Why Exxon Mobil Corporation Keeps Investing in Decarbonizing Oil Operations Rather than Trying Energy Transition?

Samuel Kwok [1,*] and Ye Wang [1]

[1] Department of Accounting, International Business School Suzhou, Xi'an Jiaotong-Liverpool University, Suzhou 215123, China; Ye.Wang21@alumni.xjtlu.edu.cn
* Correspondence: samuel.kwok@xjtlu.edu.cn

Abstract: The aim of this case study is to compare two opposite pathways, including both decarbonization and energy transition and tries to find out the reasons why Exxon Mobil Corporation (NYSE: XOM) insists on investing in decarbonizing oil operations rather than trying energy transition from the perspective of cost-effective, and provides some new ideas and practical experience for oil companies in the choice of pathways, to accelerate countries to achieve the goal of net-zero emissions. ExxonMobil Corporation and Shell plc, two Western oil giants with branches in China, are selected as research objects. Cost-effective analysis, correlation analysis, and comparative analysis were applied to study four research objectives. The 2019.4.4 version of Tableau data analysis software is used as the data analysis tool. According to the prediction results, compared with the C/E ratio of Shell's energy transition path, ExxonMobil's C/E ratio is slightly higher. However, compared with the cost-benefit before establishing the low-carbon solution business, it is still much lower. From the perspective of correlation analysis, Pearson's correlation coefficient reaches about 0.88, which reveals a strong positive relationship between the cost and net profit from 2021 to 2027. At the same time, the P value in the linear regression curve is less than 0.05, and the value of R is greater than 0.4, showing high goodness of fit. The figures and tables will be shown in paper 4. It can be seen that the development of CCS has a good impact on the net profit of ExxonMobil Corporation. The conclusion is that ExxonMobil could consider continuing to invest in this technology.

Keywords: decarbonization; energy transition; finance; oil; Exxon Mobil; case study; China

1. Project Introduction

This case study was conducted in International Business School Suzhou(IBSS), Xi'an Jiaotong-liverpool University (XJTLU). The project is called Academic Business Report, it is a graduation thesis that every master's degree graduate majoring in Professional Accounting needs to complete. All data and references were based on the database of the e-library of XJTLU and the websites of Exxon Mobil Corporation. ExxonMobil Corporation's low-carbon solution business which features in Carbon Capture and Storage (CCS) technology and Shell plc's renewable & energy solutions which features in renewable energy represented by wind and solar energy are the main objects of this study.

2. Contextualizing the Case

2.1. Macro-environment: chemical and petrochemical sector in developed countries

Petroleum is known as the "blood of industry". In recent years, with the continuous development of the economy and the steady improvement of social activities, the demand for oil consumption in the global market has been further expanded. Many developed countries and developing countries in the world have accelerated the exploration of domestic oil. Among them, there are five oil giants in the world. They are ExxonMobil Corporation and Chevron Corporation in the U.S., Shell in the Netherlands, British Petroleum, and TotalEnergies in France.

As fossil fuels are the main raw materials of chemical and petrochemical industries, these two industries are the main sources of carbon dioxide emissions (Saygin and Gielen 2021).

2.2. Exxon mobil corporation

ExxonMobil is the most representable upstream and downstream integrated oil company. It has several departments and hundreds of branches around the world. Similar to the primary activities of the value chain model, its main business includes six aspects: (1) Exploration and exploitation (2) Field development and production (3)Transportation (4) Storage (5) Processing stage, and (6) Marketing and trading (Li, Trencher, and Asuka, 2022).

There are many competitors in the energy and petrochemical industries. To meet the needs of industry and individual consumers for energy, fuel and chemical products while reducing societal anxiety about global warming, ExxonMobil and several other industry participants have expanded their investments in lower-emission energy and emissions-reducing services and technologies (Xu et al., 2024).

ExxonMobil has long been committed to the development of proprietary technology. It has a wide range of research projects designed to meet the needs of each of our business units (Annual Report, 2021).

According to *Energy and Carbon Summary 2021*, the refinery with a throughput higher than 75% of the industry average provides ExxonMobil with economies of scale for low-cost transportation fuel production, which has also become the company's unique industrial competitiveness. In addition, the results of the proxy voting below show the main challenge it faces in 2022 is that the Report on Low Carbon Business Planning was only supported by 10.5% of the shareholders. The initiator of the business needs to obtain the affirmative vote of the majority of shareholders to obtain financing (2022-proxy-voting-results, 2022). To gain shareholder support, it keeps participating in active and potentially influential organizations to promote International Energy Agency(IEA) and the Intergovernmental Panel on Climate Change(IPCC) to deploy at scale to significantly reduce overall emissions (Energy and Carbon Summary, 2021).

Table 1. Proxy voting results of 2022.

Proxy Item	Votes For (%)	Votes Against (%)
2. Ratification of Independent Auditors	96.8	3.2
3. Advisory Vote to Approve Executive Compensation	91.0	9.0
4. Remove Executive Perquisites	21.8	78.2
5. Limit Shareholder Rights for Proposal Submission	1.5	98.5
6. Reduce Company Emissions and Hydrocarbon Sales	27.1	72.9
7. Report on Low Carbon Business Planning	10.5	89.5
8. Report on Scenario Analysis	51.0	49.0
9. Report on Plastic Production	36.5	63.5
10. Report on Political Contributions	26.7	73.3

Source: Exxon Mobil Corporation. (2022) 2022-proxy-voting-results. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/proxy-materials/2022-proxy-voting-results.pdf (Accessed: 22 Oct 2022).

As ExxonMobil operates in a highly complex, competitive, and ever-changing global energy business environment, its decisions and risks often last for decades. Energy and Carbon Summary 2021 of ExxonMobil state that ExxonMobil is trying to achieve its goal of net zero emissions by 2050 by developing a detailed emission reduction roadmap for its main operating assets. This target is proposed based on the 2030 emission reduction plan established by the company and is mainly applicable to the greenhouse gas emissions in Scope 1 and Scope 2. This goal integrates the plan of achieving net zero emissions in the unconventional operation of the Permian Basin by 2030 in the emission reduction plan and continues to expand investment in low-emission solutions focusing on CCS, hydrogen, and biomass.

3. Research Problem, Questions, and Objectives

To cater to the requirements of the Paris Agreement and China's carbon peaking and carbon neutrality policies to achieve the goal of net zero emissions, it is amazing that all of the other four oil giants have chosen the energy transition path, which is a completely different path from ExxonMobil Corporation. **The above-mentioned phenomenon created the below problem statement: Why Exxon Mobil Corporation keeps investing in decarbonizing oil operations rather than trying energy transition?** To solve this problem, the research question needs to be answered: **Would investing in decarbonizing oil operations be a more cost-effective strategy for Exxon Mobil Corporation?**

Therefore, the research objectives are as follows.

Obj. 1: *Compare the C/E ratios of energy transition and CCS technologies in 2021.*
Obj. 2: *Compare the C/E ratios of energy transition and CCS technologies from 2022 to 2027.*
Obj. 3: *Find and explain the relationship from 2021 to 2027 by performing correlation analysis.*
Obj. 4: *Calculate and explain the average value of the C/E ratios of the seven years before the establishment of the low-carbon solution business and compare it with the C/E ratios from 2021 to 2027.*

3.1. Why does it focus on the low-carbon solutions business of ExxonMobil Corporation?

Until 2022, there are few case studies on the decarbonization business. Since most oil giants, including Shell plc, have established renewable & energy solutions businesses, in contrast, there is only a low-carbon solutions business represented by ExxonMobil.(Advancing Climate Solutions 2022 Progress Report - Low Carbon Solutions business and CCS, 2022) Because the CCS technology that the low-carbon solutions business focuses on most is considered to be one of the few technologies that can achieve negative CO emissions by the fifth assessment report of The U.N.'s IPCC. A comparative study of the cost-effectiveness of the key elements of the two businesses can provide new ideas for countries to achieve the goal of net zero emissions.

3.2. Why does it focus on CCS technology?

According to the share of total showed in ExxonMobil's 2021 outlook for energy and its 2021 annual report, liquids, oil, and natural gas are still an important part of the energy portfolio. Even in the lowest level model, the company still believes that oil is the energy with the most demand in the future, and clean and renewable energy is far from reaching this level of demand. *Energy and Carbon Summary 2021* of ExxonMobil state that CCS is one of the most important low-carbon technologies needed to achieve social climate goals at the lowest cost. The IPCC estimated in its fifth assessment report that if CCS was not included in the decarbonization solution, the cost of achieving the 2 °C result would increase by 138%. Therefore, CCS technology should be focused on.

Table 2. ExxonMobil 2021 outlook for energy.

ExxonMobil 2021 Outlook for Energy												
Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
Energy by Region	2000	2010	2019	2020	2025	2030	2040	2050	2019 2050	2019 2050	2019	2050
Energy by type - World												
Primary	405	512	576	541	601	626	651	659	0%	14%	100%	100%
Liquids	147	166	185	166	193	199	205	208	0%	12%	32%	32%
Oil	147	164	181	163	188	193	197	199	0%	10%	31%	30%
Natural gas	89	115	139	136	155	164	176	185	1%	33%	24%	28%
Coal	91	140	146	135	136	133	116	92	-1%	-37%	25%	14%
Nuclear	27	29	29	28	31	35	40	40	1%	38%	5%	6%
Biomass/Waste	40	45	50	48	51	52	52	52	0%	5%	9%	8%
Hydro	9	12	15	14	15	16	18	20	1%	36%	3%	3%
Other Renewables	3	7	16	17	25	33	52	72	5%	343%	3%	11%
Geothermal	2	2	4	4	5	5	6	7	2%	82%	1%	1%
Wind	0	1	5	5	9	12	21	30	6%	516%	1%	5%
Solar	0	1	4	4	7	10	17	26	6%	577%	1%	4%
Biofuels	0	2	4	4	5	6	8	9	3%	148%	1%	1%

Source: Exxon Mobil Corporation. (2021) Outlook for Energy: data pages. Available at: https://corporate.exxonmobil.com/-/media/global/files/outlook-for-energy/2021/2021-outlook-for-energy-data-pages.xlsx (Accessed: 22 Oct 2022).

3.3. Why does it focus on the Exxon Mobil Corporation?

ExxonMobil is one of the few oil companies that choose to avoid entering new business areas (such as renewable energy power generation) in the low carbon field, but adopt a low carbon strategy focusing on "decarbonization" of traditional oil and gas business, such as accelerating the development and application of CCS technologies, to achieve the goal of reducing traditional fossil energy emissions. ExxonMobil's low-carbon development strategy is more focused on the company's advantages, and uses a variety of methods such as increasing technology investment, strengthening R&D cooperation, and striving for policy support to maintain its internationally leading position in the CCS field and low-carbon fields such as biofuels. When many large oil companies choose the path of energy transformation, ExxonMobil Corporation's insistence on choosing the path of decarbonization is unique. This case study aims to study and compare two different paths to achieve the net zero emission goal, to infer whether ExxonMobil Corporation has chosen a path that is cost-effective from the perspective of long-term development and can achieve the net zero emission goal mentioned in the Paris Agreement in a timely and high-quality manner.

4. Literature Review

4.1. Current study of ways to achieve the goal of net zero emissions and the factors affecting path selection

In response to the net-zero greenhouse gas emissions aim which is set in 2015 by the United Nations Paris climate agreement, a significant amount of countries and thousands of businesses have set targets to achieve net-zero greenhouse gas emissions by 2050. However, due to the different environments and conditions of each oil enterprise, the net zero emission target means completely different countermeasures to them (Lin, 2022; Kwok et al., 2024a, 2024b). Similarly, Cherepovitsyn and Rutenko (2022) revealed that with increasing concerns about global warming and the intensive development of the renewable energy sector, it is not enough to simply abide by the new rules of the game. Oil and gas companies need to develop strategies that meet their conditions and benefit from them.

Even though there is no actual evidence to prove which path is the most effective, there is an increasing distinction between oil companies in different regions and countries in the choices of the path to achieving the aim of net-zero emissions.

Balsalobre-Lorente et al. (2019) and Zafar et al. (2020) find that it is of vital significance to invest in renewable energy infrastructure, as increased renewable energy consumption and reduced environmental degradation are positively correlated. Others, however, disagree. Wood (2020) argued that even if low-carbon energy, especially renewable energy, has achieved significant growth in recent decades, the leading role of fossil fuels in the global energy landscape has not changed, and carbon emissions are still rising. And Dong et al. (2022) observed the condition that the actual main economic growth model of most countries in the world, is not realistic to achieve an absolute reduction of carbon emissions, therefore, ways to improve energy efficiency should be considered. In addition, other researchers also showed that due to several characteristics of the process of the energy transition, such as non-linear, complexity, and uncertainty, it should not be the only solution to decrease the negative impact of human activities on the environment (Blazquez et al. 2020; Xu et al., 2024; Yu et al., 2024a).

4.2. Literature related to factors influencing path selection

A majority of previous researchers in this field have focused on how many ways to achieve the net zero emission goal, and try to convince companies to carry out energy transition with the benefits of renewable energy for the environment. However, only a minority of scholars concentrate on the reason why oil companies in different situations choose different paths, such as decarbonization to achieve the aim of net-zero greenhouse gas emission (Yu, Chen, et al., 2024; Yu, Xu, et al., 2024).

However, some evidence illustrates that the key factor that influences the choice of energy transition or decarbonization path might be financially feasible (Polzin and Sanders 2020; Khan et al. 2021a, b). As the financial challenge generated by the energy transition is considerable, without sufficient financing, the entity has to adopt other, more cost-effective solutions (Johnson, 2015).

To find the key factor which influences the choice of energy transition or decarbonization path, previous scholars had used several models and analysis methods.

To make the costs of the two companies comparable, the CAPEX ratio was used in the research (Li, Trencher, and Asuka, 2022). Firstly, as companies in the oil industry have proven to be the biggest carbon dioxide emitters in any industry, they selected four oil giants for their study. As energy transition and decarbonization are entirely different pathways, which reflect contrasting attitudes, they chose two American corporations(Chevron Corporation and ExxonMobil Corporation) and two European companies(BP, and Royal Dutch Shell).

Secondly, as the formula of CAPEX ratio is (Strategic investment+rolling investment)/total capital expenditures, all data are from the balance sheet in each company's annual report from 2009 to 2020. The financial performance of six areas is tracked and studied. The first area is the capital expenditure of upstream businesses which is related to fossil fuels, which consists of conventional fossil fuels such as gas and oil. In terms of the production process of oil and gas, six stages are evaluated. The exploration stage, the field development, and production stage, the midstream transportation stage, the storage, and processing stage, and the marketing and trading stage. Because reserves must be proved before mining, estimating the fossil fuel reserve is the second area that is also of great importance. The third area is the relevant earnings. The fourth area is the production volumes of fossil fuels. The fifth area is downstream sales, and the last one is the capital expenditures related to the production of clean energy and technologies (Xu et al., 2024). In processing data, relative amounts are used instead of absolute volumes, as they can suit the various structures of different corporations better.

Li, Trencher, and Asuka (2022) explained the purpose of these practices. For example, the purpose of calculating the percentage of fossil fuel-related capital expenditure in total capital expenditure is to reveal the dependence of the current business model on fossil fuels. In addition, the impact of fossil fuel price fluctuations on the research results is removed by calculating the incremental percentage of total oil and gas production in 2020 relative to 2009.

4.3. Theory of cost-effective analysis

According to Belfield et al. (2021), cost-effective analysis is a useful tool that helps the decision-makers to evaluate the projects and choose the one with the lowest cost and the highest benefit, especially when resources are limited, such as funds used for investment. Through using cost-effective analysis, the effects for each program are quantified through a ratio of costs. The C/E ratio, which is used to evaluate efficiency, is calculated by dividing the implementation cost (C) by its effect (E), which is commonly expressed as net profit. The principle is that among the alternatives, the one with the lowest ratio is the most cost-effective. Because it means the largest effects are obtained with the lowest amount of resources. For analysts, the templates below, which reflect the effects, cost, and cost-effectiveness could be a useful tool. Alternative X, Y, and Z represent three samples for comparison in actual operation.

Table 3. Cost-effectiveness ratio.

	Alternative X	**Alternative Y**	**Alternative Z**
Net cost per unit	C_x	C_y	C_z
effect per unit	E_x	E_y	E_z
cost-effectiveness ratio	C_x/E_x	C_y/E_y	C_z/E_z

Source: Belfield, C.R. et al. (2021) Cost-Effective Decision-Making for California's School System. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=eric&AN=ED615701&site=eds-live&scope=site (Accessed: 17 October 2022).

4.4. Theory of correlation analysis

According to Jameson, Azarian, and Pecht (2016), the Pearson correlation coefficient is a common method used in correlation analysis. It could be used to measure the linear correlation between two variables. Similarly, Juan et al. (2019) defined the Pearson Correlation Coefficient as a statistical index that measures the linear relationship between two quantitative variables. The formula of the Pearson Correlation Coefficient is as follows, the second formula is simplified from the first formula.

$$\rho_{X,Y} = \frac{\operatorname{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y},$$

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{(x_i-\bar{x})^2(y_i-\bar{y})^2}}$$

The value of the correlation index (r)varies in the interval [-1, +1]. If r=1, there is a perfect correlation and it can be said that the signals are practically the same. $0 < r < 1$ means the correlation exists. Values greater than 0.5 are considered criteria for determining the similarity between one signal and another. However, if r=0, it means there is no correlation between the elements of the sets, which implies that there is no similarity between the two signals.

4.5. Theory of time series analysis models

In a sense, the prediction using time series is based on the relationship between data points obtained from past and current field research, which makes it possible to effectively predict the future without field research. The data obtained based on the observation results of a certain period is called time series, which is represented as data varying with time on the horizontal axis. Therefore, annual and quarterly data can be used for time series analysis. We can use x to represent data observed for a certain purpose, t to represent time, and xt to represent data obtained in a certain time interval.(Atıcı and Pala, 2021).

Box-Jenkins ARIMA models, Box-Jenkins Multivariate Models, and Holt-Winters Method are the most common time series analysis models in tableau data analysis software (Tableau, 2003). According to Şahinli (2020), in recent years, prediction methods, especially popular forecasting analysis methods such as the ARIMA model and Holt-Winters Method, have been increasingly used by scholars. In the mid-1970s, the Box-Jenkins Method was first implemented by Box and Jenkins. These univariate models are used to better understand a single time-dependent variable, such as temperature changes over time, and to predict future data points for variables. These models work under the condition that the data are fixed. Analysts must explain and eliminate the differences and seasonality of past data points as much as possible. Fortunately, the ARIMA model includes moving average, seasonal difference operator, and autoregressive terms in the model. There are three parameters in this model: p represents the number of autoregressive terms, d is the number of non-seasonal differences required for stability, and q is the number of delayed prediction errors in the prediction equation. Holt-Winters method is applicable when the trend and seasonal pattern in the data exist at the same time.

The forecasting equation is constructed as follows. First, let y denote the d^{th} difference of Y, which means the following:

$$\text{If } d = 0, y_t = Y_t \quad (19)$$

$$\text{If } d = 1, y_t = Y_t - Y_{t-1} \quad (20)$$

$$\text{If } d = 2, y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2} \quad (21)$$

In terms of y, the general forecasting equation is as follows:

$$\hat{y}_t = \mu + \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} - \theta_1 e_{t-1} - \ldots - \theta_q e_{t-q} \quad (22)$$

Figure 1. ARIMA(p,d,q) model.

Source: Şahinli, M.A. (2020) Potato Price Forecasting with Holt-Winters and ARIMA Methods: A Case Study. Available at: https://eds-p-ebscohost-com.ez.xjtlu.edu.cn/eds/detail/detail?vid=0&sid=8cbd380e-4b61-4169-a3a3-1f728e497cd9%40redis&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edssjs.5D32F91F&db=edssjs (Accessed: 22 October 2022).

4.6. Principle of decarbonization technology

Papadis and Tsatsaronis (2020) found that the current decarbonization technology is mainly based on three principles. That is, starting from the process of carbon production, decarbonization can be achieved by changing the elements related to carbon. For example, to achieve decarbonization before combustion, it is necessary to choose carbon-free fuels or raw materials. It is a good choice to use renewable energy such as wind energy or solar energy to generate electricity or hydrogen as a clean energy fuel. You can also consider obtaining the required energy through nuclear fission, but because of its high cost, it is not economically feasible at present. To achieve decarbonization in the fuel combustion phase, it is necessary to improve fuel combustion efficiency. For example, use higher purity fuel and let the fuel burn in an environment with sufficient oxygen, so that the combustion is more complete, and the carbon generated is less and more pure. CCS technology is to achieve decarbonization by accurately capturing carbon dioxide in the air after combustion and transporting it to the deep sea or rock strata for storage through pipelines.

4.7. Current study of CCS technology

Núñez-López and Moskal (2019) revealed that CCS, which was mentioned in the 2005 portfolio of climate change mitigation options by the IPCC, is a technology that carbon emissions are collected at the source and are then transported to a licensed geological site, where, special pipes and machines will be used to inject these substances into the deep and safe underground for long-term storage. Furthermore, the IEA continued to recognize and strongly reaffirm this technology in its published successive reports (Kheshgi, de Coninck, and Kessels, 2012).

In the calculation of the cost of CCS systems, Rubin (2012) showed several cost measurement methods and indicators. The costs of CO2 avoided, CO2 captured and CO2 abated, and the increased cost of electricity. These elements are shown to be the most commonly considered. In addition, they also revealed a variety of methods behind the figures, which include but are not limited to Expert Inspiration, using published values, Modifying published values, deriving new results from the model, and commissioning detailed engineering studies. Similarly, Rubin, Davison, and Herzog (2015) have also made efforts to calculate the cost of CCS technology. Based on the latest literature survey since 2011, these researchers first compiled the cost results of various studies on power plants with and without specific types of CCS systems. They selected detailed studies published in the public domain by major government and industrial organizations involved in CCS and power plant technology development and evaluation. Typically, such studies are provided by well-known engineering companies in the North American and European power industries. Three types of power plants are mainly concerned, namely, the amine system used for the capture of pulverized coal (PC) and natural gas combined cycle (NGCC) power plants after combustion; Physical adsorbent based system for pre-combustion capture of integrated gasification combined cycle (IGCC) plant; And in PC plants equipped with aerobic combustion. These power plants are predicted to have a carbon dioxide capture efficiency of 90% in the next few years, so they are more representative.

At the same time, to compare the current cost estimate with the cost estimate studied by IPCC Special Report on Carbon Dioxide Capture and Storage (SRCCS) in 2005, they discounted all SRCCS costs to the current year to remove the impact of inflation on the results.

5. Methodology

5.1. Cost-effective analysis methodology for research objectives 1 and 2

The cost-effective analysis is used to compare the C/E ratios of energy transition and CCS technologies from 2021 to 2027. In addition, the costs used in calculating the C/E ratio include both CAPEX(Capital Expenditure) and OPEX(Operating Expenditure). Ananth and Sharma (2016) mentioned that OPEX is calculated based on the costs related to maintenance and operation and CAPEX is calculated based on the initial investment. For the oil industry, the formulas are adjusted as follows:

Cost = Capital expenditure(CAPEX) + operating expense(OPEX)

Capital expenditure = total capital and exploration expenditures

operating expense = maintenance cost + marketing cost + labour cost + depreciation

Cost-effectiveness ratio = cost / net profit

Maintenance cost and depreciation are often contained in the item named 'administrative expense', and the marketing cost is often included in the cost of sale, these data would be obtained from the financial statements of ExxonMobil and Shell from 2014 to 2021. Therefore, the table of the oil industry can be inferred as follows.

Table 4. C/E ratio for oil industry.

	Cost(C) (CAPEX+OPEX)	Net profit(E)	C/E ratio
ExxonMobil's CCS technologies	Cccs	Eccs	Cccs/Eccs
Shell plc's Energy transition (ET)	Cet	Eet	Cet/Eet

Note: Cccs represents the cost of CCS technology, and Cet represents the cost of energy transition. Eccs represents the effect of CCS, and Eet represents the effect of the energy transition.

The notional profit is used as the effect of this study and the formula is shown below.

Notional profit = net loss + Impairment of unconventional assets + expense related to COVID-19 + income decrease related to shrinking oil demand + unusually large investment activities + revision and updating of medium and long-term commodity prices + restructuring costs + onerous contract + expense related to the closure of subsidiaries + decline in refining margins + the increase in the write-off of oil wells + the increase of its current expected credit loss reserves + other abnormal costs (such as asset management and severance pay)

5.2. Correlation analysis for research objective 3

The Pearson Correlation Coefficient will be used for correlation analysis to illustrate the relationship between the cost and profit from 2021 to 2027. The data for 2021 used in this study will be extracted from the balance sheet and income statement in ExxonMobil's annual and quarterly reports. Since the annual report from 2022 to 2027 has not been published yet, this part of the data will be obtained by using the time series analysis and prediction function of tableau data analysis software.

5.3. Comparative analysis for research objective 4

Comparative analysis will be used. Based on the cost and net profit data in ExxonMobil's financial statements, the cost-effective analysis for the period from 2014 to 2020 will be done and the average value will be calculated before making the comparison with the results of analysis from 2021 to 2027.

6. Findings

This paper will present the findings of report, which are also the data analysis results corresponding to each research objective, and explain the meaning of the results and the reason why the trend of the data is shown like that.

6.1. Findings for research objective 1 and 2

The results of the prediction are shown below.

Note: (1) Since the seasonal analysis function of tableau software required that the data used must be positive, and in 2020, under the influence of epidemic and other factors, both of the two companies showed net losses, the notional profit formula mentioned in the third paper is used for conversion. The following explanations for the value of notional profit are the reasons for the net loss at that time. (2) What can be seen in the following figure is that the shadow part is incomplete because only the part within the shadow represents the normal range of the prediction data.

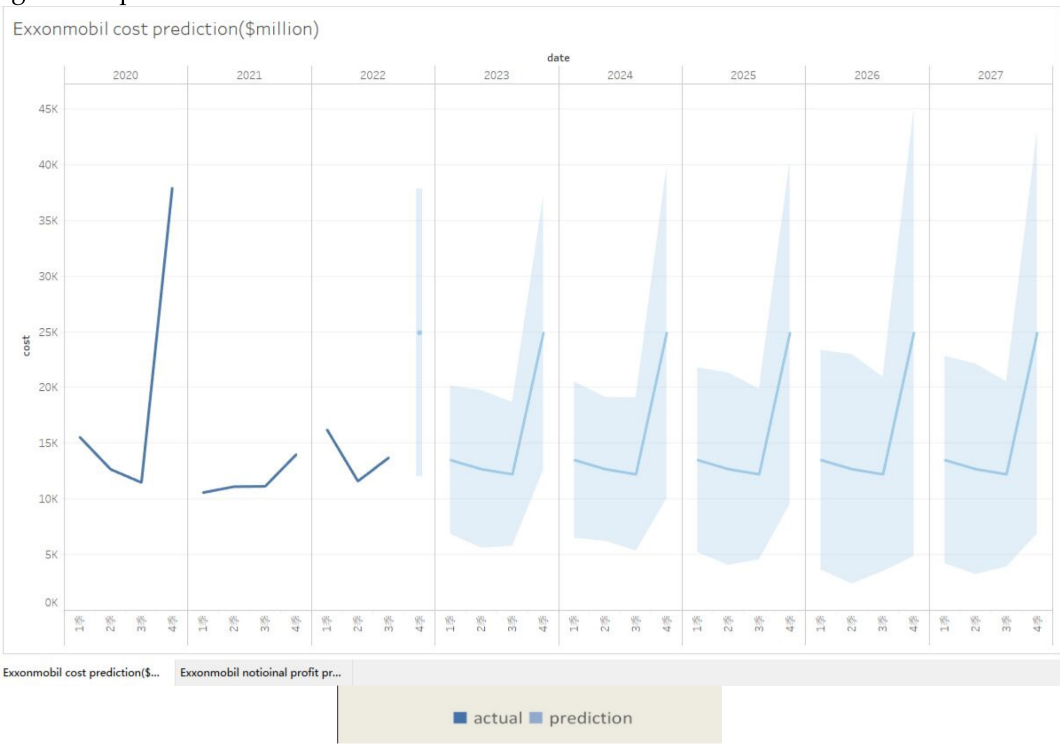

Figure 2. Time series prediction results of tableau software (Exxonmobil's cost).
Source: Tableau 2019.4.4

The reasons for the low cost in the first quarter were explained in ExxonMobil reports results for second quarter 2020. The supply and demand balance of petroleum and petrochemical products was broken in the first quarter, and the most unfavorable situation of oversupply for the petroleum industry was formed. In terms of demand, the rapid spread of COVID-19 in most parts of the world has significantly reduced consumer and commercial activities, which has led to a sharp reduction in the demand for petroleum products, oil products , and natural gas. At the same time, on the supply side, some major oil-producing countries announced an increase in production, leading to a sharp drop in the prices of crude oil and other petrochemical products.

As a result, the Company announced a significant reduction in capital expenditure and operational expenditures in 2020. The actual amount of capital and exploration expenditure is $23 billion, which is $10 billion lower than the budgeted amount. The decrease in capital expenditure resulted in a decrease in the estimated proved reserves in the 2019 annual report. At the same time, the unit depreciation rate and depletion rate of upstream assets in the first quarter of 2020 also increased compared with the previous quarter.

The specific value of operational expenditure is mentioned in ExxonMobil reports results for first quarter 2020. Administrative expenses of $2579 million and depreciation and depletion of $581.9 million in this quarter.

In the second quarter, market conditions reflected considerable uncertainty, as the world's major economies continued to be affected by COVID-19. Although some signs of recovery can be seen in commercial activities and oil consumption, due to the negative impact of the epidemic, the trading volume of the oil industry still cannot reach the level before the epidemic. Major oil producing countries have taken measures to reduce oversupply, and the credit market has gradually stabilized, providing sufficient loans for companies with high credit ratings.

The specific data are shown. Including capital and exploration expenditures of 532.7 million dollars, administrative expenses of $2.409 billion, and depreciation and depletion of $4.916 billion (ExxonMobil reports results for second quarter 2020, 2020).

The company's performance in the third quarter of 2020 included a pre-tax credit of $153 million, which was included in the "purchase of crude oil and products" in the statement of profit or loss. The rise in commodity prices led to the write-off of the book value of inventories in the second quarter. At the same time, capital and exploration expenditure was $4.133 billion, management expense was $2.444 billion, and depreciation and depletion were $4.983 billion (ExxonMobil reports results for third quarter 2020, 2020).

The cost data reached the highest value of 2020 in the fourth quarter because exceeded cost-reduction objectives, with 2020 capital spending of $21 billion below target by $2 billion; cash operating expenses more than 15% below 2019, of which $3 billion is a structural reduction. (ExxonMobil reports results for fourth quarter 2020 and provides perspective on forward plans, 2020).

Compared with the first quarter and the fourth quarter of 2020, the cost in the first quarter of 2021 is the lowest because of the significant reduction of cash operating expenses; Additional structural cost savings are accelerated.At the same time, three new directors with extensive experience in energy, capital allocation and complex business transformation were appointed. Detailed cost data include capital and exploration expenditures of 3133, administrative expenses of 2428 million dollars, and depreciation and depletion of 5.04 billion dollars (ExxonMobil earns $2.7 billion in first quarter 2021, 2021).

Funds used to pay capital investment, debt and dividends in the quarter came from operating cash flow of $9.7 billion. During the second quarter of 2021, capital and Exploration Expenditures 3,803, administrative expenses $2345 million, and Depreciation and depletion $4952 million (ExxonMobil earns $4.7 billion in second quarter 2021, 2021).

ExxonMobil earns $6.8 billion in third quarter 2021 mentioned that capital investments were funded by the cash flow from operating activities. The amount of capital investment in the future is expected to be in the range of 20 billion to 25 billion dollars; Low carbon expenditure is expected to increase by 400%. During the third quarter of 2021, capital and exploration expenditures were 3,851, the administrative expense was $2287 million, and Depreciation and depletion were $4990 million.

Cash flow from operating activities of $48 billion was the highest level since 2012, exceeding capital investment, debt reduction, and dividends. The structural cost was further reduced by $1.9 billion, and the total savings increased to nearly $5 billion compared with 2019. (ExxonMobil earns $23 billion in 2021, initiates $10 billion share repurchase program, 2021).

Due to the impact of the Russian-Ukrainian war, ExxonMobil had to announce that it would stop the operation of the Sakhalin-1 project ("Sakhalin-1") and formulate steps to withdraw from the project. The performance in the first quarter included $3.4 billion of after-tax expenses, mainly due to the operational impairment related to Sakhalin, which is the reason for the high cost in the first quarter of 2022 (ExxonMobil announces first-quarter 2022 results, 2022).

The lowest reported cost of ExxonMobil in the second quarter of 2022 is related to the sale of three companies in this quarter. The costs associated with these three companies were removed from ExxonMobil's consolidated statements (ExxonMobil announces second-quarter 2022 results, 2022).

The reason why the cost of this quarter is higher than that of the previous quarter is that the adjustment of non-cash reserves of $19 billion for depreciation and depletion was $4 billion higher than that of 2021 (ExxonMobil announces third-quarter 2022 results, 2022).

Table 5. Options for creating forecasts (Exxonmobil’s cost).

Time series:	Date quarter
Measure:	Total cost
Forward prediction:	21 quarters(Q4 2022 - Q4 2027)
Forecast basis:	Q1 2020 - Q3 2022
Ignore:	No cycles ignored
Seasonal pattern:	4 - quarter cycle

Source: Tableau 2019.4.4

Table 6. Forecast quality description (Exxonmobil's cost).

Initial	Change from initial value	Seasonal influence		contribution		quality
Q4 2022	Q4 2022 – Q4 2027	high	low	trend	season	
24,909 ± 12,884	0	2027 Q4 2	2027 Q3 1	0.00%	100.00%	determined

Source: Tableau 2019.4.4

Figure 3. Time series prediction results of tableau software (Exxonmobil's notional profit).
Source: Tableau 2019.4.4

According to the 2020 Annual Report, since January 1, 2020, the Company has adopted the latest version of Financial Instruments - Credit Loss (Topic 326). Allowance for Current Expected Credit Loss (CECL) is required by this standard for financial assets. In addition to the reduction in profit of $23.25 million (93/4) in each quarter from 2020 due to the impact of the Allowance for CECL, each quarter also has its factors that affect profit.

According to *ExxonMobil reports results for first quarter 2020*, the result of the first quarter of 2020 is a net loss of $610 million, mainly due to the adverse non-operational impact and lower upstream realization. Unfavorable non-operational impacts reflected inventory write-down and impairment.

According to *ExxonMobil reports results for second quarter 2020*, The result of the second quarter of 2020 is a net loss of $1.1 billion, which is mainly due to lower sales volume, lower upstream realization rate and lower downstream profit margin. Non-operational impacts were mainly driven by an inventory adjustment.

ExxonMobil reports results for third quarter 2020 disclosed that the allowances for the account receivable and certain other financial assets are $148 million and $436 million respectively. The influencing factors also include a decrease of $2,630 million in upstream realization. Due to the decrease in natural gas production of $90 million, partially offset by the increase in liquid sales of $30 million, the production and mixed effect decreased revenue by $60 million. In addition, the profit margin of the downstream refining industry decreased by $1,880 million, which also reduced the profit.

According to *ExxonMobil reports results for fourth quarter 2020 and provides perspective on forward plans*, the net loss in the fourth quarter amounted to $20070 million, mainly related to non-cash impairment and after-tax severance payments. In addition, the decline of the downstream profit margin led to a $3820 million drop in net profit.

The net profit in the first quarter reached the lowest level in 2021 due to the severe winter weather in Texas in February. The adverse weather events reduced the first quarter revenue of all businesses by nearly $600 million, due to the decline in production, sales, maintenance costs, and the net impact of energy procurement and sales (ExxonMobil earns $2.7 billion in first quarter 2021, 2021).

ExxonMobil earns $4.7 billion in second quarter 2021 disclosed that the net profit in the second quarter of 2021 was higher than that in the first quarter, which was related to the growth of oil and gas demand, the sale of the SantopreneTM chemical business, and the success of exploration activities in Guyana.

ExxonMobil earns $6.8 billion in third quarter 2021 disclosed that substantial growth in demand and improved operations increased quarterly revenue by $7.4 billion compared to 2020.

ExxonMobil earns $23 billion in 2021, initiates $10 billion share repurchase program. Disclosed the reason why net profit continued to grow in this quarter. On the upstream side, average crude oil cash flow increased 8% compared with the third quarter. Natural gas volumes increased 63% compared to the previous quarter. Some assets of the United Kingdom North Sea were sold to Neo Energy. In terms of downstream, global refining margins improved compared with the third quarter, and transport demand increased as liquidity restrictions eased, partly offset by higher European energy prices. Refining output in this quarter was the highest since 2013, up 2% over the third quarter, which enabled the company to benefit from the improvement of industry profit margin.

ExxonMobil announces first-quarter 2022 results discloses the reason why the net profit in the quarter reached the lowest level in the year. In the first quarter of 2022, the company decided to stop the operation of the Sakhalin-1 project in Russia, resulting in a loss of (32.55) million dollars. At the same time, the adverse production and mixed effects reduced revenue by $810 million, reflecting the reduction of Groningen's production limit, increased downtime due to bad weather, and reduced equity due to price.

ExxonMobil announces second-quarter 2022 results disclosed the reasons for the rapid increase of net profits in this quarter compared with the prior quarter. The upstream realization and the improvement of the profit margin of energy products have promoted the growth of income. At the same time, the company sold ExxonMobil Exploration and Production Romania to Romgaz S.A. A gain on the sale of approximately $300 million was recognised.

ExxonMobil announces third-quarter 2022 results disclosed the reasons for the increase of net profits in this quarter. ExxonMobil Corporation sold some upstream unconfirmed assets in Romania and upstream unconventional assets in Alberta, Canada, which resulted in a total sales income of about 600 million dollars. At the same time, the improvement of the upstream liquidity rate and the profit margin of energy products, as well as the increase of the output and the improvement of the portfolio have promoted the growth of income.

Table 7. Options for creating forecasts (Exxonmobil's notional profit).

Time series:	date quarter
Measure:	Total cost
Forward prediction:	21 quarters (Q4 2022 – Q4 2027)
Forecast basis:	Q1 2020 – Q3 2022
Ignore:	No cycles ignored
Seasonal pattern:	4-quarter cycle

Source: Tableau 2019.4.4

Table 8. Forecast quality description (Exxonmobil's notional profit).

Initial	Change from initial value	Seasonal influence		contribution		quality
Q4 2022	Q4 2022 – Q4 2027	high	low	trend	season	
19,800 ± 31,664	0	2027 Q2 2	2027 Q1 1	0.00%	100.00%	determined

Source: Tableau 2019.4.4

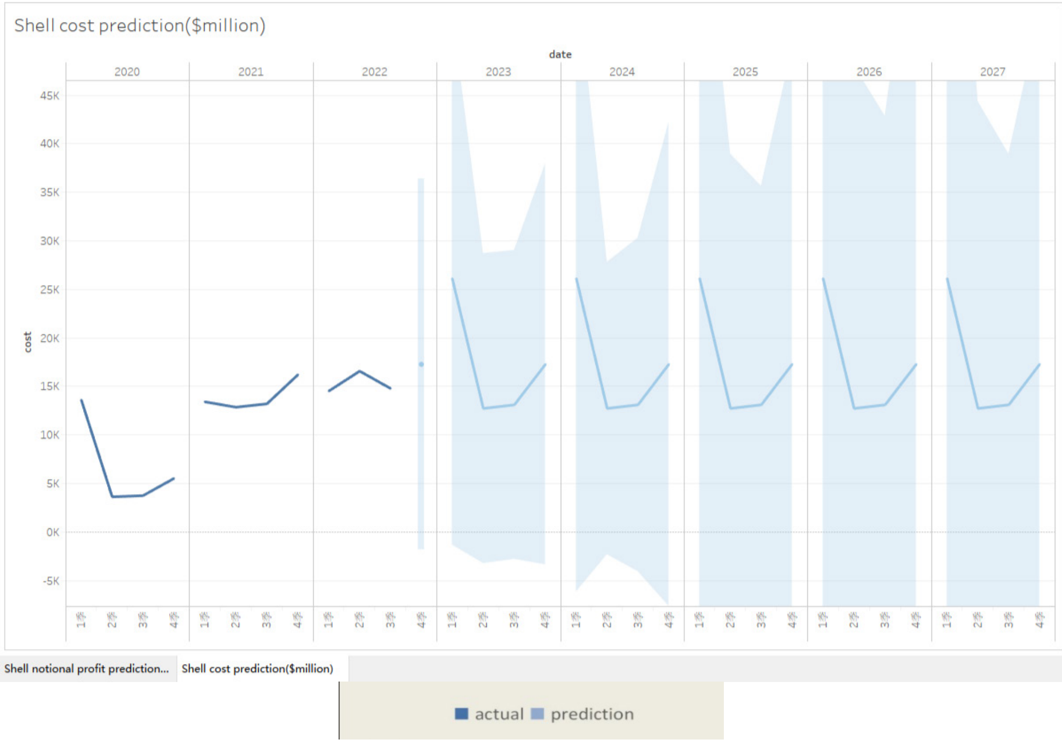

Figure 4. Time series prediction results of tableau software (Shell's cost).
Source: Tableau 2019.4.4

First quarter 2020 results financial documents disclosed the reason why the cost in the first quarter of 2020 is the highest in 2020. Shell has invested in the first phase of Arrow Energy Surat natural gas project (Shell owns 50% of the equity). Under the condition that the production of other businesses is almost the same as that of the previous year, this investment has significantly increased the cost.

According to *Second quarter 2020 results*, costs in the second and third quarters of 2020 are much lower than in the first quarter, mainly due to lower capital expenditures, future operating costs and dividend distribution.

According to *Fourth quarter 2020 results*, costs in the fourth quarter were slightly higher than in the third quarter, mainly due to strike action in 2019 and increased maintenance activities in Asia and Europe.

According to *First quarter 2021 results*, the low cost in the first quarter of 2021 compared with other quarters of this year is mainly due to the low cost of new oil fields and maintenance. There is also a decline in Liquefied Natural Gas (LNG) liquefaction due to feeding gas restrictions and maintenance activities. Higher maintenance and divestment resulted in a 9% decrease in total upstream production. In addition, due to the impact of winter storms in Texas, the utilization rate of refineries decreased by 9% compared with 2020.

Second quarter 2021 results disclosed the reasons for cost reduction. For integrated natural gas, compared with the first quarter of 2021, total oil and gas production declined by 3%, mainly due to increased maintenance activities and reduced oil fields. Due to high maintenance activities and feed gas restrictions, LNG liquefaction volume decreased by 8%. Affected by adverse seasonality and high maintenance activities, total upstream production decreased by 8% compared with the first quarter of 2021.

Third quarter 2021 results disclosed the reason why the cost in the third quarter was almost the same as that in the second quarter. For integrated natural gas, due to the reduction of maintenance activities, total production of oil and natural gas remains at the same level as in the second quarter of 2021. Therefore, the production cost is almost the same. Due to feed gas restrictions and freight time restrictions, LNG liquefaction volume decreased by 1%, partially offset by reduced maintenance activities. The decline in total upstream production, the decrease of the utilization rate of petroleum products and refineries, and the drop of the utilization rate of chemical and chemical manufacturing plants are all related to the increase of maintenance volume brought about by Hurricane Ida.

According to *Fourth quarter 2021 results*, the cost in the fourth quarter of 2021 has reached the highest level of the year, which might relate to acquisition activities, hurricane impact, and the launch of new projects. Due to the extended turnover period and the recovery from Hurricane Ida, the utilization rate of petroleum products and refineries in this quarter decreased by 3% compared with the same period last year. In addition, Shell completed the acquisition of Savion, an American solar energy and energy storage developer, and Powershop Australia, an online energy retailer, in this quarter. The company also started a hydrogen hydrolysis reactor with a capacity of 20MW in China.

First quarter 2022 results disclosed the reason why the cost in the third quarter was high but lower than that in the previous quarter. The reason for the higher cost is that Shell announced the production of four projects named PowerNap, Mero Oilfield, NCMA-4 and Block 22 respectively this quarter. In addition, Shell has formally acquired 25% of the shares of Atap Oilfield in Brazil. Compared with the fourth quarter of 2021, the decrease in cost is due to the decrease in maintenance costs due to the increase in feed gas supply.

According to *Second quarter 2022 results*, the factors causing the cost increase in the second quarter of 2022 include the development of new businesses, investment projects, production, and acquisition. In this quarter, Shell plc has approved the development of Crux, Merlot and Hanya gas fields. Shell plc was selected by Qatar Energy Company to participate in the expansion project of the oil field in northern Qatar. In addition, Shell also announced its investment in the construction of Holland Hydrogen I, the largest renewable Hydrogen plant in Europe, and acquired Solenergi Power Private Limited. These events have resulted in significant cost increases.

Third quarter 2022 results disclosed the reasons for low costs in this quarter. Compared with the second quarter of 2022, Prelude's "licensed industrial action" and production-sharing contract effect led to a 2% decrease in total oil and gas production. In addition, Prelude's "Permitted Industrial Action" and higher maintenance activities resulted in a 5% reduction in LNG liquefaction.

Table 9. Options for creating forecasts (Shell’s cost).

Time series:	**date quarter**
Measure:	Total cost
Forward prediction:	21 quarters (Q4 2022 – Q4 2027)
Forecast basis:	Q1 2020 – Q3 2022
Ignore:	No cycles ignored
Seasonal pattern:	4-quarter cycle

Source: Tableau 2019.4.4

Table 10. Forecast quality description (Shell’s cost).

Initial	**Change from initial value**	**Seasonal influence**		**contribution**		**quality**
Q4 2022	Q4 2022 – Q4 2027	high	low	trend	season	
17,273 ± 19,101	0	2027 Q1 2	2027 Q2 1	0.00%	100.00%	determined

Source: Tableau 2019.4.4

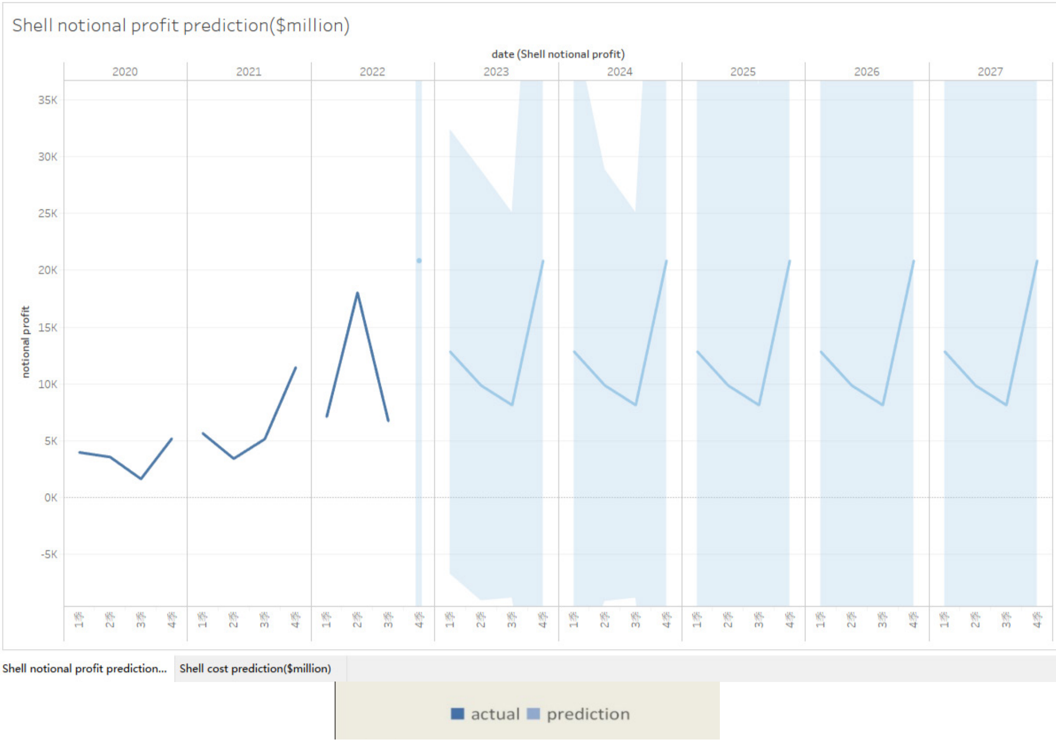

Figure 5. Time series prediction results of tableau software (Shell's notional profit).
Source: Tableau 2019.4.4
Note: Effective January 1, 2020, additional contracts are considered to be held for trading purposes, and income is reported on the net instead of gross value. This reduces the reported revenue figures.

First quarter 2020 results financial documents disclosed the reasons why the profit reached this level in the first quarter of 2020. In this quarter, the US Martinez refinery was sold by Shell to PBF Energy for $1.2 billion in cash. Shell sold the US Martinez refinery to PBF Energy at $1.2 billion. Due to COVID-19 and the sharp drop in oil prices in the first quarter of 2020, the reasonableness of the assumptions used to test the impairment of oil and gas prices has been reassessed. On this basis, the short-term price outlook for 2020 was also adjusted and used as the basis for impairment in the first quarter of 2020. At the same time, due to COVID-19 and OPEC+action, there are still major uncertainties in demand and supply.

Second quarter 2020 results disclosed the reasons for the decline in profit in the second quarter. In this quarter, the income and loss of shareholders of Royal Dutch Shell included $16.8 billion ($22.3 billion before tax) of impairment charges. According to COVID-19, macroeconomic conditions, and energy market demand and supply fundamentals, the medium and long-term price and refining profit outlook assumptions were revised. In addition, compared with the second quarter of 2019, the performance of the second quarter of 2020 also reflects that the actual prices of oil, liquefied natural gas, and natural gas are low, the refining profit margin and the sales volume of petroleum products are low, and the write off of oil wells is high. In addition, the effect on revenue for the second quarter of 2020 is a reduction of $8,028 million.

Royal Dutch Shell plc third quarter 2020 results presentations disclosed the reason why the third quarter profit reached the lowest level in 2020. The decrease in profit in the current period is mainly related to impairment charges of $1.1 billion. In addition, the actual price of oil and LNG is low, and the refining profit margin and output are also low.

Fourth quarter 2020 results disclosed the reason why the fourth quarter profit reached the highest level in 2020. In this quarter, Compared with the fourth quarter of 2019, although the actual price, output, and actual refining profit margin of oil and LNG in the fourth quarter of 2020 are still low, this is partly offset by lower operating expenses and higher chemical profit margin. In addition, Shell also sold its oil exploration lease in the Niger Delta and its 30% interest in TNOG Oil and Gas Co., Ltd. in Nigeria.

First quarter 2021 results disclosed that the factors affecting profits in this quarter were mainly related to the acquisition and restructuring plan named reshape. In this quarter, the income attributable to the shareholders of Royal Dutch Shell plc was $5700 million, including $1400 million of net proceeds from asset sales and $400 million of fair value accounting income from commodity derivatives, partially offset by $500 million of redundancy and restructuring costs, mainly related to the restructuring plan named Reshape. In this quarter, Shell plc has completed the sale of 26.25% of the shares of Queensland Curtis Liquefied Natural Gas (QCLNG) Common Factories, Shell's upstream assets in the Western Desert of Egypt, and its Duvernay Shale Light Oil project in Canada. The consideration received was $2500 million, $533 million in cash, $646 million in basic consideration, up to $280 million in additional payments from 2021 to 2024, and $208 million in Crescent Point Energy common stock.

Second quarter 2021 results disclosed that the factors affecting profits in this quarter were mainly related to Start-up and investment of new projects. Income attributable to shareholders of Royal Dutch Shell was $3400 million, including $1800 million in after-tax impairment charges and $1200 million in fair value accounting charges for commodity derivatives. In this quarter, a deep-water development project named Whale was announced to be invested by Shell Offshore Inc. Shell also launched the largest polymer electrolyte membrane hydrogen electrolyzer in Europe in its Rhine Energy and Chemical Park to produce green hydrogen.

Third quarter 2021 results disclosed that the factors affecting profits in this quarter were mainly related to investment in new projects and the sale of a business. The income attributable to shareholders of Royal Dutch Shell plc was $400 million, including $5200 million in non-cash expenses and after tax impairment expenditures of $300 million for derivatives, partially offset by the net proceeds from the sale of assets of $300 million. In this quarter, Shell plc announced the investment in the construction of biofuel facilities in the Rotterdam Energy and Chemical Park in the Netherlands and the development of Timmy natural gas in Malaysia. In addition, Shell plc also sold its business in the Permian Basin in the United States and received a cash consideration of $9500 million.

Fourth quarter 2021 results disclosed the reasons why the profit in this quarter reached the highest in this year. Income attributable to shareholders of Shell was $11500 million, mainly related to non-cash income from derivatives and net income from asset sales. Shell also sold its equity in Deer Park Refining Limited Partnership in the United States this quarter.

First quarter 2022 results mentioned that the decline in profit in this quarter was mainly due to the decline in sales. Compared with the fourth quarter of 2021, the sales volume of petroleum products in this quarter decreased significantly due to the seasonal impact of strong liquidity.

Second quarter 2022 results mentioned that the significant increase in profit in this quarter was mainly due to the sale of stations and businesses. In this quarter, affected by the Russian-Ukrainian war, Shell withdrew its oil and gas activities in Russia and sold its retail station and lubricant business in Russia.

Third quarter 2022 results disclosed the reasons for the sharp drop in profits. Compared with the second quarter of 2022, the income attributable to the shareholders of Shell mainly reflects the decline of LNG trading and optimization results, the decline of chemical and refining profit margins, and the increase of basic operating expenses, which is partly offset by the increase of barrels with higher value in deep-water areas. The income attributable to Shell shareholders in the third quarter of 2022 also includes a net loss of $1 billion from the fair value accounting of commodity derivatives and an impairment charge of $400 million. These net losses were included in the recognized items for the quarter totaling $1.4 billion. These factors have harmed profits.

Table 11. Options for creating forecasts (Shell's notional profit).

Time series:	date quarter
Measure:	Total notional profit
Forward prediction:	21 quarters (Q4 2022 – Q4 2027)
Forecast basis:	Q1 2020 – Q3 2022
Ignore:	No cycles ignored
Seasonal pattern:	4-quarter cycle

Source: Tableau 2019.4.4

Table 12. Forecast quality description (Shell's notional profit).

Initial	Change from initial value	Seasonal influence		contribution		quality
Q4 2022	Q4 2022 – Q4 2027	high	low	trend	season	
20,854 ± 31,841	0	2027 Q4 2	2027 Q3 1	0.00%	100.00%	determined

Source: Tableau 2019.4.4

Table 13. Data used to calculate ExxonMobil Corporation and Shell plc's cost-effectiveness ratio from 2021 to 2027.

Exxonmobil($million)			Shell plc($million)		
date	cost	notional profit	date	cost	notional profit
2020/3/31	15541	4,952	2020/3/31	13588	3977
2020/6/30	12652	1,799	2020/6/30	3617	3569
2020/9/30	11470	4,497	2020/9/30	3737	1643
2020/12/31	37888	4,299	2020/12/31	5503	5186
2021/3/31	10565	2,730	2021/3/31	13410	5,660
2021/6/30	11100	4,690	2021/6/30	12853	3,428
2021/9/30	11128	6,750	2021/9/30	13199	5153
2021/12/31	13983	8,870	2021/12/31	16200	11460
2022/3/31	16,196	5,480	2022/3/31	14521	7,116
2022/6/30	11,590	17,850	2022/6/30	16,571	18,040
2022/9/30	13,694	19,660	2022/9/30	14785	6,743

Source: Exxonmobil's official website. Available at: https://corporate.exxonmobil.com (Accessed: 22 October 2022). Shell plc's official website. Available at: https://www.shell.com/investors/news-and-filings/sec-filings.html (Accessed: 22 October 2022).

Table 14. C/E ratio.

	C/E ratio	
	Exxonmobil	Shell plc
2021	2.03	2.77
2022	1.06	1.36
2023	0.78	0.75
2024	0.78	0.75
2025	0.78	0.75
2026	0.78	0.75
2027	0.78	0.75

Source: Excel 2020

6.3. Findings for research objective 3

The result of the correlation analysis is shown below.

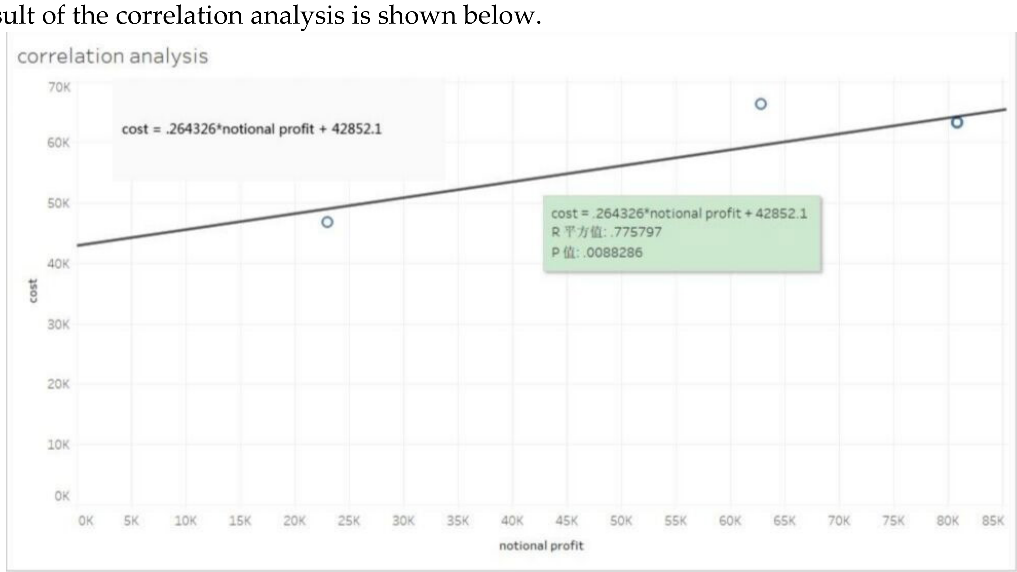

Figure 6. Pearson correlation coefficient.
Source: Tableau 2019.4.4

Table 15. Description of the Trendline model.

Model formula:	(notional profile+intercept)
Number of modeled observations:	7
Number of filtered observations:	0
Model degrees of freedom:	2
DF (Residual degrees of freedom):	5
SSE (The sum of squares due to error):	5.74E+07
MSE(Mean square error):	1.15E+07
R squared value:	0.775797
Standard error:	3388.57
P value (significance):	0.0088286

Source: Tableau 2019.4.4
Note: R squared value represents variance, indicating the closeness between the measured value and the fitting formula. The closer the value of R squared value is to one, the higher the goodness of fit is, and the more reliable the formula is. (2) The standard error represents the average distance between all the data and the average value and represents the dispersion of the data. If the standard error is small, it means that the data is concentrated near the average value. If the standard error is large, it means that the data is far from the average value, and is relatively scattered. (3) P value: In Pearson correlation coefficient, $P>0.05$ indicates no correlation, and $P<0.05$ indicates correlation.(4) MSE (Mean Square Error) is the square of the difference between the real value and the predicted value, and then the sum is averaged. (5) SSE (The sum of squares due to error): is the sum of the squares of the error between the sample data and the mean value at each level, reflecting the size of the random error.

Table 16. Description of each trend line.

area		line		coefficient				
Rows	Columns	P value	DF	time	value	Standard error	t value	P value
cost	notional profit	0.0088286	5	notional profit	0.264326	0.063548	4.15947	0.0088286
				intercept	42852.1	4628.76	9.25778	0.0002471

Source: Tableau 2019.4.4

Table 17. Description of Pearson correlation coefficient.

Role	continuous metrics
Type	calculated field
Status	Valid
Formula	CORR([cost], [notional profit])
Field	
Single value	0.88079323

Source: Tableau 2019.4.4

6.4. Findings for research objective 4

Table 18. Cost-effectiveness ratios of ExxonMobil Corporation from 2014 to 2027.

	Exxonmobil's cost-effectiveness ratio	average value of 2014-2020
2014	2.1	
2015	3.75	
2016	6.69	
2017	2.74	
2018	2.69	
2019	4.29	
2020	4.99	3.89
2021	2.03	
2022	1.06	
2023	0.78	

2024	0.78
2025	0.78
2026	0.78
2027	0.78

Source: Excel 2020

7. Discussion

This paper shows the efforts made to compare decarbonization and energy transition, which are two opposite ways to achieve the goal of net zero emissions. Firstly, the data analysis results in Paper 4 are explained in this paper. Secondly, the advantages and disadvantages of the two research methods (ARIMA model and Pearson correlation coefficient) are discussed. Finally, how the results of data analysis support the existing literature and current knowledge are discussed.

7.1. Discussion of the findings

From the comparison of the cost-effectiveness ratio between ExxonMobil Corporation and Shell plc from 2021 to 2027, it can be seen that from 2021 to 2022, the C/E ratio of CCS is lower than the C/E ratio of the energy transition, but since 2023, the C/E ratio of CCS is higher than the C/E ratio of the energy transition. Joos (2016) claimed that in 2022 when there are no technical barriers in the industrial deployment stage of CCS technology, a substantial reduction in the price of the post-combustion carbon capture process is a necessary condition to improve the competitiveness of CCS technology. Therefore, the reason for the low C/E ratio of CCS technology might be related to the high energy consumption and financial costs of the post-combustion carbon capture process. In addition, Anderson (2017) proposed that due to the inherent uncertainty in the estimation of storage resources and the lack of infrastructure needed to obtain these resources, the exploration costs spent to find long-term safe storage sites are also factors affecting the cost-effectiveness of CCS technology.

Since 2023, the C/E ratio of CCS is expected to be higher than that of the energy transition, probably because the cost of carbon capture after combustion has been reduced by using new materials, such as nano porous materials. In addition, with the accumulation of CCS technology experience, the ability to control the potential cost of geological reserves has also been enhanced.

Similarly, as CCS technology is still in the early stage of research and development, the cost of exploration and post-combustion carbon capture has not been well controlled, and the C/E ratio in 2021-2027 is lower than the average C/E ratio in 2014-2020.

However, according to the experience curve effect, with the increase of time spent on CCS technology and learning in practice, the technology cost will decrease year by year (Rubin, 2007). This might be the reason why ExxonMobil still vigorously develops CCS technology although the C/E ratios of CCS technology are low in both 2021 and 2022.

The positive correlation between the costs and profits of ExxonMobil from 2021 to 2027 might be related to the use of carbon dioxide after capture or storage. Liu et al. (2022) revealed, injecting the captured carbon dioxide into the reservoir can effectively increase oil production. Similarly, Núñez-López and Moskal (2019) found that storing carbon dioxide on the seabed can make deep-sea oil float to the surface, reduce the cost of exploration and exploitation, and improve oil recovery. Therefore, ExxonMobil increased its investment in CCS technology and reduced the cost of obtaining crude oil, thus increasing the profits of its oil-related businesses.

7.2. The strength and weaknesses of the ARIMA model

Intharathirat et al. (2015) state that both the regression model and time series model are widely used models. However, Innocent, Dieudonné, and Jose (2016) found that the regression model cannot adapt to new situations and its accuracy is poor. Therefore, time series analysis, especially the ARIMA model time series analysis is given priority in various studies because of its advantages in using appropriate statistical indicators for analysts and its efficiency and accuracy as a single variable time series prediction model (Guo, N.(1) et al., 2021).

Lu (2021) revealed that the disadvantage of the ARIMA model is that its relative error reaches 2%. In addition, the ARIMA model needs to be based on stable periodic data. In real life, most time series are non-periodic, showing trend or periodic characteristics, and it is also difficult to ensure the accuracy of data.

7.3. The strength and weakness of the Pearson correlation coefficient

According to Jameson, Azarian, and Pecht (2016), the Pearson correlation coefficient could only be used to measure the linear correlation between two variables. Therefore, the range of using the Pearson correlation coefficient is relatively limited. On the other hand, Swami and Das (2022) found that the Pearson correlation coefficient can be used to calculate distance matrix, and its inherent hierarchical clustering method can overcome the main limitations such as computational and time complexity.

7.4. Discussions with current literature

The data analysis results in this report show that for ExxonMobil, it is more cost-effective to adopt the decarbonization path and vigorously develop CCS technologies to achieve the goal of net zero emissions than the energy transformation path. This has provided support for Wood and Dong et al., which is mentioned in Paper 2 that when fossil fuels still occupy a dominant position in the global energy landscape, oil companies in various countries should choose an appropriate path to achieve the goal of net zero emissions based on their conditions, rather than blindly turning to the path of the energy transition.

8. Evaluation

Firstly, For the data used to calculate the C/E ratio, since the actual cost of CCS technology cannot be obtained from the official website and reports of ExxonMobil Corporation, and it is also hard to obtain the data of several refineries or power plants that include CCS costs and the cost without using CCS, therefore, the actual cost of CCS cannot be obtained by subtracting the data without CCS from the data using CCS as in the literature. Since ExxonMobil is regarded as the most typical company to develop CCS technology, while Shell plc is the symbol of the energy transition. Therefore, the above forecasts and the C/E ratio are calculated with the net profit as the "benefit" and the sum of capital expenditure and operating expenses as the "cost".

Secondly, as mentioned on tableau's official website, the seasonal prediction function, an important part of time series analysis, requires a total of eight consecutive quarters of data in two complete years, while the data in 2022 currently has only three quarters, which does not meet the requirements of a complete year. Therefore, the data from four quarters in 2020 are added to the database.

Thirdly, as required on tableau's official website that using multiplicative mode can greatly improve the quality of data prediction, but as the net profits of both companies in 2020 are negative, the figure of net loss has to be converted into notional profit. The reasons for the losses were found in the 2020 annual and quarterly reports of the two companies. The main reason is that COVID-19 has led to many unprecedented events, such as blockades around the world and shrinking oil demand. Impairment of some unconventional assets, unusually large investment activities, Shell's revision and updating of medium and long-term commodity prices, restructuring costs, and major onerous contract terms arising from the shutdown of the Convent. For Shell plc, the adverse effects also include the decline in the actual prices of oil, liquefied natural gas, and natural gas, the decline in refining margins, the decline in the sales of petroleum products, and the increase in the write-off of oil wells. The adverse impact of the epidemic on ExxonMobil is mainly reflected in the increase of its current expected credit loss reserves. When the demand for oil shrinks, its main business income drops rapidly due to the volume and mixed effects. In addition, there are other abnormal costs, such as asset management and severance pay, which reduce the income of its main business. Therefore, these related expenses are added back from the net loss value to obtain the notional profit.

Finally, as this report is written in Xi'an Jiaotong-liverpool University (XJTLU), all data and references are based on the database of the e-library of XJTLU and the websites of Exxon Mobil Corporation. The report's objectives are influenced by the reliability of the data and the authenticity of reports from this corporation. For example, due to the lack of internal information on enterprise management, such as management accounts, some data cannot be verified in time. In addition, as the low carbon solutions business was newly established in 2021, and the annual report of 2022 has not been published, therefore, the data from 2022 to 2027 cannot be obtained for research. This will challenge the reliability of research results. I keep my opinion for those secondary data and information.

9. Conclusions

9.1. Conclusion of objective 1 to 2

From the comparison of C/E ratios between ExxonMobil and Shell from 2021 to 2027, it can be seen that the C/E ratio of CCS is lower than the energy transformation from 2021 to 2022, which is a good start. Although from 2023 to 2027, the CCS C/E ratio is higher than the C/E ratio of Shell's energy transformation, as fossil fuels will remain the main industrial fuel and raw material for at least the next 50 years, CCS is the fundamental strategy for reducing carbon emissions. ExxonMobil should therefore continue to invest in and develop CCS technology.

9.2. Conclusion of objective 3

The model is meaningful because the P value is 0.0088286, which is less than 0.05. The value of R is about 0.78, which is greater than 0.4, also indicating good goodness of fit. In addition, the single value of the Pearson Correlation Coefficient is about 0.88, which is in the range of 0.7 to 1, indicating a strong positive correlation between the cost and profit of ExxonMobil Corporation from 2021 to 2027. Therefore, Exxon Mobil Corporation should continue to invest in and develop CCS technology.

9.3. Conclusion of objective 4

It can be seen from Table 4.14 that the average C/E ratio from 2014 to 2020 is much higher than the C/E ratio in any year from 2021 to 2027. This might be related to the high initial cost input of the CCS technology. At the same time, as CCS technology is an advanced decarbonization technology, it is still in the stage of research and development, and exploration, and has not been fully used in all of ExxonMobil's plants. Therefore, Exxon Mobil Corporation should continue to increase its investment in research and development of CCS technology, so that the actual C/E ratio from 2022 to 2027 will exceed the average value of 3.89 from 2014 to 2020 while achieving the goal of net-zero emissions in advance.

9.4. Qustions for discussion: the Potential Issues from the Current Research

According to Forbes (2022), based on the information in ExxonMobil Low Carbon Solutions to commercialize emission reduction technology, pointing out that Exxon Mobil lacks coordination and integration capabilities across departments, fields, and enterprises, lacks integrated strategic planning and innovative corresponding business models. These three factors caused the disconnection between the industrial enterprise and digital transformation. Digital transformation is to realize the collaboration and integration of multiple systems on an existing basis, to promote innovative applications. Enterprises should first realize the importance of building a low-carbon future and pay attention to reducing costs and waste through technological transformation, product innovation, and other ways in the product design process. In the operation process, enterprises should improve equipment operation efficiency, use intelligent technology, and use green energy to build manufacturing plants to reduce the impact on the environment.

9.5. Recommendations

Forbes (2022) proposed a digital transformation solution for Exxon Mobil Corporation. On the one hand, it should increase the innovation of industrial digital systems, build intelligent innovation networks, and promote the integration of new-generation information technology and existing manufacturing technology. For example, Exxon Mobil Youshida Service initiated by Exxon Mobil Corporation can provide detailed feasible suggestions for equipment maintenance and predictive analysis of oil use based on the analysis of oil sample testing equipment and production and operation status. On the other hand, promote the construction of the digital design, digital process, equipment, and digital workshop, and improve the digital level of traditional manufacturing from the hardware. At the same time, multi-scenario and full industry chain application demonstrations should be carried out, promote the integration of technology and the market, and provide more display and application stages for new technologies and products.

This report supports the rationality of the research and development of low carbon solutions business and CCS technology of Exxon Mobil and proves that the decarbonization path selected by Exxon Mobil is cost-effective and suitable for Exxon Mobil Corporation. It also provides support for literature supporting the development of CCS technology. In addition, this report also provides suggestions and recommendations for the continued development of CCS technology, such as injecting captured carbon dioxide into the reservoir to improve oil recovery. To improve the ability of cost control, Exxon Mobil should consider reducing the cost of the post-combustion carbon capture process by using new materials such as nano porous materials. For the potential issues that Exxon Mobil is facing, solutions have also been found.

References

Ananth, M. D., & Sharma, R. (2016). Cloud Management Using Network Function Virtualization to Reduce CAPEX and OPEX. 2016 8th International Conference on Computational Intelligence and Communication Networks (CICN), Computational Intelligence and Communication Networks (CICN), 2016 8th International Conference on, CICN, 43–47. https://doi.org/10.1109/CICN.2016.17

Anderson, S. (2017). Cost Implications of Uncertainty in CO Storage Resource Estimates: A Review. Natural Resources Research, 26(2), 137–159. https://doi.org/10.1007/s11053-016-9310-7

Atıcı, R., & Pala, Z. (2021). Prediction of the Ionospheric foF2 Parameter Using R Language Forecasthybrid Model Library Convenient Time Series Functions. Wireless Personal Communications: An International Journal, 1–20. https://doi.org/10.1007/s11277-021-09050-6

Balsalobre-Lorente, D., Gokmenoglu, K. K., Taspinar, N., & Cantos-Cantos, J. M. (2019). An approach to the pollution haven and pollution halo hypotheses in MINT countries. Environmental Science and Pollution Research, 26(22), 23010–23026. https://doi.org/10.1007/s11356-019-05446-x

Belfield, C. R., Brooks Bowden, A., & Shand, R. S. (2021). Cost-Effective Decision-Making for California's School System. In Policy Analysis for California Education, PACE. Policy Analysis for California Education, PACE. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=eric&AN=ED615701&site=eds-live&scope=site (Accessed: 17 October 2022).

Blazquez, J. (1), Fuentes, R. (2), & Manzano, B. (3). (2020). On some economic principles of the energy transition. Energy Policy, 147. https://doi.org/10.1016/j.enpol.2020.111807

Cherepovitsyn, A., & Rutenko, E. (2022). Strategic Planning of Oil and Gas Companies: The Decarbonization Transition. Energies (19961073), 15(17), 6163. https://doi.org/10.3390/en15176163

Dong, F., Li, Y., Gao, Y., Zhu, J., Qin, C., & Zhang, X. (2022). Energy transition and carbon neutrality: Exploring the non-linear impact of renewable energy development on carbon emission efficiency in developed countries. Resources, Conservation & Recycling, 177. https://doi.org/10.1016/j.resconrec.2021.106002

Duan, H.-B., Fan, Y., & Zhu, L. (2013). What's the most cost-effective policy of CO2 targeted reduction: An application of aggregated economic technological model with CCS? Applied Energy, 112, 866–875. https://doi.org/10.1016/j.apenergy.2013.01.047

Exxon Mobil Corporation. (2022) Advancing Climate Solutions 2022 Progress Report - Low Carbon Solutions business and CCS. Available at:
https://corporate.exxonmobil.com/-/media/Global/Files/Advancing-Climate-Solutions-Progress-Report/2022-July-update/ExxonMobil-Advancing-Climate-Solutions-2022-Progress-Report.pdf (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2020) Annual Report 2020. Available at: https://www.sec.gov/ix?doc=/Archives/edgar/data/34088/000003408821000012/xom-20201231.htm (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) Annual report 2021. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/annual-report-summaries/2021-annual-report.pdf (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) Energy and Carbon Summary 2021. Available at: https://corporate.exxonmobil.com/-/media/global/files/energy-and-carbon-summary/energy-and-carbon-summary.pdf (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) ESG Summary Shareholder Engagement 2022. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/esg-summary_shareholder-engagement_april-2022.pdf (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2020) ExxonMobil reports results for first quarter 2020. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2020/0501_exxonmobil-reports-results-for-first-quarter-2020 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2020) ExxonMobil reports results for fourth quarter 2020 and provides perspective on forward plans. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2021/0202_exxonmobil-reports-results-for-fourth-quarter-2020-and-provides-perspective-on-forward-plans (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2020) ExxonMobil reports results for second quarter 2020. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2020/0731_exxonmobil-reports-results-for-second-quarter-2020 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2020) ExxonMobil reports results for third quarter 2020. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2020/1030_exxonmobil-reports-results-for-third-quarter-2020 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) ExxonMobil earns $2.7 billion in first quarter 2021. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2021/0430_exxonmobil-earns-2_7-billion-in-first-quarter-2021 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) ExxonMobil earns $4.7 billion in second quarter 2021. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2021/0730_exxonmobil-earns-4_7-billion-in-second-quarter-2021 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) ExxonMobil earns $6.8 billion in third quarter 2021. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2021/1029_exxonmobil-earns-6_8-billion-in-third-quarter-2021 (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) ExxonMobil earns $23 billion in 2021, initiates $10 billion share repurchase program. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2022/0201_exxonmobil-earns-23-billion-in-2021_initiates-10-billion-share-repurchase-program (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) ExxonMobil announces first-quarter 2022 results. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2022/0429_exxonmobil-announces-first-quarter-2022-results (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) ExxonMobil announces second-quarter 2022 results. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2022/0729_exxonmobil-announces-second-quarter-2022-results (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) ExxonMobil announces third-quarter 2022 results. Available at: https://corporate.exxonmobil.com/news/newsroom/news-releases/2022/1028_exxonmobil-announces-third-quarter-2022-results (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2021) Outlook for Energy: data pages. Available at: https://corporate.exxonmobil.com/-/media/global/files/outlook-for-energy/2021/2021-outlook-for-energy-data-pages.xlsx (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) Proxy Statement 2022. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/proxy-materials/2022-proxy-statement.pdf (Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) 2022-proxy-voting-results. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/proxy-materials/2022-proxy-voting-results.pdf(Accessed: 22 Oct 2022).

Exxon Mobil Corporation. (2022) ExxonMobil Low Carbon Solutions to commercialize emission-reduction technology. Available at: https://corporate.exxonmobil.com/-/media/global/files/investor-relations/annual-meeting-materials/proxy-materials/2022-proxy-statement.pdf (Accessed: 22 Oct 2022).

Exxon Mobil: Energy Bulls Could Be Sorely Disappointed (2022) Available at: https://seekingalpha.com/article/4562586-exxon-mobil-stock-energy-bulls-could-be-sorely-disappointed (Accessed: 10 Dec 2022).

Fard, A. T. (2011). Evaluation of influential factors on market values of five major international oil companies, using the method of panel data with two-way error components and its application in oil and gas industries of Iran. OPEC Energy Review, 35(3), 220–226. https://doi.org/10.1111/j.1753-0237.2011.00191.x

Forbes. Available at: https://www.163.com/dy/article/HK7N0K140530UH99.html (Accessed: 10 Dec 2022).

Gardumi, F., Keppo, I., Howells, M., Pye, S., Avgerinopoulos, G., Lekavičius, V., Galinis, A., Martišauskas, L., Fahl, U., Korkmaz, P., Schmid, D., Montenegro, R. C., Syri, S., Hast, A., Mörtberg, U., Balyk, O., Karlsson, K., Pang, X., Mozgeris, G., … Mikulić, M. (2022). Carrying out a multi-model integrated assessment of European energy transition pathways: Challenges and benefits. Energy, 258. https://doi.org/10.1016/j.energy.2022.124329

Gatti, S., & Chiarella, C. (2020). Disruption in the Infrastructure Sector. [electronic resource] : Challenges and Opportunities for Developers, Investors and Asset Managers (1st ed. 2020.). Springer International Publishing. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=cat01010a&AN=xjtlu.0001729533&site=eds-live&scope=site (Accessed: 8 October 2022).

Griffiths, S., Sovacool, B. K., Kim, J., Bazilian, M., & Uratani, J. M. (2022). Decarbonizing the oil refining industry: A systematic review of sociotechnical systems, technological innovations, and policy options. Energy Research & Social Science, 89. https://doi.org/10.1016/j.erss.2022.102542

Guo, N. (1), Chen, W. (1,2), Tian, Z. (1), Jin, H. (1), & Wang, M. (3). (2021). Appling an Improved Method Based on ARIMA Model to Predict the Short-Term Electricity Consumption Transmitted by the Internet of Things (IoT). Wireless Communications and Mobile Computing, 2021. https://doi.org/10.1155/2021/6610273

Hartley, P. R., & Medlock, K. B. (2013). Changes in the Operational Efficiency of National Oil Companies. The Energy Journal, 34(2), 27–57. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=edsjsr&AN=edsjsr.41970481&site=eds-live&scope=site (Accessed: 15 October 2022).

Innocent, N. M. , & B Dieudonné. Modeling the Temporal Variations of Municipal Solid Waste Generation for Future Projection in the Douala Municipality, Cameroon.

Intharathirat, R., Abdul Salam, P., Kumar, S., & Untong, A. (2015). Forecasting of municipal solid waste quantity in a developing country using multivariate grey models. Waste Management, 39, 3–14. https://doi.org/10.1016/j.wasman.2015.01.026

Jameson, N. J., Azarian, M. H., & Pecht, M. (2016). Correlation analysis for impedance-based health monitoring of electromagnetic coils. 2016 IEEE International Conference on Prognostics and Health Management (ICPHM), Prognostics and Health Management (ICPHM), 2016 IEEE International Conference On, 1–6. https://doi.org/10.1109/ICPHM.2016.7542842

Johnson, I. (2015). Can we Finance the Energy Transition? Cadmus, 2(4), 162–183. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=asn&AN=103564839&site=eds-live&scope=site (Accessed: 15 October 2022).

Joos, L. et al. (2016). Cutting the cost of carbon capture: a case for carbon capture and utilization. (2016). https://doi.org/10.1039/C6FD00031B Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=edssch&AN=edssch.oai%3aescholarship.org%2fark%3a%2f13030%2fqt435805tv&site=eds-live&scope=site (Accessed: 14 December 2022).

Juan, E. S., Firoozabadi, A. D., Adasme, P., Soto, I., & Canete, L. (2019). Spanish Syllables Recognition by Wavelet and Cross Covariance. 2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), 2019 IEEE CHILEAN Conference On, 1–6. https://doi.org/10.1109/CHILECON47746.2019.8987522

KAGITCI, M. (2019). The financial performance of the companies from the oil sector. A comparative analysis. Theoretical & Applied Economics, 119–127. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=bsu&AN=141990902&site=eds-live&scope=site (Accessed: 12 October 2022).

Khan, M. B., Saleem, H., Shabbir, M. S., & Huobao, X. (2022). The effects of globalization, energy consumption and economic growth on carbon dioxide emissions in South Asian countries. Energy & Environment, 33(1), 107–134. https://doi.org/10.1177/0958305X20986896

Khan, S. A. R., Ponce, P., & Yu, Z. (2021). Technological innovation and environmental taxes toward a carbon-free economy: An empirical study in the context of COP-21. Journal of Environmental Management, 298. https://doi.org/10.1016/j.jenvman.2021.113418

Kheshgi, H., Coninck, H., & Kessels, J. (2012). Carbon dioxide capture and storage: Seven years after the IPCC special report. Mitigation & Adaptation Strategies for Global Change, 17(6), 563–567. https://doi.org/10.1007/s11027-012-9391-5

Kwok, S., Omran, M., & Yu, P. (2024a). Audit Digitalization, Do-Calculus, and Professional Judgment: A Practical Evidence From China. In S. Kwok, M. Omran, & P. Yu (Eds.), *Harnessing Technology for Knowledge Transfer in Accountancy, Auditing, and Finance* (pp. 1–25). IGI Global. https://doi.org/10.4018/979-8-3693-1331-2.ch001

Kwok, S., Omran, M., & Yu, P. (Eds.). (2024b). *Harnessing Technology for Knowledge Transfer in Accountancy, Auditing, and Finance* (p. 279). IGI Global. https://doi.org/10.4018/979-8-3693-1331-2

Li, M. (1), Trencher, G. (2), & Asuka, J. (3). (2022). The clean energy claims of BP, Chevron, ExxonMobil and Shell: A mismatch between discourse, actions and investments. PLoS ONE, 17(2 February). https://doi.org/10.1371/journal.pone.0263596

Lin, A. C. (2022). Making Net Zero Matter. Washington & Lee Law Review, 79(2), 679–767. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=asn&AN=158704235&site=eds-live&scope=site (Accessed: 8 October 2022).

Liu, B., Qiao, Y., Li, Q., Jia, W., & Wang, T. (2022). CO2 separation from CO2-EOR associated gas using hollower fiber membranes: A process design and simulation study. Journal of Natural Gas Science and Engineering, 100. https://doi.org/10.1016/j.jngse.2022.104451

Lu, S. (2021). Research on GDP Forecast Analysis Combining BP Neural Network and ARIMA Model. Computational Intelligence & Neuroscience, 1–10. https://doi.org/10.1155/2021/1026978

Núñez-López, V., & Moskal, E. (2019). Potential of CO2-EOR for Near-Term Decarbonization. Frontiers in Climate, 1. https://doi.org/10.3389/fclim.2019.00005

Papadis, E., & Tsatsaronis, G. (2020). Challenges in the decarbonization of the energy sector. Energy, 205. https://doi.org/10.1016/j.energy.2020.118025

Polzin, F., & Sanders, M. (2020). How to finance the transition to low-carbon energy in Europe? Energy Policy, 147. https://doi.org/10.1016/j.enpol.2020.111863

Rubin, E. S., Davison, J. E., & Herzog, H. J. (2015). The cost of CO2 capture and storage. International Journal of Greenhouse Gas Control, 40, 378–400. https://doi.org/10.1016/j.ijggc.2015.05.018

Rubin, E. S., Yeh, S., Antes, M., Berkenpas, M., & Davison, J. (2007). Use of experience curves to estimate the future cost of power plants with CO2 capture. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=edssch&AN=edssch.oai%3aescholarship.org%2fark%3a%2f13030%2fqt46x6h0n0&site=eds-live&scope=site (Accessed: 14 December 2022).

Şahinli, M. A. (2020). Potato Price Forecasting with Holt-Winters and ARIMA Methods: A Case Study. American Journal of Potato Research, 97(4), 336–346. https://doi.org/10.1007/s12230-020-09788-y

Satya Widya Yudha, Benny Tjahjono, & Athanasios Kolios. (2018). A PESTLE Policy Mapping and Stakeholder Analysis of Indonesia's Fossil Fuel Energy Industry. Energies, 11(5), 1272. https://doi.org/10.3390/en11051272

Saygin, D., & Gielen, D. (2021). Zero-emission pathway for the global chemical and petrochemical sector. Energies, 14(13). https://doi.org/10.3390/en14133772

Shell plc. (2020) First quarter 2020 results financial documents. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2020/q1-2020/_jcr_content/root/main/section/simple/call_to_action_copy__491052796/links/item0.stream/1663148265548/fd93861d91e035f990e8c3f8578278266c1eeefd/q1-2020-qra-document-final.pdf (Accessed: 22 Oct 2022).

Shell plc. (2020) Fourth quarter 2020 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2020/q4-2020.html (Accessed: 22 Oct 2022).

Shell plc. (2020) Second quarter 2020 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2020/q2-2020.html (Accessed: 22 Oct 2022).

Shell plc. (2020) Royal Dutch Shell plc third quarter 2020 results presentations. Available at: https://www.shell.com/investors/investor-presentations/2020-investor-presentations/third-quarter-2020-interim-results-presentations/_jcr_content/root/main/section/simple/call_to_action/links/item0.stream/1663164751448/9a53beca1a6094dd01e61ace1614dababdde0ca7/q3-2020-results-webcast-presentation-slides.pdf (Accessed: 22 Oct 2022).

Shell plc. (2021) First quarter 2021 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2021/q1-2021.html (Accessed: 22 Oct 2022).

Shell plc. (2021) Fourth quarter 2021 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2021/q4-2021.html (Accessed: 22 Oct 2022).

Shell plc. (2021) Second quarter 2021 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2021/q2-2021.html (Accessed: 22 Oct 2022).

Shell plc. (2021) Third quarter 2021 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2021/q3-2021.html (Accessed: 22 Oct 2022).

Shell plc. (2022) First quarter 2022 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q1-2022.html (Accessed: 22 Oct 2022).
Shell plc. (2022) Second quarter 2022 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q2-2022.html (Accessed: 22 Oct 2022).
Shell plc. (2022) Third quarter 2022 results. Available at: https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q3-2022.html (Accessed: 22 Oct 2022).
Swami, R., & Das, P. (2022). A new secure data retrieval system based on ECDH and hierarchical clustering with Pearson correlation. Innovations in Systems and Software Engineering: A NASA Journal, 1–11. https://doi.org/10.1007/s11334-022-00515-w
Tableau. (2003) Available at: https://www.tableau.com/learn/articles/time-series-analysis#models-techniques, (Accessed: 22 October 2022).
V. I. Salygin, & D. S. Lobov. (2021). Defining Major Oil and Gas Companies' Development Strategies in the Era of Energy Transition. Vestnik MGIMO-Universiteta, 14(5), 149–166. https://doi.org/10.24833/2071-8160-2021-5-80-149-166
Wood, G., & Baker, K. (2020). The Palgrave Handbook of Managing Fossil Fuels and Energy Transitions. [electronic resource] (1st ed. 2020.). Springer International Publishing. Available at: https://search-ebscohost-com.ez.xjtlu.edu.cn/login.aspx?direct=true&db=cat01010a&AN=xjtlu.0001736743&site=eds-live&scope=site (Accessed: 8 October 2022).
Xu, H., Chen, J., Lin, H., & Yu, P. (2024). Investigating Dependence Structure Among Subsectors of Technology Stocks: A Vine Copula Approach. *European Academic Journal - II*, *1*(1). https://eaj.ebujournals.lu/index.php/EAJ_II/article/view/90
Xu, H., Lin, H., & Yu, P. (2024). How IoT-Enabled New Energy Vehicles Enhance Sustainable Intelligent Transportation Systems in Smart Cities Under Unique Institutional Settings? Case Studies of China. *European Academic Journal - II*, *1*(1). https://eaj.ebujournals.lu/index.php/EAJ_II/article/view/96
Xu, H., Wang, Y., Chen, J., Lin, H., & Yu, P. (2024). Evaluating the Predictive Power of the Energy-Related Uncertainty Index on Bitcoin Volatility. *European Academic Journal - II*, *1*(1). https://eaj.ebujournals.lu/index.php/EAJ_II/article/view/89
Yu, P., Chen, J., & Xu, H. (2024). Sustainability and Stability: Asymmetric Time–Frequency Connectedness and Risk Spillovers Among EU–China ETSs, Clean Energy, Precious Metals, and Green Bonds. *Preprints*. https://doi.org/10.20944/preprints202406.0841.v1
Yu, P., Xu, H., & Chen, J. (2024a). Can ESG Integration Enhance the Stability of Disruptive Technology Stock Investments? Evidence from Copula-Based Approaches. *Journal of Risk and Financial Management*, *17*(5). https://doi.org/10.3390/jrfm17050197
Yu, P., Xu, H., & Chen, J. (2024b). Double Asymmetric Impacts, Dynamic Correlations, and Risk Management Amidst Market Risks: A Comparative Study between the US and China. *Journal of Risk and Financial Management*, *17*(3). https://doi.org/10.3390/jrfm17030099
Zafar, M. W., Qin, Q., malik, M. N., & Zaidi, S. A. H. (2020). Foreign direct investment and education as determinants of environmental quality: The importance of post Paris Agreement (COP21). Journal of Environmental Management, 270. https://doi.org/10.1016/j.jenvman.2020.110827