactor.

Both directions have their own advantages and disadvantages, possible bottlenecks and causes of failure. The choice and outcome depend on our goals and dedication towards it.

2.3 Exploring *Vertical Innovation*

Using a VIP (Vertical Innovation Process) and examining eight areas, it is possible to go from a great idea to a brilliant concept [7], see Appendix E. Each area represents pillars in which you need consider how, who and what must be done for your invention to become a success. As in other projects, one area cannot carry the others, and some areas must stand out for the project to become a success and prosper into the future. It is not necessarily the product that determines the success of the project, or one of the other areas for that matter, but the coherent synergy between the areas that will raise the project to a level otherwise unimaginable.

The idea for the *product*: a reactor utilizing a zeolite structure and bacteria was determined in advance of this point. The process of creating this reactor is however difficult given the radical technology within it. Based on the VIP in Appendix E, the peaks in the VIP that was chosen to follow are the *product*, *business* and *finances*. The political area is important because of the necessary pressure that is needed to be applied to the government to pass methane laws. The product is seen as somewhat radical product because of the technology used in the reactor and the complex synergy between the zeolites and the methanotrophs.

Creating a consumer-mark that would be attached to products with low green house gas emissions would result in higher profitability for the farmer, because of higher prices on the products. This would also increase the knowledge and insight of the consumers in what products are more enviromental friendly. From a finical view, it could be more beneficial to target organizations like Arla, or the government. This would result in fewer contracts targeting organizations instead of individual farmers. Financial support to farmers incentivising reduction of methane emissions would most definitely be benificial for our business. This is partly already stated through the Paris agreement, even though countries are still lacking in following these demands.

Instead of going the conventional way and selling the products to customers, it could be an idea to approach organizations like Arla: immediately reaching a broad consumer group. *The cultural* aspect is to go for the people who are looking for products that are saving the environment and the animals. This will be done with the GHG marking. In the beginning, there has to be pressure from the government on companies and farmers, to reduce the carbon footprint. By implementing our product, it would help the companies and the farmers reaching their goals.

By doing the VIP we were able to convert our invention into a business. Or at least think of it as a business. We where then able to do a business Canvas Model [13], on the invention, assuming that there is a market for it right now. Because our invention deals with improving the environment, we made an Environmental Life Cycle Business Canvas Model as seen in Figure 2.2. This describe how we are going to create value, deliver value and capture value to our environment.

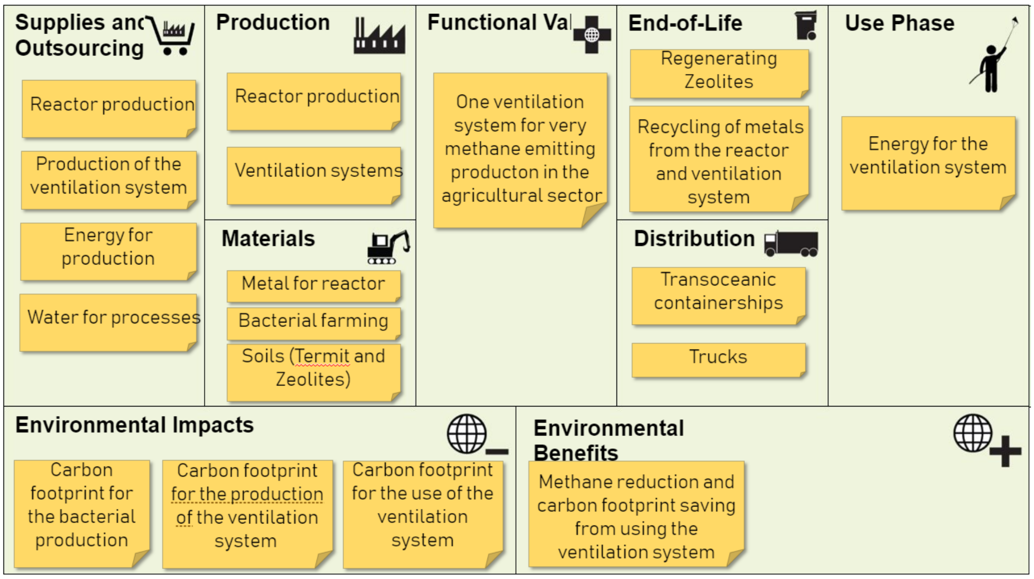


Figure 2.2: The figure shows the Environmental Business Canvas model for the invention.

2.4 Finalizing thoughts

The starting point of our innovation project was definitely influenced by a problem-solving approach where we adopted the *Discover* and *Define* phases of the Double Diamond model [14]. However, as the focusing and following ideation process developed we realized that we were trying to solve something, which the public did not consider a problem and invent something before the need was present. Therefore, we shifted our focus and adopted the CIS-model, which presented better tools for us to handle this type of innovation [8]. This model forced us to look outside the common domain and beyond applied creativity. This meant that the final invention was created on a changed thought; The original invention would have been invented to solve an existing problem, but our invention became a solution that nobody had directly asked for. It was discovered in the area between latent and tacit needs.

By postponing the final idea the team went from an incremental idea, which had a lot of competitors in the *red ocean*, to a radical and disruptive idea. Our final invention fits the market of a *blue ocean strategy*, with no apparent competitors [12], thus giving us a lot of advantages and a potential for high earnings. Using radical technology, we are however subjected to higher risks: our invention is made for a market with no demands at the moment.

As of the 19th of May 2019, even our potential new prime minister, Mette Frederiksen, proposed in an election-debate that we in the future have to focus on reducing methane levels in agriculture! This solidifies our future perspective and our approach of creating a solution before the problem has even been acknowledged.

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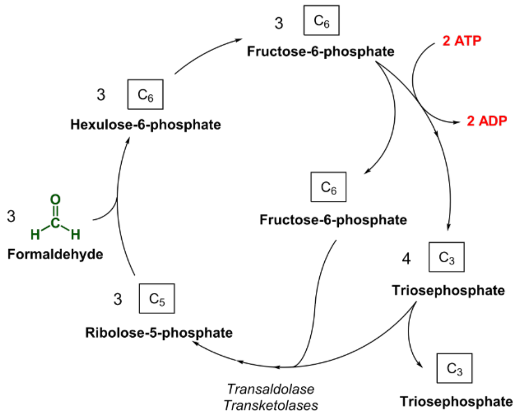
Appendices

Appendix A

Metanotrophs and Zeolites

Methanotrophs are a subset of Methylotrophs, who utilize only methane compounds as their energy and carbon source. They create formaldehyde by oxidizing methane, which then enters one of the two metabolic pathways, the RuMP (seem in Figure A.1b) or the Serine pathway, which contributes the biomass [2]. Methanotrophs can be found in methane-rich environment, such as rice paddies, marshes, etc. They can also be found in termite mounds (see Figure A.1a), living in symbiosis, as termites create a significant amount of methane [15]. Termites use this built-in filter system in their dwellings to remove methane before it's emitted into the atmosphere.

(a) Termites mound



(b) RuMP

Figure A.1: Illustration of termites mound where methanotrophs are incorporated into the soil [15], and RuMP pathway in type I methanotrophs [19].

As a nature analogy, this bacteria could be used in a reactor configuration so that it is possible to remove the methane elsewhere than in termites, for example in barns that house ruminants, who are extreme methane emitters.

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts [1]. Some of these nonporous zeolites structures could be used to trap the gas on a large scale [16].

Appendix B

Handout 1 - Focusing and initial converging

B.1 Establishing the Team

In order to establish a proper working ground, start the focusing phase and the teamwork we first had to become an actual team. To achieve this status, we discussed and implemented two key aspects, which is often considered fundamental when any group of diverse people begin collaborating. This step is also associated with the *forming phase* in Tuckman's stages of group development [18].

- First, we sat a common goal. Without a concrete formulated goal established we cannot become a team. We agreed that each team member was allowed to have their own personal ambition, whether it was a low- or high grade, but that the ambition of the team was to produce something great, so that a high grade was possible for all the members involved.
- Next, we all signed a document stating what we agreed upon in 1) as well as how and when we worked with the handout-assignments in the future. This aspect ensures that every team member is being held accountable for their effort and that everyone is willing to put time aside to work in the group and with innovation, even though it at times can be difficult and confusing.

By creating this foundation, we became a team which made the focusing phase more fluent because we were all aboard the same boat on the same mission. However, in some aspect we should also still be a group of people; allowing each other to use our diversity and individual engineering expertise when researching different areas in the future process of creating something innovative.

B.2 Breaking the Challenge Down

Starting point: "Biproducts in Agriculture"

In recent years the dairy industry in Denmark have been successful in utilizing biproducts to produce new productions line e.g "Skyr" and "Hytteost". Thinking in terms of both good and bad biproducts, we tried to locate a problem area, latent need or challenge by first creating a *fishbone diagram* inspecting what was "closed" i.e solved areas and what was "open" referring to unsolved areas and challenges. The items which was placed on the "open" side of the fishbone diagram would be potential valuable "valleys".

B.3 Focus and discover

The result of the fishbone diagram was to target "Methan Production in Agriculture"

Despite being 30 times more potent as a heat-trapping gas than carbon dioxide (CO_2), no commercialized solution exists for preventing methane pollution in the agricultural sector. Burps and farts from livestock as well as handling of manure all contributes considerably to the global methane emissions. A solution capable of capturing or eliminating methane from the air would be a major achievement towards more environmentally friendly agricultural practices. Considering the current patterns in the world's meat and dairy consumption this issue will only grow bigger and bigger so creating an innovative solution before we face environmental disaster would suddenly be a very lucrative concept.

B.3.1 Focusing technique

To get a better perspective on how to tackle the problem by pinpointing the involved components, actors and identifying the "real" opportunities the *9-windows diagram* from TRIZ was constructed, see Table B.1 [9].

Table B.1: TRIZ: Nine Windows for Methane

	Past	**Present**	**Future**
Super-System	Building Materials Fire Fuel Fertilizes	Fuel Fertilizes Building Materials	Fuel Climate Consumers Countries (Global image)
System	>Poop >Burps	**METHANE** **(Cow feces and farts)** **(Bi-products)**	Re-cycle Reduce Collect
Sub-System	Cows Grass/Food Burps and Farts	Cows Grass/Food Burps and Farts	Cows (Different breed) Food (Modification) Supplements Other stimuli

By creating the diagram, it is clear that are a several important aspects of the methane issue:

- The "present-system" box tells us the main sources of methane production in agriculture. We can hereby investigate which of these produces the greatest amount and then focus on a solution for this component.
- The "future-system" box shows that methane can be used in a system to generate energy, but also that we have various beneficial opportunities in terms of marketing and branding if we can create a product that can reduce methane: i. the product would most suddenly be welcomed in the global world because it helps reducing the climate-problems we are facing. ii. A large group of consumers prefer that their meat- and dairy products are ecological - maybe they also care if they are produced at methane-reducing barns i.e. a latent need? iii. governments can create stricter laws regarding methane-pollution, which would give great economical prospect to our potential product
- The diagram furthermore illustrates that we can alter the methane system with various approaches:

i. eliminate or re-cycle the methane which probably requires that we can collect it. ii. reduce the production of methane by livestock - for instance by looking to create new food or supplement options.

B.3.2 Researching the problem area

Due to the fact that no member in the team has in depth experience in agriculture, an optimal person to consult would be the modern farmer with a medium to high amount of livestock. This user was also pinpointed as being highly valuable using the *persona technique* [14]. Luckily one of the team members had a family relation with a farmer with a large-scale agricultural practice. The interview was conducted as part of the exploration phase; gather knowledge and try to locate latent needs. The following points sums some the findings of the interview:

- The cows have been taught to go into an automated system on specific times which milk them. This optimizes the farmers workload and is also a positive solution for the cows.
- The farmer does not think that much about the gasses in which the cows release, but he are familiar with strict laws regarding the ammonia concentration in pig barns.
- He believes that a solution regarding collecting/eliminating gasses would only be successful, if it does not hinder the farmers everyday work routine and emphasizes that animal welfare are a big topic in the general public - in Denmark at least.

During the interview we tried to assume that the farmer was lying when he discussed what he though was possible in terms of solutions and his overall needs; i.e which issues he had in the barn. A clear takeaway was the great amount of *tacit knowledge* he relied on in his everyday work routing - different procedures which was hard for him to explain if he could not show you it directly in the barn. In the group we believe that we found a some what *latent need* talking to the farmer. He was aware of the public interest in environmental friendly solution, but did not see methane as that big of an issue. We believe that with the rising patterns of meat consumption and dairy products, farmers like him will have to adopt products which removes methane from the barns to run a responsible and sustainable buisness in the future.

B.4 Valleys to explore

A big advantage for the team is that each member is a part of a university and the academic environment. This means that we are surrounded by researchers and experts who have in-depth knowledge about state-of-the-art technologies and solutions. We saw this as a great opportunity and consulted a number of researchers in the focusing phase which will be presented later in this chapter. Utilizing external resources to reach and strengthen the final product is also a crucial part of the process when working with *open innovation*. Some of the advantage to this approach is that:

- The invention is not limited to the internal knowledge of the team
- Open innovation helps the team gather information about new methods and technology quicker when consulting researchers and experts
- Open innovation creates competitive and financial opportunities when working with external partners

B.4.1 Potential lead users

With the help of the persona-technique we identified various potential lead users:

- The farmer - An obvious candidate, which could continuously help us sharpen our approach and product. This is quite possibly the first guy we should present the *pretotype* to.
- The meat- and diary consumer - A potential path to our product success could be to brand meat and diary product from farms using our product as "methane-free" products.

B.4.2 Knowledge to explore

The following researchers and areas could help the team discover and utilize state-of-the-art technologies to create a radical product:

- Biologist - Change the inside mechanism of the livestock
- Chemist - Help us understand prevention strategies for methane? Food alternatives?
- Research the technology regarding synthetic animal fabrication
- Ventilation manufacturer - How is air cleaned?
- Fluid dynamic experts - How does different substances move/act in the air?
- Haldor Topsøe - Advances and techniques in the area of catalysts

B.4.3 Other inspirational areas

Science Fiction Movies: In the science fiction movie “The Matrix” humans are being bred in an alternate world. Maybe we can house cows in alternate environments where the emissions of methane is not an issue?

Nature: Sometimes nature have an extraordinary ability to regulate substances in the world. For instance; plants consume CO2. Maybe we could locate a thing which naturally occurs in nature that consumes methane?

B.5 Defining the innovation task

As a product of the workflow throughout the chapters of this handout and as a conclusion to the focusing phase, we can herby clearly define our innovation task as the following:

We want to challenge the assumption stating that; methane emissions from livestock is part of a natural process which is too complex and difficult to alter or solve. We want to reduce the amount of methane pollution in agriculture either by;

- Eliminating it from the air (Capture strategy)
- Re-cycling it to other applicable forms of energy (Capture strategy)
- Preventing/reducing the production of methane from livestock (Prevention strategy)

Appendix C

Handout 2 - Ideation and diverging

C.1 Ideation

The overall agriculture topic was investigated through desk research and talk with a specialist. This was done to gain a diverse knowledge which could be added to the new invention. In this this area of focusing models as the fishbone diagram and the 9 window Triz model were used as described earlier. The ideation part was then started and to get the right ideas and innovate outside the normal patterns, five different techniques were used. (Experimental creativity)

First, we started the “fluency process” [6], where the Brainstorming method was used to empty every thought inside the topic of agriculture. After that, we used different methods or techniques to find new input for the ideation. We compared different pictures to generate random inputs for the ideation. then a nature anology was used and after that the structuring area was investigated with the five W’s. Finally, the operation area was investigated through the SCAMPER creativity tool and the provocation was illuminated with scenarios beyond realism.

To process the amount of inputs a data processing tool was needed. We decited to use the Rosetta program for managing all the input. First all the inputs from the five techniques was added to the Rosetta with a short description for each. Then all the inputs were discussed in the group an sorted into the colour-box. The common and ordinary ideas there was feasible and easy to implement was marked as a green ideas. The original and innovative ideas there could be breakthrough ideas but harder to implement right know was marked as a blue idea. Finally, the most radical ideas, ideas for the future and ideas that was not immidially feasible ideas was marked as a red idea.

C.2 Rosetta

To categorize all the different inputs, transform them into ideas and final to the final concept, the Rosetta software has been used, see Figure C.1. The program provides a good overview of the various inputs that can be sorted according to the color-box principle [10]. Then some of the inputs can be combined crosswise and converted into different ideas, which can also be sorted in the colors red, blue and green. Here, different team members can be assigned responsibility for different ideas. The idea process also result in more inputs, which may thus become more and new ideas. Finally, the final concept can be described and developed

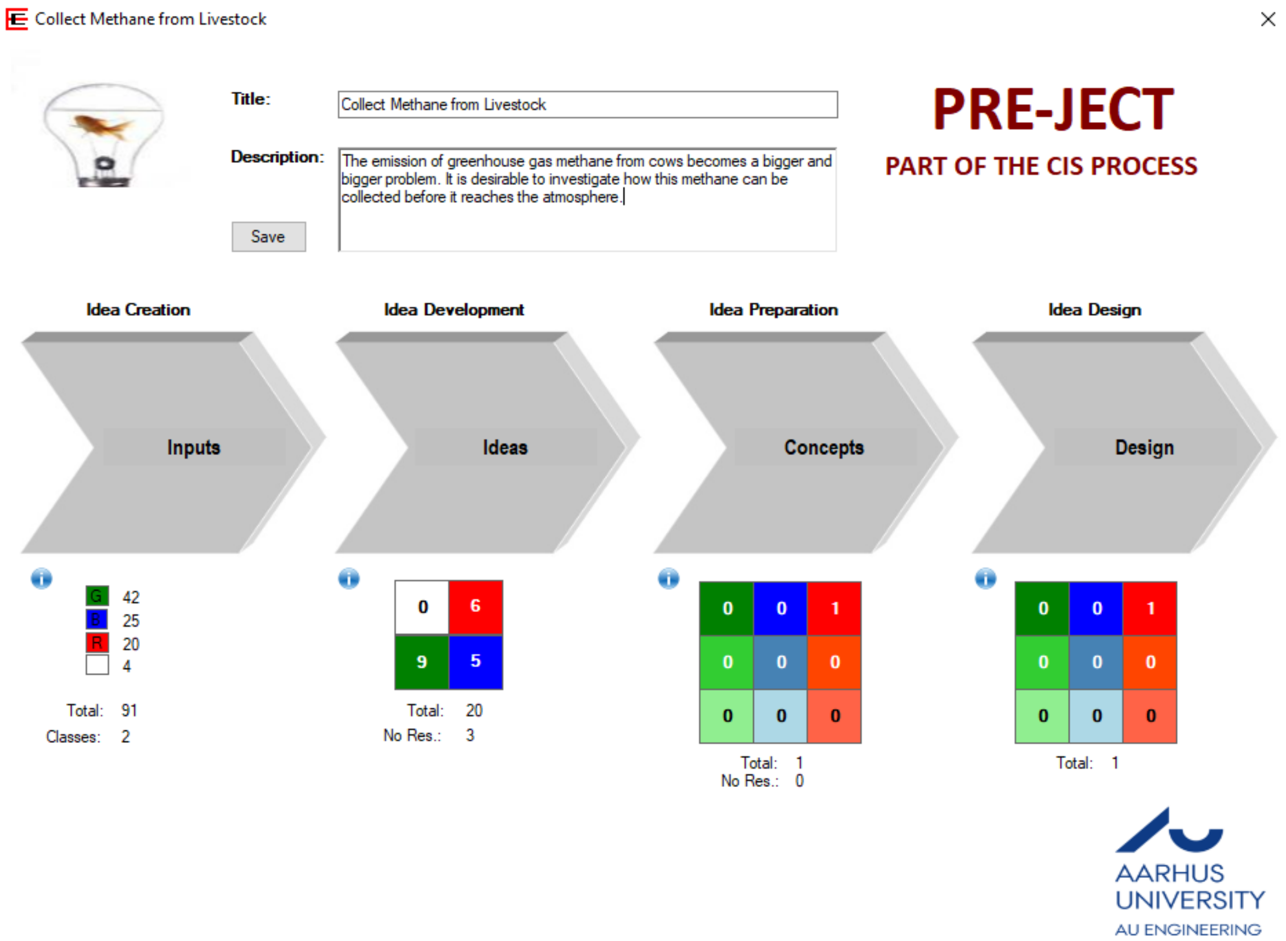


Figure C.1: Illustration of Rosetta software used to go from input to concepts.

Appendix D

Handout 3 - Ideation and patent

Using Rosetta, Appendix C.2, it was clear and easy to go from input to idea. Some of the inputs were assembled and combined into new ideas. This resulted in six red, five blue and nine green ideas. For each of the ideas, a novelty search was made to see how relevant the different ideas were. Each team member was in charge of the study of two-three ideas. The ideas were thoroughly investigated, in which several of the ideas were discussed with external experts. After some work with several of the ideas, it was decided to focus on one of the ideas. It was the idea that was most radical, but the team still could see great potential in. The idea was a reactor consisting of zeolites and methanotrophs, see appendix A for description of the two technologies.

To find out if the invention is in fact a novelty and it is possible to make a patent, a novelty search has been made [11]. The novelty search consisted of talking to various experts, trying to find something about it on the internet, including Google Patent, Patentscope and Espacenet [11]. Based on this analysis, no sign was found that our invention exists in advance The final patent is described in section D.1.

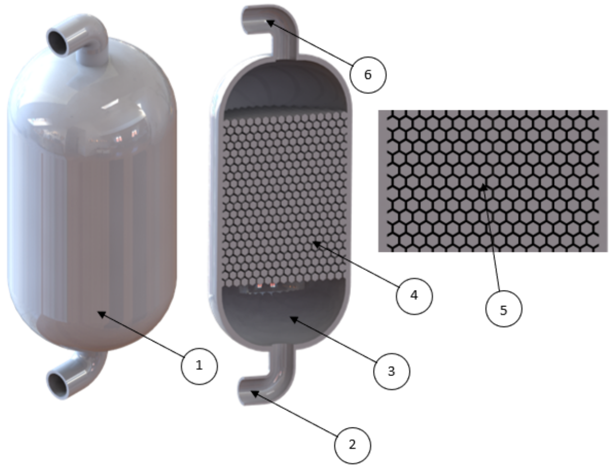
The utility of this invention has enormous potential. With the invention, it is possible to remove the methane emissions from, for example cows. This will give a new dimension to the large current discussion about climate asunder in meat production. Think if a meat product could be methane neutral. Methane is a worse greenhouse gas than, for example, CO2 [17]. It will be possible to use the invention in, for example, ventilation systems, as an ad-on, as well as filter for ammonia. It is currently possible to make pretotypes on the design, but a lot of research is missing on how to best incorporate the bacteria into the zeolite mineral.

D.1 Patent

Reactor to Remove Methane from Air

The barns are getting bigger and bigger, which makes demands on the ventilation systems, while at the same time it is necessary to reduce the emission of the greenhouse gases. This allows a reactor to be added to the ventilation system, which can filter methane from the airflow. The technology consists of a reactor consisting of honeycomb columns of zeolites, which captures the nonpolar methane molecules on its active sites. The zeolites containing the bacteria methanotrophs, there consume methane as their primary energy source, and by guiding the fluid through these columns, the methane is filtered from the air stream. The bacteria live, similarly in termite's mound, in these compressed earthy honeycomb.

1. Reactor.
2. Inlet pipe.
3. Anterior chamber.
4. Honeycomb columns of zeolite containing methanotrophs.
5. The bacteria live, similarly in termite's mound, in these zeolite honeycomb.
6. Outlet pipe.



Patent demands

1) A reactor works by a biochemical process, **whereas** this reactor works by filtering a methane-containing air stream using a bacterium; *Methanotrophs* which consumes in their metabolism.

2) A reactor usually consists of a packed bed, **whereas** this design consists of *zeolite surface* with cultivated methanotrophs.

3) A reactor interior consists of different designs, **whereas** this design consists of a honeycomb structure.

Appendix E

Handout 5 - Vertical innovation

The development of the final product concept has been carried out using the vertical innovation process (VIP) [7]. For each of the eight areas; *product, process, business, system, social, finansially, cultural and political*, different ideas have been found for all areas. The ideas were then sorted, arranged and discussed with external partners. The result can be seen in table E.1.

Table E.1: Vertical innovation process [7].

	Green	**Blue**	**Red**
Product	A filter Membrane Termite earth Ventilation system Reactor Customize to the product to a customer Generic product	Metabolism	Methannotrophs Zeolites
Process	Extraction of bacteria Grow the bacteria our self's	Flush mound with water Use the mound itself inside the ventilation Combine zeolites with the bacteria and put them inside the ventilation	Create a termite mound barn
Business	Renting the patent for others, and get royalties for the products they sell	Be able to use a badge so the farmer could get more for his products Leasing the product, and still get the badge for his food	User gets it for free, from the gov/org, and gov/org pays us User gets it for free, from NGO, and NGO pays us
System	Farmers barn Ventilations systems Carburetor Monitoring system Government's NGO's	Factories Carbon dioxide eating bacteria Supermarkets to sell products with the badge	Toilet and bathroom building companies.
Social	Reduce the carbon foot print Great customer service Use of natural products Social media campaigns The government has set a max on carbon food print in agriculture ->one way of reducing No moving parts to be worn down. Utilizing a small ecosystem as filter	Use of quality badges Innovation contest on the system Methane is an explosive gas and is therefore dangerous. We want to remove it.	
Financially	Customer pays for the product up front Customer leases the product by us Get investment by investors ->sell product Organizations pay for the system -> system is given to end users like farmers for free Farmers pays up front ->gets badge on food products ->supermarkets charge more for the products	Sell the ventilation system to orgs like Arla and let them deal with it.	Ordinary people donate to a farmer so he can buy the ventilation system -> the people will then get a discount on theses products with badges on them
Cultural	Users are searching for more environment friendly products Users are searching for more natural products Users are searching for products that are helping the animals Products produced in more eco friendly manner are more expensive Carbon food print must be reduced Farmers are not doing enough for the environment	Users are looking at badges and finds it comforting to know it is licensed	
Political	There is pressure from the government on reducing the carbon food print		

Cooperative agreement

This Cooperation Agreement concerns

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between the following partners:

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Project Description

Based on five handouts the purpose of the project is to present an innovative concept in the field of agriculture. The project include formulating a report, presenting a pitch of the product/idea and finally an oral exam.

The handout forms the basis of the report and should include the process and argumentation behind the idea and its implementation.

Participating students will after this course be able to:

- Explain, reflect upon and relate selected core theoretical concepts in the field of innovation and entrepreneurship to the process experienced in the course

- Explain, select and apply adequate methods and approaches for managing and driving an entrepreneurial and/or innovative process

- Explain, reflect upon and relate the process experienced in the course from problem definition over ideation towards defining a business concept accepted by core stakeholders

- Explain and apply business models with a specific focus on value propositions and customer segments

-Apply and analyze communication models for presenting an idea or a concept in order to obtain feedback and buy-ins from stakeholders

- Explain and apply the principles for IP rights and the related application process

Group meetings:

When agreeing upon a time of meeting the academic quarter applies. The objective of the group meetings is to complete the handouts, brainstorm about potential innovative ideas and the further progress. Breaks are when ever agreed upon. If we are assigned homework the meetings can start by presenting the results/finding of this.

Team rules:

If a group member is sick or delayed he/she should write ASAP in the facebook group-chat.

Communication is through facebook group chat and in class. File-sharing is based on the shared Onedrive folder.

Decision making upon disagreement: Majority vote

Word is used as type-writer.

In case of a decision making; silence is agreement. ("Den der tier samtykker")

Quality control:

Gramma changes and in genereal "small" changes doesn't need permission to be changed.

1-2 person should read-through the final report to ensure cohesiveness and to streamline the report.

Conflicts :
How do we deal with problems and conflicts?

As the first step the group should discuss the matter and try to reach a common ground. If this doesn't help a external part (i.e teacher) should be included in the conflict.

Upon the first two violation the punishment is to bring cake (good cake).

If the violations continues the rest of the group is allowed to exclude the group member.

Signatures:

Signed by (MUST BE SIGNED BY ALL LEGAL REPRESENTATIVES):

On DATE, in PLACE
06/03-19, Navitas

Tim Christensen
REPRESENTATIVE NAME

On DATE, in PLACE
06/03-19, Navitas

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