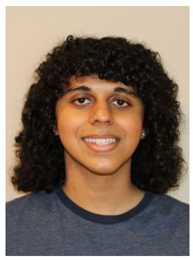
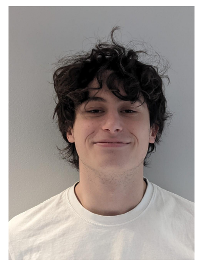
Vardhan Koripally
Chief Executive Officer, s221407



Solomon Leo
Chief Technical Officer, s221577



Kevin Sturdy
Chief Financial Officer, s204729

Thomas Aust
Chief Marketing Officer, s204769

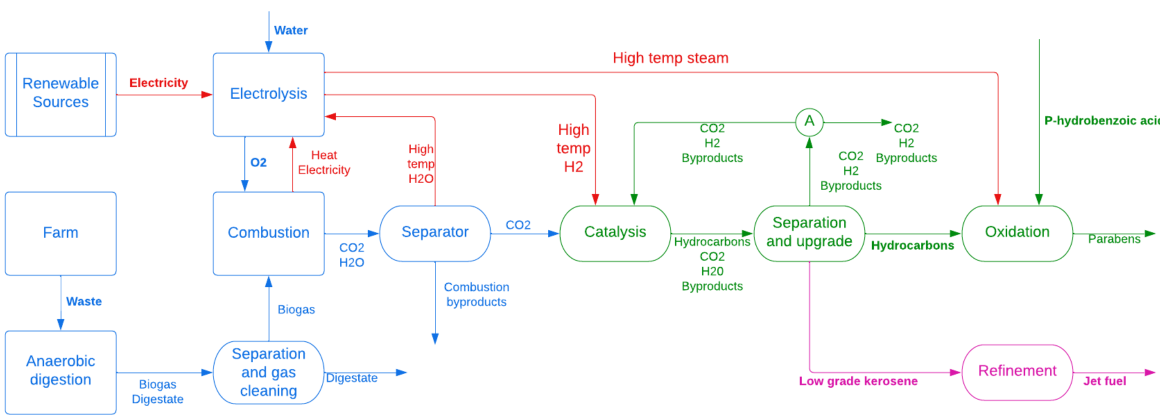


Figure 1: Process flow diagram

Our process anaerobically digests biomass from industrial ranches to create biogas, which will be combusted to provide energy for electrolyzing water and carbon dioxide. Hydrogen from the electrolyzer and carbon dioxide will be catalyzed into hydrocarbons, which are oxidized to produce parabens with minimal emission. In the future, the process will be modified and scaled up to produce green kerosene, this modification is illustrated by the purple part in the PFD.

The Team:

The LAKS Energy team is led by four engineers. Vardhan and Solomon are chemical engineers specialized in energy technologies and process engineering and optimization respectively. Kevin and Thomas are two general engineers with a specialization in living systems. Our diverse team is able to tackle all the biological, chemical, and energy processes in our company. LAKS Energy is devoted to producing environmentally friendly parabens, and in phase two we will modify our process to produce green kerosene.

We do not plan to have any partners, but we will contract a distribution and marketing company to develop a supply chain to help us sell our product internationally in Europe for parabens and in the future, domestically for jet fuel. We will also contract a consulting firm to handle our selling, general and administrative expenses. We will hire a lawyer to help us obtain a patent, protect our Intellectual Property in the future, and navigate European regulations. We believe that this will be incredibly valuable since none of us have ever filed a patent before and we do not know how to navigate these regulations.

The Problem:

The problem to be solved is that paraben and fuel production processes produce a lot of carbon dioxide, waste, and require specific materials. Our idea is to reduce emissions by capturing CO_2 from biogas combustion to synthesize longer hydrocarbon chains for paraben and fuel production. This process is known as Power-to-X, or P2X. The biogas produced in the first part of the process, shown in blue, is combusted to produce power for the high temperature electrolyzer. The byproducts of combustion are CO_2. water, and heat. The high temperature water and heat will be used in the electrolyzer, and the CO_2 will be used in the catalysis reactor to form hydrocarbons. The innovative steps in our process are the catalysis reactor, separation and upgrade, and the oxidation process shown in green.

The business idea is to produce carbon neutral parabens and kerosene from animal manure using anaerobic digestion and coupling biogas production with a modified P2X process. In order to remain environmentally friendly and reduce overhead costs, we designed our process to recycle as much water and heat as possible. This reduces the amount of water and electricity we will need to purchase and the amount of heat and water we waste. This is done by thermally coupling the electrolyzer and the combustor, diverting excess heat to other units and recycling waste water separated later in the process back to the electrolyzer. A more detailed version of the process with thermal and water recycling can be found in the **Appendix**. The thermal distribution from the electrolyzer and combustor can be seen as the red streams and the water recycle loop can be seen as the purple streams. Wastewater is recycled from the separator after combustion and from the separation and upgrade process. This water is mixed with cool water that was used to heat reactors or preheat reactant streams to be returned to the electrolyzer and combustor.

The market we are entering is red ocean but we intend to obtain a patent on our catalysis reactor, separation and upgrade process, and oxidation process. This means that we will be the only producers of green parabens for 20 years. This exclusivity will let us grow our investment to prepare to move into fuel production in Q20. The paraben market has large potential for growth, being expected to grow more than 6% in the next 8 years[1]. Being dependent only on biowaste, water, and electricity, we are prepared to take advantage of this opportunity. As such, we aim to begin producing parabens in Q10 and be fully producing parabens by Q29. We will be looking into fuel production by Q20 and we expect to be producing fuel at full capacity by Q40.

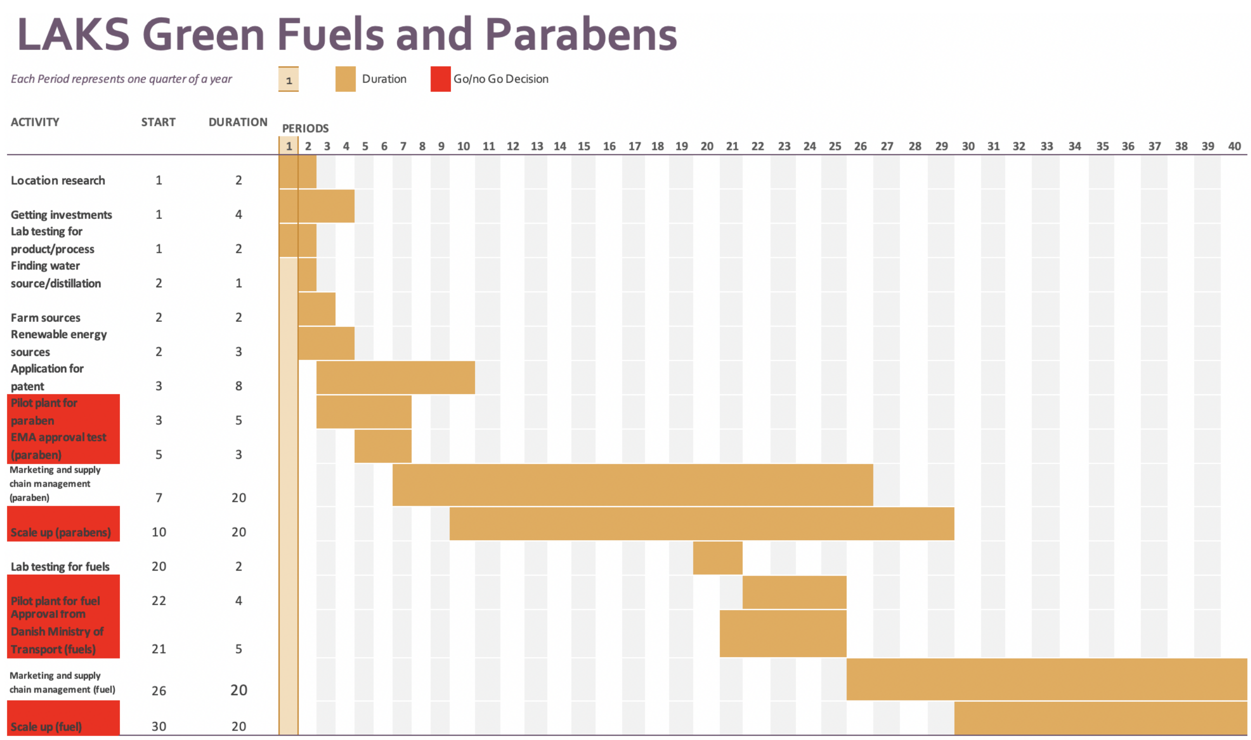


Figure 2: The GANTT diagram time scale of quarters.

The main show stoppers of our idea are the efficiency of the electrolyzer and the catalysis reactor.. The electrolysis unit must be at least 75% efficient by the end of the research and development phase as having one with low efficiency will result in a much larger and more expensive unit. Another show stopper is the catalysis reactor. The catalysis reactor must achieve at least 50% conversion by the end of the research and development phase otherwise the

[1] Data Bridge Market Research, *Global Parabens Market*

process will have an extremely low overall conversion. Other show stoppers the ability to secure funding for the project and EMA regulation. We will seek funding first before we begin lab testing to achieve a proof of concept of our idea. After this first proof of concept, we will seek funding for the pilot plant testing phase. This will allow us to show a proof of our process on a process scale. This will finally allow us to get our last and largest funding to build our process and purchase our unit operations. If we are unsuccessful in obtaining funding in any of these steps we will not be able to proceed. Following a proof of concept, we will begin to seek EMA approval for our process and product. It is critical that this happens as soon as possible otherwise we will not be able to distribute our product in the European market.

The go/no-go decisions are shown in the GANTT chart in red. For paraben production, they include that we are unable to obtain or set up a pilot plant, the EMA not approving of our product, and scale up related problems. The pilot plant decision must be made at the end of the research and development phase in Q3. The decision regarding the EMA approval must be made before the end of Q3 which is when we intend to begin pilot plant testing. Scale up problems could occur at any time in the scaling up process but they are most likely to occur in the first two years. These decisions must be made before Q15 which is when our process would be entirely implemented. For fuel production the same go/no-go decisions must be made, except instead of getting EMA approval we will need approval from the Danish Ministry of Transport. The pilot plant decision must be made by Q22. The decision about the Danish Ministry of Transport approval must be made by Q22 before we enter pilot plant testing. The fuel scale up decisions must be made before Q35.

The first year of our business will be spent in lab testing, acquiring the necessary patents and approvals, and finding sources for our raw materials. After the first year we will shift to scaling up, marketing, and working with distributors. We should see sales increases around Q15 which is toward the middle of scaling up. We should see profit increases around that time as the cost of running the process should decrease as we continue to scale up production. In Q20 we will begin branching out into fuel production and by Q35 we should see similar results to Q20 as fuel production prices will lower as we scale up production.

As a benefit to society, our process produces high demand products with minimal waste. Similar processes can be implemented to produce other products such as plastics and other fuels such as gasoline and methanol while remaining carbon neutral. This contributes to four key UN sustainability goals: 7. Affordable and Clean Energy, 9. Industry, Innovation and Infrastructure, 12. Responsible Production and Consumption, and 13. Climate Action.

The Benefit:

Our business will benefit society, the customer, and the business itself. The societal benefits of our process includes low CO_2 and waste emissions and low raw material cost both financially and environmentally, since our process uses manure, water, and renewable energy. This contributes to both the affordable and clean energy goal. Our process is also designed to be extremely efficient and minimize waste since heat and chemicals produced in the process as byproducts are used in later steps, contributing to both the innovation and infrastructure and responsible production and consumption goals. Therefore we are making the most of our raw materials thereby not contributing to a growing pollution problem, which overall contributes to the general climate action.

The benefits we bring to our customers are sustainable cosmetic ingredients as well as sustainable jet fuel with low carbon emissions. We support local farms and ranches since we buy manure locally from ranches and sell our digestate locally to farmers. Our plant will be in Kastrup, which means that we can sell our parabens to local cosmetic plants in Copenhagen, which reduces their carbon emissions from transporting parabens from suppliers abroad. Since we are close to the airport, we can also sell jet fuel to the airport with minimal carbon emissions from transportation when we expand to jet fuel production.

As a benefit to the business, we intend to capture 10% of the European paraben market by year 3 and 15% of the market by year 10. Parabens are not a very large market, so we intend to diversify into the jet fuel market in year 5. We assumed the Danish jet fuel market to be 0.02% of the global jet fuel market, which amounts to 266,250,000 DKK[2]. Our intention is to capture 5% of the Danish fuel market by year 7, and 35% of the Danish jet fuel market by year 10 due to our close proximity to the airport and domestic production. The projected profit for parabens makes the assumption that the global paraben market is 91 million USD[3] and Europe accounts for 25% of it. For parabens this is a revenue of 16,452,360 DKK per year by year 3 and a revenue of 25,036,200 by year 10. For jet fuel this is a revenue of 13,090,000 DKK per year by year 7 and a revenue of 91,630,000 DKK by year 10.

The Cost:

Thomas and Kevin will use their knowledge of biology to develop and test the anaerobic digester, and Vardhan and Solomon will be the chemical engineers to work on the process design and scale up. We will work for free for the first four years until we are able to pay off our loan. In addition, we need a chemist developing the catalysis reactor and the oxidizer. The

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[2] Allied Market Research, *Jet Fuel Market*

[3] Allied Market Research, *Paraben Market by Type*

chemist will stay on the team for product analysis and ongoing quality control in order to ensure a high quality product. The chemist will also analyze the quality of the kerosene produced since aircraft grade (a1) kerosene is held to a much higher standard than regular kerosene. We need two truck drivers to transport the manure, digestate, and parabens. We need a marketing advisor and financial advisor to help us navigate the market. We will also hire a lawyer to help us obtain a patent, navigate EMA and Danish regulations, protect our IP, and potentially represent the company in court if the need ever arises. Not having to represent ourselves in court or hire a lawyer should someone ever infringe on our patent will save us time, money, and stress in the future.

In terms of physical needs we will need to rent labs. Building new labs will be a waste of money since we will only use them for a year before we begin producing parabens and a year before we begin producing fuel. This means that out of the 10 years the labs will only be used for 2 years and therefore it does not make sense to build labs onsite. We will also need to rent a pilot plant for both paraben production and fuel production. For our paraben plant and fuel plant we will need survey land and hire a construction company to build the plants. The exact costs for each unit operation, FTE, land, and the pilot plant in the first two years is given below.

Capital/Resources	Cost per unit (DKK / unit)	Total Cost (DKK)
Separation and gas cleaning	**-**	**1,066,435**
Digester + bacteria	**-**	**715,921**
Electrolyzer	**-**	**1,431,842**
Combustion reactor	**-**	**1,421,380**
Separator	**-**	**572,737**
Catalysis reactor	**-**	**1,431,842**
Separation and upgrade units	**-**	**1,073,882**
Oxidation reactor	**-**	**429,552**
Chemist (FTE)	**-**	**1,073,882**
Financial advisor (FTE)	**-**	**1,073,882**
Truck driver x2	**713,170 DKK / person**	**1,426,340**

Marketing advisor (FTE)	**-**	**1,073,882**
Manure (363 tonnes/yr)	**70 DKK / tonne**[4]	**25,410**
Water (205 tonnes/yr)	**39 DKK/ tonne**[5]	**7,995**
Electricity (650,000 kWh/yr)	**3.46 DKK / kWh**[6]	**2,233,035**
Pilot plant	**57,386 / month**	**344,316**
Separator x10	**17,933 DKK**	**179,331**
Land (2000 m^2)	**(1,200 DKK /m^2)**[7]	**2,400,000**
P-hydroxybenzoic acid (261 tonnes / yr)	**50 DKK / tonne**[8]	**13,050**
Patent	**-**	**70,000**
Lawyer	**-**	**1,073,882**
TOTAL:	**19,138,596 DKK**	

Table 1: Estimated costs for the first year

We will assume that each worker is 1 FTE and the cost of an FTE was given to be 1,073,882 DKK. 2000 m^2 of land was estimated for the plant at a cost of 2,400,000 DKK. The costs of the needed unit operations were estimated from currently sold equivalents and are shown in the table above.

To capture 10% of the European paraben market by year 3, our revenue must be 16,452,360 DKK. Since methyl paraben is sold at 60 DKK per kg[9], the plant must produce 287,500 kg of parabens per year. To produce parabens we must first produce methanol which is then reacted with p-hydroxybenzoic[10] acid in a 1:3[11] molar ratio. We need to produce 5,668 moles of Methanol and therefore need 1,890 moles of p-hydroxybenzoic acid. This means we must produce 181,400 kg of Methanol (Equation 2) and must purchase 260,762 kg of

[4] Reuters, *Manure supplies run short as fertilizer prices soar,* Converted to DKK from USD
[5] International Water Association, *Greater Copenhagen Water Utility*
[6] Globalpetrolprices, *Denmark electricity prices*
[7] MatchOffice, *Industrial/logistics for rent on Kystvejen 24-30, 2770 Kastrup*
[8] Made in China, *P-hydroxybenzoic acid*
[9] India Mart, *Methyl Paraben - 1kg*
[10] Google Patents, *Synthesis process of methylparaben*
[11] University of Ordea, *Elaboration of a method for synthesis for methyl P-Hidroxylbenzoate*

p-hydroxybenzoic acid (Equation 3) from a general chemical producer. At a price of 50 DKK per tonne, this is an annual cost of 13,050 DKK.

$$CO_2 + 2H_2 \leftrightarrow CH_3OH$$

Figure (3) Methanol synthesis reaction

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Figure (4) Methane combustion reaction

The reaction to produce methanol from carbon dioxide and hydrogen is shown in Figure (3) above. This means that for each mol of methanol produced we will require 1 mol of carbon dioxide and 2 moles of hydrogen. For each mol of methanol we need one mol of carbon dioxide and for each mol of carbon dioxide one mol of methane must be combusted. We need 5,668 moles of methane and therefore need to produce 90,700 kg of methane. We will assume that by mass, 25%[12] of the feedstock will be converted to methane. This means that we will need 363,000 kg of manure (Equation 4). At 70 DKK per tonne, this is an annual cost of 25,410 DKK. The remaining 75% is digestate and can be sold as digestate at 0.72 DKK per kilo[13] resulting in a profit of 196,020 DKK per year.

$$2H_2O \rightarrow 2H_2 + O_2$$

Figure (5) Water splitting reaction by electrolysis

We will need 11,366 moles or 22,672 kg of hydrogen. According to figure (5) we need an equal molar ratio of hydrogen to water which means that we need 11,366 moles or 204,704 kg of water (Equation 5). At a cost of 39 DKK per tonne, this is an annual cost of 7,995 DKK.

Each kilogram of manure produces 3.75 kWh of electricity[14], and biogas will account for all of the energy supplied to the electrolyzer. 363 tonnes of manure will produce 1,361,250 kWh. It can be assumed that the electrolyzer has a 75% (LHV) efficiency which means that the heat of vaporization of the combustion products cannot be recovered from downstream. Since we need to produce 22,672 kg of hydrogen (Equation 6) and we know that each kg of hydrogen requires 44.4 kWh of electricity (Equation 7) we can find that the electrolyzer needs 1,006,636 kWh of electricity (Equation 8). This means that the combustion of only biogas can entirely support the electricity requirements of the electrolyzer. This leaves 354,614 kWh for the rest of the process. If we assume that the rest of the process requires 1,000,000 kWh of electricity to run, we will

[12] Gazpack, *Manure digestion for biogas from cow/pig/chicken manure*
[13] Environmental Protection Agency, *Digestate Alone and with Compost*, conversion in Appendix Equation 1
[14] Independent, *British farmers are turning cow poo into cow power*

only need to purchase 645,386 kWh of electricity from the grid at a cost of 2,233,035 DKK per year. The cost and revenue from each year is given in the table below:

Year	Cost (DKK)	Parabens and Digestate revenue (DKK)	Fuel Revenue (DKK)	Profit (DKK)
1	7,109,844	0	0	-7,109,844
2	16,668,596	8,324,190	0	-8,344,406
3	8,340,766	16,648,380	0	8,307,614
4	8,340,766	17,888,644	0	9,547,878
5	30,378,772	19,128,908	0	-11,249,864
6	22,050,942	20,369,172	6,950,000	5,268,230
7	22,050,942	21,609,436	13,900,000	13,458,494
8	22,050,942	22,849,700	39,810,000	40,608,758
9	22,050,942	24,089,964	65,720,000	67,759,022
10	22,050,942	25,330,230	91,630,000	94,909,288

Table 2: Estimated cost and revenue for all 10 years

For the first year our costs will consist of 3 FTEs, the land, the patent and regulations needed for our idea and the pilot plant. In our second year we will have to buy all the unit operations and resources needed for the production of parabens, all the FTEs and our pilot plant. In our third year the expenses will just be the base operating cost of 8,340,766 DKK, which accounts for the electricity, manure, water, P-hydroxybenzoic acid, and all the FTEs required to run the process. We will be able to pay off our full loan by year 4.

The cost of year 5 will be higher as when we begin producing jet fuel, we will buy another set of unit operations, hire 6 FTEs, and 2 more truck drivers. The base operating cost after year 5 is 22,050,942 DKK, which includes the cost of running both processes and 6 FTEs who will take over process operations.

Revenue was estimated to linearly increase as processes are scaled up. For example, since our goals are to capture 10% of the European paraben market by year 3 and 15% by year 10, we calculated our revenue from parabens to be 16,648,380 DKK and 25,330,230 DKK respectively.

We assume that revenue linearly increases from year 3 to year 10, and the revenue in year 2 to be half the revenue of year 3 as the plant only runs for half of year 2. The same is done for fuel production; the revenue increases linearly from year 7 to year 10, and the revenue of year 6 is half the revenue of year 7 as the plant only operates for half of year 6.

Regulatory Issues:

Since the parabens we produce will eventually end up in cosmetics, we will need to follow the Regulation (EC) N.1223/2009 of the EMA legislation. These are the rules that we must adhere to in order to sell a cosmetic ingredient. We must also follow any EMA regulation that deals with the use of bacteria in a chemical process and adhere to good manufacturing practice. We will also need to follow EMA regulations for any waste we produce again since our process uses bacteria. We also need to make sure that we can sell our parabens outside of Denmark as we hope to expand to the general European market. In terms of approvals, for our paraben process we will need marketing authorisation which requires us to submit a Common Technical Document (CTD) that includes an assessment of the quality and safety of our product.

For jet fuel we will need approval from the Danish Ministry of Transportation. We will need to perform an Environmental Impact Assessment and follow any regulation regarding emissions, especially CO_2 and NO_x. Again we will need to meet certain quality requirements in order to sell jet fuel. These tests must be carried out by us and overseen by the Ministry of Transport.

IP Strategy:

Our IP strategy is to apply for a patent on the catalysis reactor, the separation and upgrade process, and the oxidizer (green) before we get into the pilot plant phase in Q3. This will allow us to remain in a blue ocean market for 20 years and allow us to grow our capital so that we can expand into fuel production in Q20. We will wait until the end of our research and development phase to take our process and innovations public, keeping it a secret for about six months. We will begin the process to obtain a patent at around the six month mark, meaning we can minimize the risk of it taking too long to acquire by starting early. Our lawyer will aid us in obtaining the patent and help us to protect our IP in the future. Doing this will minimize the risk of the patent process taking too long and help us to prevent other companies from infringing on our IP.

Risks and Mitigation:

	Severity			
	Acceptable	**Tolerable**	**Undesirable**	**Intolerable**
Likelihood				
Improbable	Inconsiderate	Low	Medium	Medium
Possible	Inconsiderate	Low	Medium	High
Probable	Low	Medium	Medium	High
Risk Rating Key	Inconsiderate ____________ Ok to Proceed	Low ____________ Consider Mitigation Efforts	Medium ____________ Critically Acceptable Level	High ____________ Mitigation Required ASAP

Number	Risk	Mitigation Activity
1	Can not sell hydrocarbons (low price or demand)	Use excess oxygen from electrolysis to oxidize the hydrocarbons to create higher value parabens, expand low value hydrocarbon process to minimize production cost
2	Patent issues (time, cost)	Calculate profit gain vs cost of patent Apply for patent as soon as possible once we go public More people on patent team and hire own lawyer if needed
3	Expensive scale up for fuel production	Expand paraben production and market to fund fuel R&D and scale up
4	Unable to purchase the required amount of manure	Using overseas markets to purchase manure. Using different kinds of biowaste (different animal manure, etc.)

5	Water/energy requirements	Source water from ground or rainwater. Buy energy from renewable sources. Find sources and partners as soon as possible (end of R&D start of pilot tests)
6	Pilot plant	Priority to get it working as soon as possible, extensive research to make sure we have the right process and components
7	EMA does not approve our process of paraben production	EMA approval is a must, therefore we could modify the process in order to get it approved.
8	Low electrolysis efficiency	High Temp SOEC with free steam from combustion has higher efficiency but is new Increase the stack size and quantity which would increase ongoing cost
9	Low conversion for catalysis reactor	Increase the feed temperature and the temperature in the chamber.

The First Three Years:

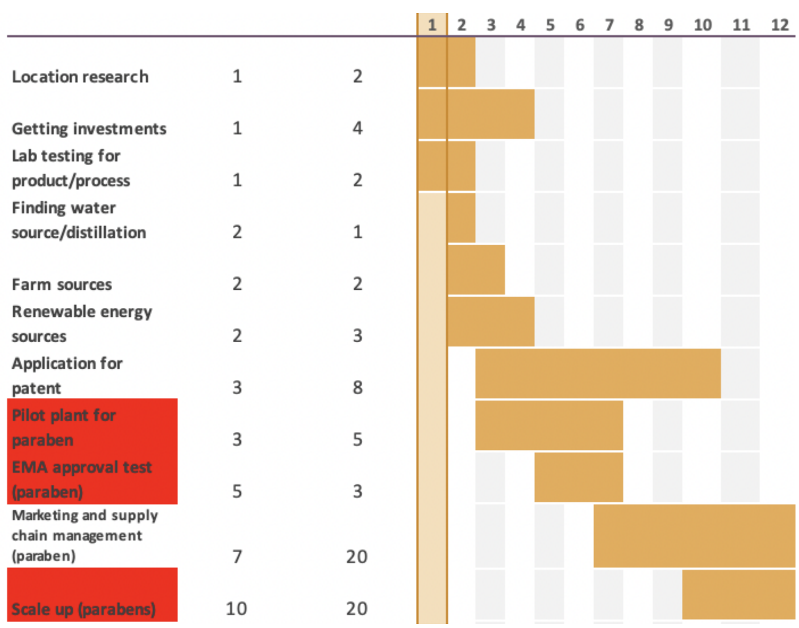


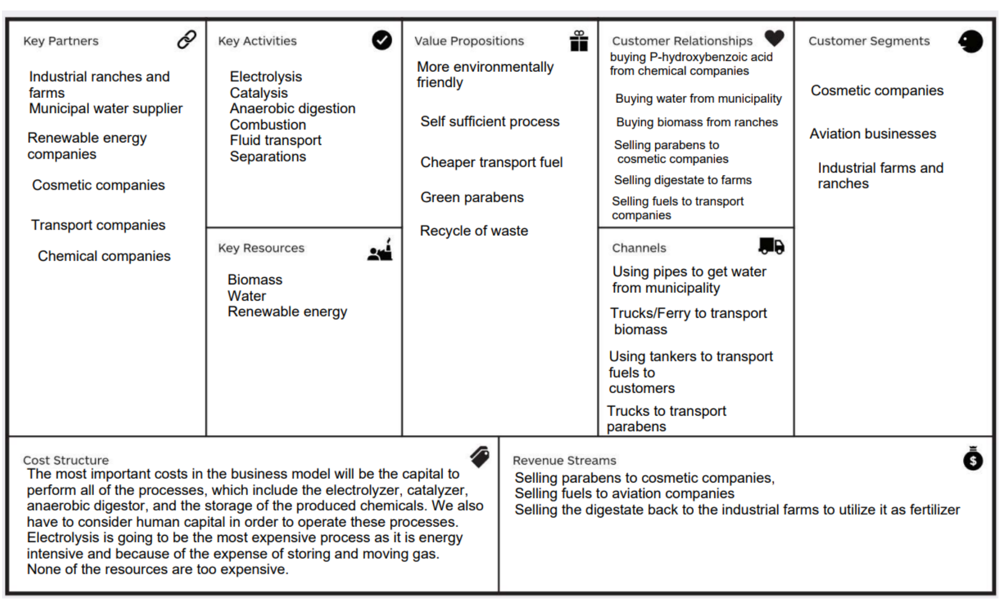
Figure 6: Three year GANTT diagram.

Within three years, our company would have established relationships with ranches and farms to buy waste from and sell our digestate product to, as well as with clients in the cosmetic industry. By this time we will also be well into scaling up our paraben production process, and intend to capture 10% of the European market by the third year. Our first patent for the process will be obtained, and our concept will be proven possible via lab testing and the pilot plant.

In the first year we will need a loan of 6,035,962 DKK in order to do R&D and lab testing for a proof of concept. In the second year after a proof of concept in lab testing, we will need a loan of 7,270,524 DKK so that we can do pilot plant testing and begin to scale up our process. Both of these loans will be fully paid off by year 4. Given the benefits to society, the cosmetic, and aviation industry, companies in those industries that are looking to reduce their carbon footprint are targets for potential investments. This is mutually beneficial since it will help these companies meet environmental sustainability goals which become ever increasingly important to investors and customers.

Based on both the diagram above and financial overview, our project has high risks of being terminated. However, having our process contribute to the four previously mentioned sustainability goals, as well as having a high efficiency and conversion rates, allows us to say that we produce sustainable and environmentally friendly parabens. We contribute to the goal of industry, innovation, and infrastructure by linking existing processes in industry in a creative way, thereby creating a new niche for ourselves. We contribute to the goals of responsible consumption and production, and climate action by making the most out of our raw materials, lowering emissions, and environmental impact by recycling heat and unreacted chemicals. These considerations of sustainability should qualify us for tax benefits from the Danish government which mitigates the risk of being terminated.

Business Canvas:



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Appendix:

(1) $0.10 \frac{USD}{Gallon} \cdot 0.26 \frac{Gallon}{kg} = 0.026 \frac{USD}{kg} = 0.72 \frac{DKK}{kg}$

(2) $287500\ kg\ M \cdot \frac{1\ kmol\ M}{152.15\ kg\ M} \cdot \frac{3\ kmol\ CH_3OH}{1\ kmol\ M} \cdot \frac{3\ kg\ CH_3OH}{1\ kmol\ CH_3OH}$

(3) $287500\ kg\ M \cdot \frac{1\ kmol\ M}{152.15\ kg\ M} \cdot \frac{1\ kmol\ P}{1\ kmol\ M} \cdot \frac{138.12\ kg\ P}{1\ kmol\ P}$

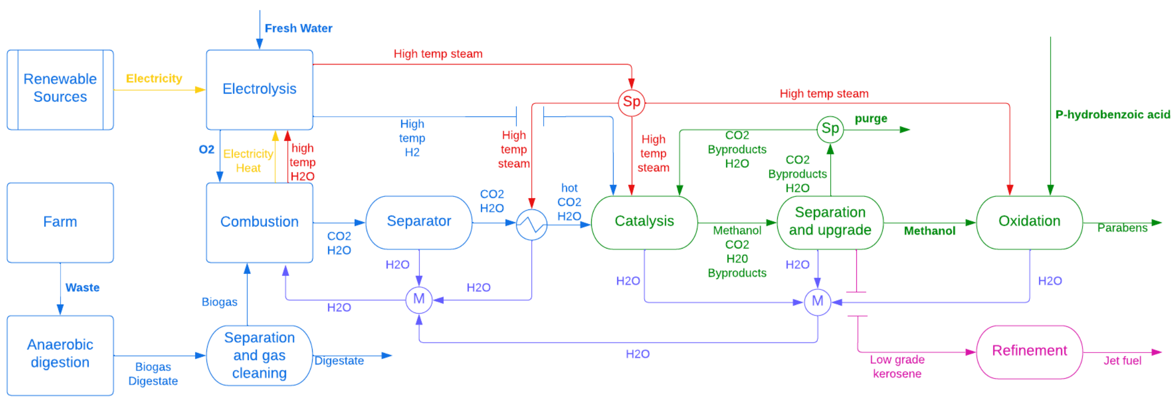
(4) $287500\ kg\ M \cdot \frac{1\ kmol\ M}{152.15\ kg\ M} \cdot \frac{3\ kmol\ CH_3OH}{1\ kmol\ M} \cdot \frac{1\ kmol\ C0_2}{1\ kmol\ CH_3OH} \cdot \frac{1\ kmol\ CH_4}{1\ kmol\ C0_2} \cdot \frac{16\ kg\ CH_4}{1\ kmol\ CH_4} \cdot \frac{4\ kg\ feed}{1\ kg\ CH_4}$

(5) $287500\ kg\ M \cdot \frac{1\ kmol\ M}{152.15\ kg\ M} \cdot \frac{3\ kmol\ CH_3OH}{1\ kmol\ M} \cdot \frac{2\ kmol\ H_2}{1\ kmol\ CH_3OH} \cdot \frac{2\ kmol\ H_20}{2\ kmol\ H_2} \cdot \frac{18\ kg\ H_20}{1\ kmol\ H_20}$

(6) $287500\ kg\ M \cdot \frac{1\ kmol\ M}{152.15\ kg\ M} \cdot \frac{3\ kmol\ CH_3OH}{1\ kmol\ M} \cdot \frac{2\ kmol\ H_2}{1\ kmol\ CH_3OH} \cdot \frac{2\ kg\ H_2}{1\ kmol\ H_2}$

(7) $Power = \frac{LHV_{H_2}}{eff_{LHV}} = \frac{119.96\ MJ}{0.75\ kg\ H_2} \cdot \frac{1\ MWh}{3600\ MJ} \cdot \frac{1000\ kWh}{1\ MWh}$

(8) $22675\ kg\ H_2 \cdot \frac{44.4kWh}{1\ kg\ H_2}$



A more detailed visual of the process with more detailed water and heat recycle loops