MASTERS IN MANAGEMENT (MIM)

MASTERS FINAL WORK

PROJECT

THE ROLE OF CARBON CAPTURE AND STORAGE IN THE EUROPEAN OIL AND GAS INDUSTRY: REGULATORY, TECHNOLOGICAL, AND FINANCIAL PERSPECTIVES

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ABSTRACT

Since the rise of the hydrocarbons the demand for fossil fuels has been steadily growing, however the negative side-effects started to appear. Fossil fuels are among the accelerators of climate change, however many countries have started to decarbonize their economies and set up targets to become carbon-neutral in the future. As the European Union accelerates its decarbonization efforts, carbon capture and storage (CCS) has emerged as a potential solution for reducing greenhouse gas (GHG) and it can drive the oil and gas industry into a more sustainable future as well.

This master’s final work examines if CCS is the right tool to reach net-zero emission goal, moreover it analyses the regulatory, technological, and financial dimensions of CCS, with a focus on its implementation within major European oil and gas companies. It uses a mixed method, as it applies qualitative and quantitative research. Through in-depth interviews with industry experts at MOL Plc. presents the real-life application aspects of the technology, while with an empirical analysis of financial and emissions data from nine leading firms the master final work explores the feasibility, economic implications, and long-term results of CCS implementation.

The findings reveal that while CCS can contribute to emission reduction and provide financial benefits in the long term, its large-scale implementation faces critical challenges. These include high costs, regulatory uncertainties, and the finite availability of suitable storage reservoirs. However, financial analysis indicates a positive correlation between emissions reduction and profitability, which should enhance the proliferation of the technology as it mitigates GHG emissions and increases the companies’ profitability. Despite the positive effects, experts caution that CCS alone is not a sufficient long-term solution. Instead, it serves as a time-gaining measure, allowing companies to reduce their emission in the short-term, while transitioning toward more sustainable energy sources.

Keywords: Net Zero Industry Act, Carbon Capture and Storage, Greenhouse Gases, Emission Reduction, Carbon Neutrality

RESUMO

Desde o surgimento dos hidrocarbonetos, a procura por combustíveis fósseis tem vindo a crescer de forma constante, no entanto, os efeitos secundários negativos começaram a aparecer. Os combustíveis fósseis estão entre os aceleradores das alterações climáticas, contudo, muitos países começaram a descarbonizar as suas economias e a estabelecer metas para se tornarem neutros em carbono no futuro. À medida que a União Europeia acelera os seus esforços de descarbonização, a captura e armazenamento de carbono (CCS) surgiu como uma solução potencial para reduzir os gases com efeito de estufa (GEE) e pode conduzir a indústria do petróleo e gás a um futuro mais sustentável.

Este trabalho final de mestrado examina se o CCS é a ferramenta certa para alcançar a meta de emissões líquidas zero, além disso, analisa as dimensões regulatórias, tecnológicas e financeiras do CCS, com foco na sua implementação nas principais empresas europeias de petróleo e gás. Utiliza um método misto, aplicando metodologias qualitativa e quantitativa. Através de entrevistas aprofundadas com especialistas da indústria na MOL Plc., apresenta os aspetos de aplicação prática da tecnologia, enquanto, com uma análise empírica de dados financeiros e de emissões CO_2 de nove empresas líderes, o trabalho final de mestrado explora a viabilidade, implicações económicas e resultados a longo prazo da implementação do CCS.

As conclusões revelam que, embora a CCS possa contribuir para a redução das emissões e proporcionar benefícios financeiros a longo prazo, a sua implementação em larga escala enfrenta desafios críticos. Isto inclui custos elevados, incertezas regulamentares e a disponibilidade finita de reservatórios de armazenamento adequados. No entanto, a análise financeira indica uma correlação positiva entre a redução de emissões e a rentabilidade, o que deverá aumentar a proliferação da tecnologia, uma vez que mitiga as emissões de GEE e aumenta a rentabilidade das empresas. Apesar dos efeitos positivos, os especialistas alertam que a CCS por si só não é uma solução suficiente a longo prazo. Em vez disso, serve como uma medida de ganho de tempo, permitindo às empresas reduzir as suas emissões a curto prazo, enquanto fazem a transição para fontes de energia mais sustentáveis.

Palavras-chave: Regulamento Indústria de Impacto Zero, Captura e Armazenamento de Carbono, Gases de Efeito Estufa, Redução de Emissões, Neutralidade de Carbono

ABBREVIATIONS

2P: Proved and probable (reserves)

Bi: Billions

CCS: Carbon capture and storage

CCUS: Carbon capture utilization and storage

CEE: Central Eastern Europe

CO_2: Carbon dioxide

EOR: Enhanced oil recovery

ETS: Emission trading system

EU: European Union

GHG: Greenhouse gas

IEA: International Energy Agency

IETA: International Emission Trading Association

IRENA: International Renewable Energy Agency

M&A: Merges and acquisition

Max: Maximum

Mb/d: Million barrels per day

Mboepd: Thousand barrels of oil equivalent per day

MFW: Master final work

Min: Minimum

Mins: Minutes

Mmboepd: Million barrels of oil equivalent per day

MS: Member state

Mt: Million tons

NASA: National Aeronautics and Space Administration

NZIA: Net Zero Industry Act

Obs: Observation

R&D: Research and development

Std. div: Standard deviation

TAM: Technology acceptance model

TRL: Technology readiness level

USA: United State of America

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CHAPTER 1 - INTRODUCTION

Oil and gas industry dates back to the 1850s, when people found out how they can extract hydrocarbons from the ground and substitute the old commodities - such as whale oil - for similar usage (Hermann et al., 2013). In 1870, John D. Rockefeller founded Standard Oil, which soon became the biggest and one of the best-run companies in history and since then the importance of oil has become unquestionable in the modern world (Wu & Chen, 2019).

The sector has become unusually potential and soon oil and gas production were replacing the old commodities, when people figured out that hydrocarbons can be used in many other diverse ways, compared to their old substitute-product (Brydson, 1999). Beside fuel and heat, people discovered in the early 1900s that they can create a new material from oil: plastic (Dennis, 2024). Furthermore, there are plenty of other products, such as clothes, shoes, mobiles, tyres, chemicals and furniture, which are based on the modification of some kind of hydrocarbon. These materials became the backbone of the modern economy due to their crucial role in transportation, heating and agriculture, and the demand has been steadily increasing over the last decades (Johnsson et al., 2019).
This master final work (MFW) focuses on the implementation of carbon capture and storage (CCS) technology in the oil and gas industry in Europe, as it may be a useful tool to achieve carbon neutrality by 2050 as the European Green Deal aims it (European Commission, 2019). It questions whether CCS is the right tool to decarbonize the industry and how it helps to reach the net-zero targets. Beside this, it concentrates to depict the opinion of the experts from the sector on the current state of the implementation of the technology, examines the financial and emission data of the nine largest European oil and gas companies, and unveils what are regulatory, technological and financial challenges that companies must face.

The oil and gas industry are responsible for ~55% of global greenhouse gas (GHG) emission (IEA, 2023), which is a major accelerator of climate change, hence the regulation and the reduction of emissions are crucial points in the fight against climate change. Even though it is clear how badly the industry affects our environment, the demand for oil and gas has been constantly growing and experts predict that the interest will be long-lasting. This industry and its products are forming an essential part of daily life and today it is impossible to imagine life without them. However, technologies such as CCS, can eliminate the negative effects of it and they might offer a long-term and sustainable solution for the problem.

On the one hand, CCS is an obligation for companies as the European Union (EU) has made certain regulations connected to the technology, while on the other hand it is a great opportunity as the industry can be better off financially. Also, many countries have realized that they need to alter and decarbonize their economies, which can be feasible through CCS and the underground storage of carbon dioxide (CO_2) (Shen et al., 2022). Companies like MOL Plc., possess the knowledge and depleted reservoirs to exploit this accelerating business, while hard-to-abate sectors are relying on these storage capacities to avoid paying fees and penalties after their GHG emissions. However, even though the oil and gas sector has been highly profitable, decarbonization challenges it due to the large investment cost and the shortage of time, although without them carbon neutrality is not achievable (Hastings & Smith, 2020).

For this MFW, two in-depth interviews were conducted with experts from MOL Plc, to present the two sides of the coin: Upstream and Downstream. Besides the interviews, the financial results and GHG emissions were examined of industry players in Europe to see how these companies are reflecting on the current challenges, how their financial performances are connected to their emissions, and how their profitability is influenced by the current changes.

As it comes to the structure of this work, Chapter 2 presents the Literature Review, Chapter 3 reveals the Frame of References, including the Technology Acceptance Model and the Financial Variables. Chapter 4 explains the Methodology, while Chapter 5 presents the Project for the Company (MOL Plc.), the Discussion of the Results and the Recommendations to the Company. Finally, Chapter 6 brings Conclusions, Limitations and Further Research Suggestions of the master final work.

CHAPTER 2 – LITERATURE REVIEW

2.1 The Environmental Impact of Hydrocarbon Use: Emissions, Challenges and Global Demand

Due to its importance in the economy, the oil and gas industry has become utterly influential and crude price has become one of the most crucial macro indicators in economics (Lang & Auer, 2020). In 2023, the size of the market was worth 6,705.68 billion USD, and Antriksh (2023) writes in his research that this number will grow up to 8,917.4 billion USD by 2030 (Antriksh, 2023). Not only the economic worth, but also the demand is huge for the products of this sector: apart from the pandemic in 2020, the demand has been steadily increasing over the decades. As Figure 1 shows based on the data retrieved from Energy Institute (Energy Institute, 2024), in 2023 the demand for oil reached an average of 102.21 million barrels per day (mb/d), which is a historic record, however in 2024 an even greater demand is expected (Ritchie & Rosado, 2024). Moreover, according to the International Energy Agency, oil and gas production will reach 114 mb/d by 2030, which is against the goals of decarbonization (IEA, 2023).

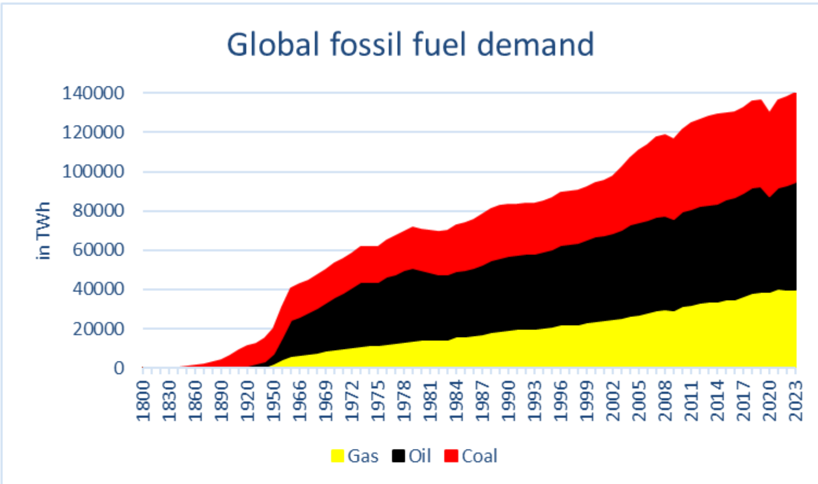

Figure 1 – Global fossil fuel consumption since 1800
Source: Own elaboration based on Richie & Rosado, 2024

Although there has been a successful proliferation of hydrocarbons, the drawbacks have started to emerge as well. Not only the use of hydrocarbons creates pollution, but also their extraction and processing. Burning hydrocarbons for heating and transportation purposes creates carbon-dioxide, which is one of the main drivers of climate change, moreover it is responsible for higher mortality rate and early death due to increased pollution (Smith et al., 2009). The emission which is made by humans, companies or other entities during their businesses can be divided into three groups: Scope 1, Scope 2 and Scope 3 (Hertwich & Wood, 2018).

Scope 1 incorporates all emissions which can be connected directly to the organization (for example emission from a factory or burning fuel of the company's vehicle). Scope 2 is the emission that the company causes indirectly through its business. This does not occur from sources owned or controlled by the company, however the company is responsible for it (e.g.: pollution due to generating electricity). Scope 3 includes all emissions which are not produced by the company and are not the results of the company's activities but created up or down in the value chain. A good example when an oil company sells fuel to the customer and the individual creates CO_2 while drives the car (Hertwich & Wood, 2018). As oil and gas companies cannot control their customers how to use their products, they can hardly control Scope 3 emission, while Scope 1 and Scope 2 can be altered much easily as it is under the influence of the company. This perspective embodies the reporting style of the companies, because they mostly report only their Scope 1 and Scope 2 emissions (Brander et al., 2018).

Since the rise of hydrocarbons, the pollution has skyrocketed simultaneously, however many countries have realized the harmful effects of it, and they have started to decarbonize their economies for the sake of a sustainable future (Shen et al., 2022). Nonetheless, many emerging countries – for instance BRICS members – still rely on coal, oil and gas as these are the engines of energy production and these countries demand a lot to improve their economy (Karakurt, 2021). According to Karakurt's (2021) findings, the share of primary energy consumption from fossil fuels is still more than 80% in the majority of countries, which matches with Richie and Rosado's results (Richie & Rosado, 2024).

As many people live in emerging countries, their needs and aims for development will increase the demand for fossil fuels in the future. The need for energy is constant and carbon-based products are more reliable than renewable ones, such as wind or solar. According to the International Energy Agency's forecast, the crude consumption of India for instance will reach 6.6 million barrels per day (mb/d) by 2030, which is 1.2 mb/d higher than the recent quantity (IEA, 2023). This trend does not present the desired decarbonization of the industry which has become a flagship in many Western countries recently. The IEA reported in 2023 as well, that the activities of oil and gas industry (producing, transporting and processing hydrocarbons) created 5.1 billion tons of CO_2-equivalent Scope 1 and Scope 2 emissions in 2022, which are accountable for 15% of total energy-related GHG emissions. However, if Scope 3 is incorporated as well, GHG emission increases by 40% due to the use of hydrocarbons (IEA, 2023).

2.2 Paris Agreement Goals: Strategic Pathways for Oil and Gas Companies to Reduce Emissions and Transition to Renewable Energy

In 2015, the Paris Agreement was signed with the aim to keep the average global temperature-rise below 1.5°C compared to the pre-industrial temperature (United Nations, 2015), however in 2024 the global temperature rise reached 1.6°C, which was the first time when humanity crossed the 1.5°C limit (Copernicus Climate Change Service, 2025). The consequences of non-compliance with the Paris Agreement will cause unforeseen changes, however the economic costs and risks are distributed unproportionally among the countries (Estrada & Botzen, 2021). In order to maintain the average temperature-rise below the Paris Agreement goal, oil and gas companies need to reduce their emission intensity, meanwhile they need to provide energy to the households and economic players securely (Turton & Barreto, 2006). According to the Renewable Energy Agency, a rapid change is necessary in our energy consumption, and renewable energy must cover two-third of the global energy supply by 2050 to reach these goals (IRENA, 2018). This means that oil and gas companies should reduce their exploitation and parallel their GHG emissions. To achieve the desired reduction, these business entities need to focus on five key strategic pillars as it was written in the IEA report in 2021 (IEA, 2021):

- Tackling methane emission,
- Eliminating non-emergency flaring,
- Electrifying upstream facilities,
- Enhancing carbon capture utilisation and storage (CCUS),
- Expanding the use of low-emissions electrolysis in refineries.

However, external factors such as only partial compliance or the withdrawal of major countries can seriously hinder the decarbonization aims (Sanderson & Knutti, 2017), hence the importance of the Paris Agreement regarding oil and gas companies' effort toward emission reduction is not that influential.

2.3 Acceptance and Resistance of New Technologies

Due to the heavy competition and rapid technological changes, companies often need to alter their strategies and course to stay competitive. However, when a new technology arises, the implementation of it faces many challenges due to the users' responds (either individuals or institutions) towards it. The outcome of new innovations can either positively or negatively influence the companies' competitiveness (Bissola et al., 2014), however Kotter and Schlesinger (2013) claimed that often resistance is a key barrier to successful transformation, which can be altered by tailoring the measurements accordingly and adapting the transformation strategy to the situation (Kotter & Schlesinger, 2013). When a new technology is accepted, it usually increases the number of sales, generates more cash flow and causes higher profitability, while helping the company to achieve better market position (Markham & Lee, 2013). However, when a newly introduced technology is rejected, sales can drop, the companies' competitiveness decreases, and the profitability is jeopardized due to the unsuccessful investment (Liao et al., 2015).

There are many factors which can cause resistance towards a new technology. Srivastava (2011) examined why Australian business community rejects using digital signature and found that culture of manual signature, ignorance of the new technology, legal and security concerns, the cost of the technology and its complexity makes it not favourable (Srivastava, 2011). As it shows, the barriers can be detected on a wide range from technological, to psychological, organizational and to ethical reasons. However, with certain methods – such as education (explaining the changes and expected benefits), participation (involving stakeholders in the implementation), facilitation (training the stakeholders and providing support), negotiation (offering incentivization) and coercion (promoting participants) – resistance can be managed and the acceptance can be achieved (Kotter & Schlesinger, 2013).

CHAPTER 3 – FRAME OF REFERENCES

3.1 The Technology Acceptance Model

For the qualitative analyses of CCS in real-life application, this MFW applies the Technology Acceptance Model (TAM) proposed by Fred D. Davis as it provides a framework how users come to accept and use new technologies (Davis, 1989). The model says that there are external variables (e.g., family, society, market, etc) which influence the users' attitude, however there are other important factors, such as perceived usefulness and perceived ease of use, attitude toward using and behavioural intention, which determine if the user will apply the technology in real-life. TAM is usually used to examine how individuals accept a new technology, for instance Ong et al. (2004) analysed how engineers accept e-learning systems to train new-joiners in high-tech companies, unveiling that the need for training without personal and time constraints is highly required, hence e-learning is a handy solution to provide trainings (Ong et al., 2004). However, there are also studies using TAM for analysing non-individuals and their attitude toward a new technology. Cloete and Doens (2010) examined e-marketplace adaptation for agricultural companies in South-Africa, finding that most of the companies are already using e-commerce in some forms, as it provides an easy and safe access for better export possibilities (Cloete & Doens, 2010), while Moradi and Dass (2022) investigated the application of artificial intelligence in business to business marketing, unveiling market players' perceived usefulness, including replacement of human workforce and solutions for data privacy challenges, after adapting artificial intelligence (Moradi & Dass, 2022). According to Chau (1996), the perceived short-term usefulness has the most important influence on the intention to use a given technology, albeit long-term usefulness also acts positively, although with a smaller impact (Chau, 1996). Study shows that in TAM, most of the external factors have a significant and positive relationship with the perceived ease of use, however the external factors vary based on their stabilities (Yuanquan & et al., 2008). Based on 79 studies from 73 high-quality articles Turner et al. (2010) found in their research that at the end, behavioural intention correlates the most with actual use, while the other factors of TAM, like perceived usefulness and perceived ease of use correlate a bit less (Turner et al., 2010).

Table 1 presents the dimensions for the qualitative data analyses, as based on the previously presented papers these are the most widely used dimensions, when TAM is applied in business environment.

Table 1 – Frame of Reference

Dimension	Description	Authors
External variables	External variables influence the adaptation of the technology indirectly by affecting the perceived usefulness and perceived ease of use. These are not strictly forming part of TAM, however help to understand the reason behind the acceptance.	Yuanquan et al., 2008
Perceived usefulness	Perceived usefulness presents a degree to which the user believes that having the particular technology will help her to perform better.	Chau, 1996; Moradi & Dass, 2022
Perceived ease of use	Perceived ease of use refers to the degree to which the user believes that she can use effortlessly the technology.	Cloete & Doens, 2010
Actual use	Actual use is the real-life application and frequency of use of the technology.	Turner et al., 2010

Source: Own elaboration

The presented dimensions of TAM provide the base of the question for the interviews, in order to detect the experts attitude in the company towards CCS. The questions incorporate aspects of external dimension, perceived usefulness, perceived ease of use and actual use, as these are the most crucial ones considering the wide-spread implementation of CCS at MOL Plc. The structure of TAM helps to conduct the interviews thoroughly, hence the dimensions investigate every aspects of a newly introduced technology, therefore a broad and detailed understanding can be created on the topic.

3.2 Financial Performance and Emission Reduction

Besides the beforementioned qualitative dimensions, this MFW also focuses on the quantitative data analyses, to detect how the financial performance of a company alters due to the emission reduction. In his paper Lewandowski (2017) investigated 1640 international companies' financial performance and carbon emission (Scope 1 and Scope 2) from 2003 to 2015 and finds that there is a curvilinear link between the annual carbon emission and financial performance, unveiling it is financially beneficial for companies to mitigate their emission after a minimum level of CO_2 performance (Lewandowski, 2017), while Delmas et al. (2015) find that after a short-term financial drop the company performs better in the long-term (Delmas et al., 2015). Their findings are supported also by Ganda and Milondzo (2018), who conclude that there is a positive relationship between Scope 1 and 2 emissions reduction and financial performance based on their research among South-African firms (Ganda & Milondzo, 2018), while Russo and Minto (2012) show that there is a positive, however week relationship between corporate environmental performance and financial performance, which indicates that it is worth to become greener (Russo & Minto, 2012). Considering long-term profitability, Vatavu et al. (2018), claimed that if oil companies would like to maintain their high profitability they need to switch towards eco-friendly policies as shareholders approve renewable energy (Vatavu et al., 2018), while Abel (2017) highlighted the importance of capital structure, saying that more profitable firms should have higher leverage ratios (Abel, 2017). This matches with the findings of Chen et al. (2015), who state that optimal debt ratio is a key element of profitability (Chen et al., 2015). Focusing on the financial performance of companies, Aastvedt et al. (2021), highlighted that green innovations incentivize it, and it has a positive effect on the returns on sales (Aastvedt et al., 2021). Meanwhile, study presents that the right cash conversion cycle makes companies more liquid, requiring less debt and providing higher returns (Ebben & Johnson, 2011). Wang (2019) mentioned that this is crucial, thus firms with higher cash conversion cycles need more short-term debt, which causes low performance during a crisis (Wang, 2019).

As Table 2 depicts, for the financial analyses of the companies' Profit margin is used as a dependent variable, while Market capitalization, Debt ratio, Capital Intensity, Cash flow, Tobin's q, Scope 1 and Scope 2 emissions as independent variable, like many other studies did for examining the financial and carbon performance of certain companies (see Equation 1).

Table 2 – Description of Dependent and Independent Variables

Variable type	Name	Description	Authors
Dependent variable	Profit margin	Profit margin is a common measure of a company's profitability, which is expressed as the percentage of revenue that the company keeps as profit.	Lewandowski, 2017; Delmas et al., 2015
Independent variable	Market capitalization	Market capitalization is the product of the number of outstanding shares and their current market price, which shows how much the market values a given firm.	Lewandowski, 2015; Vatavu et al., 2018

	Debt ratio	Debt ratio is a percentage which compares the total debt of the company with its total assets.	Abel, 2017; Chen et al., 2015
	Capital intensity	Capital intensity refers to the companies' sales compared to their equity, showing how much capital is needed to generate revenue.	Aastvedt et al., 2021
	Cash flow	Cash flow is the net amount of cash and cash equivalents which is transferred in and out of the company.	Ebben & Johnson, 2011; Wang, 2019
	Tobin's q	Tobin's q measures the relationship between the companies' market value and intrinsic value.	Delmas et al., 2015; Busch et al., 2022
	Scope 1 emission	Scope 1 emissions are GHGs that a company emits from its own sources or controls them directly.	Lewandowski, 2017; Hertwich & Wood, 2018
	Scope 2 emission	Scope 2 emissions are indirect emissions of a company, deriving from purchasing energy.	Lewandowski, 2017; Brander et al., 2018; Ganda & Milondzo, 2018

Source: Own elaboration

$$\textit{Profit Margin}_{i,t} = \beta_0 + \beta_1(\textit{Market Cap}_{i,t}) + \beta_2(\textit{Debt Ratio}_{i,t}) + \beta_3(\textit{Capital Intensity}_{i,t}) + \beta_4(\textit{Cash Flow bi}_{i,t}) + \beta_5(\textit{Tobin's q}_{i,t}) + \varepsilon_{i,t} \qquad \text{(Eq 1)}$$

Based on Table 2, the following potential relationships are expected between the dependent and independent variables. Firms with higher market capitalization have economies of scale, resulting in higher profit margin, while higher debt ratio is associated with increased financial risk, which can potentially reduce profitability. High capital intensity may cause lower short-term profits, but higher long-term ones, moreover strong cash-flow indicates profitability as well. Lastly, high Tobin's q (valuation of the company) also results in increased profitability expectations.

To extend the regression model, Scope 1, Scope 2 and the sum of these two independent variables are added as Equation 2, 3 and 4 present. Some studies examine only Scope 1 emission (Chen & Gao, 2012), while other studies use Scope 1 and Scope 2 separately (Kleimeier & Viehs, 2016), also others combine the two of them (Trumpp & Guenther, 2015; Lewandowski, 2017). In this MFW Scope 1 and Scope 2 are used separately and cumulatively as well (see Equation 2, 3, and 4) to see the optional differences between the results.

$$\textit{Profit Margin}_{i,t} = \beta_0 + \beta_1(\textit{Market Cap}_{i,t}) + \beta_2(\textit{Debt Ratio}_{i,t}) + \beta_3(\textit{Capital Intensity}_{i,t}) + \beta_4(\textit{Cash Flow bi}_{i,t}) + \beta_5(\textit{Tobin's q}_{i,t}) + \textit{Scope 1}_{i,t} + \varepsilon_{i,t} \qquad \text{(Eq 2)}$$

$$Profit\ Margin_{i,t} = \beta_0 + \beta_1(Market\ Cap_{i,t}) + \beta_2(Debt\ Ratio_{i,t}) + \beta_3(Capital\ Intensity_{i,t}) + \beta_4(Cash\ Flow\ bi_{i,t}) + \beta_5(Tobin's\ q_{i,t}) + Scope\ 2_{i,t} + \varepsilon_{i,t} \quad \text{(Eq 3)}$$

$$Profit\ Margin_{i,t} = \beta_0 + \beta_1(Market\ Cap_{i,t}) + \beta_2(Debt\ Ratio_{i,t}) + \beta_3(Capital\ Intensity_{i,t}) + \beta_4(Cash\ Flow\ bi_{i,t}) + \beta_5(Tobin's\ q_{i,t}) + Scope\ 1\&2_{i,t} + \varepsilon_{i,t} \quad \text{(Eq 4)}$$

CHAPTER 4 – METHODOLOGY

This MFW applies qualitative and quantitative data analysis to provide a broad and thorough insight of CCS implementation in the European oil and gas market. Its successful implementation relies on many aspects, such as the attitude of the company and its employees, regulations, technological feasibility and changing financial indicators, hence the combination of qualitative and quantitative methods present the best the issue. In this way not only the attitude and opinion of market players can be revealed, but also financial and emission performances of the companies can be analysed (Saunders et al., 2024). As the consequences of using CCS widely in an oil and gas company is not clearly identified, applying an inductive approach allows to draw conclusions from the accessed data, and compare it with the previous literature, which is useful to better understand the application of CCS (Saunders et al., 2024). The MFW uses mixed method, however the timeframe of the two methods is different. Qualitative data was collected cross-sectional, while quantitative data was retrieved longitudinal (financial and emission data was analysed from 2019 to 2023). Both qualitative and quantitative data were gathered through non-probabilistic and judgmental sampling, as interviews were conducted based on expertise and experience in the company, while for the financial analysis only the largest oil and gas companies were examined in Europe (Saunders et al., 2024).

4.1 Qualitative Study

For the qualitative part of the MFW two in-depth interviews were conducted to present the point of view of the experts on CCS in a multinational oil and gas company. The inductive approach allows to gather the information about the topic and later examine how it matches with the literature. The questions for the interviews align with the dimension of the TAM, namely the external variables, perceived usefulness, perceived ease of use and actual use (see the questions in Appendix, Annex I). The dimensions of TAM serve a great framework and guideline to conduct the interviews, as each dimension investigate a crucial aspect of the new technology. Hence grounding the interview-questions on the TAM allows to recognize all the important factors which are influencing the technology. The data was gathered cross-sectional, on the 13th of December 2024, at the headquarter of MOL Plc, in Budapest, Hungary. The interviewees were selected in a non-probabilistic, judgemental way, based on the expertise on carbon capture and storage and their position in the company (Saunders et al., 2024). The aim was to conduct interviews with those experts who are on the highest level in the corporate and have a deep knowledge on the topic.

4.2 Quantitative Study

The quantitative study applies the regression models which use the data of nine oil and gas companies in Europe from 2019 to 2023. The dataset was retrieved in December 2024 from Moody's Orbis database and the annual reports of the companies, which are available on their websites. The data was analysed during a 5-year long period, as the emission performances on the companies' websites were available only for this specific timeframe. Moody's Orbis database is a comprehensive global dataset, which contains the financial, corporate, and economic information about more than 550 million companies. It provides detailed financial statements, ratios and key performance indicators (e.g.: profit margin, return on equity, etc), which are crucial for conducting a financial analysis (Moody's, 2025). The data was collected to create regression models in order to examine the financial behaviour of the selected companies and detect how GHG emissions affect the performance of the firms. The quantitative data was analysed through a deductive approach, based on the findings of Lewandowski and Ganda and Milondzo (Lewandowski, 2017; Ganda & Milondzo, 2018). The data was collected longitudinally, presenting the financial data and Scope 1 and Scope 2 emissions through 5 years. The selected companies were chosen non-randomly and judgmentally, based on their market size and importance in the European oil and gas industry. The aim of using quantitative data is to present if it is worth financially for oil and gas companies in Europe to mitigate GHG emission and seek towards being net-zero emitter. As many studies highlights, if companies reduce their emissions, they are better off long-term, because their profit margin increases simultaneously (Busch et al., 2022; Delmas et al., 2015).

CHAPTER 5 – PROJECT FOR THE COMPANY

5.1 Company Presentation

MOL Plc. is a fully integrated international oil and gas company, which was founded in 1991, and since then has become a major player in the Central-Eastern European (CEE) market. The company has Upstream, Midstream, Downstream and Retail segments which results in 348 million barrels of oil equivalent (mmboe) 2P (proven and probable) reserves with a production of 94 thousand barrels of oil equivalent per day (mboepd), 3 refineries in Hungary, Slovakia and Croatia with a 16.42 million tons (mt) throughput capacity, 2 petrochemical facilities and more than 2,400 service stations. The company is also the main shareholder of INA, the most influential Croatian oil and gas company (MOL Group, 2024).

In 2023, MOL Plc. gained 25.9 billion USD operating revenue, which meant 6.1 billion USD gross profit and 1.5 billion USD net income. The company's total assets achieved 22.2 billion USD, which was divided among 10.1 billion USD total liabilities and 12.1 billion USD equity, which result in 45,51% debt ratio. The return on equity reached 16,46%, which can be considered average in the sector; 8,97% return on assets and 7.72% profit margin, which was a bit below compared to its peers (MOL Group, 2024).

Regarding GHG emission, in 2023 MOL Plc. had 6.65 mt equivalent CO_2 Scope 1 emission, from which approximately 5.5 mt (~85% of total emission) was Downstream emission and the rest is connected to the other segments (MOL Group, 2024). The company has a long history with CCS and carbon capture utilization and storage (CCUS) as they started enhanced oil recovery (EOR) activities at Szank in 1992, which has a 0.16 mt storage capacity and was the first CCS storage in Europe as well (Global CCS Institute, 2023).

5.2 Carbon Capture and Storage: A Pathway to Achieving Climate Goals and Reducing Industrial Emissions

In their paper Johnsson et al. (2019) argue that in order to realize the joint efforts towards GHG emission mitigation either hydrocarbons should be left unexploited underground or advanced CCS technologies must be proliferated, nonetheless the combination of both paths would be beneficial as well (Johnsson et al., 2019). However, it is unlikely that fossil fuels will evaporate from the modern economies. On the one hand, the alternative energy sources (renewable ones, such as solar and wind) are influenced by natural conditions and their investment costs are high (Sang-Bing et al., 2017), while on the other hand technical, political and social factors are also influencing the different regions and their attitude towards the topic (Xiaofeng et al., 2019). Hence, CCS is the handiest solution to tackle the current challenges and short-term problems, even though major R&D activities must take place to successfully execute GHG reduction in the near future (Johnsson et al., 2019).

Carbon capture and storage has been recognised as a useful technology against climate change since 1970s, and it could help to meet the Paris Agreement targets and decarbonize the oil and gas industry (Bui et al., 2018). CCS offers long-term solution for emission reduction as it injects CO_2 underground storage locations, preventing the gas to enter the atmosphere and accelerate global warming, furthermore thanks to this process, GHG emission can be reduced drastically, which is beneficial both economically and environmentally (Gibbins & Chalmers, 2008).

However, not only oil and gas companies can be the beneficiary of this technology, but also companies from hard-to abate industries (e.g.: cement, iron and steel, petrochemicals), which cannot mitigate their emission (Paltsev et al., 2021). In the European Union or other countries in the world, these companies face a huge extra cost by buying CO_2 quotas in the local emission trading system (ETS), but thanks to CCS they can reduce their costs, and the planet remains cooler too, as CO_2 is not emitted (Narassimhan et al., 2018).

As Yasemi et al. (2023) depicted in their paper, the mechanism of CCS consists of three main parts:

- Capturing it from industrial activities (purifying and compressing it as well),
- Transporting it to the storage location and,
- Injecting it to the ground.

At the end of the process CO_2 is safely stored in a depleted or mature reservoir permanently, while GHG emission is eliminated from the industrial activity (Yasemi et al., 2023).

For the description of the different technologies the technology readiness level (TRL) is used, which was implemented by the National Aeronautics and Space Administration (NASA) in the 1970s. The TRL scores between 1 (lowest) and 9 (highest) according to the readiness of the technology (Mankins, 2009). Capturing the CO_2 is the most expensive step as only pure CO_2 (or at least 99% concentration) is worth to be injected. The technology for removing other elements is well-known since decades as natural gas must be purified from other gases after extraction, but providing the purest ingredient is still challenging (Bui et al., 2018). Chemical absorption has been used for decades (TRL 9), but a much more effective polymeric membrane only reaches TRL 7, which means demonstrating phase (Bui et al., 2018). The industry differentiates three major capturing types: post-combustion (TRL 9), pre-combustion (TRL 9) and oxy-fuel combustion (TRL 7), which are used in different situations (Yasemi et al., 2023). Post-combustion is the easiest, most widely spread and also the most cost-effective technology, however its efficiency rate is relatively low compared to the two others, as it captures only 85-90% of emitted CO_2 (Bui et al., 2018). Pre-combustion is more efficient than post-combustion, with approximately 95% of capturing rate, however it is the most expensive of the three technologies (Yasemi et al., 2023), while oxy-fuel combustion has up to 99% capturing rate and is also cost-effective. This technology is based on burning hydrocarbons in oxygen, making flue gas with high CO_2 proportion and vapor. From the flue gas, CO_2 can be easily captured thanks to the high concentration (Bui et al., 2018).

After the CO_2 is captured, the stock needs to be transported to the depleted reservoir which can be executed through pipelines, trains, ships or trucks. Pipeline transportation is the cheapest and the quickest option for long distances (there is a ~7000km long pipeline worldwide; TRL 9), however it has great limitations as well. Storage locations might be encountered in areas where pipeline connection is not available, however the installation is expensive (Bui et al., 2018). The storage of CO_2 must be realized only in geologically safe reservoirs, which can store the gas eternally. Depleted reservoirs or deep saline aquifers are perfect locations as they have been storing crude and natural gas for millions of years. Oil and gas companies possess the know-how and location to implement the injection, hence the safe storing of CO_2 can be granted (Gibbins & Chalmers, 2008). However, in 2023 only 4 CCS facilities were operational in Europe (in Hungary, Iceland, Norway and on the Nordic Sea), while 6 facilities were under construction and 109 in early or advanced development (Global CCS Institute, 2023).

If companies are not open for CCS, they have two options: they either decrease their emission, which is quite unlikely (Johnsson et al., 2019; IEA, 2023), or they can buy CO_2 quotas (Narassimhan et al., 2018). In the 2022-2025 period, the average carbon price in the EU ETS is expected to be around 84 EUR per metric tons of CO_2, albeit according to the International Emission Trading Association the average price per metric ton will reach

100 EUR in 2026-2030, which means a nearly 20% increase (IETA, 2023). As time progresses, the perceived usefulness of CCS will be growing, which will alter the attitude and the technology acceptance of the market players (Davis, 1989). Hence CCS can become an economically viable solution and alternative, for instance in the hard-to-abate industry, where the expenditure on quotas is forecasted to be growing (Paltsev et al., 2021).

5.3 Regulatory Framework in the EU

In the European Green Deal (COM/2019/640), the European Commission has strictly appointed the desired path towards tackling the challenges of climate change and its aim to decrease GHG emission 55% by 2030 and achieve full carbon neutrality by 2050 compared to 1990 (European Commission, 2019).

After the European Green Deal, the Net Zero Industry Act (EU/2024/1735) was proposed in 2024, which creates a regulatory framework to enhance the competitiveness and technologies which are inevitable for the decarbonization of the EU (European Parliament & Council, 2024). The NZIA targets to establish annually 50 mt CO_2 injection capacity – which is 40% of the EU's annual deployment need – by 2030 with a market of for CO_2 storage services, however it will be increased to 550 mt by 2050. To achieve this ambitious goal, the EU involves oil and gas industry to the process, placing a strong obligation on producers to comply with the new legislation by investing into their assets, knowledge, and skills to make CCS a reliable solution (European Parliament & Council, 2024). Companies will receive a tailormade injection target, based on their average oil and gas production in 2020-2023, thus the 50 mt storing capacity will be distributed proportionally among the market players (European Parliament & Council, 2024).

The right execution of the NZIA is supported by European Parliament's Directive 2009/31/EC on the geological storage of carbon dioxide, which was enacted in 2009 to create a well-organized and structured approach towards CCS to help the member states (MS) meeting their emission reduction targets (European Parliament & Council, 2009). The directive applies to all storage locations across the MS territories, their economic zones and continental shelves, while the chosen sites must undergo thorough risk assessment to avoid any leakages by using stable, suitable and naturally secure geological reservoirs. For implementing CO_2 injection into the selected reservoir site, a permit must be issued by the state, confirming that the area is safe and suitable environmentally, geologically and sanitarily for the given purpose, while the public must be informed and engaged in the decision-making (European Parliament & Council, 2009). The operator of the site must monitor the behaviour of the stored material and ensure that no migration or leakage happens, or detect any discrepancy as soon as it occurs, moreover the operator has to report the results annually to the competent authority. After 20 years of the closure of the storage, the responsibility can be transferred to the local authority as the operator proved that the site suitable for long-term CCS activity and smooth operation was experienced since the injection (European Parliament & Council, 2009).

Besides the abovementioned two policies, the EU Industrial Carbon Management Strategy (COM/2024/62 final) is the other policy which will play a crucial role in the forthcoming years (European Commission, 2024). This policy aligns with the results of Paltsev et al. (2021) that the hard-to-abate sectors must be dealt with special attention to achieve the emission reduction goals (Paltsev et al., 2021). Nonetheless, capturing and storing the emitted GHGs from these companies offers a great business opportunity for oil and gas companies.

5.4 Qualitative Data Results

As it was previously mentioned, the qualitative study applied two in-depth interviews. Table 3 presents the sample characterization of the interviewees.

Table 3 – Sample Characterization of the Interviewees

Interviewees	**Division in the company**	**Titel**	**Years at the function**	**Duration of the interview**	**Form of the interview**	**Number of pages of transcription**
Interviewee 1	Downstream	Technology Development SME	3 years	74 mins	Online	45 pages
Interviewee 2	Upstream	Lithium and CCS Project Manager	2 years	28 mins	Presential	13 pages

Source: Own elaboration

The first and second interview lasted 74 minutes and 28 minutes, respectively. The interview questions were based and grouped around the TAM dimensions, that Table 1 presented in a pervious chapter. Both interviews were conducted in Hungarian language, recorded and transcribed in Microsoft Word. To support the judgmental selection of candidates, it is important to highlight that Interviewee 1 has been working for MOL Plc.

since 2001 and obtained his diploma at University of Pannonia as a chemical engineer with organic chemistry major. He made his career in positions such as designing engineer, process engineer and recently polymer process engineer at Downstream. Interviewee 2 has been working for MOL Plc. for 8 years, holds his degree in Geology from University of Szeged, obtained his postgraduate degree in Business Data Analysis at Corvinus University of Budapest and currently attends an MSc on the field of Oil Engineering at Miskolc University.

External variables are not strictly forming part of TAM, but as Yuanquan et al. (2008) wrote in their paper, they facilitate to understand the factors which lead to acceptance (Yuanquan et al., 2008). During the interviews both interviewees started with the importance of regulations as a key aspect of application CCS in the sector. Both experts explained that the company has always been aware of its own responsibility towards the environment, while Interviewee 1 said: *"I believe, we, engineers have always taken more care about nature compared to economists, because we do not approach everything based on its profitability"*. However, after the Paris Agreement was signed MOL Plc. reviewed its own climate strategy based on financial aspects, however this was completely changed when the NZIA was introduced. Interviewee 2 said:

> *"The NZIA is already knocking on our door. By June we need to present to the regulator our strategy how MOL Plc. will provide the allocated storing capacity. The NZIA says that member states need to store 50 mt CO_2 annually from 2030, however we still do not know the exact quantities. It makes quite hard to make a strategy if you do not know what to prepare for".*

As the NZIA says, oil and gas companies with mining activities must provide cumulatively 50 mt storing capacity on EU-level by 2030, and this 50 mt will be divided among the players proportionately based on their average GHG emission in 2020-2023 (European Parliament & Council, 2024). The lack of exact data constrains MOL Plc. to use estimations based on international databases, and they currently expect that 1.3 mt storing capacity will be allocated to the company. Interviewee 1 explained how the regulation affects Downstream:

> *"So let's make it clear, the NZIA does not affect Downstream directly like it does with Upstream. The majority of GHG emission is produced by us, nearly 85%, but you can't change boilers, steam reforming units, crackers, fluid catalytic crackers and hydrocrackers that easily. Of course we are searching*

> *for possibilities to reduce our emission, as it is desirable for the nature and for the company as well, but it takes time. Also, I do not believe that CCS will help to Downstream".*

As the regulation considers companies with mining activity, regardless of other functions, it is essential to MOL Plc. to decrease Downstream emission. Overall, it can be detected that regulation has a huge effect on MOL Plc. Although the company was aiming to become eco-friendlier even before the NZIA, the deadline for providing storage capacity for CCS accelerated the processes and has been motivated the divisions to find solutions.

The second external factor which was mentioned during the interviews is electricity price. Interviewee 1 explained why it is crucial in the case of Downstream: *"We are responsible for the majority of GHG emission, and if we want to decrease our emissions, we need to electrify our facilities. In other words, you want to convert your steam locomotive into an electric locomotive, while it is moving. It is not easy".* Moreover, the volatility of prices makes it unpredictable the returns of such an investment, not to mention the initial investment costs. De Maigret et al. (2022) concluded the same result in their paper, emphasising that the great financial investment is needed to renew Downstream, as most GHG emission is connected to the burning of refineries' fuels for heat and power, however the consumers' demand should be satisfied seamlessly as well (de Maigret et al., 2022). Although, electrifying Downstream would significantly decrease the GHG emission of MOL Plc, electricity price is such an influential constrain that it hinders the process and incentivize the division to keep using fossil fuels in the facilities.

Interviewee 1 from Downstream mentioned a third external variable, which influence their long-term operation: ETS quota prices. Although this topic was not among the question, the expert highlighted why they are so important. As he previously depicted, the NZIA does not affect this division directly, electrifying the facilities is not simple, however they aim to decrease their emission instead of injecting it underground. ETS quotas play a crucial part of it, as in 2023, Downstream produced 5.5 mt GHG emission, from which only 3.4 mt was covered by free quotas and the rest was financed from the European ETS market, but soon the major part needs to be backed from the market thus the number of free quotas will be decreased, which will challenge the company financially (Gregory & Geels, 2024). The EU indeed amins to decrease the number of free quotas steadily (European Commission, 2003), and the less quotas available, the more they cost

(Van den Bergh et al., 2013). The expert said: *"Our goal is to not produce emission"*. It can be concluded that ETS quota prices represent also an external factor, which mostly affects Downstream, albeit expand its effect on CCS implementation and GHG emission reduction process,

The other dimension of TAM is perceived usefulness, which highly determine the success of a given project. Interviewee 2 from Upstream told that on the one hand CCS is a regulation that needs to be complied, on the other hand this can be a business opportunity for MOL Group as well. Regarding the regulatory part it was mentioned, that in case of non-compliance the penalty must be deterrent, which increase the inclination of implementing the technology. Steen et al. (2024) found in their research as well that CCS will offer a great financial opportunity for oil and gas companies as they can provide their services to other businesses which struggle to reduce their GHG emission (Steen et al., 2024). Interviewee 2 mentioned a considerable cross-country agreement with Croatia, as INA's (MOL Plc. subsidiary) useful offshore storage capacity might reach 10-20 mt, while onshore Irena field might cover 30-40 mt. Furthermore, the Croatian government is financially supporting the location sourcing (Croatian Hydrocarbon Agency, 2025), which is also beneficial for MOL Plc. Building international relationships and enjoying the financial subsidizes from the government enhance the acceptance of CCS and helps to proliferate in the sector. However, Interviewee 1 from Downstream had different perspective on the usefulness of CCS:

> *"Once the depleted reservoirs are full, CO_2 injection is not possible anymore. CCS does not provide a long-term solution for GHG emission, it only delays facing with the problems. That is the reason why we do not count with this technology to much at Downstream, instead we are searching for opportunities and technologies which can help us to decrease the emission. Now we are implementing "low-hanging fruit" projects, basically increasing efficiency wherever it is possible".*

Reflecting on this statement the expert from Upstream also shared his thoughts on long-term usefulness of CCS. The interviewee admitted that with the ongoing pace it is unlikely that the European Union can reach its net-zero targets by 2050 (European Commission, 2019), and CCS will fulfil the expectation in the emission reduction. These believes match with the result of Martin-Roberts et al. (2021) who found that the projected CO_2 capacity will cover only 10% of what is required by 2050 (Martin-Roberts et al., 2021). Summarizing the perceptions towards the usefulness of CCS it can be stated that Downstream expert does not consider it as useful tool to decrease GHG emission, while Upstream expert believes that it is a good business opportunity and due to regulatory compliance it must be implemented to avoid paying penalties, however he admits as well that CCS and the current pace of implementation is not applicable to fulfil its designated purpose and reduce GHG emission drastically.

The next dimension of TAM is the perceived ease of use, around which some questions were grouped for the interview. Regarding the challenges of the technology and applying it on the fields, the Upstream expert told that MOL Plc. has been using this technology for decades for EOR projects. He added: *"There is nothing new about injecting CO_2 underground, we do it since 1994 on Szank field. The company possesses the know-how and expertise to do it. The challenge is to find reservoirs which are applicable for long-term CO_2 storage, and they are also close to the emitter".* As he explained the company is currently measuring its own reservoirs to select where CCS might be feasible, thus the actual start of implementing will not be in the near future. In Hungary, there are four-five potential locations with approximately 25-30 mt storing capacity, but in many cases the fields had been drilled numerous times for the acceleration of production (for example Üllés field in Hungary which has probably 45 mt storing capacity). Today these holes embody a potential leakage source for the injected CO_2 (Bui et al., 2018), thus the location might not be applicable for CCS purposes. However, potential cross-border agreements might be pivotal for the flourishing deployment (Martin-Roberts et al., 2021) and the Global CCS Institution points it out as well, mentioning the significant milestones achieved by Norway and the Netherlands joint efforts (Global CCS Institute, 2024).

The low level of readiness for implementing the technology is not unusual in the EU. Figure 2, which was released by the Global CCS Institute in 2024, presents CCS projects and their readiness (early development, advanced development, in construction, operational) across Europe.

Figure 2 shows that most of the projects are in either early or advanced development stage, and at least half of the current projects are located in the United Kingdom, in Norway or on the Nordic Sea, which do not belong to the EU and the NZIA is not applicable for these territories. These areas have a naturally great potential for CCS deployment (Onarheim et al., 2015), thus companies here, such as Northern Lights, can launch CCS projects based on market demand of other companies which do not want to spend on ETS quotas (Steen et al., 2024).

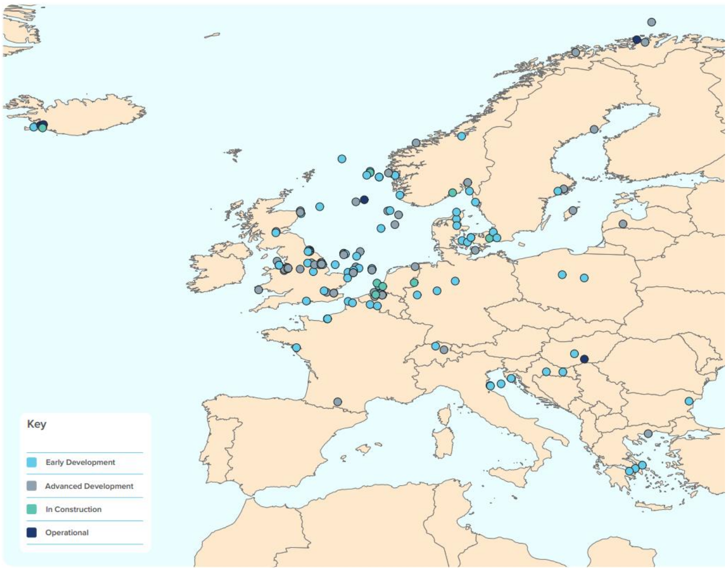

Figure 2 – CCS projects across Europe in 2024
Source: Global CCS Institute, 2024

According to Upstream expert, in the EU the deployment of CCS happens slower than it was expected, which matches with the findings of Martin-Roberts et al. (2021) who concluded that CCS implementation progresses slower than reaching the emission reduction goals would require, and accelerating the processes would be essential to reach the net-zero targets (Martin-Roberts et al., 2021).

Interviewee 1 shared why CCS implementation is slower:

> *"I think is not about usefulness or ease of use…everyone knows how to do it and what are advantages and disadvantages. The thing is that nobody wants to make the first step, because if the EU changes the regulation, a lot of money was spent in vain. However, also nobody wants to lag behind, because that can be fatal as well. Now the companies are waiting, because changes might come in the regulation. They are prepared, but they won't launch the project until it is 100% sure."*

Although this answer was not connected to this dimension of the TAM, it assured the previous finding, that the regulator plays a crucial role as an external variable.

The reports of Global CCS Institute back up this reasoning. The development stages of the projects have not significantly changed from 2021 to 2023, which shows that companies are not keen on to finalize their projects (Global CCS Institute, 2021; Global CCS Institute, 2024).

Returning to perceived ease to use dimension of the TAM, finding a suitable location for injection is a crucial step in CCS, hence the easiness of it influences the actual use of the technology a lot. During the interview, Interviewee 2 presented the three core pillars of CCS: capturing, transporting and storing and highlighted that the better connection between the GHG source and the storage site, the economical the project. He added that for Upstream the main target will be to find a suitable depleted reservoir for the big emitters as close as possible to them. He reminded that the NZIA only demands the provision of reservoirs for the injection (European Parliament & Council, 2024). Hence capturing remains on the emitter, which is the most tedious and expensive part, as CO_2 must be purified and cleaned from other gases to be suitable for injection (Gibbins & Chalmers, 2008). Interviewee 2 said that although in this case the perceived ease to use CCS will decrease among the emitters, they will be still better off with CCS rather than buying ETS quotas. According to him, the perceived usefulness overwrites the disadvantages of using the technology.

Another aspect of the perceived ease of use is the purification of the emitted GHG. Both interviewees agreed that for a financially viable CCS solution big emission centres are needed, where capturing is easy. For instance, MOL Downstream possesses huge Scope 1 emission locations at the refineries (in Slovakia at Slovnaft), where the cracker produces massive volume of CO_2, however the concentration is merely 15-20%, while for CCS at least 99% is needed (Bui et al., 2018). Although other facilities, such as hydrocrackers, provide higher concentration which eases the purification, the sources are dispersed, which makes capturing tedious and expensive. Evaluating CCS from the purification aspect results such as capturing. Even though it is tedious and expensive, the perceived usefulness of CCS over ETS quotas are better, which overwrites the disadvantages of the purification process.

The last aspect of this dimension of the TAM is the perceived ease to use CCS considering transportation. Transportation is a key element of CCS, and it must be safe, effective and economical (Cole et al., 2011). After capturing and purifying the gas it must be moved to the location (Bui et al., 2018) which is challenging as the polluter might be located hundred kilometres away, hence factors such as volume, distance, construction cost, pipeline optimization and cost efficiency must be strongly considered (Tea et al., 2024). Interviewee 2 said that pipeline transport is the cheapest and most preferred way, which is mentioned in many papers too (Bui et al., 2018; Munkejord et al., 2016; Cole et al., 2011; Tea et al., 2024), while for offshore injection ships are preferred. He added:

> *“MOL Upstream has a huge pipeline network in Hungary and Croatia, but this connects the reservoirs to the refineries, not the emitters to the reservoirs. Setting up a new pipeline cost a lot of money, and it might be worth only for big polluters, which are relatively close to the reservoir. Otherwise, trucks can be used but then comes the question of economy of scale”.*

It can be said that according to the experts, transporting the purified CO_2 can hinder the implementation of CCS the most.

The final dimension of the TAM analyses the actual use of CCS. Both experts agreed that given the adverse circumstances, it is hardly possible that MOL will use its own reservoirs to inject its own emission. Although it would drastically decrease its own Scope 1 and Scope 2 emissions and bring closer its own net-zero emission targets, financially it is not a viable solution. Interviewee 1 from Downstream stated that he does not believe that CCS can offer real solution for the question how to mitigate GHGs, however he admitted that CCS is a useful tool in the short run, which gains time to the industry players until they find a long-term and sustainable solution. Expert from Upstream said that CCS can be a good path to tackle the current challenges, however the pace of implementation is slow. Moreover, he admitted that now MOL Upstream could not comply with the NZIA, due to the lack of suitable depleted reservoirs, and more time is needed to search for potential locations.

Regarding the question, what kind of other technology they can imagine instead of CCS, which can help to reduce GHG emission, both experts highlighted energy transition, and referred to it as the only sustainable solution. Their opinion matches with the findings of numerous studies, which concluded that reducing fossil consumption is the most beneficial in order to mitigate the negative effects of GHGs (Gallo et al., 2016; Cantarero, 2020).

5.2 Quantitative Data Results

The presented quantitative results are based on the regression models which used the data of the nine largest oil and gas companies in Europe (Austria – OMV, France – Totalenergies, Hungary – MOL, Italy – Eni, Norway – Equinor, Poland – Orlen, Spain –

Repsol and the UK – Shell and BP). These companies covered approximately 67.4% of the European market based on their revenue in 2023 (RystadEnergy, 2025), excluding Russian companies, which are not presented due to the currently effective international sanctions (US Department of the Treasury, 2025).

Table 4 presents the descriptive statistical results of the companies (market capitalization and cash flow are in billions). Profit margin has moderate variability, although some firms experienced losses (-0.149 profit margin) while others are highly profitable. Market capitalization shows that the selected companies vary a lot based on their size, while debt ratio, which shows the equity-debt balance, is stable (with 0.587 mean and 0.0746 std. dev.) suggesting comparable leverage. High capital intensity (the maximum is 2.909) depicts great variety among the companies, showing that some of them can achieve much higher sales compared to the equity. Cash flow results match with profit margin, unveiling that some companies are not profitable in the pool, moreover Tobin's q, which compares the companies' market and intrinsic value, shows moderate spread among the firms, exposing different valuation levels.

Table 4 – Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
Profit margin	45	0.0910	0.123	-0.149	0.521
Market capitalization bi	45	0.0625	0.0568	0.00145	0.214
Debt ratio	45	0.587	0.0746	0.420	0.735
Capital intensity	45	1.948	0.521	0.832	2.909
Cash Flow bi	45	0.0159	0.0156	-0.00542	0.0608
Tobin's q	45	0.943	0.183	0.560	1.370

Table 5 examines the linear correlation between the dependent and independent variables. In case of market capitalization and debt ratio, results are not statistically significant, which implies that these factors do not have an influential impact on the profit margin. However, capital intensity, cash flow and Tobin's q are significant at 1%. Table 5 shows that there is a positive relationship between profit margin and the abovementioned, statistically significant independent variables. Capital intensity suggests that the more sales is achieved with the same amount of equity, the more profitable the company is, while cash flow and Tobin's q indicate that higher cash flow and higher company valuation are linked to increased profits.

Table 5 – Pearson Correlation

	Profit margin	Market capitalization bi	Debt ratio	Capital intensity	Cash Flow bi	Tobin's q
Profit margin	1					
Market capitalization bi	0.234	1				
Debt ratio	0.106	0.374**	1			
Capital intensity	0.399***	-0.0298	-0.0688	1		
Cash Flow bi	0.377***	0.865***	0.188	-0.0413	1	
Tobin's q	0.461***	0.623***	0.752***	0.035	0.420***	1

Note: This table presents the Pearson correlations of the variables used in this study.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6 presents the VIF test, which could show optional multicollinearity among the independent variables in the model. The value above 10 would indicate severe multicollinearity, while the reciprocal VIF test indicates the proportion of variance explained by other variables (Meng, Jing & Mander, 2017). As Table 6 depicts, there is moderate multicollinearity in case of market capitalization (5.91) and cash flow (4.44), however in the other cases there is no serious multicollinearity, and their overall mean is 3.48. Hence, ordinary least squares regression can be performed without any issue as it is confirmed by the panel unit root test, which help to analyse the statistical properties of the series, such as mean and variance (see Appendix, Annex III).

Table 6 – VIF Test and Reciprocal VIF Test

Variable	VIF	1/VIF
Market capitalization bi	5.910	0.169
Cash Flow bi	4.440	0.225
Tobin's q	3.510	0.285
Debt ratio	2.480	0.404
Capital intensity	1.030	0.968
Mean VIF	3.480	

Annex II presents the regression models, in which the coefficients explain the relationship and strength between the dependent and independent variables. R-squared values show how well the model presents the variation the independent variables, while standard errors show the statistical confidence. The financial metrics and emission performance are based on the nine companies' performance in 2019-2023, hence 45 observations are presented. Column 9, which is derived from Equation 1, applies all independent financial variable without the emission factors with a relatively high R-squared value (0.685), meaning that it explains 68.5% of the variation in profit margin. Columns 10 presents Equation 2, as Scope 1 is added as an independent variable, while column 12 presents Equation 4 incorporating the sum of Scope 1 and 2. The R-squared values are the highest in these two cases (column 10 – 0.759 and column 12 – 0.766), which reveals that these independent variables alter significantly the model and explain profit margin with the highest precision. As market capitalization, which is statistically significant at 5% when all factors are included, it has a strong negative influence, suggesting the larger firms have lower profit margins when they reduce their GHG emissions. Debt ratio remains unsignificant in these models as well, while capital intensity unveils a positive and statistically significant relationship at 5%, indicating higher sales on equity reside in higher profit margin. Even though the effect of emission reduction is incorporated, firms can increase their sales and gain more profit. Cash flow has a very strong and positive relationship with profit margin at 1%, which says that companies with better cash flow tend to have much higher profit margins. Tobin's q is also a positive and highly significant coefficient at 1%, meaning that stronger profitability is connected to higher valued firms. Analysing just Scope 1 and the sum of Scope 1 and 2 shows that these variables have a negative, however statistically significant effect on the profit margin at 1%, which means that the decrease GHG emissions cause increased profit margin to the firms. Overall, Annex II presents that GHG emission effects negatively the profit margin and companies better off financially when they start to reduce it.

CHAPTER 6 – DISCUSSION, CONTRIBUTIONS, CONCLUSIONS, LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

6.1 Discussion of Results and Recommendations to the Company

The findings of the qualitative and quantitative data analyses show significant correspondence to the literature review, however there are some detours. Although it was mentioned during the interviews that CCS is a good option for eliminating the effects of GHG emission, experts are concerned if oil and gas companies have enough suitable storage capacity, where CO_2 injection can be executed in a safe secure and financially feasible way. Other studies only mention how CCS needs to be realized and what are the regulatory, technical and financial constraints (Bui et al., 2018; Johnsson et al., 2019; Gibbins & Chalmers, 2008), however they do not take into consideration the finite number of reservoirs and the fact that not all depleted reservoirs are suitable for this purpose. Moreover, even though studies proved that reducing GHG emission is financially beneficial for market players (Ganda & Milondzo, 2018; Lewandowski, 2017), companies have not accelerated their CCS projects according to the Global CCS Institute (Global CCS Institute, 2024), which contradicts to the rational behaviour of a profit orientated company. Although profit decrease can be experienced at the beginning of the emission reduction implementation, later companies are better off significantly (Busch et al., 2022; Delmas et al., 2015). Annex II aligns with the other academic studies, presenting that Scope 1 and Scope 2 emissions have a negative and significant effect (at 1%) on profit margin. However, Annex II also shows that some variables, such as debt ratio and cash flow, do not have a significant impact on the profit margin, which contradicts of the finding of other papers (Wang, 2019).

Based on the findings of this MFW, it can be recommended to the company to invest into CCS technology as it provides solution for the near-term challenges regarding GHG emission reduction efforts, moreover it also complies with the regulatory expectations. According to the findings, thanks to the Scope 1 and Scope 2 emission mitigation MOL Plc. will be able to increase its profit margin as well. However, it is also recommended to start searching for new technologies, which can be utilized in the following decades, when reservoirs become full and CCS-based CO_2 mitigation will not be available.

6.2 Academic Contribution

This master final work contributes to the academic research by connecting the technological and regulatory framework of CCS and the practical application in the field of sustainable and decarbonization strategies of European oil and gas companies. The work enriches the academic knowledge by presenting the challenges and obstacles that companies face, and by applying the models on the accessed data it depicts how the technological changes currently effect the operations of the selected companies.

6.3 Industry Related Contribution

This master final work offers practical value to the industry players most importantly by providing data on the correlation between emission reduction and profit margin increase. Companies can review industry-wide financial and emission data which supports the fact that emission reduction cause higher profitability, which may enhance their dedication towards decarbonization and drive them towards an accelerated implementation of CCS or other emission reducing technologies.

6.4 Conclusions

The master final work aimed to present the current stage of implementation of CCS in Europe, focusing on the usefulness of the technology to reach carbon reduction targets. Moreover, it presented the opinion of market expert from MOL Plc., analysed the financial and emission data of the nine largest European oil and gas companies and presented the regulatory, technical and financial dimensions of the topic.

In 2019, the European Union introduced its decarbonization plan, and a few years later the NZAI was enacted, which requires oil and gas companies to provide annually 50 mt storage capacity for CO_2 depletion from 2030 to mitigate the negative effects of GHG emission (European Parliament & Council, 2024). Although companies are legally bound to comply with the regulation, the implementation of CCS projects proceeding slowly forward and studies show that the current pace will cover only 10% of the desired storing capacity (Martin-Roberts et al., 2021). During the interviews, which were based on the dimensions of Technology Acceptance Model, experts from MOL Plc explained that external factors, such as uncertainties around the regulation, swiftly changing electricity and ETS quota prices hinder the wide-spread implementation of CCS. It was presented that the perceived usefulness is obvious for oil and gas companies, however there are some doubts about the perceived ease of use, such as transporting the purified CO_2 or finding suitable reservoir to the emitters. The financial analyses revealed with statistically significant (1%) results that companies can increase their profitability when they reduce their Scope 1 and Scope 2 emissions. These findings correspond with several other academic research, that concluded it is worth for companies to decrease their GHG emissions, thus their financial performance strengthens as a consequence of this.

This MFW concludes that it is worth for oil and gas companies to promote CCS and decrease their GHG emission. Even though it does not offer a final solution due to the finite storage capacity, CCS offers a solution for the near future, until energy transition becomes more feasible.

6.5 Limitations and Suggestions for Further Research

This MFW examines the current state of implementing CCS in Europe, relying on two in-depth interviews with market experts from MOL Plc., and focusing on the financial and emission data of nine major, non-Russian oil and gas companies. Due to the novelty of CCS implementation in the sector in Europe, there are only few experts with whom valuable interviews could have done, hence in the future more interviews can be recorded with experts from different companies to receive a more detailed and layered aspect of their attitude towards the technology. As there are still many uncertainties connected to the regulations, further research can be done after the penalty- and non-compliance system is introduced to detect the alteration of point of views of the market players. Furthermore, the MFW focuses only technology acceptance of the oil and gas companies, however the public acceptance is also crucial for the proliferation of the technology, thus research can made based on this topic as well. During the interviews it was highlighted that CCS faces its own limitations too, namely the finite storage capacity, hence further research can be done to detect the potential GHG emission reduction options when reservoirs become full.

This MFW focuses only nine European oil and gas companies, but further research can be done to compare CCS application in other parts of the world, focusing on policymakers aims, regulatory boundaries, and financial feasibility. The retrieved data covers the companies' financial results and emission performance only until 2023, thus the regression tests can be retaken year after year to see the changes. The MFW examines especially the relationship between the profit margin and independent variables in the oil and gas sector, hence the research can be extended to other sectors to examine if GHG emission reduction has the same positive effect on profit margin. Last but not least, financial comparison can investigate if oil and gas companies are better off with using CCS or starting abandonment procedures on mature reservoirs would be more beneficial.

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APPENDIX

Annex I. Interview Questions

Dimension	Title of reference	Measurement	Question
Introduction	Research methods for business students	Characterization of the sample	What is your academic and professional background?
			How long have you been working for MOL Plc?
			What is your exact position and how long are you in this position?
External Factors	Perceived usefulness, perceived ease of use, and user acceptance of information technology Net Zero Industry Act	There are many different external factors that can affect a technology. The NZIA is a key dimension in CCS, how does it affect the company	What is the most important external factor that influences CCS currently?
			What other external factors can you mention?
			Do these factors influence positively or negatively the attitude towards CCS?
			How does the NZIA effect MOL Plc?
			How does the NZIA effect Upstream / Downstream (respectively)?
			How much will be the allocated storage capacity the MOL Plc needs to provide?
Perceived usefulness	Perceived usefulness, perceived ease of use, and user acceptance of information technology Carbon capture and storage (CCS): The way forward Carbon capture and storage at the end of a lost decade Carbon Capture and Storage: Application in the Oil and Gas Industry	Perceived usefulness presents a degree to which the user believes that having the particular technology will help her to perform better	What are the benefits of implementing CCS?
			Without the NZIA regulation, would MOL accelerate the use of CCS?
			What are the consequences if MOL does not implement it?
			Does CCS any limitation which would hinder its application?
			Is CCS a right tool to achieve net-zero emission goals?
Perceived ease of use	Perceived usefulness, perceived ease of use, and user acceptance of information technology Carbon capture and storage (CCS): The way forward Review on carbon capture	Perceived ease of use refers to the degree to which the user believes that she can use effortlessly the technology.	Does the company have enough know-how to execute CCS projects soon?
			If not, how do you plan to obtain this knowledge?
			Are the reservoirs applicable for CCS?
			How many depleted reservoirs have MOL Plc for this purpose?
			What is the biggest challenge to implement wide-range CCS?
			Which is the hardest/easiest part of the process?
			What can MOL Plc gain/lose while using CCS?

	and storage (CCS) from source to sink; part 1: Essential aspects for CO2 pipeline transportation Carbon Capture and Storage: Application in the Oil and Gas Industry CCS technological innovation system dynamics in Norway		What are the difficulties/easiness to use CCS in its different stages (capturing/purifying/transporting/storing)?
Actual use	A multi-objective optimization approach in defining the decarbonization strategy of a refinery Perceived usefulness, perceived ease of use, and user acceptance of information technology Carbon capture and storage at the end of a lost decade	Actual use is the real-life application and frequency of use of the technology.	Do you believe that CCS will be widely used in Europe? Would MOL Plc use CCS to mitigate its own emission? Who can be the beneficiary of CCS? Is it a right tool achieve net zero targets? If yes, how much time does it take to accelerate the proliferation? If not, why do you use it and what other/better option exist?

Annex II. Regression Models (2019-2023)

VARIABLES	(1) VII	(2) VII	(3) VII	(4) VII	(5) VII	(6) VII	(7) VII	(8) VII	(9) VII	(10) VII	(11) VII	(12) VII
Market capitalization bi	0.509**								-2.365***	-1.519**	-2.115**	-1.501**
	(0.072)								(0.216)	(0.459)	(0.467)	(0.496)
Debt ratio		0.175							-0.715***	-0.215	-0.655***	-0.221
		(0.234)							(0.127)	(0.130)	(0.207)	(0.144)
Capital intensity			0.096**						0.082**	0.064**	0.071***	0.063**
			(0.034)						(0.017)	(0.019)	(0.015)	(0.019)
Cash Flow bi				2.973***					7.704***	8.917***	9.410***	9.207***
				(0.524)					(0.290)	(0.506)	(1.061)	(0.520)
Tobin's q					0.312***				0.705***	0.399***	0.622***	0.394***
					(0.082)				(0.106)	(0.123)	(0.190)	(0.138)
Scope_1						-0.002**				-0.004***		
						(0.000)				(0.000)		
Scope_2							-0.002				-0.019	
							(0.004)				(0.010)	
Scope_12								-0.001**				-0.004***
								(0.000)				(0.000)
Constant	0.059	-0.012	-0.097	0.044	-0.203**	0.136**	0.095**	0.132***	-0.289***	-0.234**	-0.226**	-0.223**
	(0.038)	(0.097)	(0.066)	(0.039)	(0.044)	(0.040)	(0.034)	(0.040)	(0.046)	(0.052)	(0.049)	(0.050)
Observations	45	45	45	45	45	45	45	45	45	45	45	45
R-squared	0.055	0.011	0.160	0.142	0.213	0.061	0.000	0.051	0.685	0.759	0.734	0.766

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Annex III. Panel Unit Root Test

Variable	Level	First difference
Market capitalization bi	32.3872**	
Cash Flow bi	24.3677	41.8007***
Tobin's q	28.9236**	
Debt ratio	17.4685	17.8566*
Capital intensity	29.3807**	

Notes: All panel unit root tests were performed without intercepts, drifts or trends for all variables. Level of significance: * <0.10, ** <0.05, *** <0.01.