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DEVELOPING A BUSINESS MODEL FOR A GERMAN DIRECT AIR CAPTURE COMPANY: A CASE STUDY

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Introdução
Climate change, fueled by human activities and the greenhouse effect, is reshaping our planet with rising temperatures. Direct Air Capture (DAC) emerges as a promising solution to combat this crisis. Though in early stages and facing cost challenges, DAC's potential to remove carbon from the atmosphere is vital in our fight against climate change. Urgent efforts are needed to devise profitable strategies and attract investors and clients, emphasizing the necessity for a well-structured business model to increase the chances of success for a DAC company.

Problema de Pesquisa e Objetivo
Research problem: What would be an ideal business model for Company X to ensure the thriving of its technology in the current and future market? Objective: Develop a business model for a German company specializing in direct air capture within the environmental technology sector.

Fundamentação Teórica
The literature review begins with an exploration of Direct Air Capture (DAC) technology, where DAC is likened to an intricate system proficient at directly extracting carbon dioxide from the atmosphere using specific chemicals and processes. Following this, we delve into the realms of carbon credits and carbon offsets, clarifying their role in monetizing CO2 removal. Lastly, we dissect the significance of business models, emphasizing their influence on a company's journey to success, maintaining a balance between formality and reader-friendliness for our article.

Metodologia
This study employs a qualitative approach, focusing on "Company X," a leader in direct air capture (DAC) technology. Data sources include company-provided information, author-conducted observations, and a literature review. The research includes an overview of Company X, a market analysis of competing technologies, an examination of other DAC companies and their models, and a customer analysis. The final section analyzes key elements for building Company X's business model, utilizing data from the literature review, internal sources, and market analysis.

Análise dos Resultados
The study initiates by providing an in-depth exposition of Company X's concept and organizational structure. Subsequently, it conducts a market analysis, benchmarking direct air capture (DAC) against alternative carbon dioxide removal (CDR) technologies. Further, it undertakes a comparative evaluation of Company X vis-à-vis other DAC players. A meticulous customer analysis ensues, shedding light on potential product consumers. Finally, leveraging insights gleaned from the literature review and market analysis, a tailored and well-structured business model is crafted for Company X.

Conclusão
This article presents a comprehensive analysis of building a business model for a Direct Air Capture (DAC) company, using Company X as a case study. DAC holds significant promise for addressing carbon mitigation and sustainability goals, offering advantages like low land use and scalability. However, challenges like cost and energy requirements persist. In order to effectively overcome these pressing challenges, a well-structures business model can be an asset for the company, increasing its chances for success.

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Palavras Chave
Direct Air Capture, Carbon dioxide, Climate Change

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1. INTRODUCTION

Climate change, a worldwide debate, profoundly transforms our planet and affects every aspect of our lives. It refers to long-term shifts in Earth's temperatures and weather patterns, primarily caused by the greenhouse effect, where atmospheric gases trap solar heat and warm the planet. Since the 1800s, human activities, notably the industrial revolutions and increased fossil fuel usage, have dramatically amplified this effect. Consequently, we confront global warming, where heightened greenhouse gas concentrations intensify heat retention, leading to rising temperatures worldwide.

Five major greenhouse gases, including carbon dioxide (CO_2), methane, nitrous oxide, fluorinated gases, and water vapor, contribute to global warming through the greenhouse effect. CO_2 stands out as the primary driver, responsible for roughly 76% of all human-caused emissions. While global efforts have been made to reduce CO_2 emissions through renewable energy investments, greener technologies, and sustainable practices, these measures alone are insufficient. The concept of direct carbon capture (DAC) has emerged as an innovative approach to decarbonizing the atmosphere by directly removing CO_2 from the air.

The urgency of the matter transcends national borders, necessitating international cooperation to achieve feasible solutions for a net-zero trajectory. The historic Paris Agreement, signed during the 2015 UN Climate Change Conference (COP21) by leadersfrom 194 Parties (193 States plus the European Union), is a legally binding international treaty on climate change that came into force on November 4, 2016. Its mission is to reduce global greenhouse gas emissions and limit the century's temperature increase to 2 degrees Celsius, ideally even 1.5 degrees compared to pre-industrial levels. Each country commits to emission reduction goals, guiding a global effort toward a net-zero emissions world and aligning with the Sustainable Development Goals.

Investing in renewables, improving energy efficiency, and avoiding deforestation are critical steps to reverse climate change, but they might not be enough. The deployment of carbon removal initiatives is critical to achieving global emissions reduction targets by2050. Globally, scientists predict that up to 10 $GtCO_2$ will need to be removed annually from the atmosphere by 2050, with an increased removal capacity of up to 20 $GtCO_2$ peryear by 2100 (W. R. INSTITUTE, 2022).

Direct Air Capture (DAC) holds promise in the climate change battle but remains in early development, requiring substantial research for optimal readiness. The primary hurdle is its high cost, making profitability, investment, and support challenging. Urgent efforts are needed to devise profitable strategies and attract investors and clients, emphasizing the necessity for a well-structured business model.

In this study, we analyze Company X, a player in the direct air capture (DAC) industry, with the primary objective of identifying the optimal business model to ensure its success in the market.

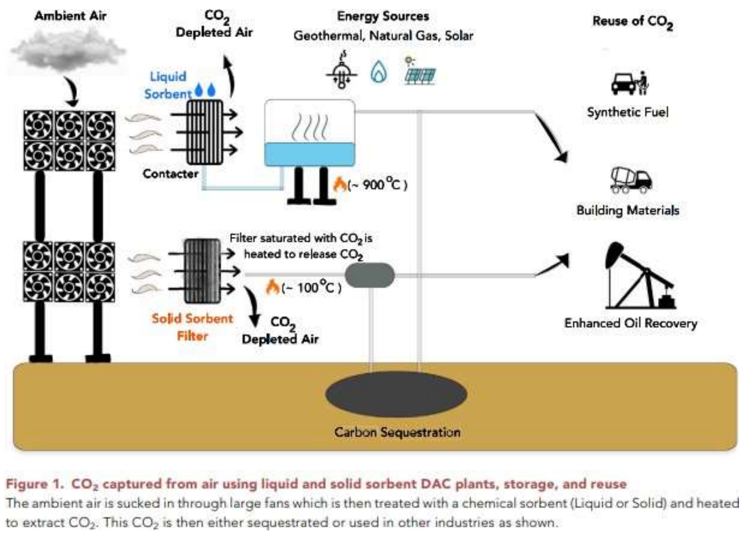
2. LITERATURE REVIEW

2.0.1. Direct air capture (DAC)

Direct air capture (DAC) emerged as a technology capable of directly removing carbon dioxide from the atmosphere. The working principle is to use chemicals capable of binding CO_2, thereby removing it from the air. The captured CO_2 can then be sold to industries that require carbon dioxide as an input, like enhanced oil refineries (EOR), conversion tofuels and chemicals, and carbonated drinks producers, or the CO_2 can be injected into underground permanent storage sites (DACCS).

The technology involves three major steps: capture, transport, and storage. In the first step, the air is sucked in by large fans and is directed towards a contacter, where the CO_2 will be trapped using a sorbent (that can be either liquid or solid) containing chemicals that react with CO_2, and the carbon-free air can pass through and return to the atmosphere. The sorbent then needs to be heated so that the CO_2 can be released, which is then regenerated and can start a new capture cycle. The CO_2 is then transported and stored underground in geological formations or used in various products and applications within different industries (DACCS). The process is schematized in Figure 1.

Figure 1. CO_2 capture using DAC plant, storage, and reuse.



Source: [9, p.3].

The sorbent material choice is a critical part of direct carbon capture technologies. The sorbent can be either liquid or solid, the second being the most common and also the one analyzed in this article. Generally, solid sorbents have better kinetics, are less prone to volatilize into the atmosphere and avoid heat losses from evaporating a liquid (SHI, 2020).

To guarantee a significant amount of net CO_2 removal, the electricity and heat inputs must come from low-carbon sources, otherwise removing CO_2 would also imply releasing CO_2, which will counterbalance the positive effect of CO_2 capture.

2.1. Carbon Credits and Carbon Offsets

Carbon credits and carbon offsets work as “permission slips” that are issued to offset unavoidable carbon emissions or to remove CO_2 from the atmosphere. Carbon credits are transacted in the carbon compliance market, while carbon offsets transactions happen in the voluntary carbon market. Purchasing one carbon creditor carbon offset is equivalent to removing one metric ton of greenhouse gases from the atmosphere.

Carbon credits are associated with cap-and-trade systems in which governments limit the carbon emissions that specific industries can release. Companies exceeding their allowances must buy new credits to increase their cap (HASHGRAPH, 2023). The number of credits issued every year changes depending on the emissions targets, which vary according to country and industry. The tendency is that the limit (cap) for emissions will decrease over time, which will make the credits scarcer and consequently more expensive so that the emissions target can be achieved.

The carbon credit system works by using financial incentives to force businesses to reduce their emissions, which can be done either by rewarding those who manage to use fewer credits or by penalizing those who use more.

The voluntary carbon market, however, refers to a system in which individuals, organizations, and companies can voluntarily offset their carbon emissions by purchasing carbon offsets. Purchasing carbon offsets means that the company is investing in projectsthat help reduce greenhouse gas emissions, which can be done by projects like planting trees, CCS technologies, renewable energy, energy efficiency improvements, and other projects that remove greenhouse gases from the atmosphere.

The voluntary carbon market operates parallel to the compliance carbon market. While the second one is regulated by government policies and mandatory emissions reduction targets, the VCM offers flexibility and wider participation for individuals and smaller organizations.

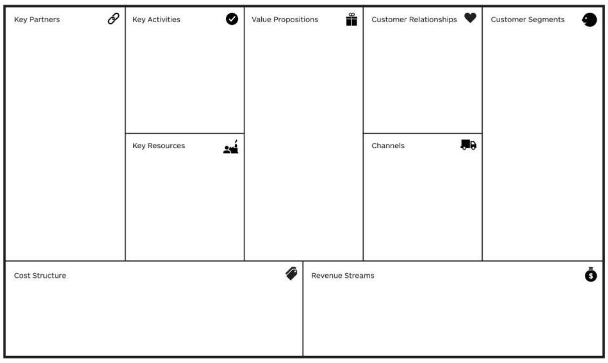
With the creation of carbon credits and carbon offsets, a new market emerged, where CO_2 emissions were given a price and became a commodity. According to Refinitiv, one of the world's biggest providers of financial markets data and infrastructure, the carbon credits market was valued at US$261 billion in 2020, representing 10.3Gt CO_2 equivalent traded on the compliance markets for that year. The voluntary carbon market for offsets, even though smaller, is expected to grow in the following years. According to BCG (2023), the voluntary carbon market was valued at $2 billion in 2021 — four times its value in 2020.

2.2. Building a business model

A business model describes an architecture for how a firm creates and delivers value to customers and the mechanisms employed to capture a share of that value (TEECE, 2018). It acts likea blueprint that tells how a company operates, differentiates itself from competitors, andultimately achieves profitability and sustainable growth.

The elements of a business model must cover the three main areas of a business: desirability, viability, and feasibility, and can be described through 9 building blocks: Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships, and Cost Structure (AG, 2019). In Figure 2, is an example of what a framework for a Canva Business Model looks like.

Figure 2. Example of Business Model framework.



Source: (AG, 2019).

This visual representation allows for a comprehensive view of the company's bigpicture, making it easier to communicate and understand the strategic components that drive its operations.

For the purpose of this study, the company will focus on the Canva business model, as it is simple and convenient, especially considering the novelty of this technology. Nonetheless, for future development and when the technology reaches more mature levels, other business models should be explored, in particular sustainable business models.

The literature review in this study provides an overview of the current knowledge and research on Direct Air Capture (DAC), encompassing technological aspects and carbon markets. It also delves into the concept of a business model and its key components. This review forms the basis for subsequent discussions and conclusions aimed at developing an effective business model for a DAC company.

3. METHODOLOGY

3.1. Classification of the study

This study adopted a qualitative approach based on a single case study. The purpose is to develop a business model for a company developing a direct air capture technology (DAC). For confidentiality, the company's name was changed to "Company X". The companyis one of the front-runners in developing direct air capture products, more specifically through retrofitting cooling towers.

In this study, the main sources of information will be the data provided by the company, the data collected by the author while observing the company and taking notes, and a thorough literature review.

3.2. Data collection and analysis

In conducting the literature review, the primary sources of data comprised online articlesand research publications. Additionally, to gather firsthand information about company X, the author engaged in a 6-month period of observation, starting from January 2023 to June 2023. This involved direct interaction with the company, conducting interviews withkey stakeholders, and reviewing company documents.

After all the data Is collected, the first topic to be developed is a dive-in into the company and its technology, where an overview of the company is provided along with technical information about the ongoing and future products. The second step was to develop a market analysis, where other competing technologies were analyzed, especially in terms of competing in the voluntary carbon market for selling carbon credits. Other DAC companies were studied, focusing on their technology and business models, and then finally a customer analysis.

In the section "Building a business model", all of the relevant elements of a business model, outlined during the literature review, were analyzed in the context of Company X. For each topic inside this section, data obtained from the literature review, the data collection inside the company, and the market analysis were analyzed and interpreted by the author.

4. ANALYSIS AND DISCUSSION OF RESULTS

The Results and Discussion chapter of this article provides a comprehensive analysis and interpretation of the collected data, focusing on its application in structuring the business model of Company X. By the end of this chapter, a clear understanding of the envisioned business model for Company X will be attained.

4.1. Study environment

Founded in 2021 by two sustainability-driven engineers, Company X embarked on its mission to decarbonize the atmosphere with passion. With an initial fundraising effort that attracted three venture capitals and seven individual investors, amounting to a total of 1.35 million euros, the company managed to assemble a small dedicated team. Company X then organized itself into three main areas: chemical and process, mechanical, and business.

The company is running entirely on investments and grants, with the first profits expected to be generated in 2025, once the first modules can be installed. The company intends to reach a price-point of 532 €/t by 2025, before realizing 106-161 €/t in 2030.

The upcoming market-ready modules represent a significant milestone, with an anticipated capture capacity of 62.5 tons of CO_2 per year. Looking ahead to 2024, Company X plans to install 8 modules, resulting in a combined capture capacity of 500 tons of CO_2 annually. Recent progress has been made as the company successfully constructed the initial prototype, enabling comprehensive testing and experimentation to identify areas for optimization and refinement.

Elaborating on the technology, the upcoming product is a modular capture unit capable of capturing CO_2 directly from the air. Company X uses a low-temperature, Vacuum Temperature Swing Adsorption (VTSA) process, using an amine-based solid sorbent, placed on a structured bed from additive manufacturing. One of the biggest advantages of solid sorbents is the lower temperatures in the process (80 to 120 °C), which are easier to achieve in a smaller-scale company.

The airflow in the final product will be provided by a cooling tower, which must still be retrofitted so that the module can be integrated into the process. Currently, the first prototype capable of capturing CO_2 has been successfully developed and it is undergoing tests and optimizations. The airflow is temporarily provided by a fan, while the retrofitting of cooling towers composes the next phase for the company.

The initial concept was to focus solely on leveraging cooling towers, so that the carbon dioxide present in the air passing through the cooling tower could be captured, but new possibilities arose during research and development. Waste heat integration is being explored as an alternative path, so that the business can expand beyond cooling towers. With this approach, any industry generating sufficient amounts of waste heat could then be a possible client for the company. Nonetheless, those are future improvements that stillneed to be properly researched.

4.2. Direct air capture market analysis

When it comes to DAC, there are currently nineteen DAC facilities active worldwide, capturing almost 0.01 Mt of CO_2/year, and a 1 Mt CO_2/year capture plant is in advanced development in the United States. In the Net Zero Emissions by 2050 scenario, direct aircapture is scaled up to capture almost 60 MtCO_2/year by 2030 (IEA, 2022). Plans for a total of eleven DAC facilities are now in advanced development. If all of these planned projects were to go ahead, DAC deployment would reach around 5.5 MtCO_2 by 2030; this is morethan 700 times today's capture rate, but less than 10% of the level of deployment needed to get on track with the Net Zero Scenario (IEA, 2022).

Looking into the economic side, as of 2022, the real voluntary carbon market is valued at around \$2 billion, while the compliance carbon market is valued at \$899 billion (NEUFELD, 2023). Despite the compliance market being more significant, the voluntary market has grown over five times what it was 3 years before, and it is expected to grow even further.

According to a 2020 report by the World Bank, carbon prices on the VCM start at less than US\$1/ton CO_2e and increase to US\$119/ton CO_2e. And the prices for almost half of the emissions are at less than US\$10/tCO_2e (CarbonCredits, 2023). In 2021, a total of 493 MtCO_2e were traded in the VCM.

On one side the VCM is growing rapidly, as more companies are increasingly investing in carbon dioxide removal approaches. On the other hand, the prices of carbon offsets are very competitive, as most CDR projects can achieve the US\$10/tCO_2e margin, making it difficult for technologies such as DAC that have a higher price to infiltrate without governmental assistance.

Shifting to the environmental sphere of this analysis, according to the IPCC (Intergovernmental Panel on Climate Change), we'll need to remove 10 billion tons (or gigatons) of CO_2 from the atmosphere by 2050. We have removed around 0,01% so far (CDR, 2023),which means that CDR technologies have to increase significantly.

To limit the temperature increase to under 2°C by the end of the century, a yearly capture and removal of 20 GtCO_2 would be necessary (OZKAN, 2022). Currently, the global carbon dioxide capture and storage rate is 0.0385 GtCO_2 per year, including a DAC capacity of 9,000 tCO_2 per year (OZKAN, 2022). If these rates persist, it would take over 20 thousand years to achieve the goals outlined in the Paris Agreement.

4.2.1. Products analysis

There are currently a few products available in the market that can actively remove CO_2 from the atmosphere. These technologies are known as carbon dioxide removal (CDR) technologies. That assortment of products includes targeted afforestation and reforestation, enhanced weathering, coastal blue carbon, soil carbon sequestration, peatland rewet-ting, direct air capture (DAC), and bioenergy with carbon capture and storage (BECCS),amongst others.

The readiness level of DAC is the lowest amongst all of the CDR technologies. This is mainly because the technology is still relatively new. The elevated cost of the technology prevents it from being able to thrive on its own, thus more optimizations are necessary for properly deploying DAC at an acceptable level.

Furthermore, direct air capture (DAC) technology can assist in addressing emissions that are difficult to avoid and emissions originating from distributed sources. Theseinclude annual emissions from concrete manufacturing, transportation, the iron-steel industry, and wildfires. DAC falls short on the cost and energy use, but if those barriers canbe surpassed, DAC has the potential to thrive in this market, especially due to its low land requirement and flexibility, as it can easily be applied almost anywhere.

4.2.2. Competitors analysis

Company X faces direct competition from other companies engaged in DAC projects. Currently, the most notable competitors in the DAC space include Climeworks, Carbon Engineering, and Global Thermostat, with numerous smaller companies also entering the field. Each of these competitors employs unique operational strategies and revenue-generation methods.

Multiple aspects of the process can vary among different companies. Variations may arise in how air is transported through the contactor, either naturally or through the use of mechanisms such as fans. Additionally, companies have the flexibility to select from a range of sorbents, encompassing choices within both liquid and solid categories. The contactor itself can adopt diverse shapes and sizes. The ultimate destination of the captured CO_2 can differ based on the company's partnerships and geographical location. Furthermore, the overall cost can fluctuate depending on factors such as the construction methodology, resource allocation, and other related considerations.

Analyzing the major players today in the DAC industry, the features that seem to be important in the product are having a modular design, scalable, with low energy demand, and big capture capacity. On the business side, having good partnerships is a must, and offering the lowest possible price. The consensus seems to be achieving the below 100$/t$CO_2$ mark, but most companies are aiming at achieving this goal by 2030 atthe earliest.

4.2.3. Customers analysis

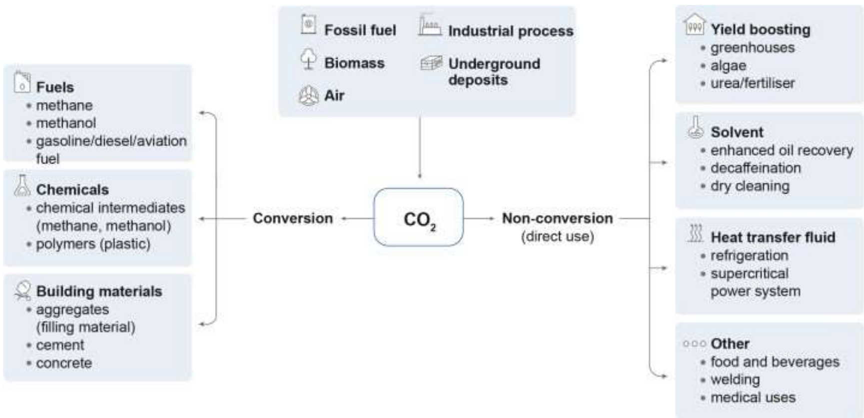
As was shown during the competitor analysis, a direct air capture company can have a wide range of clients, depending on their business model and the solutions they offer. The most common tracks among DAC companies are selling carbon offsets, selling the captured CO_2 to utilization companies, selling the device itself to other companies, and partnering up with storage companies to provide a full capturing cycle.

Targeting companies such as energy and utility, companies operating power plants, renewable energy facilities, or industrial installations may seek direct carbon capture services to reduce their CO_2 emissions. These companies may be looking to comply with environmental regulations, improve their carbon footprint, or align their operations with sustainability goals. The same applies to companies within the industrial sector, across various segments, such as steel, cement, petrochemicals, chemicals, and more, which can benefit from direct carbon capture to reduce their emissions. Industries that are significantCO_2 emitters are increasingly showing interest in carbon capture and storage solutions tomitigate their environmental impact.

Another very relevant field worth mentioning is the transportation sector. Transportation companies, such as airlines, shipping operators, and logistics companies, oftenhave elevated emissions and may seek direct carbon capture solutions as part of their efforts to reduce them. Direct air capture can be a viable option for offsetting the emissionsgenerated by their operations.

On the utilization side, carbon dioxide can be used as an input for a variety of industries. One of its primary uses is in the carbonation of beverages, such as carbonated water, soft drinks, and beer. The food industry utilizes CO_2 for cryogenic freezing and chilling, as well as for extending the product longevity of packaged foods by displacing oxygen. It is embedded in fire extinguishers, especially when water-based suppression systems are not suitable, such as server rooms, electrical installations, and chemical storage areas. It plays a role in enhanced oil recovery, where it is injected into oil reservoirs to increase oil flow. It serves as a chemical feedstock for the production of compounds like urea and methanol. In agriculture, CO_2 is supplied to greenhouses to enhance plant growth and consequently improve yields, through efficient photosynthesis. It is used in polymer production, where CO_2 serves as a raw material and helps to mitigate the environmental impact of plastics, in a process called carbon dioxide utilization or CO_2 conversion. It can serve as a chemical solvent when in the Supercritical CO_2 state, offering advantages such as low toxicity and easy removal after use. Finally, CO_2 supports algae cultivation for the production of biofuels and valuable by-products. These diverse applications highlight the versatility and potential for utilizing CO_2 as an input in various industries and processes. An overview of CO_2 uses can be seen on Figure 3.

Figure 3. Possible pathways for using CO_2.



Source: (IEA, 2019).

4.3. Building a business model for Company X

After analyzing multiple competitors and studying the market of direct air capture, a business model can be built for company X. The factors that will be considered in the process are value proposition; customer segments; revenue streams; cost structure; customer relationships and channels; key partnerships; and key resources and activities.

4.3.1. Value Proposition

Company X's value proposition is to develop a low-cost and innovative direct air capturemodule, leveraging cooling towers and waste heat.

During the products analysis, the key aspects of the most relevant CDR technologies were explored. DAC falls short in terms of cost and electricity use when compared to most of the other solutions. On the other hand, it is the one using the least amount of land and has the advantage of geographical flexibility. The deployment of Direct Air Capture (DAC) is feasible in various locations since the concentration of CO_2 is relatively consistent across different areas. Besides that, the majority of the DAC companies are focusing on having a modular, scalable device. This means that it is not constricted to one specific size, and can be easily adapted depending on the customer request. Lastly, most DAC companies have implemented mechanisms that enable convenient tracking of the amount of CO_2 captured. This feature simplifies the reporting and certification process, ensuring transparency and accountability of the captured CO_2.

Compared to other DAC companies, Company X uniqueness includes the next-gen reactor design currently under development, and the cooling towers retrofitting approach, which will lead to a complete patent family, ensuring that the business is legally protected in the long run. The focus on IP development, even though making company X differentiate from others, also implies in a need for strategic investors, that can provide legal support and guidance.

The technology itself differs on various points from other DAC companies. For one, utilizing waste heat and airflow from cooling towers can lower the cost of the capturing process, as the company is re-purposing underutilized streams. Essentially, cooling towers worldwide are operating to remove heat from a process or a building and use large amounts of ambient air to do so. Based on an internal Techno-Economic Analysis (TEA), along with experimental results developed by the company, Company X's team is able toprecisely quantify the potential of such streams.

Another significant advantage is being highly accessible and geographically flexible. It was mentioned before that this is already an advantage when compared to other CDR technologies, but it is also a differential when compared to some DAC companies. Theoretically, it should be possible to deploy DAC anywhere, but many competitors, suchas Climeworks, are focusing on building their plants in remote areas, due to storage availability. However, this often leads to significant challenges in terms of construction and maintenance, resulting in consistently rising prices, particularly in recent years due to supply chain issues and rising transportation costs.

4.3.2. Revenue Streams

Company X set two phases for generating revenue, with a total of three paths for profiting. Two of the paths will be applied during phase one, while the third path will only begin inphase two.

The first phase, called Go-to-market (2023-2025), consists of selling CO_2 to utilization companies and selling future carbon removal credits. During the go-to-market phase, company X will sell their carbon capture devices to customers that are using CO_2 as a feedstock for their products or services. In parallel with the utilization companies' strategy, future carbon removal credits will be offered to companies with a net-zero target.

The second phase, Licensing (2027+), consists of licensing the use of the technology to scaling partners, especially cooling tower manufacturers and other industrial players. This means that the capturing unit can be embedded in the manufacturer's product, allowing the company to scale very quickly without the need to set up its own international production capabilities or maintenance fleets. They will be overseeing the deployment of carbon capture units using the company's technology themselves and paying a licensing fee to do so.

4.3.3. Customer segments

There will be three types of customer segments to be considered, one for each of the presented paths for revenue, those being utilization, carbon credits, and licensing.

In an internal market analysis conducted by company X, several groups of companies were identified as potential customers in terms of utilization. The industries that were identified are illustrated in Figure 4.

Figure 4. List of possible utilization companies.

Carbonated drinks	Dry ice production	Lab-grown diamonds	Pulp paper and packaging
Carbonated snow	E-Fuels	Manufacturing - Automobiles	Steel hardening
Cement/concrete production	Fertilizer	Manufacturing - Aviation	Steel production
CO2 hubs-connected companies	Food	Manufacturing - Shipping	Water treatment
CO2-cooling	Glass	Oil drill sites	Welding
Composites (carbon fiber & graphite)	Greenhouse/Vertical farm	Petrochemical companies & textile fiber	

Source: Company X internal analysis.

As part of the analysis, a total of 305 companies were contacted to determine the most significant industries for the go-to-market strategy. The findings showed that carbonated beverage manufacturers and greenhouses, especially vertical farms, exhibited the highest interest in adopting the company's technology. Another sector that also appeared promising was Lab-grown diamonds, even though behind the previous two.

In terms of carbon credits, currently, there are only voluntary buyers, like Airbus, Stripe, Shopify, and Microsoft. Company X already has strong partnerships in this realm, in particular with one marketplace where the first credits are being offered to a potential buyer at a price of €1100 per ton of CO_2. This offering encompasses the delivery of 50 tons of CO_2 scheduled for 2025.

The last track, licensing, involves scaling partners, which are companies that are licensing the company's technology during the scaling phase from 2027.

4.3.4. Cost Structure

In Company X, the costs are currently classified into three primary categories: product development, product research, and operational costs.

For the product development category, these costs encompass different stages of the carbon capture product's evolution. Initially, resources were allocated to set up the research setup for the first minimum viable product (MVP) of direct air capture. This setup enabled the capture of small amounts of CO_2 at a laboratory scale.

Subsequently, significant investments were made to develop the first autonomous engineered prototype, which allowed for the capture of CO_2 at a kilogram scale. Moving forward, Company X aims to transition to on-site research projects, which involve installing the prototype at industrial sites for validation purposes with utilization customers and scaling partners. These projects require substantial resources and involve negotiations with relevant stakeholders.

The expenses can be attributed to the acquisition of components such as software subscriptions, pumps, tanks, heat exchangers, fasteners, tubes, hoses, connectors, tools, machines, and services such as welding and external manufacturing. Moreover, high-quality materials, such as stainless steel, are utilized, further contributing to the overall cost. Additionally, the sorbent, the chemical responsible for capturing CO_2, also represents an expensive resource.

For the product research realm, the costs so far are related to the development of an In-depth Techno-Economic Analysis (TEA), assembling a characterization setup, and developing a novel reactor. For the Techno-Economic Analysis, the analysis was optimized based on data and learnings from the real-life tests performed in the MVP. The analysis showed that the biggest cost drivers of the product today are electricity and heat requirements, as usual for DAC technologies, and the sorbent and reactor design.

For the novel reactor, the company worked in collaboration with established industry players and research institutes to bring fundamentally novel technologies to the world of DAC, leading to a potential capture cost of 532 €/t in late 2025 and 161 €/t by 2030. An in-depth analysis of the price progression can be seen in Table 1, along with capture capacity and energy requirement.

One of these collaborations resulted in the design and simulation of a novel reactor using additive manufacturing technologies, and the latest version was translated into reality through a first small-scale prototype print. This will enable the first physical validation ofthe reactor design, and inform the next design iterations. The research and development efforts surrounding the new reactor involved a considerable financial investment. Further funding is expected to be allocated for the validation phase following the upcomingfundraising activities.

From the first to the second prototype, the optimizations can be attributed to the development of a novel reactor, structural redesign, higher efficiency, and novel manufacturing, it is also where the patents come into place. From the second prototype to the first plant, the previous prototype is upscaled, with one industrial installation including eight modules combined, and at this step, the waste heat is integrated into the process. Moving from the first plant to at-scale plants involves having multiple operating plants, the integration of a new sorbent, and airflow retrofitting. Finally, the megaton scale is achieved by economies of scale.

Table 1. Predicted capture cost of CO_2, capture capacity, and energy requirement for the current and next versions of Company X's product.

Product version	Capture capacity (t/year)	Cost (C/t)
First prototype	5	1,715
Second prototype	62.5	798
First plant	500	532
At-scale plants	3,000	256
Megaton Scale	8,000	161

Source: Company X internal analysis.

Operational costs are related to general expenses like administrative and overhead costs, travel and transportation, maintenance and repairs, insurance, office supplies, and other general expenses.

4.3.5. Key Partnerships

Company X's success relies heavily on having the right partners, those being the entities that collaborate with the company in strategic alliances to achieve shared goals or objectives.

The first one worth mentioning are pilot companies, which are companies responsible for running a paid pilot, meaning to cover the company's costs within 2023 to validate the proposed approach outside of the workshop. In these agreements, the company will run a module similar to the prototype developed in 2023 on their site, while coveringCAPEX plus additional expenses.

Another significant partnership to be considered is with sequestration companies. These companies specialize in storing CO_2 deep underground in decommissioned gas fields located between 2 and 3 kilometers below the Earth's surface. Alternatively, some sequestration companies convert CO_2 into mineralized concrete. Company X already has a strong partnership with a company that is developing new carbon-negative concrete. This type of concrete enables the creation of carbon-negative buildings, which implies that the more these buildings are constructed, the greater the positive impact on the climate.

Scaling partners or multipliers are industrial players such as cooling tower operators, where the approach developed by company X can be validated faster. These partners play a vital role in the scaling process by providing real-world testing opportunities and leveraging their existing infrastructure and expertise.

For conducting research and development, advisors, niche experts, and academic institutions have become important partners, as they enable the company to accelerate its development. Moreover, a partnership with several regulatory bodies ensures that company has a comprehensive view of the regulatory landscape regarding direct air capture. This includes already solid partnerships with German and Global entities.

4.3.6. Customer Relationships and Channels

In Company X, the two founders actively engage in various activities to build and cultivate customer relationships. They participate in industry events to connect with potential partners and customers, proactively schedule introduction calls to establish initial connections, and bring along excellent storytelling and a compelling pitch deck to effectively communicate their value proposition. Moreover, they are constantly investing in developing a global network, actively looking for opportunities to expand their connections and establish impactful relationships. These efforts help build strong relationships with customers and boost the company's growth opportunities.

The main channel through which the company connects with partners and customers for the first time is by sending emails or calling to set up an introductory meetingand present their product, spreading the company's name. Once a relationship is finalized, they keep in touch via email, where updates are sent monthly and a direct line of communication is open. Additionally, the company maintains an active presence on LinkedIn, recognizing its significance as a leading social media platform for professionalnetworking.

4.3.7. Key Activities and Resources

The key activities that must be performed by Company X to ensure that the value proposition will be delivered to customers can be divided into two realms, the business and the product side. On the product side, these activities are research and development, manufacturing and testing, installation and maintenance, delivery and transportation of modules. On the business side, these activities include marketing, market analysis, establishing partnerships, customer acquisition, regulatory compliance, financial management, and ongoing support.

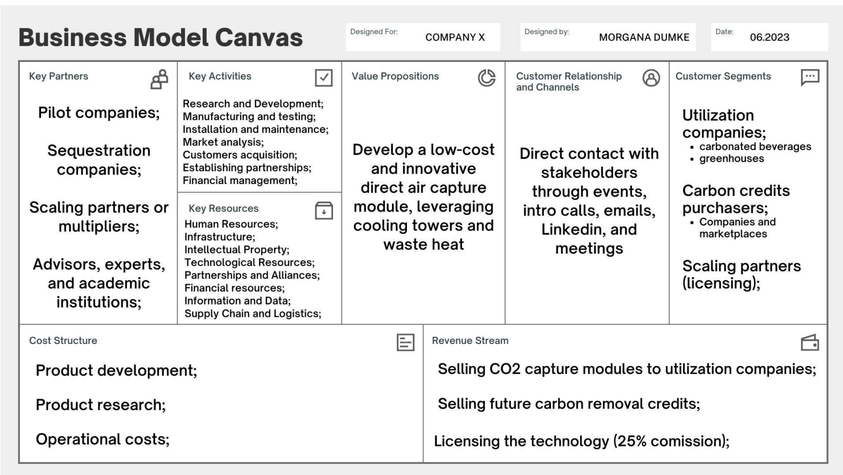
The Key Resources, on the other hand, are related to the fundamental assets, capabilities, and elements that are necessary for its operation and value creation. Key Resources and key activities are often analyzed together as they are interdependent and mutually reinforcing. In the case of Company X, the main resources required are human resources, infrastructure, intellectual property, technological resources, intangible assets,partnerships and alliances, financial resources, information and data, supply chain, and logistics.

4.4. Proposed Business Model for Company X

After individually analyzing every component of the business model for Company X, thefindings can be summarized using a visual tool. The result can be seen in Figure 5.

The company's value proposition is to develop a low-cost and innovative direct air capture module, through the use of cooling towers and leveraging waste heat. The company generates revenue through three primary channels, each catering to specific customer segments. Utilization companies buy the captured CO_2 to use as feedstock in theirproducts or services, carbon credit purchasers pay for carbon removal credits delivered by the company, and scaling partners pay a 25% commission for licensing the technology.

Figure 5. Canva business model for Company X.



Source: Author, adapted from (AG, 2019).

When examining the revenue streams, certain concerns emerge that must be addressed. Firstly, selling future carbon removal offsets entails companies paying for offsets that will only be implemented at a later date, potentially years after the purchase. This raises questions regarding the repercussions if a company closes down before the offsets are fulfilled or fails to deliver the promised offsets. Considering the newness of the technology and the need for further optimization to attain the desired level of maturity, the risks of potential failure and falling short of the desired performance levels remain significant.

It is important to address these concerns surrounding the revenue streams and develop strategies to mitigate the associated risks. Clarifying contractual obligations, ensuring financial safeguards, and establishing contingency plans can help safeguard against possible adverse outcomes. Additionally, actively pursuing technology improvements and performance optimization can help minimize the likelihood of failure and enhance the re-liability and effectiveness of the carbon removal process.

The sale of carbon capture modules appears to be the most secure revenue track as it involves immediate purchases, granting clients instant access to the technology upon acquisition. However, it remains crucial for the company to ensure adherence to appropriate procedures, encompassing maintenance and the delivery of promised results.

To establish a strong foundation for customer satisfaction and trust, it is imperative for the company to prioritize the implementation of robust protocols. This includes regular maintenance to ensure the modules function optimally and deliver the expected outcomes. By providing reliable after-sales support and promptly addressing any concerns or issues that may arise, the company can foster long-term customer relationships and uphold its commitment to delivering promised results.

Furthermore, clear communication of the company's obligations, as outlined in contractual agreements, can help set proper expectations with clients. By prioritizing adherence to procedures, providing comprehensive maintenance support, and consistently delivering the promised results, the company can uphold its commitment to customer satisfaction and bolster the reliability of its revenue stream derived from module sales.

The third revenue track, licensing, presents numerous uncertainties and is not intended for implementation prior to 2027. Consequently, it is crucial for the company to develop a well-defined plan to navigate this avenue successfully.

A crucial starting point is ensuring that the necessary patents are in place. This step is essential to protect the company's intellectual property and establish a solid foundation for licensing agreements. Additionally, drafting comprehensive and robust contracts with clients is paramount. These contracts should clearly outline the terms, rights, and obligations associated with the licensing arrangement. Once all the bases are covered, licensing has the potential to become a significant and reliable source of income for the company.

Overall, with the implementation of the proposed business model, Company X is well-positioned to successfully deploy its products and gain a substantial market share in the direct air capture industry. Other companies were analyzed, and considering the similarities and differences outlined during the competitor's analysis, Company X seemsto be in a position where is not the most mature company in terms of technology readiness but has differentiators that place them in a good spot. The commitment to developinga strong network has been bringing multiple benefits to the company, paving the way to receiving investments and building strong relationships with possible consumers and partners. Additionally, Company X integrated two technological aspects that set them apart, those being waste heat integration and repurposing existing infrastructure (coolingtowers).

5. FINAL CONSIDERATIONS

This article has provided a comprehensive analysis of how to build a business model for a Direct Air Capture (DAC) company, with a specific focus on Company X as a case study.

The findings of this research reveal that DAC shows a big potential in addressing the urgent need for carbon mitigation and achieving sustainability goals. DAC has some advantages when compared to other Carbon Dioxide Removal (CDR) technologies, like low land use and scalability, however, cost and energy requirements are still challenges. The analysis of competitors highlights the unique selling points and differentiation strategies that Company X can leverage to position itself favorably in the market, like the incorporation of cooling towers and waste heat into the product.

The examination of the voluntary carbon market highlights the increasing demand for carbon removal credits and the potential revenue streams available to DAC businesses. In the voluntary carbon market the competition with alternative - and cheaper - CDR technologies is intensive, and the elevated cost of DAC puts this industry in a tough spot. While DAC companies currently can only offer prices between 400$/t$CO_2$ to over 1000$/t$CO_2$, afforestation and other CDR projects can offer prices as low as 10$/t$CO_2$. In order to achieve economies of scale, and reach the desired 100$/t$CO_2$, there are four main steps, which are: successfully integrating waste heat into the process, optimizing the technology with a focus on reducing energy demand, researching new sorbents, and building an innovative more advanced contactor, leveraging additive manufacturing.

After analyzing every aspect of Company X's business in the context of a business model, a visual business model was proposed, including value proposition, revenue streams, cost structure, customer segments, key partners, key activities and resources, customer relationships and channels. The proposed business model considered the company's current structure and inputs from the literature review and author assessment, resulting in a holistic business model that can lead the company to achieve its goals and conquer a spot in the direct air capture market. While challenges persist, including cost implications, logistical complexities, and the need for supportive policy frameworks, the article concludes that building a cohesive business model for a DAC company is both viable and necessary. By addressing these challenges, harnessing technological advancements, fostering strategic partnerships, and capitalizing on the growing demand for carbon removal, Company X can establish itself as a key player in the DAC industry.

In conclusion, this article emphasizes the growing potential of DAC as a solution for combating climate change and provides a roadmap for developing a successful business model in this thriving field. By exploiting Company X's unique strengths, market differentiators, and relevant regulatory frameworks, the company can pave the way for a more sustainable future while creating long-term value for stakeholders and contributingto global carbon reduction efforts.

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