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Transformation in the Oil and Gas Industry: A Novel Hydrocarbon Storage Solution

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Em.O.Univ.Prof. Dr.h.c.mult Dipl. Ing. Dr. Peter Kopacek

Maria Cristina Luna Loya

11936041

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Affidavit

I, **MARIA CRISTINA LUNA LOYA**, hereby declare

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2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
API	American Petroleum Institute
AR	Augmented Reality
BMC	Business Model Canvas
BP	British Petroleum
CAPEX	Capital Expenses
CCUS	Carbon Capture Storage and Utilization
CO_2	Carbon Dioxide
COVID-19	Corona Virus Disease 2019
CRE	Energy Regulatory Commission
CSA	Canadian Standards Association
DOF	Mexican Official Journal of the Federation
EIA	Environmental Impact Assessment
EPO	European Patent Office
HE	His Excellency
HPC	High Performance Computing
IEA	International Energy Agency
IOGP	International Association of Oil and Gas Producers
IoT	Internet of Things
IPIECA	International Petroleum Industry Environmental Conservation Association
KPMG	Klynveld Peat Marwick Goerdeler
LCD	Lean Customer Development
LNG	Liquified Natural Gas
LOI	Letter of Intent
MIT	Massachusetts Institute of Technology
MNC	Multinational Company
NDA	Non-Disclosure Agreement
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
PCT	Patent Cooperation Treaty
PDO	Petroleum Development Oman
SDS	Sustainable Development Scenario
SENER	Mexico’s Secretary of Energy
SWOT	Strengths, Weaknesses, Opportunities and Threats
TBL	Triple Bottom Line
UNO	United Nations Organization
WIPO	World Intellectual Property Organization
WPC	World Petroleum Congress
WTI	West Texas Intermediate

ABSTRACT

The digital age and stronger focus on sustainability of energy production have brought a wave of new advancements to the world. Nonetheless, the traditional fossil fuels will continue to be the main source of energy for the next decades. However, the oil and gas industry must adapt to the new era and increase its agility to quickly respond to the fluctuations in supply and demand in upcoming and developing markets. In this paper, a literature review is first presented describing the challenges and opportunities faced in the industry. Two strategies are presented which have shown to propel forward other industries and could help the oil and gas industry adapt to current times. Following this literature review, the findings will be applied to the development of a novel flexible hydrocarbon storage solution. The intention of this project is to present improvements, by which the industry could become more agile and responsive by offering a more economic and quick-to-build solution to replace carbon steel storage tanks. The implementation of such a solution would substantially improve the balance of economic, environmental, and social focus of the industry and offer a step forward starting from the midstream sector, the one responsible for moving hydrocarbons to where they are needed.

1 INTRODUCTION

The oil and gas industry has had many ups and downs since its early days, when the first oil well started production on August 27, 1859 in Pennsylvania, USA. The most recent bust caused by the outbreak of a new strain of coronavirus, the COVID-19 pandemic, was the latest and greatest down ever experienced. According to the Organization of Petroleum Exporting Countries' (OPEC) Secretary General, HE Mohammad Sanusi Barkindo, there has never before been such an abrupt and precipitous decline in oil demand side-by-side with a consequent swelling of inventory levels (Barkindo, 2020, p. 1). Such precipitous decline in demand, especially in April 2020, filled the available crude oil storage in some parts of the world.

The worldwide decline of oil demand also caused a large drop on crude oil prices, taking a very deep dive down to the negative numbers. Prices have leveled back around $40 USD per barrel of crude oil as governmental lockdowns eased and the agreement achieved by OPEC-plus countries in June 2020 helped to cut production to avoid flooding the market. Nonetheless, the price of crude oil is still below what it used to be just a few years ago. The industry must be able to survive this down term and continue to strengthen its operations to be able to continue to provide necessary energy to the world.

Although the oil demand in 2020 decreased by 20% due to the COVID-19 pandemic, global energy demand is expected to continue growing in the medium and long term, increasing by around 25% between 2019 and 2045 (Al-Qahtani, 2020). In this forecast, it is expected that energy demand in the 37 member countries of the Organization of Economic Co-operation and Development (OECD) will have a slight decline and the non-OECD countries will contribute the largest part of the growth. Non-OECD countries, mostly India and China, will be the drivers behind this energy demand growth.

This thesis will highlight some of the most important challenges and opportunities currently in the oil and gas industry based on a literature review. Macro challenges include providing supply of energy demand sustainably, doing more with less, and demographics influencing future developments. On the opportunities side, digital transformation will be a main driver for increase in productivity, decrease in operational expenses and reduction of safety hazards for oilfield personnel. The opportunity to turn from an "oil and gas" to an "energy" industry will also be explained.

The third opportunity covered in this thesis will be the growth in developing economies and how this represents a valuable prospect for the industry.

Taking into consideration the challenges and opportunities, two innovation strategies that have not been widely implemented in the oil and gas industry will be studied for the applicability to strengthen the industry's future. Reverse Innovation will be covered in this thesis because the largest drivers of energy demand will be in non-OECD countries like India, China, Brazil, Singapore, South Africa, Malaysia, and Thailand. Most of the Non-OECD countries are emerging markets. Emerging countries do not seek to be imitators of technology, they want to be leaders in innovation and become globally competitive. Such was the case in Vietnam where companies started developing high quality products instead of cheap, mass produced products because it resulted more profitable (Kopacek, 2019). For this reason, emerging markets in the oil and gas industry will find a way to get up to speed by the increase of development of new products to meet their growing demand. The second strategy focuses on the digital world since it was found that the digital era customers are calling for a digital experience. Because of the fast population and demand growth, strategies will have to be agile and make the oil industry more responsive to the market.

A product in need of increased agility in the oil and gas industry is the popular carbon steel storage tank. As it was experienced during the last industry downturn, storage capacity was remarkably close to being filled in many parts of the world. Because carbon steel storage tanks are expensive to build and take a long time to design, manufacture and install, they cannot respond rapidly to the changes in demand of the market. The proposed storage solution intends to be more economical and take a fraction of the time for the product to be built in comparison to carbon steel storage tanks. Such products will be the future of the industry because they will allow more flexibility and responsiveness to the changes in demand and supply.

A brief description of the workings and interconnections of the industry follows. The oil and gas industry is divided into three different sectors, which are upstream, midstream, and downstream. Oilfield companies focus their efforts on either exploration and production, transportation, or refining, respectively. Following are brief descriptions of each one of them.

1.1 UPSTREAM

The upstream sector involves activities related with exploration and production. Exploration entails searching for reservoirs of hydrocarbon in areas that have high potential based on the local geology or nearby resources. This is done utilizing high technological seismic instruments with the goal of locating and estimating potential resources. If high potential is found in an area, exploratory wells are drilled to test and confirm the finding. In the event of a successful discovery, further wells are drilled, production equipment is installed replacing drilling equipment, and hydrocarbons are pumped out of the reservoir. Exploration and production can take place either in land or offshore. Offshore water depths range from shore to 2,450-meter water depth.

1.2 MIDSTREAM

As the name implies, the midstream sector lays between the upstream and downstream segments of the industry. The activities in this sector include processing, storage, and transportation of produced fluids, i.e., crude oil and gas. Transportation is accomplished via pipelines, trucking fleet, tanker ships, and rail cars. Processing of produced fluids is performed by facilities that measure the production rate, separate oil, gas, and water, and remove impurities to prepare the fluids for the next step in the logistics chain. Storage facilities include bulk terminals, refinery tanks and holding tanks that distribute production fluids into pipelines or ships.

1.3 DOWNSTREAM

The downstream sector is responsible for refining crude oil and gas into a wide variety of finished products. Activities in this sector include petrochemical refining, distributing and retail of petroleum products. Some of the finished products include gasoline, diesel, jet fuel, synthetic rubber, plastics, fertilizers, lubricants, pesticides, to name a few. The downstream industry provides thousands of products to end users around the world.

1.4 SUMMARY

The year 2020 will forever be remembered as the year that the world stopped. There was no industry that did not feel an effect from the COVID-19 pandemic. The oil and gas industry was not an exception, it suffered like no other time before. Going forward, the industry must recover to be able to provide the energy demand that the growing population needs. Non-OECD countries will have the highest increase in demand, most of them being emerging markets. This thesis will present the challenges (sustainable supply of energy demand, doing more with less and demographics) and opportunities (digital transformation, shift from “oil and gas” to “energy”, growth in developing economies) that the oil and gas industry faces. The thesis will also present two strategies (Reverse Innovation and Digital Strategy) to be applied in the industry. Based on the literature research performed, a project will be presented in the last section of this thesis which strives to replace a rigid, inflexible, and slow-to-respond product currently used in the industry – the carbon steel storage tank. The development of a novel hydrocarbon storage solution that will be more economical, quicker, and easier to build than the current standard carbon steel storage solution will be presented. By introducing a new type of storage to the industry it will increase the responsiveness and flexibility of the industry as a whole and will allow it to survive a lower breakeven point based on a lower barrel price of crude oil.

2 CHALLENGES IN THE OIL AND GAS INDUSTRY

This list is of challenges in the oil and gas industry are not intended to be exhaustive or comprehensive, but rather should offer enough information to create a general perspective.

2.1 SUSTAINABLE SUPPLY OF ENERGY DEMAND

According to the General Director of the World Petroleum Council (WPC), Pierce Riemer, the energy consumption in the next 20 years will grow by about 35 to 40 percent and 80 percent of the world's energy matrix will be a mix of coal, natural gas, and oil (Riemer). This means that the oil and gas industry will continue to have a huge impact in the years to come. Although the natural resources to supply the world's demand are plentiful, the challenge lays in delivering these to the consuming markets. Supplying the energy demand for the world is not a small task, doing so sustainably makes it even a greater one.

In accordance with the Cambridge Dictionary, the meaning of the word 'sustainable' is causing little or no damage to the environment and therefore being able to continue for a long time. According to Systems Engineering Professor Edmond Hajrizi, sustainable development means keeping a balance between the environment and human quality of life and contributing to reduce environmental issues. Furthermore, a sustainable development must also be profitable and beneficial. For sustainability to exist, all these factors must be in balance. This is commonly called the 'Triple Bottom Line' or TBL, where the three components of sustainable development – economic, environmental, and social – are of central focus.

At the last WPC, the head of state of the host nation, Turkey's president Tayyip Erdogan stated that resources were being pumped into large midstream projects to ensure security of supply for the wider region (Deduleasa, 2017, pp. 14-15). Moreover, the CEO of the oil company British Petroleum (BP) asserted at the last WPC that energy demand is continuing to grow, driven by the fast-growing economies around the world (Schmidt, 2017, p. 28). Fast forwarding to 2020, the economic environment changed due to the implications caused by the COVID-19 pandemic. This caused a downturn where significant resources for the industry had to be reconsidered. Some of them were deferred, meaning that production will arrive later to the market. Some of it will not come through at all, either because new projects are being shelved or because some existing production is shut-in due to the pandemic and not restarted (IEA, 2020). The oil and gas industry that will emerge after 2020 will be considerably different from the one before. In some ways, this pandemic represents an opportunity to rethink the course of action to a more resilient, secure, and sustainable path.

Focusing on the topic of sustainability, renewable energy is of course an increasingly attractive source of power. Realistically, however, renewables will remain relatively expensive in the near term and will not fill the energy demand soon. It is clear that changing the energy source mix will be necessary to increase sustainability, but it will not be sufficient to achieve the energy-related Sustainable Development Goals set by the United Nations. A cleaner energy mix must be complemented by considerable efficiency improvements, the rapid deployment of low-carbon technology, and large changes in behavior towards more sustainable drilling, production, refining, and consumption (UnitedNations, 2020).

The oil and gas industry has a huge sustainability challenge to overcome as it has, in some instances, have had a bad image. This is because some oil and gas companies have caused environmental crises which have had grave consequences for many societies leaving negative lasting effects. Three of the largest catastrophic accidents caused in the industry are listed below to name a few.

1. Niger Delta Oil Pollution – Nine to thirteen million barrels of oil have been spilled over fifty years since commercial oil production began there in 1958 (Kadafa, 2012) making it one of the most polluted areas in the world. This has caused forest destruction and biodiversity loss which in turn affected the livelihood of indigenous people depending on the ecosystem.
2. Deepwater Horizon disaster in the Gulf of Mexico in 2010 – Estimated at nearly five million barrels spilled to the gulf in three months, this catastrophe represents the largest oil spill in United States history. This affected beaches, wildlife, fisheries, and tourism.
3. Kuwait Oil Spill in 1991– The Persian Gulf war oil spill, a man-made disaster, caused about 11 million barrels of oil to be released into the ocean. This represents one of the largest ecological tragedies in the world, damaging more than 800 km of Kuwaiti and Saudi Arabian beaches, devastating wildlife, and killing thousands of birds (Sadiq & McCain, 1993).

Environmental catastrophes like the ones previously mentioned have prompted a search for measurable improvement in performance and greater transparency and operation in oil and gas industries (Mojarad, Atashbari, & Tantau, 2018), leading to a call for a more sustainable supply of energy demand. This has been an important factor that explains the introduction of the concept of sustainability into the oil and gas industry. It is better late than never to begin a sustainable path, since fossil fuels will continue to be the major reliance at least for the next two decades (Hansen & Brown, 2011). To be able to have a sustainable energy supply in the coming decades, companies in the oil and gas industry must strive for a balance between increasing their hydrocarbon production while reducing their impact on the environment. Some organizations such as the International Petroleum Industry Environmental Conservation Association (IPIECA), American Petroleum Institute (API), and the International Association of Oil and Gas Producers (IOGP) are actively organizing sustainable development management standards and encouraging companies in the industry to adhere to sustainable development strategies (Mojarad, Atashbari, & Tantau, 2018). State and federal organizations have not only encouraged companies to adhere to regulations but have implemented penalties to those not adhering to new sustainability campaigns, laws and regulations. These are becoming more and more stringent and represent a challenge for companies to invest resources where needed or where demanded. Nonetheless, organizations like the World Bank Group create initiatives to help the oil and gas industry reach its sustainability goals. World Bank Group created the initiative called "Zero Routine Flaring by 2030" where oil companies are challenged to make development plans for new fields with zero routine flaring, while seeking economically viable solutions to end routine flaring no later than 2030. The initiative already has 24 governments signed in – including the US, Russia, Canada, and Iraq – as well as 32 companies, including Shell, BP, Total, Statoil, Eni, and Lukoil (O'Cinneide, 2017). Routine flaring is the act of releasing gas during production operations due to the lack of sufficient equipment to deal with it otherwise (i.e. injection to wells, utilization on site or sold to market).

2.2 DOING MORE WITH LESS

Doing more with less has become the unofficial slogan for the oil and gas industry lately. This is because the industry must adjust their operations to be able to breakeven with the lower price of crude oil. It is no doubt that the price of crude oil has had many peaks and valleys. The deepest valley ever experienced brought the price of West Texas Intermediate (WTI) crude down to around negative $37 USD per barrel, dropping by almost 300% on April 20, 2020. This historical crash happened due to the spread of COVID-19 along with a price war between oil giants Saudi Arabia and Russia in March 2020. This made it difficult for executives to deliver dividends and meet investor expectations. Since then, prices have stabilized at around $40 per barrel of crude oil (average of Brent, Dubai and WTI crude in the summer of 2020). The challenge for the industry is to be able to provide more energy with lower earnings to work with. Also, the IEA reports that there have been many cuts in fuel supply investment in 2020 which have applied to all types of resources and companies. Because of the major fall in demand due to the pandemic and subsequent stay-at-home mandates, the reduction in investments was a natural and necessary market response. The risk of doing so can only be evident down the line if the deep in investment is not proportional to the demand heightened after when the world is in post-recovery phase.

Traditional cost cutting executed in the industry normally followed a textbook approach of actions. First, companies reduce discretionary operational expenses and force suppliers to lower their costs. Second, head count mostly in support functions is reduced. Freezes of salary increases and hiring are also applied actions. As confirmation of this fact, the global head of energy for KPMG in the US has stated that many large companies have already announced capital spending reductions, hiring freezes, and some even cutting down staff (Mayor, 2020). Continuing with the cost cutting measures, as a final approach, capital projects and major investment are either delayed, shelved, or dialed back (Streubel & Ravishankar, 2017). These actions yield substantial savings. The challenge is what type of company is left after this is achieved, and what it can still accomplish.

The cost to produce oil and gas have increased. To this date, it is costing more to find and produce oil and gas. One reason for this is that production of heavier crude oil is gaining up on the easier lighter crude production. Heavier crude is more difficult to produce, transport and refine, increasing costs in all sectors of the oil and gas industry. Moreover, reservoirs found lately tend to be in more remote locations and deeper offshore waters. This also increases the challenge since remote locations do not have infrastructure to easily store and transport produced fluids to connections with the rest of the supply chain. This incurs more costs that must be covered no matter what, making the challenge of doing more with less even tougher.

Doing more with less not only has to do with economic terms. From a human resources perspective, a Deloitte study from 2019 estimates that about 50% of the workforce will be retiring in the next 5 to 7 years (Dunn, 2020). The oil and gas industry will have less experienced personnel to tackle these challenges and will create a high learning curve for the incoming employees.

2.3 DEMOGRAPHICS PLAY A ROLE

According to the United Nations, the world's population is expected to increase by 2 billion people in the next 30 years, from 7.7 billion to 9.7 billion in 2050. Most of this growth is expected to take place in Asia and sub-Saharan Africa. With the increase of population, comes an increase of energy demand. By 2030, energy demand is expected to rise by 40% to 16.6 billion tons of oil equivalent per year where more than 95% will come from non-OECD countries, mostly China and India (MCETeam, 2019). The increase in population will be the driving force for growing global urbanization. The UNO projections indicate that by 2040 the global urban population will be almost double the rural population (Raffaini, et al., 2014). The challenge will be for the oil industry to provide the infrastructure to the growing economies in order to provide the energy demanded.

Ben van Beurden, the CEO of Shell, stated that there is a huge opportunity where population increase will take place, and where the energy demand is going to emerge. In European countries, infrastructure will have to be renewed or evolved. In emerging parts of the world, infrastructure is minimal, and finances are limited. These sites will require hydrocarbons to develop their industries (Palmigiani, 2017, pp. 16-17). The challenge for the oil and gas industry will be to provide the necessary infrastructure in an agile and flexible manner to service the needs where demographics and population growth dictates, not only where reservoirs are found.

Demographics, data relating to the population and different groups within it, indicate that the developed world has an ageing population while the developing countries have a relatively young population (MCETeam, 2019). This can be a challenge for the oil and gas industry because the method of communicating with younger population differs from that of elder generations. That means that the industry must rejuvenate and revitalize itself to be an attractive energy solution and area of employment for younger generations. A recent poll conducted by EY (multinational professional services network) reflects that only 6% of Generation Z (those born between 1997 to 2012) respondents and 18% of Millennials (those born between 1981 to 1996) find a career in the oil and gas industry "very appealing". The rest of the responses can be seen in the figure that follows.

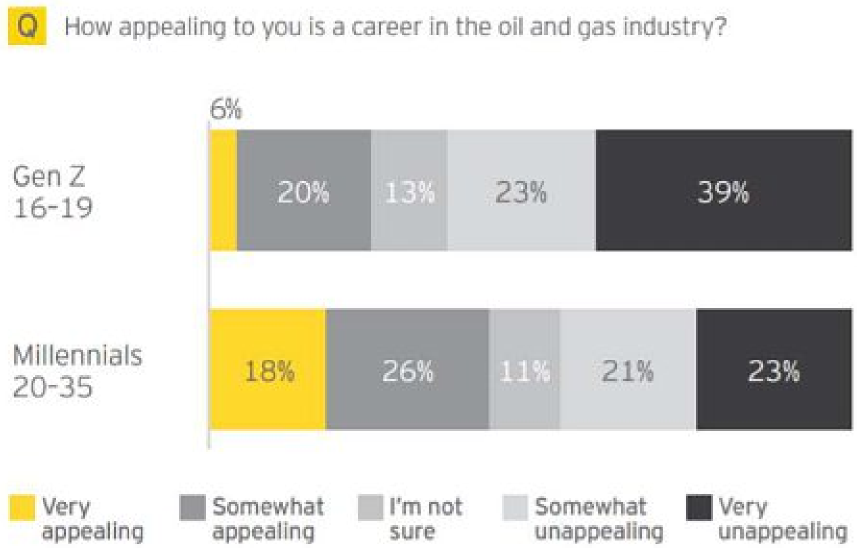

Figure 1. Appeal of a career in oil and gas industry *(EY, 2017)*.

According to Deborah Byers, EY Americas Industry Leader, the perception of the public can have a great impact on the industry's ability to recruit and retain talent, access capital necessary for growth, and pursue new projects. It is imperative that the oil and gas industry faces this challenge by becoming faster to respond to the market, more flexible in its solutions, and even more technological to be able to connect with the future generation of workers and leaders.

2.4 SUMMARY

The oil and gas industry has many challenges to face and overcome in this and the coming decades. The number one challenge presented in this thesis is continuing to meet the energy demand in a sustainable manner. In the next two decades, 80% of the world's energy matrix will be fossil fuels. It is therefore a priority for the oil and gas industry to become more sustainable promptly to provide energy while reducing the impact on the environment. For the industry to be more sustainable it means balancing the three components of the 'Triple Bottom Line' – economic, environmental, and social. Renewable energy might be an attractive source of power to achieve sustainability, but realistically, this is an expensive solution in the near term and will not fill the energy demand soon. Therefore, new laws and regulations have been implemented that are intended to reduce the negative effects of the industry towards the environment. The industry has already come together to help each other reach its sustainability goals.

Second challenge is doing more with less. The price per barrel has dropped considerably in the last years. The challenge for the industry is to be able to provide more energy with lower earnings to work with. Reducing costs internally can affect the strength of the companies, it will be a challenge to work with less resources to fulfill the larger energy demand. Moreover, the ‘easy oil’ era is long gone, and producing oil these days is a higher challenge. Also, there will be less experienced personnel since a large amount is retiring in the next 5 to 7 years.

Last challenge is demographics. The world population will increase mostly in emerging markets. Infrastructure is minimal and the population distribution indicates that the developed world has an ageing population while the developing countries have a relatively young population. A small percentage of the younger generation see the oil and gas industry as an attractive place to work, it is important for the industry to increase their acceptance and expand their reach into developing markets.

3 OPPORTUNITIES IN THE OIL AND GAS INDUSTRY

This chapter will describe three opportunities for the oil and gas industry to strengthen its presence in the world. Hypotheticals and real case applications will be described in the following subsections.

3.1 DIGITAL TRANSFORMATION

Digital transformation in the oil and gas industry has the potential to unlock $1.6 trillion USD of value for the industry and its customers (Weinelt, et al., 2017). It could also benefit our environment reducing CO_2 equivalent emissions by 1,300 million tons, saving about 800 million gallons of water, and avoiding oil spills equivalent to about 230,000 barrels of oil (Weinelt, et al., 2017). To achieve this, a combination of digital advancements must be employed to create a revolutionized future for the industry. The top digital subjects of interest for the Oil and Gas Industry are big data and analytics, IoT, and mobile devices according to a survey performed by Accenture in 2016.

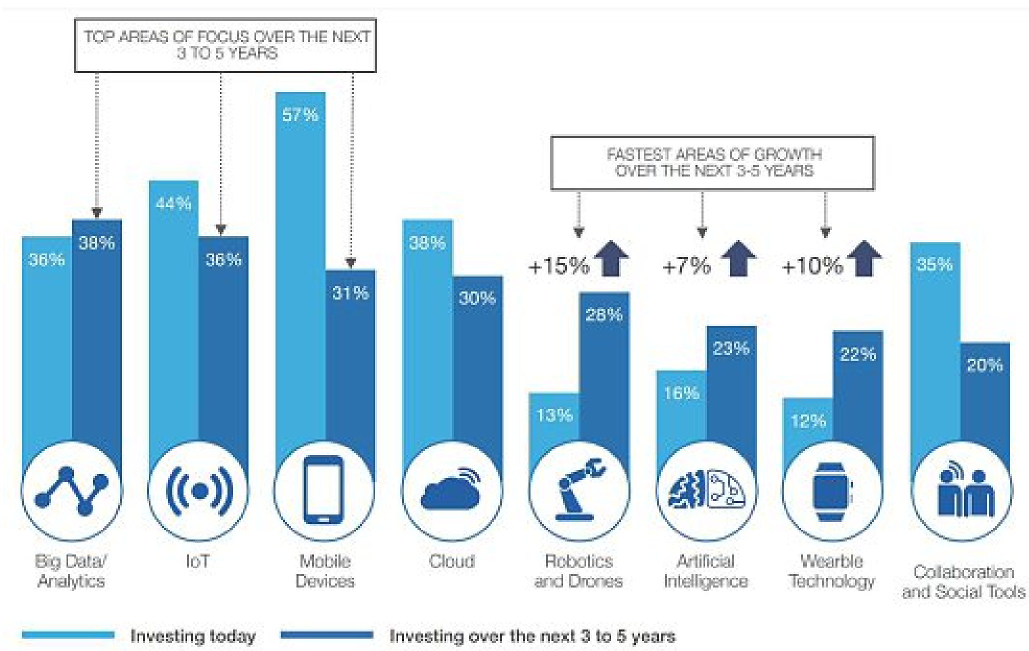

Figure 2. Digital Technologies Investments in the Oil and Gas Industry by Accenture, The 2016 Upstream Oil and Gas Digital Trends Survey *(Weinelt, et al., 2017)*.

The opportunities that going digital can create are countless – increase productivity, cost savings, make operations safer, just to name a few. One example of such improvement is depicted in the graph below where digital transformation in exploration has increased the success rate of United States oil finds. The graph shows the US discovery and recovery efficiencies since 1950. The blue line is a normalized curve. The timing of major technology developments is depicted as well as new interpretive disciplines.

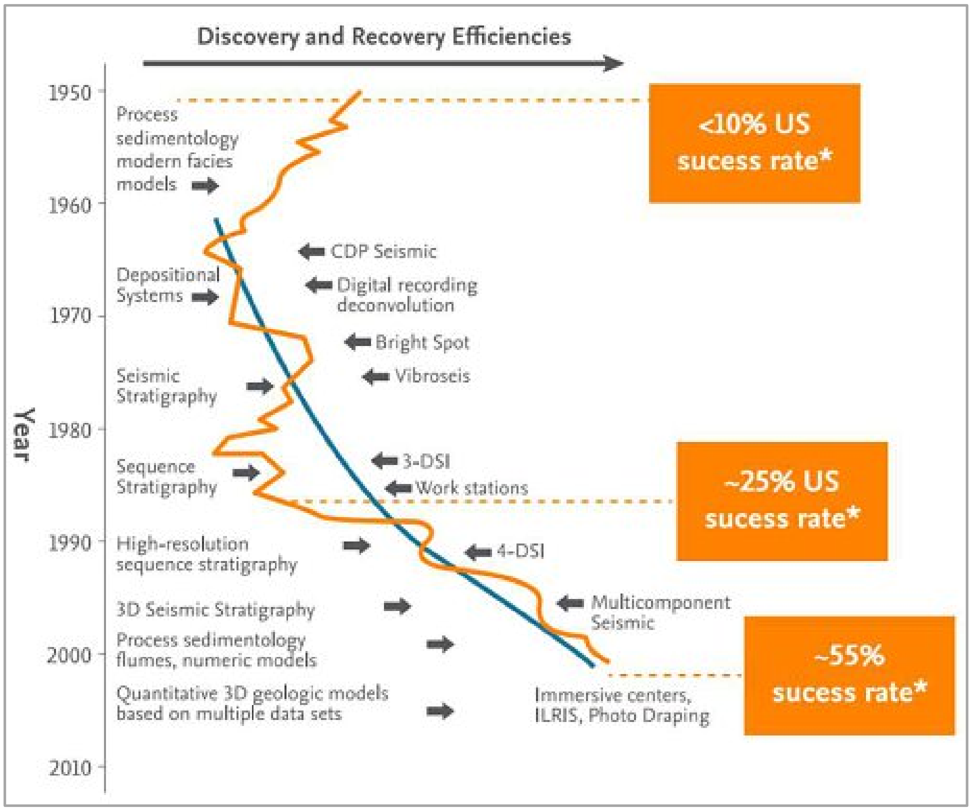

Figure 3. Digital transformation increasing success rate of US oil finds *(Slatt, 2013)*.

Opportunities for digitalization can expand to all areas of the oil and gas industry, the key is to have creativity and ingenuity to find the best use of it. The following subsections will cover three areas where digital transformation opportunities have already strengthened the oil and gas industry.

3.1.1 RESEARCH AND DEVELOPMENT TRANSFORMATION

An example of digitalization can be shown by Shell's top-tier HPC (High Performance Computing) facility. It is used to model chemical reactions rather than testing them in laboratories. This saves time and resources and is a much faster way to test multiple hypotheses in parallel. Molecular level computations that involve more than 100,000 interacting particles would require 800,000 core hours of computer capacity. Without

HPC, 100,000 computers working together for one hour would be needed. Instead, HPC is capable of running the entire algorithm to solve this calculation in one hour. This was able to be accomplished by researchers' coding optimization used to tailor a publicly available software (GROMACS) to their simulation needs to make the code run faster, therefore, lowering the costs of the project.

The purpose of Shell's computing development is not only to improve their laboratory capabilities, but also to enable an energy transition to hydrogen. This HPC technology is being used to lower the carbon intensity of today's energy products and to advance the clean technologies that will be central in tomorrow's decarbonized energy system (Sanyal, 2020). Moreover, computational scientists in Shell have developed a digital model to understand the effect of the roughness of electrolyser surfaces in boosting hydrogen production (Maheshwari, Kruijsdijk, Sanyal, & Harvey, 2020), further increasing the HPC's capabilities.

3.1.2 INTERNET OF THINGS BRINGS INTELLIGENT OIL FIELDS TO LIFE

The telecommunication industry has been able to provide intelligent phones, helping us with our daily life activities. Bringing similar technology and connectivity used in our personal lives to the oilfield would drive major efficiencies at a time when the industry needs to do more with the same or a smaller number of workers. For that, the implementation of Internet of Things – the network of physical objects connected to the Internet – has come to present a new opportunity for the oil industry. Physical objects can be anything, from valves, pumps, separation equipment, wearable devices, vehicles, and any other thing that can be embedded with electronics, software, sensors, and network connectivity. The power to transmit data without any human interaction allows previously unparalleled amounts of data to be collected and exchanged with other equipment or devices, or through a control center. More and more, innovative oil and gas companies are developing bold approaches for managing data, leveraging "brownfield" IoT infrastructure, and developing new business models (Vaccaro, Clark, & Rowland, 2020).

A joint venture between the government of Oman, Shell, Total and Partex is an example of utilizing the Internet of Things (IoT) to bring intelligent oilfields to life managing a large amount of data. The joint venture, called Petroleum Development Oman (PDO), is already rolling out a mobile platform which collates 1 million data values every couple of minutes from 10,000 wells and other PDO crucial equipment (George, 2020). By automatically transferring all this information to a mobile platform it allows engineers to take better decisions to optimize reservoirs and increase production.

With the implementation of Internet of Things in the shape of sensor-based preventative maintenance and improved equipment monitoring across oilfield sites and platforms, the oilfield sector has the potential to reduce production costs by more than $500 million (Hosn, Merey, & Lee, 2020). Even the failure of a single piece of equipment can slow or stop production and could even cause severe regulatory non-compliance. Utilizing IoT devices that can automatically send an alert to notify malfunctions replace the dependance on intermittent field-inspections by operators.

Moreover, without this technology, as it is done in most parts of the oilfield, an inspection of a component needing adjustment would not count with the help of experts with access to this data in real time. With the coming of intelligent oilfields, changes that would take days to decide based on outdated data now takes a few minutes because communication is transferred much faster.

Digitalization by the aid of IoT also has the advantage of being able to continuously monitor operations in remote and hard-to-reach operation sites. With sensors, field data is collected and uploaded to a support platform to optimize productivity and increase the safety of the oilfield operations. It also helps to increase the safety of the operators working in the field by reducing the number of visits that must be done to remote locations. This has proven to be extremely helpful in countries like Mexico, where not only the oilfield represents a hazard but also drug gang related shootings in remote places close to oilfields that put in danger the safety of oilfield personnel.

Another key benefit of IoT is that it allows companies to monitor environmental conditions precisely and helps assure compliance with regulations on emissions. Previously, an inspector would visit a site maybe once a quarter to take samples and evaluate them in the lab or perform analysis in the field but only taking point specific data without looking at a larger amount of information. This old-fashioned method would not provide a full picture to assure compliance with metrics such as oil leaks or gas emissions, IoT can monitor on a continuous basis utilizing data in real time to automatically fix operating parameters as needed in case a leak is detected. With the digitalization of the oilfield, the Global Enabling Sustainability Initiative estimates that digital technologies across all industries have the potential to enable a 20% reduction of global metric tons of CO_2 emissions by 2030, holding emissions at 2015 levels.

3.1.3 AUGMENTED & VIRTUAL REALITY / ARTIFICIAL INTELLIGENCE / ROBOTICS

With the aging workforce retiring and taking years of oilfield experience with them, the oilfield is turning to digital technologies to equip and train their new workforce with tools and knowledge required to perform at higher levels of productivity, safety, and quality. New technologies like augmented reality and artificial intelligence are bringing up to speed a new generation of workers at an accelerated rate.

Augmented Reality (AR) is a technology that enriches visual view of the environment around us with digital information. AR augments graphics, sounds, and real-time contextual information to the world in front of us challenges the way we interact with the world.

According to Yuri Sebregts, Shell's Chief Technology Officer, COVID-19 has accelerated the adoption of digital technology. Shell's employees do not have a typical work from home office. Inspectors working from home complete safety rounds assisted by robots. Technicians are being assisted by experts thanks to augmented reality embedded in helmets. As working from home increases, AR and AI are likely to be adopted by more and more companies. Likewise, the development of unmanned platforms being replaced by onshore control centers – reducing the number of offshore workers – is likely to accelerate, making the industry more resilient, cost effective and safer (Delacroix, 2020).

Although autonomous robots have not made their full debut in the oil and gas industry, this may soon change in the coming years. Initial proof of it are the following examples.

- The O&G Technology Centre in the UK announced in May 2018 its investment in three robotics projects to transform pressure vessel inspections which costs the industry hundreds of millions of dollars every year and represent significant safety challenges (Nahkle, 2018).
- Newsweek Vantage also reported that the oil company Total announced in 2018 that it would deploy an autonomous ground robot for the first time for offshore inspection purposes on its Alwyn platform in the North Sea.

These are just a few examples of autonomous robotic machines that present an opportunity for the oil and gas industry to cut labor costs, improve continuous monitoring, and increase the safety of oilfield personnel.

3.2 SHIFT FROM "OIL AND GAS" TO "ENERGY"

A shift from "oil and gas" to "energy" is an opportunity for companies in the oilfield to manage transition risks. This switch has been announced by some large oil producers to supply a diverse range of fuels, electricity, and other energy services to consumers (McGlade, Waldron, & Gould, 2020). For companies, this will mean moving into different sectors, mostly electricity, where projects are far away from the traditional oil and gas exploration and production activities. Electricity represents a long-term opportunity for growth and aids in the reduction of greenhouse gases emissions.

The oil and gas industry will be a critical key player for clean energy technologies to be developed. The industry has resources and skills that can be implemented to help tackle pollution emissions. Some developments worth mentioning are the carbon capture storage and utilization (CCUS), low-carbon hydrogen, biofuels, and offshore wind (McGlade, Waldron, & Gould, 2020). These technologies represent the opportunity for the shift to "energy" to take place. Below is a graph demonstrating a strong driving force for the implementation of new technologies to aid the switch. If the oil and gas industry would focus its efforts to transition to an "energy" company, the opportunity to reduce emissions that occur during combustion of fuel by end users could drop by around 25% by 2040.

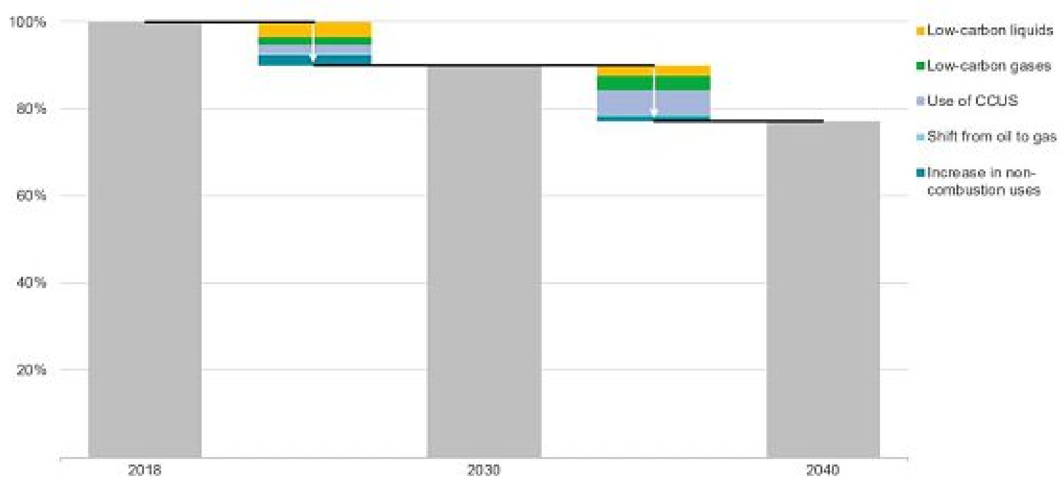

Figure 4. Changes in emissions of liquids and gases consumed in Sustainable Development Scenario *(McGlade, Waldron, & Gould, 2020)*.

The energy transition will not take place over night. Taking Shell as a guiding example of what such a transition could look like is described as follows. In the short term, Shell will continue to provide the oil and gas that the world needs while preparing a portfolio to move into lower-carbon energy when it makes commercial sense (Shell, 2018). In the medium term, Shell will expand in the power market (expected to be important in the energy transition, as mentioned before) while reducing costs and CO_2 emissions. Moreover, Shell acknowledges that business must be adjusted to meet changing demand in different countries (Shell, 2018). Therefore, investments are growing for wind generation in the Netherlands, supplying power to retail customers in the UK, and offering LNG, biofuels, hydrogen, and electric car charging in European markets (Shell, 2018). For the longer term, Shell intends to remain strategically flexible to adapt with society's needs to move towards a lower-carbon future. To show their commitment, Shell has an ambitious goal to halve their Net Carbon Footprint of the energy they produce by 2050.

Although this thesis only presents the path that Shell has described to take advantage of the opportunities presented from the switch from "oil and gas" to "energy", there are many different paths to this transition. As stated by the IEA Executive Director, Dr. Fatih Birol, "no energy company will be unaffected by clean energy transitions. Every part of the industry needs to consider how to respond. Doing nothing is simply not an option" (McGlade, Waldron, & Gould, 2020).

To be able to determine how much attention is applied on this opportunity, it is worth investigating the investment that oil and gas companies are allocating outside of their core business areas. So far, it has been less than 1% of total capital expenditure. One of the highest ratios spend by individual companies is 5% on CAPEX on projects outside core oil and gas supply, with the largest outlays in solar photovoltaics and wind (McGlade, Waldron, & Gould, 2020). A much more significant change in overall capital allocation would be required to accelerate the shift from "oil and gas" to "energy".

3.3 GROWTH IN DEVELOPING ECONOMIES

Emerging markets represent a huge opportunity for all industries around the world, and oil and gas is not an exception. The growth in emerging markets is due to an expanding middle class, high population growth rates and stronger economic growth potential. Growth in developing economies, led by India and China, will drive demand across energy, utilities, and resources sectors. Asia will account for 77% of the global oil demand growth through 2025 since this part of the world is not rich in natural oil reserves and will require larger imports to sustain their growth rates (MCETeam, 2019). In conformance with this last statement, the International Energy Agency has stated that this growth is creating major opportunities for oil producing countries that can boost exports.

The increase in energy demand will mostly come from countries with increasing population and high economic growth potential, while developed countries in the OECD will be focusing their resources on energy efficiency and low-carbon technologies (OPEC, 2020). This can be better observed in the table below.

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2019	2025	2030	2035	2040	2045	2019–2045	2019–2045	2019	2045
OECD	111.1	108.7	109.0	108.4	107.4	106.7	–4.4	–0.2	38.4	29.5
Non-OECD	178.1	194.3	212.9	229.8	244.9	254.6	76.5	1.4	61.6	70.5
World	289.1	303.0	321.9	338.1	352.3	361.3	72.1	0.9	100.0	100.0

Table 1. Total primary energy demand per region, 2019 to 2045 *(OPEC, 2020)*. Note: p.a. = per annum. Units are millions of barrels of oil equivalent per day.

With regards to oil demand, specifically, below is a table with forecasted numbers. The largest contributor to this incremental demand is anticipated to be India, adding some 6.3 mb/d between 2019 and 2045 (OPEC, 2020).

	2019	2020	2025	2030	2035	2040	2045	Growth 2019–2045
OECD	47.9	43.0	46.8	44.6	41.5	38.0	34.8	–13.1
Non-OECD	51.8	47.8	56.9	62.6	67.4	71.2	74.3	22.5
World	99.7	90.7	103.7	107.2	108.9	109.3	109.1	9.4

Table 2. Oil demand, 2019 to 2015 *(OPEC, 2020)*. Note: Units are million barrels per day.

Based on the information presented in these tables, it is evident that non-OECD countries represent a huge opportunity for the oil and gas industry to fulfil the demand.

3.4 SUMMARY

Three main opportunities for the oil and gas industry have been presented in this chapter. The first one is digital transformation, which has the potential to unlock trillions of USD of value and reduce environmental impact. Examples of areas that have already taken advantage of this transformation are Shell's Research and Development increasing computing capacity, Internet of Things turning simple oilfields into smart oilfields, and Augmented & Virtual Reality / Artificial Intelligence / Robotics to accelerate training of new generation of workers.

The second opportunity is for companies to switch from "oil and gas" to "energy" companies. This expands the field of work for the existing companies and heightens the resources and skills that can be implemented to help reduce pollution emissions. So far, less than 1% of total capital expenditure is being allocated outside of the core oil and gas business areas. More will be needed to take advantage of this opportunity for the industry.

Lastly, developing economies represent a large opportunity for the oil and gas industry. Most of the growth in energy demand will come from these expanding markets. It will be important for the industry to meet the demand by focusing on these in the coming years.

4 STRATEGIES TO STRENGTHEN THE OIL AND GAS INDUSTRY

For several years, the oil and gas industry was faced with low crude oil prices, a high capital and operational cost pressure, and requirements to reduce its environmental impact. Nevertheless, the industry must continue to deploy new technologies to ensure it has a strong future. To find out how the industry can be strengthened, this chapter will present two different strategies and innovation techniques that could be implemented to improve the oil and gas industry although it faces a very challenging environment.

The importance of strategy cannot be understated. In a survey, 263 energy professionals at senior executive and management level in companies related to the oil and gas industry were asked to choose the most important drivers of technological change. The most frequently chosen option was company strategy, at more than 40% (Nahkle, 2018, p. 18). To aid the industry in developing a strong strategy for the future ahead, reverse innovation and digital strategy will be covered in this section.

4.1 REVERSE INNOVATION

Companies in the oil and gas industry are moving away from traditional high-cost, complex systems (Rao, 2017), according to a survey of more than 20 key organizations in the global oil and gas industry published in the 2017 Oil and Gas Report. One of the oil companies, BP, shares the same view. BP's CEO, Bob Dudley, aims to simplify by doing less, not more and roll back bureaucracy, aiming to use common sense at a large scale across the organization (Schmidt, 2017, p. 28).

To achieve a strategy of simplification, but still developing disruptive technologies for the industry, Reverse Innovation can be an especially useful tool. Reverse Innovation is a technique consisting of developing ideas for an emerging market and then leading them to flow uphill to Western markets (Govindarajan, 2012). Some multinational companies are starting to catch on to reverse innovation, where products are first designed for consumers in low-income countries and then adapted into disruptive offerings for developed economies (Winter & Govindarajan, 2015). The concept behind this methodology is the idea that applying innovation in an emerging market allows for developing a novel solution that performs 100% of the job at 10% of the price. To close the Reverse Innovation loop, the product is tweaked and sold in developed markets at a higher price with more advanced features.

The term Reverse Innovation was first described in 2009 in a Harvard Business Review article cowritten by Vijay Govindarajan (Duke University Business Professor) and Amos Winter (Mechanical Engineering Professor at MIT). Reverse Innovation has just recently achieved visibility in the global marketplace, although it has been a topic of conversation among academics and executives (Malodia, Gupta, & Jaiswal, 2014). A decade after the term was coined, only a few Multinational Corporations (MNCs) – Coca Cola, General Electric (GE), Harmon, Microsoft, Nestlé, PepsiCo, Procter & Gamble, Renault, Nokia, and Levi Strauss – have managed to create products in emerging markets and sell them worldwide. Others have tried but failed to create products that would catch on in both emerging and developed markets.

As a tool to develop a new strategy for the oil industry, Reverse Innovation stands to offer many strengths. The biggest benefit of it is that companies could deploy and review their newly designed products "in the field" in emerging markets, while exploring and tweaking them for new markets searching for growth. This avoids being stuck wasting money in the development phase by doing repetitive cycles of innovation to achieve the highest possible technical solution to solve all problems.

Another strength offered by Reverse Innovation is that it allows companies to become more competitive worldwide by developing products for the emerging markets. If a company fails to offer solutions for emerging markets, then an opportunity is missed to develop solutions for a large unexplored market that could represent a huge economic growth.

When a company focuses its innovation in an emerging market, it gains a plethora of experience in the field by providing a product for customers and getting direct feedback from them. This way, a more efficient innovation can also be attained instead of waiting to develop the most high-tech product without being in touch with the potential customers. Also, in general, regulations are normally more laid back in emerging versus developed markets. This allows companies to avoid hindrance from regulations that sometimes prevent innovation from happening.

Since the oil and gas industry must adapt to a lower crude oil price era, now is the time to investigate the applicability of this innovation method to the industry to develop new products that are more economical by doing 100% of the job at 10% of the cost, and that decreases project complexity.

4.2 DIGITAL ERA CUSTOMERS CALL FOR A NEW DIGITAL EXPERIENCE

The oil and gas industry has existed for many generations and has served a plethora of different end-customers and consumers. To date, 68% of petroleum consumption is used in the transportation sector according to a study performed by the United States Energy Information Administration in 2019. In the largest oil consumer country of the world, the United States of America, the most consumed hydrocarbon product is gasoline. This indicates that the consumer with the highest weight for the oil and gas industry are people at fuel stations pumping gasoline into their vehicles. These consumers have become more tech-savvy with the coming of the digital era and they expect a new kind of digital experience to satisfy their needs.

The digital era generation has arrived, and it is here to drastically change how the world operates. The year 2020 when the COVID-19 pandemic struck the world and stopped many interactions in the physical world, these were shifted to the digital world. This gave a big push forward to digital connectivity and digital interactions, forcing businesses to rethink the way they communicate with consumers and customers. The oil and gas industry should not be a business exempt of attending their main consumers through their preferred channel of communication, digitally.

In the past, the companies that operate in the oil and gas industry have focused primarily on strategies related mainly to products and costs. The traditional sequence in their business model would include exploration, production, refining, and distribution. In the digital era, these segment strategies alone will not be enough to differentiate and propel companies forward. According to the Oilman Editor, the expectations of the retail and commercial consumers have evolved significantly. Consumers seek a next generation digital experience that is more convenient, transparent, and innovative.

The relevance of customer service cannot be emphasized enough. According to an Accenture Global Consumer Trends Survey in 2013, 55% of consumers switched brands or businesses due to poor customer service. Of those that switched, 82% said the company could have done something to stop them. To fulfill the expectations of consumers and customers in the digital era, the oil and gas industry must think of a strategy to provide a digital experience.

A renown example of digital strategy is the case of the famous Starbucks Coffee Company which has managed to excel and increase its sales through a focus on digital relationships with customers via the use of Information Technology. Starbucks developed a digital flywheel strategy six years ago which created a business ecosystem where data analytics were a part of a much larger system where everything functions and interacts together. Starbucks digital flywheel strategy consists of four digital components. These are rewards, personalization, payment, and ordering. The strategy was built around enhancing customer experience by building a digital customer relationship with personalization tools. By 2018, 18% of Starbucks' 75 million customers where members of their loyalty program, these represent 36% of their sales (Franklin, 2018). According to Matthew Ryan, Global Chief Strategy officer of Starbucks, the 13.5 million active reward customers compared to about 75 unique customer visits to the stores each month represent a much larger value for Starbucks digital technology to provide meaningful information and business improvements.

Such efforts must also be implemented in the oil and gas industry's strategy. It is obvious that there is a huge difference between Starbucks and a company in the oil and gas industry. The most important difference is that Starbucks is a Business to Customer (B2C) and an oil and gas company is a Business to Business (B2B) type of organization. Operations in these two different types of businesses differ from one another, but this should not hinder research to apply proven success methodologies from B2C to B2B.

In the oil and gas industry, companies have many commonalities being that they are all producing hydrocarbons to provide energy for the world. For companies so similar to be able to stand out, each brand must find innovative ways to showcase their competitive advantages. This could be done by applying a scientific approach towards the customer side of the business, creating a more customer-centric culture. It is important for oil and gas companies to implement a digital strategy to take the most advantage out of the digitalization era to better support the millions of customers served daily. This task is not a simple one, since there is a complex ecosystem of consumers of the oil and gas industry ranging from different businesses, manufacturers, consumers of refined products, etc. Based on literature research, the following points could help build a digital strategy.

1. Data collection and utilization about customers, not only production data.
   The oil and gas industry is increasing its data analytics capabilities mostly on the production side in this digitalization era. This could be extended to the customer side to analyze consumer and customers' preferences and needs to

enable business decision makers to obtain valuable and actionable insights to maximize creation of value.

2. Invest in technologies that strengthen customer engagement and earns customer loyalty.

   This could be a strong way of differentiating oil and gas companies and increasing competitiveness.

3. Identify new ways to improve processes and touchpoints.

   According to Touchpoint Experience, touchpoint is every point in time the customer “touches” or connects with a company throughout the entire product / service delivery (that is before, during and after purchase). It is crucial for oil and gas companies to expand their touchpoints and communicate with customers their strengths.

4. Investigate, analyze, learn, and implement.

   The digital era is ever changing, it is important for oil and gas companies to remain vigilant of new technology trends that could be helpful for the industry to stay strong and to serve its consumers of this advanced digital generation.

4.3 SUMMARY

Reverse innovation strategy and digital experience strategy are two important tools that could help strengthen the oil and gas industry for the future ahead. Reverse innovation takes into consideration the fact that the most energy demand growth will come from emerging countries. For this reason, it would be wise to develop new product solutions targeted to these countries by making them more economical to build. To close the reverser innovation loop, the product solutions should be then introduced to developed economies by offering a more technologically advanced option. With regards to the digital experience, this is a strategy that is crucial in the digital era / generation. It represents an opportunity for companies in the oil and gas industry to better communicate their competitive advantage and to communicate with customers in their preferred channel, digitally.

5 NEW PRODUCT DEVELOPMENT: HYDROCARBON STORAGE SOLUTION

The oil and gas industry has many challenges and opportunities to face in the coming decades. The common theme that was found throughout the research is the fact that the industry needs to increase its flexibility and speed to respond to the changes of the energy demand in the market. Fortunately, the industry will continue to be the largest supplier of energy for the world in the coming two decades. Past this period, the demand for hydrocarbons will start to drop because newer greener energy will become more efficient and less expensive as time progresses. For this reason, the oil and gas industry must already be preparing for a transition to an "energy" industry. This transition will not happen immediately, but it is one that will give more resilience and longevity to companies involved in the exploration, production, refining and distribution of hydrocarbons. Because the energy demand will continue to increase due to the increasing population in the world, the oil and gas industry will continue to produce hydrocarbons and will strive to produce at a higher rate to fulfill the demand. Consequently, more infrastructure will be required mostly in the midstream sector of the industry which is the one responsible for the storage and transportation of hydrocarbons. The reason for midstream requiring more infrastructure than other sectors is because developing economies will be the ones experiencing the highest amount of population increase. Considering the Reverse Innovation strategy to serve developing market needs and taking into consideration the midstream sector infrastructure need, this represents an opportunity to evaluate the modernization of one of the most common products in the midstream sector – storage tanks.

Storage tanks have a long history of existence, they have been around since the beginning of production of hydrocarbons because the need to store produced hydrocarbons has always gone side by side with production. When the first oil well started production in Titusville, Pennsylvania in the United States back in August 1859, people where rushing over to wells carrying any type of container that they were able to find for storage. Even bath basins were used to store the precious "black gold" that was gushing out of producing wells. Not long after, producers knew that a longer-term storage solution would be necessary to safely store the hydrocarbon fluids that had taken incredible amount of effort to extract. Wooden barrels where first used to store hydrocarbons, but they did not prove to be a long-term solution because gases would seep out, creating a dangerous environment where they were being collectively stored. Afterwards, carbon steel was utilized, and the storage of hydrocarbons became safer and more reliable. The year when the first carbon steel tank was produced was 1922 and to this date, they continue to be the most commonly used storage tanks in the oil and gas industry.

Fast forwarding time to 2020, many different storage solutions have been developed that compete with the popular carbon steel storage tanks. Ingenious solutions like caverns and floating oil tankers are now used on a regular basis around the world to store hydrocarbons. This is because the storage of hydrocarbons is not only useful by the producing companies of the world, but because nations have determined that having a national hydrocarbon reserve is an important strategy to ensure a country's energy supply stability. Below is a table that summarizes the different types of storage solutions, highlighting their advantages and disadvantages in a green (most advantageous), yellow and red (most disadvantageous) color scale. Note that because cost estimates of each type refer to different sources, the basis assumptions may be different across types. The costs shown in the table are the construction costs only and do not include operational expenses or procurement of stockpiled oil (Yoshikazu Kobayashi (ed.), 2015).

	Novel Solution	**Aboveground Tank**	**Salt Cavern**	**Rock Cavern**	**Floating Tank**	**Oil Tanker**	**Collapsible Storages**
Typical unit capacity (m^3)	**300,000+**	95,000	1,500,000	1,600,000	500,000	50,000	**2,000**
Construction time (years)	**0.5**	**3 to 4**	**7 to 10**	**7 to 10**	**3 to 4**	**2 to 3**	Several Weeks
CAPEX (USD/m^3)	**< 80**	200 to 400	75	450	400	3,000	420
OPEX (USD/m^3 yr)	**< 2.5**	15	2.5	5	11	35	Unknown
Monthly renting rates (USD/m^3)	**1.5 - 5**	2 to 4	1.5	2 to 3	4 to 6	4.5 to 9	Unknown, ~5 to 15
Limited suitable locations	**None**	None	Large and consistent salt domes required	Close to sea coast with sufficient amount of underground water	Calm wade and tide, sufficient water depth	None	None
Comparative risk level (e.g. Fire / Spills)	**Medium**	Medium	Low	Low	High	High	Medium

Table 3. Comparison of major stockpiling and storage systems.
Multiple Sources ([Mitsubishi Research Institute, International Energy Agency, compiled by IEEJ], Wikipedia, science.howstuffworks.com, loopllc.com, Investopedia.com, euronav.com, Qingdao Highway Rubber & Plastics).

From the table above, it is evident that the capacity of the collapsible storage is much smaller than that of the other storage systems. The reason for this is the material of construction of the collapsible storage solutions which is normally a type of polymer geomembrane with increased physical properties. Nonetheless, the construction time is much shorter in comparison to the other storage systems and the CAPEX (capital expense) required to build such a product is also much less. Suitable locations are not limited for this type of storage solution and the comparative risk level is considered to be at a medium level based on fire and spills risks. Based on these summarized characteristics, an opportunity gap for a new storage solution can be found by creating a comparison between the two most important characteristics – price and construction time – as demonstrated graphically below.

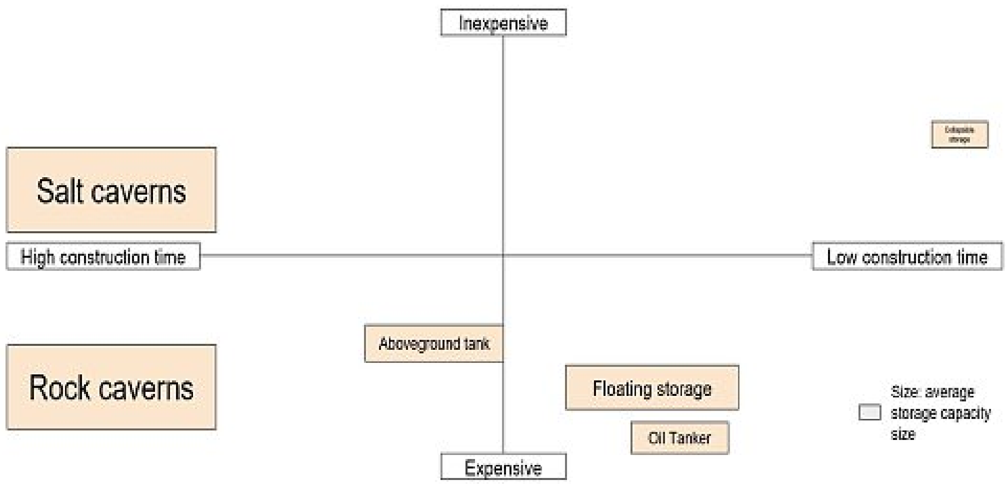

Figure 5. Graphical comparison between six different storage tank solutions.

As can be seen, there are no products that meet the low-construction-time and inexpensive quadrant in the figure above. To fill this gap found in the market, a project was initiated with a Startup in Vienna, Austria to develop a novel hydrocarbon storage solution that is quicker and cheaper to build than the current storage solutions available in the industry.

Before officially starting the project, the Porter's Five Forces analysis was performed to understand the level of competition of the storage tank industry and to assess the potential business. This analysis was developed by a Harvard University business strategy professor named Michael E. Porter in 1979. The main goal of this analysis is to set profitability expectations since the profitability of a business decreases as competition increases (Staff, 2020). Below is a drawn representation of the five components of the technique.

Figure 6. Porter's Five Forces Model *(Eloquens, 2020)*.

The relevance of each one of them is briefly explained below.

1. Rivalry among competitors in the industry – The larger the number of competitors or similar/equivalent products/services offered, the lower the power of a company.
2. The bargaining power of buyers – The lower the number of clients, the more bargaining power the buyers have to lower prices.
3. The bargaining power of suppliers – The lower the suppliers to an industry, the more a company would depend on them. This would drive up input costs.
4. The potential entry of new competitors – The lower amount of time and money it costs for a competitor to enter a market, the more an established company could be weakened.
5. The power of firms with substitute products – The least product substitutes available, the more power a company will have to increase prices and achieve favorable terms.

The analysis applied to the storage tank industry is as follows.

Porter's 5 Major Forces	Score	Observations
Competitor rivalry	High	High number of competitors in the industry, many established competitors.
Bargaining power of buyers	Low	There is a large quantity of potential customers.
Bargaining power of suppliers	Medium	There are only a few suppliers of material needed for construction.
Potential entry of new competitors	Low	High capital cost of entry, the industry is considered conservative.
Power of firms with substitute products	High	Other companies have similar offerings currently.

Table 4. Porter's Five Forces Analysis for Storage Tank Solution.

Based on the analysis results, the competition in the storage tank indsutry appears to be fierce. On average, there is a medium intensity of competition in the industry. Porter's analysis does not stop here though, it contiues on by analyzing 7 major barriers of entry that could prevent a new company from entering a new market. Barriers to entry act as a deterrent against new compatitors. These barriers must be taken into high consideration because of the folowing two reasons.

1. A company entering a business with high entry barriers would be at a large disadvantage against other competitors that could be difficult to overcome.
2. Companies that become market leaders must be completely aware of how to protect their position by creating barriers to entry.

Below are the seven barriers of entry summarized with a brief description of what they represent (Stapleton, 2019). Then, they are presented as evaluated for the storage tank industry from a point of view of the Startup in Vienna entering the hydrocarbon storage tank business.

1. Customer switching costs:
   These are costs that customers face when changing suppliers.
2. Supply-side economies of scale:
   Spreading fixed costs over a larger volume of units reduces the cost per unit.
3. Demand-side economies of scale:
   Buyer's willingness to buy a product / service increasing due to other people's willingness to buy.
4. Capital requirements:
   High amout of capital required to start up within a industry can be a deterrent to new competitors.
5. Cost disadvantages independent of scale:
   Established businesses tend to have some advantages over new entrants.
6. Unequal access to distribution channels:
   If there is a limited quantity of distribution channels for a product/service, new incomers may find it challenging to sell since existing competitors may have a claim on them.
7. Restrictive government policies:
   These can help or obstruct new entrants.

Porter's 7 Major Barriers	Strategy to overcome barrier
Customer switching costs	Offer a discount for first-time users and provide in-depth training of usage of storage tank.
Supply-side economies of scale	Create a long-term high-volume contract with a selected supplier to create a partnership that is beneficial for both parties.
Demand-side economies of scale	Perform an in-depth market analysis to select the effective positioning where target customers will be willing to try a different product in the market.
Capital requirements	Plan to leverage existing investments with the supplier partnership. Hire personnel that is multi-tasking to tackle different operational tasks.
Cost disadvantages independent of scale	Find a "champion" customer that is willing to go through a steep learning curve with a new company.
Unequal access to distribution channels	Distribution channels are not a challenge for the storage tank industry.
Restrictive government policies	Investigate all the regulations and requirements for the acceptance of a new storage tank solution. Work closely with regulatory agencies to avoid barriers.

Table 5. Porter's Seven Major Barriers for Storage Tank Business from point of view of a Startup in Vienna.

This analysis was performed for the primary and secondary competition to this business. In reality, not every oil storage company is a direct threat. Primary competition is that which represents independent companies renting only to to third party companies. Secondary competition are companies partly using their capacity for storing their own products and partly renting. Captive storage is that which companies use to store only their own products. A view on the size of the market based on primary and secondary

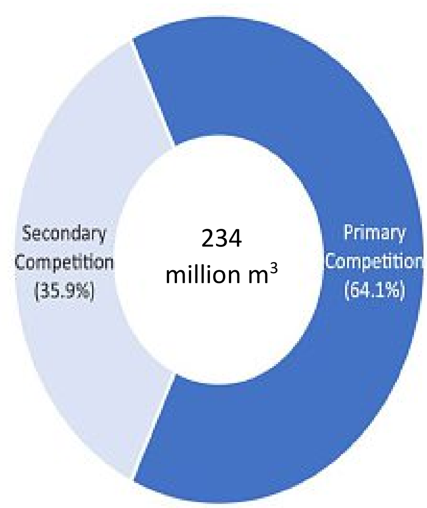

Figure 7. Oil storage market capacity *(Vopak, 2014)*.

competition has been depicted to the right of this paragraph.

It can be summarized from the previous information that the hydrocarbon storage tank industry is one that represents a challenging market to enter. For this reason, it is crucial to analyze and propose a plan that will tackle the challenges. The following sections describe the process followed to develop the new storage solution for the oil and gas industry.

5.1 PROJECT STRUCTURE

There are many ways to go about when embarking in the design of a new product. Dealing with an engineering project requires a high level of organization and structure to ensure a project reaches its desired outcome. In the Engineering Management realm, different Project Management tools are available for the purpose of successfully leading a project to completion. For the development of a new storage solution for the oil industry, the selected Project Management / Planning / Tracking method was the Systems Engineering approach. The main reason for utilizing this approach is because it encompasses the entire life cycle of a system without drilling down on the particularities of a single product but making sure that the ensemble of all parts will be utilized efficiently. According to the authors of the Systems Engineering and Analysis book, Benjamin Blanchard and Wolter Fabrycky, the definition of systems engineering is usually based on the background and experience of the individual or the performing organization. In general, the International Council on Systems Engineering simply defines Systems Engineering as an interdisciplinary approach and means to enable the realization of successful systems. In detail, the authors Blanchard and Fabrycky refer to systems engineering as follows.

> Systems Engineering is a functionally oriented, technologically based interdisciplinary process for bringing systems and products (human-made entities) into being as well as for improving existing systems. The outcome of systems engineering is the engineered system as previously described. Its overarching purpose is to make the world better, primarily for people. Accordingly, human-made entities should be designed to satisfy human needs and/or objectives effectively while minimizing system life-cycle cost, as well as the intangible costs for societal and ecological impacts.

It is important to note that the systems engineering approach does not focus on a single product as a final solution. From this perspective, a single product cannot be an engineering system, no matter how complex it may be. The benefits of utilizing the

Systems Engineering approach is that it helps to manage complexity and reduce risks by avoiding omissions and invalid assumptions. It also provides a better understanding of customer needs and helps to manage change effectively through the project lifecycle (Smith & Brown, 2014). Moreover, by utilizing this approach, project budgeting and costs as well as timelines can be handled more efficiently because there is greater visibility of project requirements and issues, and consequences of changes can be seen with greater ease. Economic benefits shown by research demonstrate that the effective use of Systems Engineering can save 10 to 20 percent of the project budget (Smith & Brown, 2014).

As mentioned before, the Systems Engineering approach encompasses not only the useful life of a single product and bringing it to market, but an entire life cycle of it instead. A product's life cycle begins with the identification of a need and extends on until its disposal. Following is a list of the stages of the life cycle of a product / system which are the following (Blanchard & Fabrycky, 2013):

1. identification of a need,
2. conceptual / preliminary design,
3. detailed design and development,
4. production and / or construction,
5. utilization and support, and
6. phase-out and disposal.

Based on the previously stated stages, correlating life cycle stages for the engineering system for a hydrocarbon storage solution have been named and are as follows:

1. identifying the need – finding the gap,
2. storage tank design and development,
3. construction subsystem,
4. maintenance subsystem,
5. operating and support subsystem, and
6. phase-out and demolition subsystem.

For the Systems Engineering approach, it is important to first define explicitly what will be the objective of the system. With this, the system components can be designed to accomplish the desired outcome. Only then, can the effectiveness of a system be determined. For this project, the main objective of the system will be to store hydrocarbons in a collapsible tank that can connect directly to the existing piping infrastructure where the tank will be installed. Because the project will focus on the design of the storage tank, the piping connecting the stored fluids to the facilities in the area will be considered part of the environment of the system. Therefore, the limit of this system will be at the inlet and outlet of the tank itself.

The first step in the Systems Engineering approach calls attention to identifying the need, meaning finding the gap in the market. To accomplish this for the development of the new hydrocarbon storage solution, a Lean Customer Development (LCD) approach was utilized. This approach differs from traditional marketing techniques because the goal is not only to understand customer behavior, but to learn how to change it and build a sustainable business (Alvarez, 2014). The term "lean" was first utilized in a Toyota manufacturing setting to imply that waste was being eliminated from processes and that the finished product was something that the customer wants. Applying lean techniques to the customer development process means striving to reduce wasted time by streamlining the product development process and ensuring that the end-product will be desired by customers. Furthermore, the lean approach is commonly a good match for Startup companies because of the smaller resources than larger companies. Nonetheless, this process is applicable for small, medium, and large enterprises because lean tactics can help reduce waste in companies of all sizes and in all industries.

Following is a list of the Lean Customer Development process.

1. The Lean Customer Development process is born from an "Insanely Great Idea", as coined by Cindy Alvarez. In this project, it is to create a large hydrocarbon storage solution that is made of a flexible material and that utilizes earth walls to help support the material to contain the fluids.
2. Create a list of assumptions with the team involved in the project to ensure all ideas/problems are highlighted.
3. Write a problem hypothesis. In this project the hypothesis is as follows:
   I believe decision makers in the oil and gas industry (up-, mid-, and downstream sectors) experience profitability and possibly even competitive problems when they run out of affordable storage (e.g., in increasingly dynamic market environments).
4. Map the target customer profile. For this project, the persona created can be seen in the first appendix.
5. Based on the persona created, determine who should be interviewed.
   For this project, it is ideal to interview logistic managers in up-, mid- and downstream sectors.

6. Create a questionnaire to interview targeted people. Questions should call for an open-ended answer without them being biased with the assumptions or hypothesis created.
7. Based on responses from interviews, validate or modify original hypothesis.
8. Adapt customer development according to the responses obtained.
9. Start with product development based on input from interviews.

An additional benefit of the Lean Customer Development process is to start building a relationship with potential customers and to listen to the needs and daily struggles that the Persona must overcome with the current market products. This highlights the topic of collaboration and how crucial it is for a new product development to be successful taking into consideration the customer needs. For this reason, managing innovation either in an open or closed environment makes a difference about how to proceed with a project. The next subsection will emphasize some important points about this matter.

5.2 OPEN OR CLOSED INNOVATION

One of the biggest challenges for a Startup is the lack of resources and the research and development that Multinational Companies count with. The way to tilt the balance and help Startups with this weakness is Open Innovation. Open Innovation is “the purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively” (Chesbrough, Vanhaverbeke, & West, 2006, p. 1).

Open Innovation is not only a topic applied in industry, but it has also helped academia. The discipline of mechatronics, for example, is an academic discipline of open innovation in which collaboration between mechanical engineering, control engineering, electrical engineering, electronic engineering, and computer technology has had many technological advances for society. Such are also the efforts in TU Wien, MIT, and other universities around the world where the combination of different areas of study are proving to be more effective in reaching innovative ideas and development of new theories than independent work by different siloed departments.

In the past, work organizational structures have been shaped to fit the traditional innovation model. This means that, in general, MNCs have created Research and Development (R&D) centers located only in developed countries where all innovation takes place. In such centers, the innovation method is generally closed, meaning, there is little collaboration between different areas of the company, much less outside of the company.

In contrast, open innovation calls for collaboration between companies, universities, laboratories, manufacturing, etc. Utilizing a more open concept of innovation can allow companies to achieve higher levels of innovation by building together a better solution utilizing the best technologies in the world. For the startup in Vienna working to develop a novel hydrocarbon storage solution, Open Innovation will have to be performed with strategically selected companies. Such companies will have to be specialized in their sector, and the startup will function as the working mind putting together the parts to come up with a new product.

5.3 INTELLECTUAL PROPERTY PROTECTION

When working with the Open Innovation methodology it is imperative for the novel idea to be safeguarded to avoid jeopardizing patentability and exclusive ownership of the invention. To do so, intellectual property protection will be particularly important because it rewards creativity and human endeavor which fuels the progress of society. Intellectual property rights allow creators of patents, trademarks, or copyrighted works to benefit from their own work or investment in a creation (WIPO, 2004). It is also important to know the requirements in the jurisdiction intended to work under since the particularities can differ. For example, in Europe and China, no disclosure is permitted before the filing of a patent application. In contrast, both in the US and Canada, the requirements are less stringent – a patent application must be filed within 12 months of any public disclosure (Heer, Latoszewsa, & Kutsyna, 2020). It is important to note that although conversations could be intended as private, they could become public and present an obstacle to file for a patent.

To safely navigate open innovation with potential collaborators without jeopardizing the novel idea, there are two alternatives that can be used to protect ownership of the invention. The first is to ask anyone who will obtain crucial confidential information about the invention to sign a non-disclosure agreement (NDA). An NDA legally prevents someone from disclosing or misusing confidential information. The second option is to file a provisional patent application to claim a filing date. Obtaining a filing date already protects an idea since disclosure of contents of the application could be made without losing patent rights. Getting a filing date as soon as possible is important because Canadian and US patent law both work on a first-to-file basis (Heer, Latoszewsa, & Kutsyna, 2020). This means that the person entitled to a patent of a particular invention will be the one that filed for it first.

In the case of the novel hydrocarbon storage solution project with the startup in Vienna, both the NDA and provisional patent options were utilized. For my personal participation in the project with the startup, an NDA was signed assuring that I would not disclose confidential information from this project to others. For this reason, the information published in this thesis cannot reveal specific details about the invention. A provisional patent was filed under the Austrian jurisdiction in the Fall of 2020. A patent was preferred over an NDA because seeking for partners utilizing the Open Innovation methodology means sharing part of the idea upfront to be able to find the companies with the skills and capabilities of interest for the project.

The contents of the patent preliminary application included the background and a description of the invention. It was accompanied by a rough sketch diagram that described the invention in greater detail. The application also contained various "claims" which help determine the extent of protection to be granted by the patent. This was the most important part of the specification, since only the technical features included in this section are taken into consideration as the protected subject matter (IPR-SME-Helpdesk, 2017).

To this date, the priority date was approved since the Austrian Patent Office considered the invention to the patentable. It is worth noting that the priority patent date can be transferred worldwide even though the patent application was filed in Austria. Moreover, additional claims can be added later to the invention, but a different priority date will be given for it if approved.

According to the Austrian Corporate Service Portal, a patent provides a territorially restricted exclusive right for a limited period of time (maximum of 20 years). If the market of an invention extends beyond the geographical borders where the patent was filed, the inventor could obtain additional international protection. Although additional patent applications could be filed per each country of interest, this process could be tedious and complicated since requirements could differ from one country to another. It is a fact that a global patent does not exist, but it is possible to file in multiple countries or regions with one single application. There are two organizations that can help to accomplish this which will be briefly listed below.

1. European Patent Office (EPO) – It offers a single patent granting intellectual property protection in over 38 European countries.

2. Patent Cooperation Treaty (PCT) – This international agreement enables applicants to simultaneously seek protection for an invention through a central payment application procedure to be implemented in up to 148 countries. This is managed by the World Intellectual Property Organization (WIPO).

For the new hydrocarbon storage solution, the PCT route is recommended to pursue intellectual property protection in the most relevant hydrocarbon producing, importer and exporter countries.

5.4 REGULATORY

The regulatory aspect of a project is a top priority for new product development and one that requires engineering management attention. If regulatory requirements are overlooked or not dealt with since the conception of the project, it could result in a delay in the start of operations and hence loss of opportunity revenue and additional investment than budgeted (Neville, et al., 2007). Just as concerning, a delay in the project could also help competitors gain an upper hand. Examples of such concerns can be seen around the world in different emerging market projects. According to Vinod Gupta, Senior Vice President of Indorama Polymer Limited in Thailand, many projects were delayed for years for companies not doing their homework from the start and for lack of contacts and lobbying capabilities. In a particular case, a site had to be changed even after its development had already occurred. In other cases, projects were delayed by a couple years without obtaining approvals on time.

Regulatory affairs are not only important to make sure that a project is approved without delays. As it was discussed in the Technical University of Vienna's Engineering Management - Medical Engineering / Medical Device Technology course by Professor Martin Zauner, regulatory affairs aim to ensure safety and effectiveness of products. It is no different in the oil and gas industry, the intention of regulatory affairs is to warrant a standard set of requirements to ensure product safety, product effectiveness as well as manufacturing and validation of products utilized in the oilfield.

In the oil industry, regulatory approval carries a big weight into the acceptance of a product for the market. Because the industry is one where a single mistake can cause catastrophic disasters for people and the environment, regulatory organizations try to standardize the approach of bringing to life new designs and installations in the field. Regulatory organizations can be at a federal, state, or private level, or they could be a mutual agreement between different countries like the European Union. There are hundreds, if not thousands of different regulations around the world that could be applicable for the construction of a new hydrocarbon storage tank. For that reason, and because each country has different regulatory requirements, the first step is to select the target country or countries where the project will be deployed. This does not necessarily mean that other regulations must be ignored, but it focuses the efforts to start a dialogue with regulatory personnel in the country of interest. The oil and gas industry, although it is large, circles around a small world of trusted organizations for design and manufacturing standards. As a general rule of thumb, no matter what country is selected, the international trusted organizations will be mentioned as reference in country-based regulatory standards.

For this project, the country selected to first bring the new storage solution to market is Mexico. Below are the reasons for this selection.

1. Mexico is considered an Emerging Market, and this helps in the application of the Reverse Innovation methodology. Moreover, since the United States is its neighboring country, the cycle of reverse innovation can be completed by offering an advanced solution for this market where logistics could be strategic to handle from Mexico.

2. The oil and gas industry in Mexico experienced a Constitutional Energy Reform which was approved in December 2013. This allowed private and foreign investments across the energy value chain for the first time in 75 years. In other words, this means that PEMEX (Mexico's National Oil Company) is not the only company directly involved with the handling of hydrocarbons. To this date, there has been 107 exploration and extraction contracts awarded to 73 different Oil Companies from 20 countries around the world (México, 2019).

3. New legislations enacted in 2016 together with permits granted by the Energy Regulatory Commission (CRE, abbreviation in Spanish) in Mexico have increased the participation of the private sector in the storage of gasoline, diesel and turbosine (Strategy&, 2019). The Energy Regulatory Commission has been the Mexican organization responsible for the regulation of storage of hydrocarbons and its derivate products, among other topics related to energy matters. It is a decentralized administrative organization belonging to the Secretary of Energy, Mines and Parastatal Industry (SEMIP, abbreviation in Spanish). The CRE has the responsibility of solving matters related with the application of regulatory

dispositions stated in the Mexican Constitutional Article 27 dealing with Energy (CRE, 2020).

4. The author's professional experience in the oil and gas industry spans over 8 years working both in the United States and in Mexico. Job experience includes performing field inspections in the upstream sector to sell chemical solutions for problems related with production, mostly in upstream and midstream. This included the inspection of storage tanks close to production wells and having constant communication with personnel in the field as well as managers capable of making purchase decisions. This professional experience is important to count on in a development project because having a strong network in the targeted country helps move the project from one stage to another within the expected timeline.

5. The largest gap found to select this country aside from the reasons mentioned previously is the fact that Mexico only has 3 days of hydrocarbon inventory as strategic reserves in case of local or national contingencies (Strategy&, 2019). This is a significantly low inventory level in comparison with other member countries of the International Energy Agency (IEA) and the OECD. Member countries hold a policy of maintaining strategic reserves to guarantee the efficiency of supply in their own countries. This volume varies according to each country with regards to gasoline, diesel and turbosine sold per day. The inventory of Italy stands at 56 days, the United States of America has 27 days of reserves, and Mexico only has 3 days of storage (Strategy&, 2019).
Through the Public Policy of Minimum Hydrocarbon Storage established in the Mexican hydrocarbon law, Mexico seeks to increase its energetic security. For this reason, companies involved with hydrocarbon selling and distribution must increase their inventory in a stepwise manner to meet new fiscal obligations. The announced plan is to increase inventory to 8 or 9 days of inventory by 2022 and then 10 to 13 days by 2025 (Strategy&, 2019). Due to the existing gap between the current and the future desired situation, this represents an opportunity for the project to succeed in the Mexican hydrocarbon market.

6. According to PwC, the CRE has only awarded a total of 171 permits for the storage of hydrocarbons, the first ones being awarded only 3 years ago. In comparison to other permits in the oilfield industry in Mexico, 171 permits represent only 1.2% of

the total (see image below for a breakdown of hydrocarbon related permits in Mexico). This number continues to be insufficient to cover the needs of the oil storage market in Mexico. Below is a graphical representation of the distribution of governmental permits that have been awarded in Mexico for the oil and gas industry. From this image, it is evident that the storage permits are lagging, and there is a huge gap for incoming companies to request them.

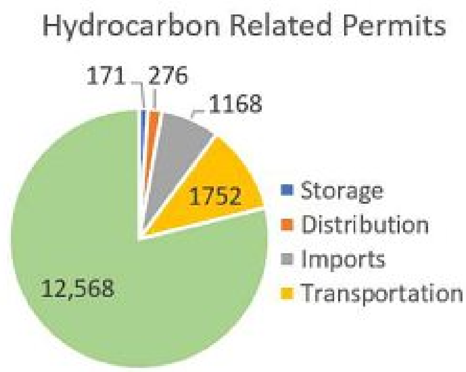

Figure 8. Hydrocarbon related permits granted by the Mexican Energy Regulatory Commission (CRE).

Once the target country has been selected, the next step is to select the region of interest within the country. This is important because, as mentioned before, some countries have state-specific additional regulatory requirements that must also be taken into consideration. Such is the case in the United States, where states have different additional requirements to protect the environment and human safety.

The Mexican region of interest was selected by analyzing the current available hydrocarbon storage infrastructure and finding a gap in the market where additional storage will be needed in the coming years. Currently, more than half of the hydrocarbons consumed in Mexico are imported. The port with most activity is located in Tuxpan, Veracruz, where a little over a third of imports (40%) came in through in 2018 (Strategy&, 2019). Moreover, the state of Veracruz is the second highest producing state of hydrocarbons in the country. Also, the gasoline distribution originating from this port serves the center of the Mexican country including important cities like the capital Mexico City, Queretaro, Puebla, to name a few. This port has the potential to competitively and efficiently meet the needs of the large Mexican automotive and aerospace industries located in the central region of Mexico (Teodosijević, 2019). This port is also the closest to the country's largest consumer centers. Proof of high interest to further develop the Tuxpan region is the high investment to improve the land connectivity between the Tuxpan area with the center of the country. The highway participates in the Central Economic Interoceanic Corridor which gives an additional benefit of intermodal competitiveness to this port area. Following is a map of the hydrocarbon storage and transportation infrastructure in Mexico. As it is evident from this image, there is a lack of private terminals in the Tuxpan region encircled in blue below.

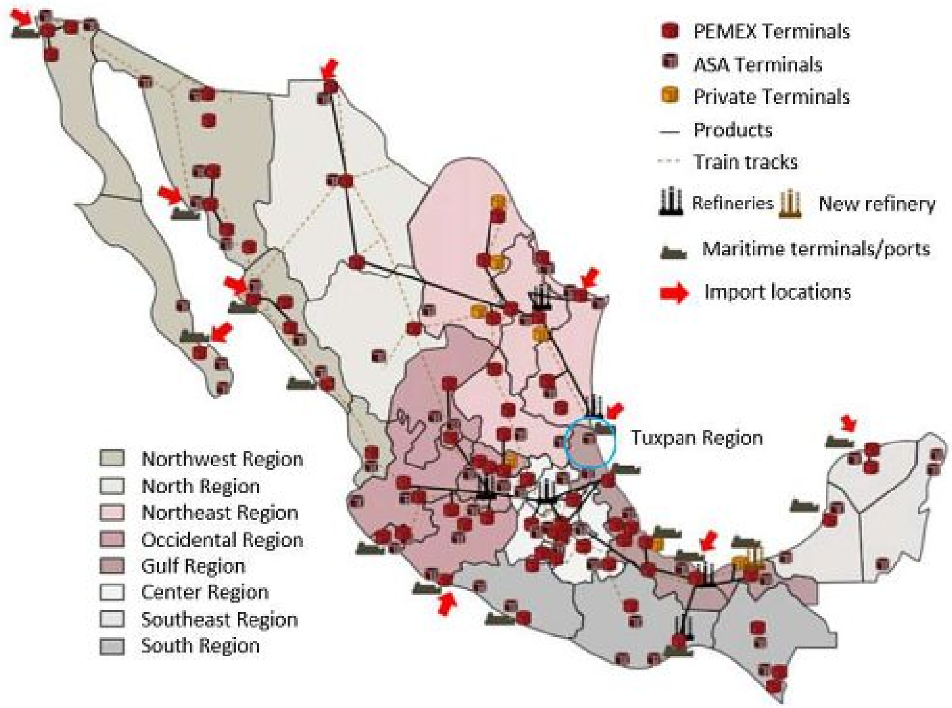

Figure 9. Current hydrocarbon storage and transportation infrastructure adapted from Pemex Logistics, ASA (Airports and Auxiliary Services), Mexican Train (Ferromex) and SENER (2018 Hydrocarbon Industry Diagnosis and Infrastructure Map).

Once the country and the region are selected, the next step is to investigate the applicable regulations to adhere to, ensuring that the product will be approved in a timely manner for its offering in the market. In Mexico, the Official Federal Journal published on August 11, 2014 the Hydrocarbon Law where Article 95 establishes that the Oil and Gas Industry is of exclusive federal jurisdiction. For this reason, only the Federal Government can dictate technical, reglementary and regulatory dispositions in this matter. This includes activities related to the sustainable development, ecological equilibrium, and the protection of the environment in the development of the oil and gas industry. Under the same Hydrocarbon Law in Article 129, the National Agency of Industrial Safety and Environmental Protection is made responsible for the protection of the environment being able to promote and develop, in a sustainable way, the activities involved in the industry. This agency as well as the National Consulting Committee of Standardization with regards to Industrial, Operative and Environmental Safety for the Hydrocarbon Industry worked in collaboration with a list of private and public organizations to develop Norm NOM-006-ASEA-2017.

The "Official Mexican Norm NOM-006-ASEA-2017 Specifications and Technical Criteria for Industrial Safety, Operational Safety and Environmental Protection for the Design, Construction, Pre-startup, Operation, Maintenance, Shut-down and Dismantling of Terrestrial Installations for the Storage of Hydrocarbons and Crude oil, except for Liquified Petroleum Gas" is the guiding document for regulatory purposes dealing with hydrocarbon storage tanks at a national level in Mexico. There are no additional regulations at the state level in Mexico because everything is handled at the federal level. The Mexican Norm NOM-006-ASEA-2017 is an 88-page document that was officially published in the Mexican Official Journal of the Federation (DOF, abbreviation in Spanish) on March 23, 2018. This norm was written in preparation for the expected increase in involvement of private national and international companies with the activities of production, distribution, and commercialization of hydrocarbons which implies an immediate increase in the demand for more installations of hydrocarbon storage in land. The expected increase in involvement is due to two different factors occurring in Mexico. One is based on an analysis performed by the Mexican Secretary of Energy which expects an increase in production and demand of hydrocarbons for the next ten years (Oficial, 2018). The second factor is the Energy Reform which changed the Mexican Constitution on December 20, 2013 to allow private companies to explore and produce Mexico's hydrocarbon resources. This norm is intended to provide legal assurance to topics related with industrial and operational safety that must be observed during the design, construction, pre-startup, operation, maintenance, shut-in and dismantling of hydrocarbon storage in land.

One of the references mentioned in the norm NOM-006-ASEA-2017, the RES/899/2015 Resolution, states that the Mexican Energy Regulatory Commission (CRE) is the one responsible of approving the general administrative dispositions for open access and lending of the pipeline transportation services and storage of hydrocarbons. This coincides with Treaty A/053/2015 published in November 24, 2015 which publishes that the CRE is responsible for interpreting (for administrative purposes) the Hydrocarbon Law, with the purpose of defining the reach of the regulation of hydrocarbon matters (Oficial, 2018). This means that the CRE is the organization that must approve new projects, including the new hydrocarbon storage solution developed for this thesis project.

The norm NOM-006-ASEA-2017 contains a chapter titled "Procedure for the Evaluation of Conformity" which dictates the activities that must be evaluated in three milestone stages. These stages are (1) design, (2) pre-startup and (3) operation and maintenance. Each one of these stages must be evaluated by a verified, accredited, and approved organization to approve or deny the engineering work involved. The evaluation is accomplished by performing an inspection of documents and an inspection of installations of hydrocarbon storage in land. In some cases, it could be more challenging to obtain approval of actual operations rather than initial project approval. This is because when the inspection is performed in the field, it must be in line with the earlier declarations made. In most of the large projects, initial declarations are made with certain assumptions, which may not be in line with the actual execution (Neville, et al., 2007). Therefore, it is particularly important to inform amendments to avoid denial or delay in approval of operations. For this reason, it is strongly recommended to have local engineering management experts that can handle this situation and obtain the necessary approvals.

To be able to get the new hydrocarbon storage solution approved for its utilization in Mexico, the milestones in the project must be in line with the milestones set in the Mexican norm. The details in the norm also include environmental impact assessments (EIA). This is one of the most difficult and time-consuming process in almost every country because it requires many documents and commitments by the project owner (Neville, et al., 2007). By taking timely action and having a clear management plan, execution delay can be avoided.

To avoid delays in the new hydrocarbon storage solution project, starting communication with the evaluating agency / organization as soon as possible would call for the best working scenario. The CRE has a list of approved companies specialized in the evaluation of conformity with the requirements for the storage of hydrocarbons in Mexico. It would be wise to select one to partner up with, or ideally, with a regulatory company involved in creating new regulations. Such was the successful example of SEI Industries back in 2014. This company was able to create a new standard for collapsible fabric storage tanks (bladders) in partnership with the Canadian Standards Association (CSA). The regulation is called CAN/CSA B-837 and it represents the world's first standard for collapsible bladder fuel storage tanks or pillow tanks. For several years, regulators, operators and manufacturers in Canada had no credible reference document that specified the minimum requirements for pillow bladders (Mining, 2014). SEI's involvement with CSA started back in 2018 when Paul Reichard, manager of SEI Industries' Remote Site Environmental division, was a participating member and vice-chair of the CSA standards technical committee who prepared the new standard. The initial reason for his involvement was the fact that the federal environmental regulations in Canada "accidentally excluded collapsible fabric fuel tanks from the regulations, making it difficult for major clients like the Department of National Defense and mineral exploration companies to use bladder", said Reichard. The new standard set out to recognize bladders as a safe, cost effective and environmentally friendly solution for the temporary storage of fuel in remote sites. Just as in Mexico, Canada also requires an accredited third party to certify a product. By now, SEI Industries has certified its bladder storage solutions. Without it, Reichard states that the fuel bladder can get a bad reputation. Now with the CAN/CSA B-837 standard, there is a greater comprehension, knowledge, and credibility with these types of storage solutions.

For the new hydrocarbon storage solution, the regulatory framework must possibly open new paths similar to SEI Industries to be able to prove that the new product will be reliable for hydrocarbon storage.

5.5 TECHNOLOGY

The task of designing a new product for the oil and gas industry requires an in-depth analysis of what products are currently available and how can they be improved. This is not only useful to determine what current technologies are available in the market as competitors, but it is also helpful to obtain inspiration from within and outside the oil field to develop a better solution. As mentioned before, the industry is undergoing a digital transformation and the benefits that come with it are going to be an elemental part of the selling point for a new storage solution product. The implementation of new technologies like sensors and devices, networks, software platform, Bluetooth or wireless connectivity for Internet of Things is also primordial.

The novel storage solution that is being designed by the Startup in Vienna will utilize the support of earth walls to contain the fluids stored. To do so, a hole will be dug into the ground and the earth removed will be pilled on the sides to create the walls for the storage tank. For structural purposes, the wall height should be a third of its base to ensure that the walls will hold the volume contained. Inside the cleared space, a membrane will be used to provide a secondary containment in case of a spill. This membrane will be attached at the maximum height of the earth wall. The primary containment will be a deflated bubble made of a geomembrane that is compatible with hydrocarbons and that will lay on top of the membrane utilized as secondary containment. The primary containment will also be attached to the maximum height of the wall. An inlet pipe will be attached to the top of the storage solution and an outlet pipe will be attached at the bottom. Each primary containment will be custom-built by joining prefabricated flexible panels on site by a process similar to welding, implementing heat to join all panels together into a three-dimensional shape. This primary containment deflated bubble becomes fully inflated when filled with the hydrocarbon fluid. A mechanical system on the inside is used as a liquid spreader and will ensure that the liquids remain homogeneous through rotation, avoiding deposits of highest density to accumulate at the bottom of the storage solution. This is only a broad description of the tank design; pending patent registrations do not allow technical details to be published at this time. Further development of the design will be required to meet the necessities in the market.

To create a novel offering for the industry, the 6th Force of Michael E. Porter will be implemented. Michael E. Porter, the Harvard Business professor that created Porter's Five Force Model, extended its model to include this 6th Force in the mid-1990s, he called it Complementary Products. This refers to products or services that are compatible with what a particular industry sells. It is the force that indicates that complementary goods offer more value to the costumer together than apart. The impact of complementary products can be either advantageous or disadvantageous for the market's profitability, it will depend on how reliant a product or service is on the compatible product (Stapleton, 2019). If one of the products portrays difficulties functioning properly without the other, the impact is high. The intention in this project is to implement the Complementary Products force by bringing together different product offerings from different industries to offer a new hydrocarbon storage solution for the oil and gas industry.

The inspiration for the development of a novel storage solution can be depicted in the images below. The image on top-left of Figure 10 demonstrate the application of concept of an earth-wall storage covered with a flexible geomembrane which is compatible with hydrocarbons. This type of construction is used currently, mostly for water storage. This design is ideal for areas with particularly favorable geographical conditions like presence of natural walls, valleys, or easy to move earth nearby. If these conditions are present, the solution would ensure high safety standards and lowest possible capital and operational expenses. The image on the top-right of Figure 10 demonstrate the proof of concept of a membrane-wall storage. This would be a preferred solution for locations which are particularly flat and whenever building time and scaleup should be as quick as possible. This solution could be installed anywhere with only minimal limitations on its dimensions. The added benefit for both portrayed solutions is that there would be no gap space between the flexible “deck” and oil. This helps reduce the evaporation losses of the stored hydrocarbons. This solution resembles the benefits of a floating roof tank, which is expected to dominate the oil storage terminal market share between 2020 and 2027 (Insights, 2020). It is expected that, if a new product comes to market offering similar technological benefits as the market leader solution, then the new product could be well accepted by the conservative oil and gas industry. Furthermore, if the price of the new storage solution is lower because of a selection of more economical material, this novel solution could prove to be the preferred solution after all.

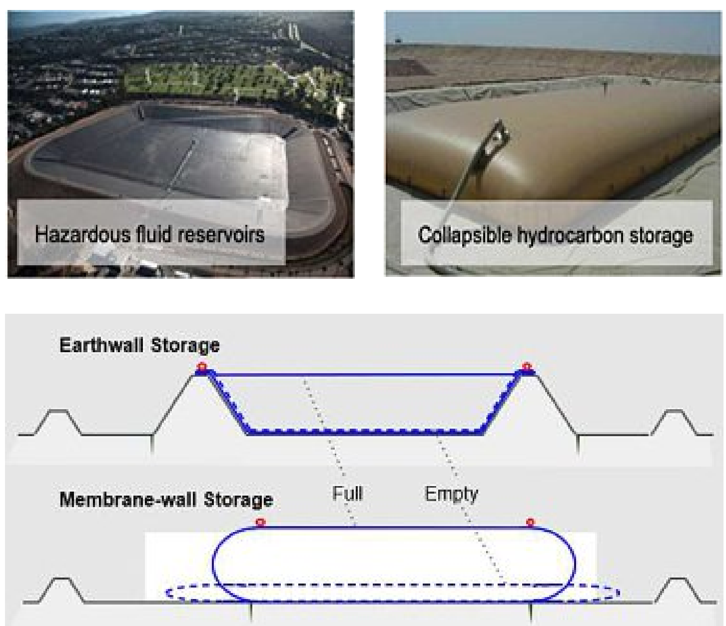

Figure 10. Inspiration for new hydrocarbon storage solution.

It is common knowledge that the storage of hydrocarbons presents a high risk due to the flammability of the fluids. Overcoming challenges with proven technologies in other industries will be extremely helpful for the conservative oil and gas industry to accept the novel storage solution. It is desirable to apply successfully proven technologies to achieve same or even better standards than the current state of the art storage solutions. In addition, since existing solutions would be adopted in a new way, it will be possible to patent the innovation. Such is the case of a self-sealing mechanism that would prevent leaks in case of puncture of the storage material of construction. These types of mechanisms are normally used for the armed forces to protect fuel tanks of airplanes from gun shots. As the name implies, the self-sealing wall prevents fuel from flowing out of the tank by sealing itself.

Another complementary product coming from a different industry is the usage of a pneumatic dome to provide a cover for the flexible storage tank. This would prevent the contact of the material of construction with the environment and it would reduce the wear and tear of the geomembrane material that would be in touch with the hydrocarbon fluids. Pneumatic domes are fairly recent inventions that appeared in the second half of the twentieth century. They have proven to be a unique and cost-effective solution to cover large areas. In comparison to conventional building materials like concrete or wood, these domes are significantly less weight, less material and represent a significant cost reduction.

Such complementary opportunities from other industries should not be missed because they represent a huge saving in time and resources for research and development that not all startup companies have.

5.6 MAJOR MILESTONES

The figure below is a graphical representation of the technical, market and regulatory milestones that must be accomplished to de-risk the project and to roll-out and scale up the production of the novel hydrocarbon storage solution.

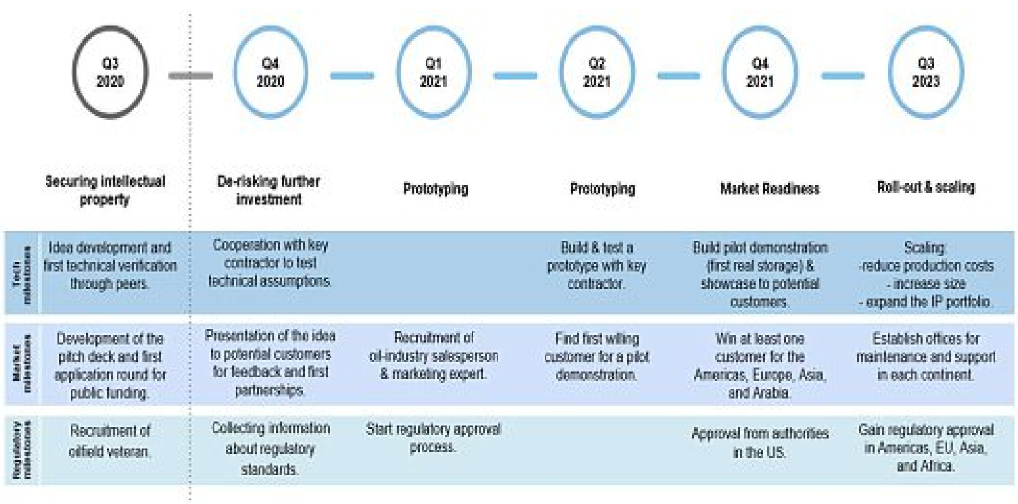

Figure 11. Major milestones for the novel hydrocarbon storage solution.

As it can be seen, the foremost priority is securing intellectual property. The technical milestone under this section calls for the development of the novel storage solution idea and a first technical verification through peers. This is an important step because, as it was seen from the Lean Customer Development process, this project development is born from an extraordinary idea that the market will pull for, instead of the Startup in Vienna having to push the product to the consumers. The market milestone consists of development of a pitch deck presentation and first application round for public funding from the Austrian government. In the pitch deck the main topics that are presented cover the market opportunity, the product technology and general characteristics, business model, financing, and SWOT (Strengths, Weaknesses, Opportunities and Threats). In the regulatory milestone, the recruitment of an oilfield veteran is important to ensure that the product will be accepted by regulatory agencies to be utilized in the oil and gas industry.

By the 4th quarter of 2020, de-risking further investment is necessary to progress in the project. This means that cooperation with a key contractor to test/model technical assumptions is crucial. Then, through interviews with identified user personas, a group of them can be selected to present the novel storage idea for the startup company in Vienna to obtain feedback and to ideally create first partnership. For these first approaches, it is crucial to be able to start with why, as Simon Sinek proposed in his golden circle idea. The "Why" should be the purpose, the cause and the believe of the existence of the organization. People do not buy what a company does, but they buy why they do it. The goal is to sell something people believe in, not necessarily something that they need. A company must be able to clearly express *why* they are producing a new product. Only this way can people be attracted to believe what a company believes. This, in the end, builds loyalty and makes for the most valuable customers a company can have. For this project, the following statement applies.

> Agility and flexibility are at the core of who we are, innovation and thinking outside the metal can is what defines us. We produce products easy to install and ready to use. We build flexible and quick-to-build storage solutions for the oil and gas industry.

With this slogan in place the startup can immediately position itself as an agile, innovative, and fast solution-provider. The goal is to attract like-minded potential customers that will be willing to provide detailed feedback and a valuable perspective from first-line users of storage solutions. This way, customers can be a part of the development process which would be highly beneficial for a startup company with limited resources.

In the first half of 2021 prototyping is the main goal. To achieve this, the regulatory milestone must be to already start the regulatory approval process since this step can be quite long and tedious. For this thesis, the focus on regulatory has been Mexican regulations. Recruitment is also a milestone because the project needs will increase as the product development continues to advance. The beginning of building and testing a prototype with a key contractor will also be an important milestone for the second quarter of 2021. Finding and selecting a key contractor will take time, therefore, it is important that this is achieved at the early stages of the project.

By the end of 2021, the project's goal is market readiness. By the end of this year, a pilot demonstration of the first real storage tank should be built to be able to showcase to potential customers. Ideally, sales of at least one storage unit would be sold in the Americas, Europe, Asia, and Arabia. For the purpose of this thesis, the main focus continues to be Mexico. Approval of regulatory agencies should already be granted by this date for the first customers to be able to utilize the storage solution.

The last goal presented in this diagram is the roll-out and scaling by the third quarter of 2023. The time between the first purchase to this date would be used to obtain feedback from users on the field to perform continuous improvement on the product design. Scaling up production will be crucial to reduce production costs, increase size of storage products, and to expand the Intellectual Property (IP) portfolio by continuing innovating on the solutions offered. Moreover, offices should be established for maintenance and support in each continent close to the storage tanks. Lastly, regulatory approval in Americas, EU, Asia, and Africa should also be accomplished by this date. This should be easier to achieve after the first country has already approved the first product. It is known that the regulatory agencies in different countries have similar requirements, therefore, approval should not be a huge challenge to achieve.

To accomplish the milestones mentioned above, below is a general overview of the tasks with estimated duration, estimated costs, expected results, options to proceed and funding sources for each step of the project.

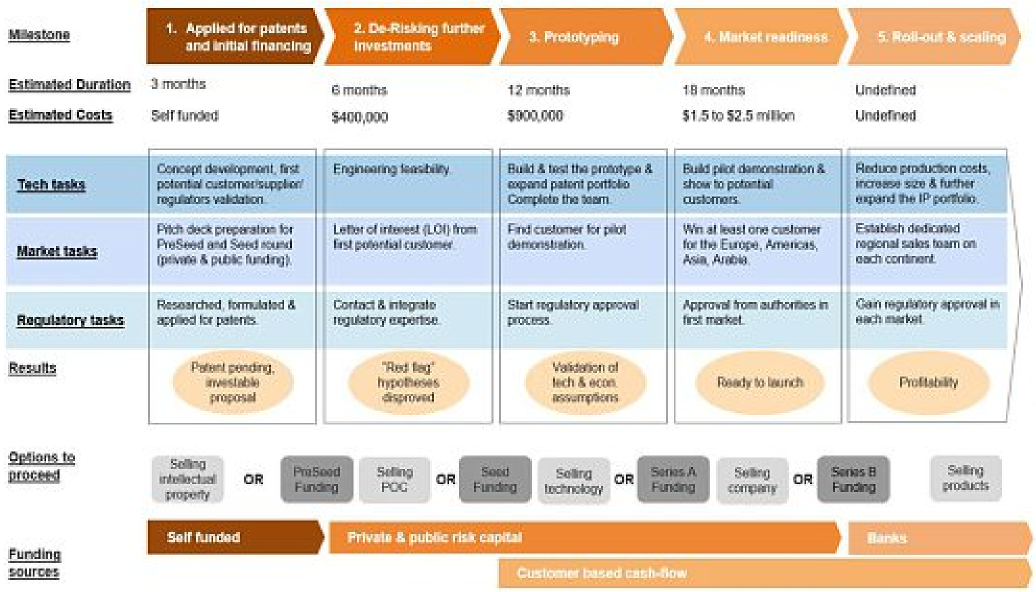

Figure 12. General overview of the Novel Storage Solution project.

The figure above depicts the most important results that must be attained to be able to advance to the next step of the project. If this result is not achieved, then it is not recommended to proceed. If the results are achieved, then the options to proceed are presented in this figure as well. Selling the intellectual property, meaning the concept development is also considered to be valuable for an existing company to acquire it. It is not the preferred option, but it is an option that could be evaluated if the project could not proceed for unexpected and unforeseen reasons.

With regards to funding, the terminology used was taken from the common jargon in the Startup environment. Pre-seed funding refers to a small investment needed to get a business started. The funds could come from founders themselves, friends, family, or close supporters. Seed funding is the first official equity funding stage. The funds could come from incubators, institutional investors or "angel investors" which are high net-worth individuals. If a Startup cannot gain traction before the money runs out, then the business could fold (McGowan, 2018). If the company makes it through this stage, then it is ready to raise a Series A round to advance to the next stage of the project. Whether a company makes it to the next stage will depend on Key Performance Indicators set by the company which could be a number of Letter of Intent (LOIs), a certain amount of revenue, etc.

In the Series A round, the Startup company must already have a defined business plan and the money raised is expected to be used to increase revenue (McGowan, 2018). Series A funding is much higher than the seed funding. Investments could be anywhere between $2 to $15 million USD. For this reason, investors will expect to see more information and positive results before they commit large sums of money. The funds usually come from venture capital firms or from crowdfunding. If the Startup in Vienna cannot secure this level of investment, then it will not be able to advance to the next stage of the process. For this reason, it is crucial to work on a detailed process to meet the expectations of Series A round.

According to the Startup Information Library, Series B funding is reached once the Startup company has found the perfect product or market fit and needs help expanding further. In this stage, the Startup company could expect a valuation between $30 to $60 million. The funds typically come from venture capital firms, commonly, the ones who previously invested into the company already. Technically, the series of funding continues until Series E, but these are not included into this project to limit the scope.

With regards to the estimated costs presented in this figure, the topic will be further covered in the economic feasibility subsection.

5.7 BUSINESS MODEL CANVAS

A business model is simply a representation of how an organization makes or pretends to make money. One of the greatest mistakes a company can make to achieve it is to write a formal business plan. This counterintuitive advice was suggested by Alexander Osterwalder, ranked one of the top ten business strategists in the world according to the Thinkers50 Group (world's most reliable resource for identifying, ranking, and sharing the leading management ideas of our age). In Alexander Osterwalder's own words given at the 2018 Global Peter Drucker Forum (an international management conference dedicated to the management philosophy of Peter Drucker) in Vienna, he stated the following:

> "Business plans are a way to maximize the risk of failure. Why? Because it involves refining a fantasy that will look so good that you will go and execute it, build a product and will notice too late that it was probably wrong."

Instead of getting stuck in the process of writing an extensive business plan, the innovative and simplified Business Model Canvas (BMC) is a great tool to get a pictorial representation to clarify a business idea or concept. The BMC was invented in 2005 by Alexander Osterwalder under the supervision of his Ph.D. supervisor Yves

Pigneur as result of Alexander's work on business model ontology researching how to map business models at the University of Lausanne in Switzerland. What differs between this model and a traditional Business Plan is that the BMC is practical, simple, and visual. This is a tool used for innovation. It was tested and proven by 470 co-creators from 45 different countries of the book Business Model Generation (authors are Alexander Osterwalder and Yves Pigneur). Now, over 1.5 million books have been sold in 30 languages and the BMC has been used in a large variety of industries and companies of all sizes. By its format, it invites anyone in a company to contribute. It represents a shared language to for a team to create together. The BMC helps to have a visual object that people can focus on as a team, it represents a thing that can be worked on together without being something abstract like a strategy or innovation (Fischer, 2019). The improvement of a business model can be done more systematic with the use of the BMC. The model is simple but not simplistic, it can be used for companies of any size, from startups to large corporations.

The BMC is an excellent way to think of an entire business in one page since a business model can be defined as a simplified description of how a company does business without having to include complex details of all its strategy, processes, rules, hierarchies, workflows, and systems (Osterwalder, Blog of the Business Model Alchemist, 2005). A research of literature performed by Alexander Osterwalder has found that there are mainly 9 building blocks that describe a business model, and they are the following.

1. Value proposition of what is being offered to the market.
2. Client segment(s) that are being targeted by the value proposition.
3. Distribution and communication channels to approach clients and offer them the value proposition.
4. Client relationships created.
5. Key resources needed to bring the business model to reality.
6. Key activities required to put the business model into action.
7. Key partners and their motivations to be a part of the business model.
8. Revenue flows to be generated by the business model.
9. Cost structure resulting from the business model.

The best way to put together a BCM is to collaborate with the team working on a project. For the novel hydrocarbon storage solution, the BCM looks as follows.

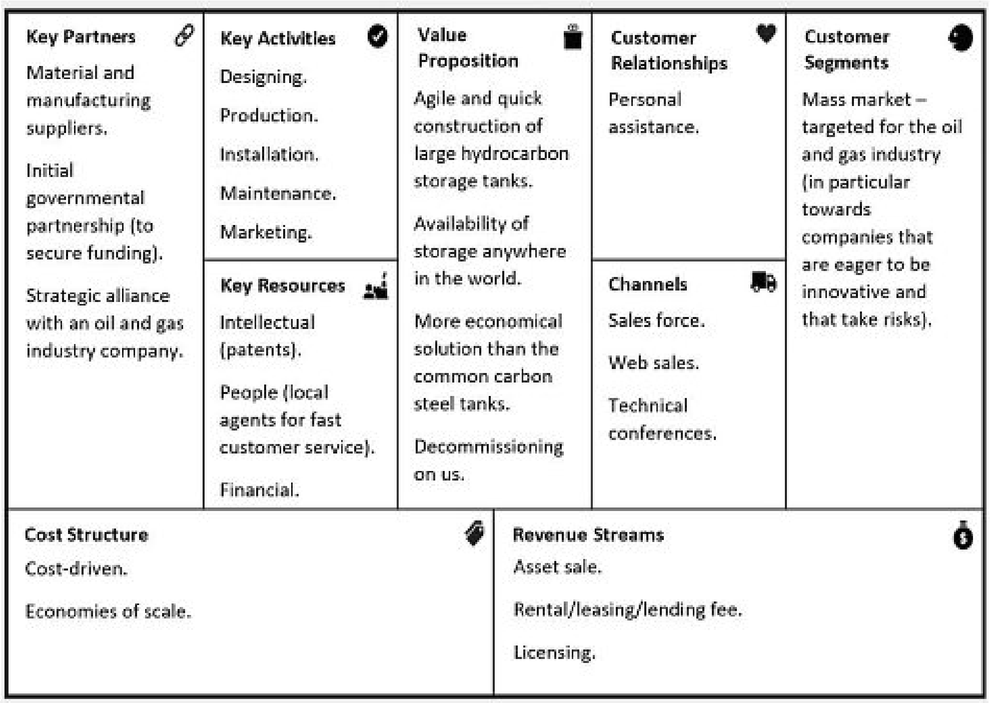

Figure 13. Business Model Canvas for the Novel Hydrocarbon Storage Solution.

The Business Model Canvas shown above was particularly built for the novel storage solution developed by the Startup in Vienna. There is a reason for the placement of the nine elements in the figure above. In the middle is the value proposition which is the most important part of the canvas. For a novel hydrocarbon storage solution business to be successful in the oil and gas industry, it was determined that the value proposition should include quick construction time, availability to install in any part of the world without limitation of location, and for this solution to be more economical than the carbon steel storage tanks that dominate the storage industry. A part of the value proposition block is also “Decomissioning on us”, which means that the Startup company would be the one responsible for removing / reutilizing the storage tank in the case of a customer that must dismantle operations. This offering enforces the concept of the systems engineering life cycle support for all storage solutions that the Startup company intends to produce.

The elements on the left side of the canvas are related to the efficiency of the business. Key Partnerships are a fundamental part of the Startup business. For the Startup in Vienna, three key partnerships are a necessity. The first one is to secure a material and manufacturing supplier. In the era of technology, it is not crucial to narrow down suppliers based on location. The most important criteria to locate the right partner is quality and reliability. Initial governmental partnership will also be crucial at the beginning of the project to secure funding. It is important to note that the funding must not come only from a governmental source, also Venture Capital investors could be attempted to secure funding. The last but not least key partnership for this business is a strategic alliance with an oil and gas industry company that could participate in the early stages of development to ensure that customer needs are being met in the product being developed. The key activities of this business model will include designing, producing, installing, maintaining, and marketing the novel hydrocarbon storage solution. The key resources for the business are three. The first one is intellectual resources, referring to patents that protect the invention of the novel solution. The second one is people; it will be crucial to have local agents located at the countries of installment to be able to provide a fast customer service and maintenance of products. Since the intention is for the first storage offering to be in Mexico, it will be crucial to have a team that will be located in the country to support the customer. The third key resource will be financial since every business needs to make a profit to survive.

The elements on the right side are related to value. For customer relationships, personal assistance through exceptional customer support by locals will be offered as part of the business model. The distribution and communication channels will be through sales force, web sales and technical conferences. The last element on the value side are customer segments. For this project, the mass market for the oil and gas industry is the targeted customer segment highlighting that companies that are eager to be innovative and that like to take risks are the primordial target profile.

On the bottom part of the BCM are elements related to financials. The cost structure for this business model will be cost-driven since the goal is to develop a storage solution that will be more economical than the existing carbon steel storage solution. Also, economies of scale will play a role in this business model because the more tanks are produced with the selected supplier, the higher the revenue expected. The revenue stream is also an element on this bottom part which is related to finances. There are three different revenue streams that are expected for the endeavor of this new business. The first one is a direct asset sale, meaning that a customer purchases a storage tank directly from the Startup in Vienna. The second option is a rental / leasing / lending fee, whereby the customer will rent the storage space without owning the storage tank. This is not an uncommon situation in the oil and gas industry. The last revenue stream is licensing which considers that a patent application will be approved, and the intellectual property can be licensed out to other companies. The next subsection will cover more in detail the economic feasibility of this project.

5.8 ECONOMIC COMPARISON

To clearly describe the economic analysis of this project, the following table has been created to compare the novel hydrocarbon storage solution to the vertical/cylindrical carbon steel storage tanks, the most commonly used hydrocarbon storage tank in the industry.

	Prototype	Novel Storage Tank	Carbon Steel Tank	Novel Storage Tank	Carbon Steel Tank
Volume (Barrels)	1,960	73,360	70,000	1,600,560	1,600,000
Volume (m^3)	313	11,720	11,130	255,680	254,372
Diameter (m)	15	50	30.5	140	5 x 60m tanks
Area occupied (m^2)	506	5,625	1,395	44,100	70,000
Potential annual rent* (USD)	7,884	115,427	115,427	3,221,575	3,221,575
ROI	0.05	0.09	0.03	0.47	0.05

Table 6. Economic comparison between the novel storage solution and a carbon steel tank. * Estimated at 70% storage capacity.

Three different scenarios are presented in the table above. The first one is the construction of a prototype with a volume of 1,960 barrels. The next two volume sizes (70,000 and 1,600,000 barrels) were selected to represent a wide range of capacities that are seen in the industry (the world's largest storage tank built has a capacity of 1.5 million barrels). In terms of actual construction of the novel storage solution, this will depend on the end customer's needs. The carbon steel tank diameter used for comparison was 50 meters with a height of 18m. It is important to note that the cost of the land was not taken into consideration for this analysis since it varies greatly according to location.

The most significant difference is seen in construction costs. The 70,000-barrel steel tank costs almost 4 million USD, while a 73,000-barrel novel storage could be built for 1.3 million USD, a third of the cost. The difference is even greater when comparing the largest capacity tank: 66 million USD for a steel solution versus less than 7 million USD for the novel solution. This is a saving of almost 90%. The construction costs reflect in an ROI (Return on Investment) calculation considering a potential annual rent at 70% capacity. A large novel storage solution could repay the investment cost within a little over 2 years, while a steel construction would need 20 years. The main cost difference can be attributed to the material cost.

The clear cost advantage of the novel storage solution should outweigh any risks associated with implementing a new technology, especially in areas where land is economical and thus no big factor on the cost calculation.

5.9 SUMMARY

The process of developing a novel hydrocarbon storage solution for the oil industry via a Startup company in Vienna has been presented in this chapter. The most commonly sold storage solutions for the oil and gas industry have been carbon steel tanks, but the development and construction of these can take years and it is extremely expensive. This represents a huge disadvantage for the industry which needs to increase its flexibility and speed of response to the demand swings, as well as decrease its investment costs. The Reverse Innovation strategy fits this challenge perfectly since it is desired to develop a much cheaper storage solution for emerging markets, where most of the population increase will take place and where most of the energy demand will come from in the next decade or two. Based on Porter's Five Forces analysis it appears that the competition in the hydrocarbon storage sector is at a medium intensity. Porter's 7 major barriers were analyzed, and a strategy was provided to overcome these barriers.

The project structure recommended for the development was based on a Systems Engineering approach because it takes into consideration the entire life cycle of the product. The first step in this approach was to identify the need in the market. This was done following a Lean Customer Development approach in which a Persona was created. The intellectual property (IP) protection was also discussed since the intention of the Startup company is to collaborate with suppliers to manufacture the novel storage solution. For this reason, a patent application was filled to protect the IP. Regulatory requirements for Mexico, the selected first country to market the novel solution, where presented. Mexico was selected as first country because it meets the emerging market description to apply the Reverse Innovation (RI) strategy. To close the RI loop, a model would be further developed for the United States. Technology was also discussed, in particular from Porter's 6th Force point of view, complementary opportunities. Leveraging the advances in other industries to offer a new product in the oil and gas industry is described.

Major technical, market and regulatory milestones were highlighted in a broad timeline under five different project stages which where securing intellectual property, de-risking further investment, prototyping, market readiness and roll-out/scaling. Information about the expected results from each milestone are also provided as well as options to proceed after each milestone. A business model canvas was also created to visually display the 9 building blocks that describe the most important parts of the business. Lastly, the economic feasibility of the project was demonstrated, showing a clear advantage in return on investment when comparing it to a carbon steel tank.

6 SUMMARY AND PATH FORWARD

The first purpose of this thesis was to investigate the current status of the oil and gas industry. As it was found through literature research, the industry will continue to be the one providing most of the energy demanded by the growing population around the world. Nonetheless, the industry must overcome some challenges to be successful in the years to come. For starters, companies in the oil and gas industry must be able to sustainably supply energy by taking into serious consideration the impact on the environment. To be sustainable, the Triple Bottom Line – economic, environmental, and social – must remain central to be able to tackle the challenges ahead. One could think that renewable energy could be the best solution for a sustainable energy supply, but research has found that renewables will remain relatively expensive in the near future and will not fill the energy demand soon. For this reason, more and more sustainable campaigns, laws, and regulations have been put in place to reach sustainability goals which highlights the challenge for companies having to invest resources in activities that reduce the impact on the environment.

Doing more with less is the second challenge that was found in the industry. Companies must adjust their operations and spending to be able to breakeven with lower prices of crude oil. Moreover, the easy oil era is long gone, meaning that the hydrocarbon production to date requires more economic resources to be able to achieve the same production as before. Furthermore, the challenge is increased even more because new reservoir findings are located in more remote locations or ultra-deep waters which further require higher economical resources. To complicate matters even further, experienced personnel in the industry are retiring and are leaving behind a workforce with less experience and less mentorship. More energy demand is required from the oil and gas industry, but less is the economic return that they can obtain in such challenging circumstances.

The third challenge found was demographics playing a role in the future of the oil and gas industry. The areas which will have the greatest increase in energy demand will be in emerging markets. In these countries, the population is relatively young in comparison to developed aging population. This matters because the method of communicating with younger population differs from that of elder generations. The oil and gas industry must reinvent itself to be an attractive energy solution and area of employment, or else, it could be rapidly displaced.

For the industry to rejuvenate itself, areas of opportunities where researched. Digital transformation is the first and most important opportunity for the industry to date. This has the potential to increase efficiency, reduce operational costs, and increase workforce knowledge by optimizing the use of information that has long been available but never effectively managed. To do so, the Internet of Things, augmented and virtual reality, artificial intelligence and robotics can be deployed to transform the way the industry operates. A shift from “oil and gas” to “energy” is also an enormous opportunity that must be further investigated by the companies in the industry. This is because the industry could be a critical key player for clean energy technologies to be developed, and their resources and skills could be implemented to help tackle pollution emissions. Third opportunity for the industry is the growth in developing economies which will have an expanding middle class that will drive demand across energy and utilities sectors. It is important that the companies in the oil and gas industry are focusing their attention to the developing markets which will represent an increase in value for the market.

Two strategies where presented that can help the oil and gas industry through this current era. The first one is Reverse Innovation which added benefit is that of simplification of development of new disruptive technologies. This is accomplished by designing products “in the field” in emerging markets by developing an economic solution and deploying it first in emerging markets without wasting money in the development phase to achieve the highest possible technical solution. Once the product is operational, research is continued and the product is tweaked to be sold in developed markets at a higher price with more advanced features, closing the Reverse Innovation Loop. Such strategy can be utilized to develop new solutions for the oil and gas industry by offering it to emerging markets and then further developing it for emerging markets. The second strategy for the oil and gas industry to implement is creating a digital experience which matches with the digital era that we currently live in. It should be customer centric and should be able to communicate with the digital savvy customers and businesses in the world.

The application of the theory found in the research literature and in the Engineering Management course was put into practice by developing a novel hydrocarbon storage solution for the oil and gas industry with a Startup company in Vienna. Storage activities correspond mostly to the midstream sector of the industry, which is one that will be needing much support in the years to come since transportation and storage will be important activities for the emerging markets where most of the energy demand will be located. The storage solution was discovered to be a product that needs to be reinvented and modernized because the current offerings take too long to build and are very expensive. This, in turn, causes the industry to be less responsive to the changes in demand and to be less flexible to quickly respond to the industry's needs. Porter's Five Force Model was utilized, and it was discovered that the competition is considered to be at a medium level in the storage industry. The project structure selected was a Systems Engineering approach where the full life cycle of the product can be taken into consideration. A Lean Customer Development process was followed to understand customer needs and to fortify the hypothesis of a new storage solution requirement. An open innovation was utilized to be able to collaborate with manufacturers and suppliers in the development. To be able to protect the intellectual property of the design, a patent application was filed. Regulatory requirements were also investigated to make sure that the product will be accepted in the first target market country, Mexico. The technology to develop the storage solution is also an important part of the development of the product. Porter's sixth force called Complementary Products was utilized to be able to highlight the implementation of solutions from different industries in the design. Major milestones with a general timeline were presented in which expected results were discussed. Then, a business model canvas was developed to clearly state the value proposition to be presented in the market. Lastly, an economic comparison between the novel storage solution and the traditional carbon steel storage tank was performed to demonstrate the clear advantage of the novel solution.

The main work of this thesis has demonstrated that the oil and gas industry should consider the replacement of the traditional carbon steel storage solution by implementing the novel flexible hydrocarbon storage solution. As future work, it is recommended to build a partnership with an oil and gas producing company in Mexico to bring to reality the first prototype of the novel storage solution. Future work is also encouraged to utilize the strategies presented in this thesis towards improving the oil and gas industry further by developing more economic solutions to strengthen the future of the industry.

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APPENDIX A

User Persona created for the Novel Hydrocarbon Storage Solution project.

Jose Martinez

Age
55 to 64 years

Highest Level of Education
Master's degree (e.g. MA, MS,

Social Networks

Industry
Technology

Organization Size
1001-5000 employees

Preferred Method of Communication

- Email
- Phone

Tools They Need to Do Their Job

- Project Management
- Email
- Cloud-Based Storage & File Sharing Applications
- Reporting Software

Job Responsibilities

Manage the transportation of hydrocarbons from production sites to storage sites to refining sites.

Their Job Is Measured By

Rental contract costs, avoiding delays in scheduling, clear organization of storage systems, avoiding maintenance issues.

Reports to

Supply Chain General Manager

Goals or Objectives

Save money while ensuring reliable storage of hydrocarbons.
Avoid delays or reduction of storage capacity due to maintenance.
Keep track of storage utilized and plan ahead to avoid running out of capacity.
Create new storage renting contracts.

They Gain Information By

Attending to technical conferences, word-of-mouth from colleagues, technical magazines, ads on LinkedIn.

Biggest Challenges

- Resources
- Communication
- Project Management & Disorganization