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Final Thesis

Stranded assets and Transition risks: Financial Implications for the EU's Oil and Gas Sector in the Low-Carbon Era

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Abstract

The European Union's commitment to reducing carbon emissions and transitioning to a low-carbon economy poses significant challenges for the energy sector. Transition risks, alongside the risk of stranded assets, are critical concerns for oil and gas companies. This thesis aims to assess the vulnerability of these companies to the ongoing energy transition and explore its potential financial and operational implications. The study combines quantitative financial analysis with qualitative assessments to provide a comprehensive understanding. Stricter regulatory measures and shifting market demands are increasing the exposure of EU companies to these risks, highlighting the need for diversification and investment in renewable energy to safeguard financial stability in a rapidly evolving regulatory and market environment.

Introduction

August 2024 was 1.51°C above the pre-industrial level and is the 13th month in a 14-month period for which the global-average surface air temperature exceeded 1.5°C above pre-industrial levels.[1] This alarming milestone underscores the urgency of addressing climate change and highlights the pressing need for a global shift towards a low-carbon economy. The European Union (EU), with its ambitious goal of carbon neutrality by 2050, is playing a pivotal role in this transition.

Energy is at the heart of the climate challenge – and central to the solution. Fossil fuels, such as coal, oil and gas, are by far the largest contributor to global climate change, accounting for over 75% of global greenhouse gas emissions and nearly 90 percent of all carbon dioxide emissions.[2] The EU's dependency on these energy sources makes its oil and gas sector particularly vulnerable in the face of growing climate imperatives and regulatory changes. As the EU strengthens its commitment to climate action, this sector must contend with the risks posed by an accelerating energy transition.

In this context, two critical risks stand out: transition risks and stranded assets. Transition risks refer to the financial risks that could arise from the process of adjusting to a lower-carbon economy. Stranded assets, on the other hand, are assets whose profit expectations will be drastically reduced or become obsolete as the world moves toward cleaner energy sources. As the EU ramps up its efforts to meet the goals of the Paris Agreement, oil and gas companies will face growing exposure to these risks. To protect their financial stability, it's becoming increasingly crucial for these firms to diversify their investments and shift toward renewable energy technologies.

The core objective behind this thesis project is to answer the following questions:

How vulnerable are the EU's oil and gas companies to transition risks in the shift toward a low-carbon economy, and what are the potential financial and operational implications of this transition?

[1] COPERNICUS, *Surface air temperature for August 2024*, September 2024 https://climate.copernicus.eu/surface-air-temperature-august-2024

[2] UNITED NATIONS, *Climate Action*, September 2024 https://www.un.org/en/climatechange/raising-ambition/renewable-energy

Through a combination of qualitative and quantitative methods, this thesis will analyze patterns and trends in the European energy industry, focusing on how it navigates the evolving European regulatory framework and mitigates transition risks and the potential for stranded assets.
However, it is important to note that little research and knowledge currently exist in the field of stranded assets risk. This gap in understanding amplifies the uncertainty oil and gas companies face as they navigate the transition to a low-carbon economy, making this area of study both pressing and essential for the future of the energy sector.

The contributions of this project are listed as follow:

1. Investigate and give and overview on current knowledge on transition risks and stranded assets.
2. Examine the current state of the European energy sector.
3. Outline the existing EU legislative framework.
4. Asses the exposure of oil and gas companies to transition and stranded assets risks.

1 Literature Review

1.1 Transition risk

As the latest IPCC report (Intergovernmental Panel On Climate Change (Ipcc), 2023) made clear, rising climate impacts and higher societal awareness call for urgent and ambitious action at all scales. While the impacts of climate change are becoming more pronounced, our timeframe to achieve a 1.5 – 2 °C warming is narrowing. To reach emission levels consistent with a below 2 °C pathway in 2030, the cuts required per year are 5.3 per cent from 2024, reaching 8.7 per cent on average for the 1.5 °C pathway (United Nations Environment Programme, 2023). Meeting the target established by the Paris Agreement will likely require swift and ambitious climate policy measures. Such an ambitious and sudden policy may create both microeconomic and macroeconomic risks.
Mark Carney, former Governor of the Bank of England, addressed this issue in a seminal speech at Lloyd's in 2015. He coined the "transition risk" term, highlighting that climate change can affect financial stability through three main channels (Mark Carney, 2015). First, physical risk, which includes the effects of natural disasters. Second, liability risk, referring to the impacts that could arise if parties who have suffered loss or damage from climate change seek compensation from those they hold responsible. Lastly, transition risk – the focus of this chapter – defined as:

> The financial risks which could result from the process of adjustment towards a lower-carbon economy. Changes in policy, technology and physical risks could prompt a reassessment of the value of a large range of assets as costs and opportunities become apparent.[3]

The vulnerability of firms' values to transition risk, according to a critical review of the conceptual and historical literature (Semieniuk *et al.*, 2021), stems from three different sources: climate policy, technological change and changes in consumer preferences. The Task Force on Climate-related Financial Disclosures (TCFD), in a 2017 report, brakes transition risks into four different categories/sources: market, technology, reputation and policy and legal risks. While market risk is varied, the main channel through which it affects companies is shifts in supply and demand for certain commodities, products and

[3] CARNEY M., *Mark Carney: Breaking the tragedy of the horizon - climate change and financial stability*, 2015

services. Also tied to shifts in consumer behavior is reputation risk which focuses on an organization's contribution to or detraction from the transition to a low-carbon economy. Technological improvements or innovation fostering the transition of the economy can also have significant impact on an organization. Winners and losers may emerge because of a "creative destruction" process. Finally, policy actions impact financial profitability depending on the nature and the timing of the policy change, indeed organization should assess also the potential second and third order effects on their supply and distribution chains (TCFD, 2017).

Table 1 *Transition risks and potential impacts on firms' value*

Category	***Risks***	***Financial impacts***
Market	Changing customer behavior Uncertainty in market signals Increased cost of raw materials	Reduced demand for goods and services Increased production costs Unexpected shifts in energy costs Re-pricing of assets
Technology	Substitution of existing products and services with lower emissions options Unsuccessful investment in new technology Costs to transition to lower emissions technology	Write-offs and early retirement of existing assets Reduced demand for products and services R&D expenditures in new alternative technologies Costs to adopt/deploy new practices and processes
Policy and Legal	Increased pricing of GHG emissions Enhanced emissions-reporting obligations Mandates on and regulation of existing products and services Exposure to litigation	Increased operating costs Write-offs, asset impairment, early retirement of existing assets Increased costs and/or reduced demands for products and services
Reputation	Shifts in consumer preferences Stigmatization of sector Increased stakeholder concern or negative stakeholder feedback	Reduced revenue form decreased demand for goods and services Reduced revenue from decreased production capacity Reduce revenue from negative impacts on workforce management and planning Reduction in capital availability

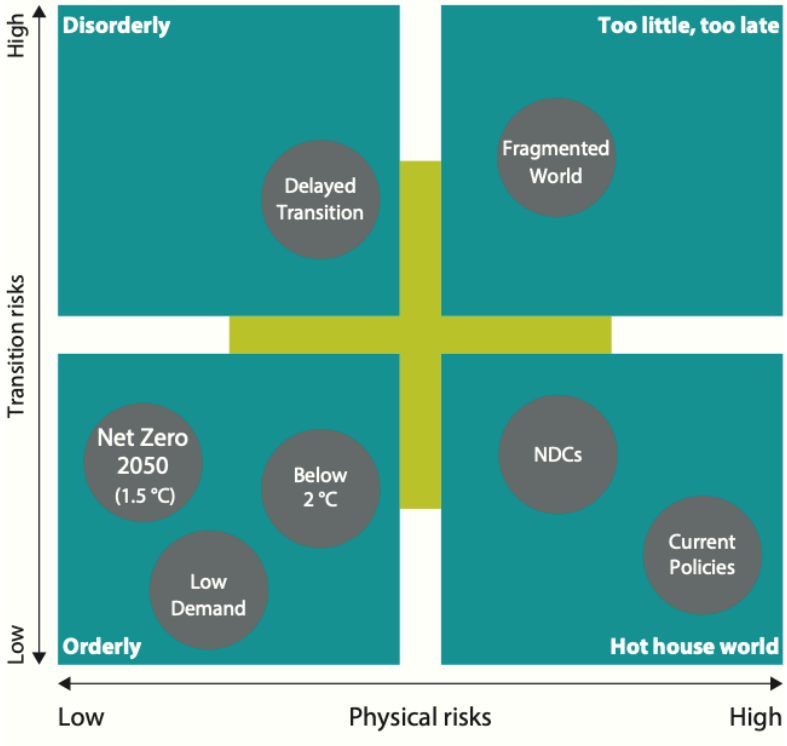
Adapted from TCFD, 2017

On a macroeconomic level, transition risk largely depends on how policies are implemented, and countries are aligned. On this respect, the Network for Greening the Financial System (NGFS) developed long-term climate scenarios to inform analysis and guide policy worldwide. These scenarios intend to map out how economies might develop

under different assumptions for how climate policy, emissions, temperatures and physical risk impacts evolve.

The NGFS explore a set of seven scenarios: Delayed Transition, Net Zero 2050, Below 2°, Low Demand, Fragmented World, Naturally Determined Contributions and Current Policies (see *Figure 1*). The scenarios are grouped into four main frameworks. First, orderly scenarios, the most optimistic out of the seven, assume early introduction and increasing stringency of climate policy leading to relatively subdued transition and physical risks. Disorderly scenarios are characterized by higher transition risks resulting from delayed policies and divergences across countries and sectors. Hot house world are those scenarios that consider insufficient global efforts to halt global warming leading to severe physical risks. Lastly, too-little-too-late scenarios depict fails in to limit both physical and transition risk due to late and uncoordinated transition.

Figure 1 *NGFS scenarios framework in Phase IV*



Source: *NGFS Scenarios for central banks and supervisors, 2023*

Climate change has a negative impact on GDP in every plausible scenario. Nonetheless, the Net Zero 2050 scenario shows that negative short-term impacts on GDP are more than offset by long-term cost-savings. Accordingly, the evidence implies that, in the longer

term, an immediate coordinated transition will be less costly than inaction or disorderly transition.[4]

Going back to a microeconomic perspective, transition risk has to do with the potential impact of the transition to a low-carbon economy on a firm's value. The empirical evidence shows that firms with the lowest exposure to climate transition risk perform better in terms of returns on assets (ROA), returns on equity (ROE), earnings before interest, tax, depreciation and amortization (EBITDA) and Tobin's q ratio (Reboredo and Ugolini, 2022). The study on climate transition risk, profitability and stock prices carried out by Reboredo and Ugolini also shows that firms in the energy sectors – which are the focus of the following chapters – along with those in the materials and utilities sectors exhibit the highest exposure to transition risk in both the European and US markets.

The adjustment towards a greener economy can affect both micro- and macroeconomic variables. However, evidence of those impacts is still scarce, and effects of this transition will manifest only in the long-term.

At the time of writing, there is growing awareness of the fact that unmitigated climate change and a disorderly transition could affect the profitability of several economic activities. Nonetheless, markets' underpricing of transition risks could acerbate the negative impacts discussed so far even further, eroding market value and increasing the volatility of certain assets.

1.2 Stranded assets

The Carbon Tracker Initiative (CTI) (Leaton *et al.*, 2011) more than two decades ago suggested a new way of looking at the carbon emissions problem by focusing on fossil fuels reserves. Accordingly, the CTI stated that the threat of fossil fuels assets becoming stranded could lead to considerable value destruction comparable to the losses resulted from the dot.com boom and the 2008 financial crisis. This hypothesis is known as "carbon bubble."

As meeting decarbonization targets become increasingly urgent, substantial emissions reduction become pressing. The carbon budget – the quantity of cumulative GHG emissions that can still be released in the atmosphere without exceeding a given level of

[4] TCFD, *Recommendations of the Task Force on Climate-related Financial disclosures*, 2017

warming in degrees Celsius – necessary to limit the average global temperature to rise below 2 °C or even further 1.5 °C is directly embedded in the amount of fossil fuels combustion that is permitted (Firdaus and Mori, 2023). The required transition from fossil fuels to low-carbon technologies implicates that a significant portion of reserves must be left in the ground leading to book value losses, operationally unneeded CAPEX, forgone income and underutilization (Daumas, 2024). Simply put, the economy is exposed to stranded asset risk.

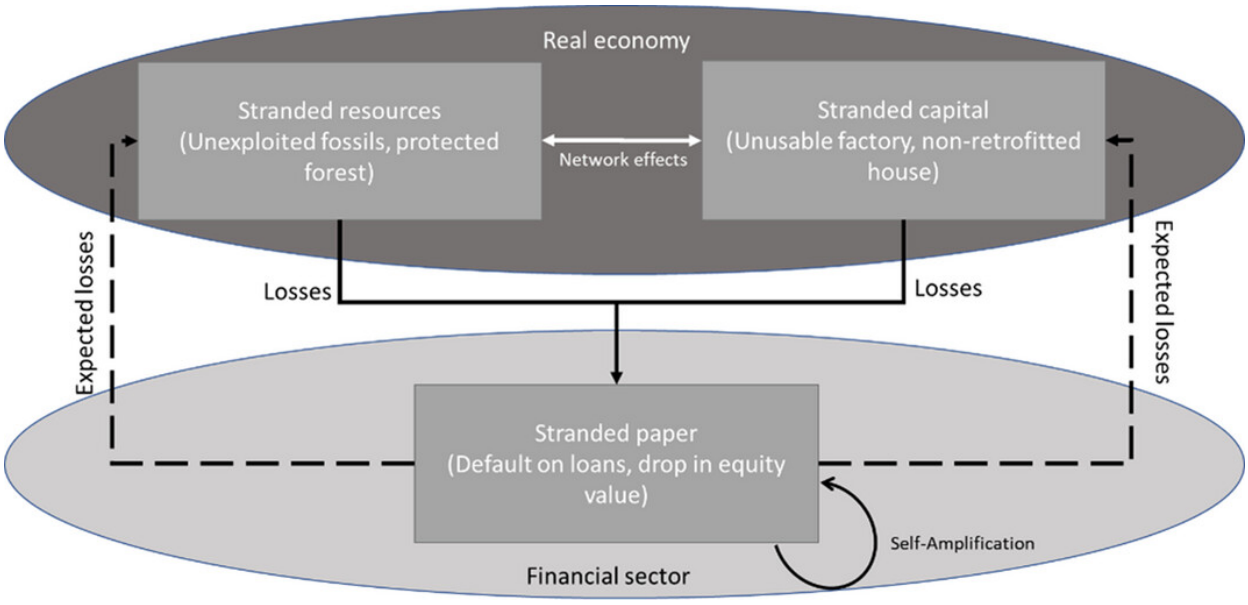
A general definition of stranded asset, budling on past research, is given by Louis Daumas in its critical review of the theoretical and applied literatures:

> Stranded assets in the context of the low-carbon transition are assets whose profit expectations will be drastically reduced compared to when economic agents had first invested in them when the economy decarbonizes. This phenomenon emerges because of costly reallocation or transaction costs preventing these assets to be easily put to other uses or liquidated.

More generally, stranded assets arise from assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities, and they can be caused by a range of environment-related risks.

The literature often associates this phenomenon with premature decommissioning, asset underutilization, or active divestment.

Figure 2 *Stranded assets categories and interactions*



Source: *Financial stability, stranded assets and the low-carbon transition – A critical review of the theoretical and applied literatures, 2024*

Three categories of stranded assets can be defined (see *Figure 2*). Stranded capital refers to production assets that are at risk of losing significant value or becoming obsolete. This typically necessitates costly reconversion or abandonment of these assets. Fossil fuels reserves (such as coal, oil and natural gas) can remain untapped leading to financial losses. These unextracted reserves along with unexploited forests and agricultural lands are referred to as stranded resources. Expected losses stemming from the stranding of resources and capital may yield to default on loans, drop in equity value, devaluations on the asset side of financial companies implying stranded paper. Mutually, expectations of losses in the financial sector due to paper stranding might adversely affect the real economy worsening capital and resource stranding (Daumas, 2024).

Frederick van der Ploeg, on his part, distinguishes four types of asset stranding. First, stranded carbon which is comparable to the abovementioned stranded resources. Second, stranded physical capital narrowly refers to part of the infrastructure and capital invested in the up- and down-stream fossil fuel industry. Third, prices of fossil-fuel-based assets in carbon intensive industries which anticipates industry shuts down and climate policies. Fourth, uncertainty in policy changes and announcements (Ploeg and Rezai, 2020).

Stranded asset risk is significant in the energy sector. Being characterized by sunk investments, long operating lifetimes, systemic path dependency, complementary capital investments, and deep embedding in society; energy systems are threatened by the transition to a low-carbon economy (Firdaus and Mori, 2023). Through a systematic literature review, Fridaus and Mori identified that stranded assets in the energy sector are further categorized into three clusters: stranded asset risk in the upstream energy sector, stranded asset risk in the downstream energy sector, and the implications of stranded asset risk on the energy transition. The first one comprises countries with abundant resources being forces to leave them untapped and fossil-fuels importing countries which conversely will benefit from fostering renewable energy alternatives. The second cluster focuses on the downstream energy sector, highlighting its central role in decarbonization efforts due to its incompatibility with climate targets. Finally, the third cluster integrates the other two, revealing their broader implications and emphasizing the adoption of cleaner technologies as a pivotal issue.

Assets in the fossil fuel industry are at risk of losing market value due to unanticipated advancements in renewable technologies and the intensification of climate policies by

governments committed to the Paris Agreement's goals. The emergence of stranded assets is driven by uncertainties regarding the timing of these technological and policy developments, along with substantial costs related to investment adjustments across various timeframes and sectors.

A disorderly transition to a carbon-free economy will likely yield asset stranding and abrupt market value deviations if two conditions are met: unexpected future changes impacting the viability of fossil fuel assets, and the costly or impractical reallocation of capital stocks to productive uses in other sectors following the energy transition.

The effectiveness of current and future climate policy developments, as well as their impacts – such as the potential devaluation of natural and physical capital – are significantly influenced by the perceived probability and credibility of policy announcements. Indeed, even the Paris Agreement was perceived as "paper promises" resulting in a relative stoic indifference of share prices. Conversely, the rapid development of alternatives to coal, oil, and gas is driving down the cost of carbon-free energy sources, which could eventually render fossil fuels obsolete. Potentially, a technological breakthrough could lead to a sudden decline in market valuation of carbon-intensive industries with some of their assets becoming stranded (Ploeg and Rezai, 2020). The literature also connects asset stranding to broader environmental challenges, including sudden and unexpected shifts in the perception of environmental issues, changes in the natural resource landscape, evolving social norms and consumer behavior, and alterations in statutory interpretations.

Estimating stranded assets risks requires making simplifying assumptions and forecasting possible energy futures based on present expectations, leading to inevitable uncertainties (Hansen, 2022). According to McGlade and Ekins (2015), the cumulative carbon content of proven reserves reported by major fossil fuel companies exceeds the global carbon budget by a factor of 3 to 10-11. Moreover, the IPCC's Special Report on Global Warming forecasts a decline in share of primary energy use relative to 2020 levels of 1-7% for coal, 39-77% for oil and 13-62% for natural gas, across pathways limiting warming to 1.5°C with no or limited overshoot (Masson-Delmotte *et al.*, 2019). This implies that to avoid surpassing the global mean temperature thresholds of 1.5°C or 2°C, a substantial share of fossil-fuels reserves must remain unexploited.

Three studies provide high-level quantitative estimates on asset stranding, offering valuable insight of the potential impact of untapped fossil fuels reserves.

The first study, conducted by Christophe McGlade and Paul Ekins, examines the implication of the emissions limit for fossil fuel production in different regions. The research uses a single integrated assessment model (IAM) that contains the estimates of the quantities, locations and nature of the world's oil, gas and coal reserves and resources. The research results indicate that policymakers' inclination to rapidly and fully exploit their territorial fossil fuels is, overall, incompatible with their commitments to maintaining this temperature limit.

The second study, published by Welsby *et. al.*, extends the aforementioned work to estimate the levels of unextractable fossil fuel reserves out to 2100 under a 1.5 °C scenario (50% probability), using a 2018–2100 carbon budget of 580 $GtCO_2$. To achieve this, a global energy systems model is applied to assess the amount of fossil fuels that would need to be left in the ground both regionally and globally. The findings suggest that nearly 60 per cent of oil and fossil methane gas, and 90 per cent of coal must remain unextracted. This represents a significant increase in the estimates of unextractable reserves and implies that most regions must reach peak production at the least within the next decade.

Table 2 *Levels of unextractable fossil fuel reserves*

	McGlade and Ekins (2 °C)			***Welsby et. Al. (1,5 °C)***		
Country or region	*Oil*	*Gas*	*Coal*	*Oil*	*Gas*	*Coal*
Africa	26%	34%	90%	51%	49%	86%
Canada	75%	24%	82%	83%	56%	83%
China and India	25%	53%	77%	47%	29%	76%
FSU	19%	59%	97%	38%	63%	97%
CSA	42%	56%	73%	73%	67%	84%
Europe	21%	6%	89%	72%	43%	90%
Middle East	38%	61%	99%	62%	64%	100%
OECD Pacific	46%	51%	95%	40%	29%	95%
ODA	12%	22%	60%	36%	32%	42%
USA	9%	6%	95%	26%	24%	97%
Global	**35%**	**52%**	**88%**	**58%**	**56%**	**89%**

Adapted from McGalde and Ekins (2015) and Welsby et al. (2021)

The third study, from T.A. Hansen, focuses on wealth losses from stranded assets for the upstream fossil fuel industry by estimating their magnitude and distribution. This study integrates methods and data that emulate the valuation procedures and expectations used by fossil fuels firms and IEA's 2019 World Energy Outlook scenarios projections. The results point to strategic demand reduction of fossil fuels as a key strategy for overcoming industry resistance to climate stabilization as they show that fossil fuel reserves will suffer a devaluation of 37%–50%, amounting to $13-$17 trillion. The magnitude of wealth losses is disaggregated into two effects: price and carbon budget. The analysis shows a significant predominance of the price effect over the carbon budget effect. Consequently, the main drawback for the industry arises from price decreases for fossil fuels that are still extracted and sold during the period of climate stabilization. This price effect underscores the importance of strategic demand reduction in weakening the industry's economic and political power. While policies aimed at cutting supply can be pivotal in fostering the green transition, the ultimate goal remains to reduce society's dependency on fossil fuels through demand reduction (Hansen, 2022).

The assessment of stranded asset risks underscores the critical need for a strategic approach to fossil fuel dependency and climate policy. The combined insights from these studies underscore the critical need for a calculated shift in energy policies and investments, emphasizing the importance of transitioning to sustainable energy sources to mitigate the economic risks associated with stranded fossil fuel assets. The potential economic impacts and the necessity for leaving fossil fuel reserves unexploited pose a significant threat to the industry and the broader economy. However, these measures are essential for meeting global temperature targets. To further understand these implications, the next chapters will focus on the energy sector, with a particular emphasis on Europe, analyzing its exposure to stranded assets and the potential economic ramifications.

2 Energy sector

2.1 Overview

The global energy sector comprehends all industries and activities involved in the production, distribution, and consumption of energy, making it crucial in supporting the global economy.

The complexity of the energy sector arises from its diverse energy sources, technological variability, regulatory and policy frameworks, and volatile economic factors. It is an intricate and dynamic field that requires high-level management and policymaking to effectively navigate its challenges and exploit its opportunities.

Current economic, geopolitical, trade, policy, and financial factors, combined with environmental concerns, have further complicated the delicate balance within the sector. A significant concept gaining traction in industry literature and among practitioners is the "energy trilemma," which addresses three often conflicting challenges: energy security, equitable access to energy, and environmental sustainability. Balancing these components is deemed crucial for achieving decarbonization, decentralization, and digitalization (Liu *et al.*, 2022).

High commodity prices and growing concerns over energy security are creating urgency to diversify supply and accelerate the energy transition, leading to a radical transformation of the energy sector (Deloitte, 2023). Nonetheless, uncertainties remain about the resilience of energy supply chains and whether the process of change will be sufficiently rapid to avoid very severe impacts from a changing climate (International Energy Agency, 2023).

A multifaceted crisis demands solutions that are similarly all-encompassing. Consequently, new energy and industrial policy frameworks are emerging as countries compete for strongholds in the emerging clean energy economy, driven by concern about energy security and resilience.[5]

As the World Energy Outlook (2023) underlines, global energy demands rose by 1.3% in 2022, reflecting the unavoidable dynamics of the energy system: an expanding global economy and population inherently require more energy services. Therefore, modeling

[5] IEA, *World Energy Outlook*, 2023

the future pathways of the sector should begin with an analysis of the global energy demand.

Global total energy demand is projected to uphold its upward slope from 2030 to 2050, driven by growth in emerging economies offsetting declines in advanced markets. However, most Integrated Assessment Models (IAMs) and projected scenarios anticipate substantial changes in the shares of energy supply and demand shaped by the urgency of energy security and sustainability matters.

Transition outlooks and future pathways are heavily influenced by the goals of the Paris Agreement, with many scenarios offering alternatives based on varying carbon budgets or degrees of warming. Achieving the preset targets for GHG emissions and limiting average temperature rise leaves little time for adjustment and demands an exact configuration of supply and demand by fuel in the energy sector. This new configuration has yet to fully manifest but will have significant implications for all stakeholders involved.

The scenarios examined in the following analysis, cover a wide range of potential outcomes, influenced by diverse underlying assumptions. These varying assumptions lead to distinct trajectories and implications for the energy sector, with relevant consequences in the future outlooks of fossil fuels.

The International Energy Agency (IEA) in its "Net Zero by 2050 – A Roadmap for the Global Energy Sector" presents the Net-Zero Emissions by 2050 Scenario (NZE), which outlines the necessary developments for the global achievement of the Net-Zero pledge.

Accordingly, despite significant increases in the global population and economy, total energy supply falls to 550 exajoules (EJ) in 2030, 7% lower than in 2020.[6] By 2050, significant changes in the energy mix are anticipated. The NZE scenario predicts a substantial reduction in fossil fuel use, dropping from 80% in 2020 to just over 20% in 2050. Conversely, renewable energy is expected to account for two-thirds of energy use, and nuclear power supply is projected to nearly double (International Energy Agency, 2021). On its part, total final energy consumption (TFC) falls to 340 EJ between 2025 and 2050, marginally rebounding from its drop in 2020 but never returning to 2019 levels.

[6] IEA, *Net Zero by 2050 - A Roadmap for the Global Energy Sector*, 2021

Total final energy consumption (TFC) is currently 442 exajoules (EJ).[7] In a 2023 report, the World Energy Outlook (WEO) presents three plausible developments for TFC, depending on the scenario considered:

- Stated Policies Scenario (STEPS): Based on the latest policy settings, including energy, climate, and related industrial policies, this scenario projects a 1.1% per year increase in TFC until 2030, followed by a slower growth rate through 2050.
- Announced Pledges Scenario (APS): Assumes that all energy and climate targets are met in full and on time, leading to a gradual decline in TFC starting from the mid-2020s.
- Net Zero Emissions (NZE) Scenario: Aims to limit global warming to 1.5°C, resulting in an average annual decline in TFC of 0.9%.

In line with the IEA findings, each WEO scenario indicates that demand for coal, oil, and natural gas will peak by 2030 at the latest. The dominance of fossil fuels is projected to decline due to rapid growth in renewables and nuclear energy, decreasing by 73% in the STEPS, 69% in the APS, and 62% in the NZE scenario (International Energy Agency, 2023).

Similar findings are presented in the 2023 McKinsey "Global Energy Perspective." These scenarios, modeled as part of McKinsey's Climate Math effort, forecast sharp declines in fossil fuel demand, projected to peak by 2030.

Additionally, the International Renewable Energy Agency (IRENA) outlines new outlooks for both total final energy consumption and total primary energy supply under a 1.5°C Scenario. Accordingly, renewable energy is expected to grow from 18% of TFC in 2020 to 82% by 2050, and from 16% of total primary energy supply in 2020 to 77% by 2050 (International Renewable Energy Agency, 2023).

Energy investments are crucial for reaching any of the abovementioned pathways. The “World Energy Transition Outlook” published in 2023 by the IRENA stresses the pivotal role of investments in driving the transition.

IRENA presents two set of assumptions leading to two different scenarios. Under these assumptions, a concomitant rise in capital spending would require an additional USD 47 trillion, for a total of USD 150 trillion in the 1.5° Scenario, compared with the USD 103

[7] IEA, *World Energy Outlook*, 2023

trillion under the Planned Energy Scenario.[8] Even though global investments across all transition technologies reach record high in 2022, annual investments would need to more than quadruple to stay on the 1.5° pathway (International Renewable Energy Agency, 2023).

McKinsey projections, on the other hand, indicate that by 2040, approximately 20-40% of investments will still be allocated to fossil fuels to meet demand and balance the energy system. However, a gradual yet sustained shift towards green technologies is expected, with investments in these areas growing from 20% to approximately 40-50% of total investments by 2040 (McKinsey & Company, 2023).

Energy investments are critically important in each of the IEA's scenarios. Overall, the total increase in investment is larger in the APS and NZE scenarios, with shares increasing to 40% and 80%, respectively, by 2030. Differences exist between advanced and developing economies, with the latter showing a five-fold increase in investment by 2030 in the NZE scenario compared to today's levels (International Energy Agency, 2023).

Achieving the abovementioned changes will require a major reallocation of capital and reconfiguration of the global financial infrastructure.[9] Effective channeling of funds, especially in emerging markets and developing economies, will demand significant effort and coordination among governments, financial institutions, private investors, and international organizations. The transformation of the energy sector will require systemic changes, policy reforms, and a firm commitment to build a resilient and inclusive financial system that can drive global sustainability goals.

2.2 Fossil fuels

In recent years, fossil fuels technologies are losing market share to clean energy technology across various sectors, and in many cases fossil fuel-powered technologies have already seen a peak in sales or additions (International Energy Agency, 2023).

The International Institute for Sustainable Development (IISD), in its 2022 report compares multiple scenarios in line with the 1.5°C target, showing how oil and gas production needs to decline following each set of assumptions.

[8] IRENA, *World Energy Transition Outlook*, 2023

[9] IEA, *World Energy Outlook*, 2023

Table 3 highlights the pace of phase-out required according to the scenario analysis conducted by IISD. Despite minor differences across scenarios and timeframes, the findings consistently indicate the need to prevent explorations and development of any new oil and gas fields, and to ensure an orderly and managed phase-out of fossil fuel production.[10] Given the urgency of this phase-out, energy investments and regulatory measures should aim to facilitate the transition while mitigating the increased risk of stranded assets that companies are facing.

Table 3 *Oil and gas phase-out*

		2030	*2040*	*2050*
IPCC median	Oil	29%	57%	78%
	Gas	29%	42%	42%
IEA NZE	Oil	21%	54%	76%
	Gas	6%	45%	56%
IPCC IMP-Ren	Oil	3%	47%	77%
	Gas	33%	58%	78%
IPCC IMP-LD	Oil	47%	75%	90%
	Gas	47%	75%	85%
IRENA	Oil	37%	-	86%
	Gas	22%	-	48%
OECM	Oil	31%	89%	98%
	Gas	14%	54%	100%
BNEF	Oil	1%	56%	83%
	Gas	7%	56%	85%
DNV	Oil	12%	44%	74%
	Gas	12%	39%	69%
Navigant	Oil	24%	95%	91%
	Gas	36%	75%	85%
BP	Oil	6%	44%	76%
	Gas	0%	30%	55%

Source: *Navigating Energy Transitions, 2022*

[10] IISD, *Navigating Energy Transitions*, 2022

Focusing on the scenarios analyzed in the previous paragraph, coherently with IISD analysis, significant reductions are mandated for the production of each fossil fuels.

The World Energy Outlook, highlights several changes in demand and supply trends (International Energy Agency, 2023):

- STEPS: oil demand reaches its peak in the late 2020s, declining to 97 million barrels per day (mb/d) in 2050. Natural gas demand peaks by 2030, with a gradual decline of approximately 100 billion cubic meters (bcm) by 2050. Global coal demand and supply also decline gradually.
- APS: oil demand undergoes a pronounced decline, reaching 55 mb/d in 2050, while existing sources of supply fall at a faster rate. Natural gas demand peaks sooner than the STEPS one, being 7% lower by 2030 than 2022 levels. Global coal demand and supply drop 75% below current levels by 2050.
- NZE Scenario: oil demand falls to just under 25 mb/d in 2050, with production decreasing across all regions by 2030. Natural gas demand is projected to fall by more than 2% a year from 2022 to 2030 and by nearly 8% a year between 2030 and 2040, accompanied with a sharp decline in global production. Global coal demand and supply are expected to decrease by 90% and 85%, respectively, by 2050.

Significant divergences persist between advanced economies and emerging markets across all scenarios. While coal demand peaked in 2007 for developed countries, it continues to rise in developing economies. Additionally, evidence suggests that by the end of this decade, transportation will no longer drive oil demand growth, with oil demand in advanced economies having peaked in 2005. The so-called "Golden Age of Gas" also appears to be nearing its conclusion (International Energy Agency, 2023).

The IISD conducted a comprehensive analysis of various energy scenarios, revealing consistent trends across different models. Its findings indicate that oil and gas production must decrease by at least 65% by 2050 to align with sustainable energy goals. (International Institute for Sustainable Development, 2022). Similarly, McKinsey's "Global Energy Perspective" forecasts a significant reduction in coal demand, showing a decrease of almost 25% to 85% between 2019 and 2050, primarily due to the phase-out of coal plants across regions. Conversely, the outlook for oil and gas appears less stringent, with increasing natural gas demand projected until 2040 and a lower percentage decline in oil demand, highlighting a volatile and uncertain future for the sector.

The findings discussed underscore significant shifts in global energy demand and production, presenting both risks and opportunities for the economy, particularly for all stakeholders in the energy sector. The mandated reductions in fossil fuel production and the rise of renewable energy sources highlight the urgent need for oil and gas companies to adapt to an evolving energy landscape.

The following paragraph offers an in-depth analysis of the risks and opportunities facing oil and gas companies. The purpose of this analysis is to explore how the energy sector and the broader economy can successfully navigate the transition, turning this century's challenges into opportunities for business growth and societal advancement.

2.3 Risks and opportunities

The global energy market, a major contributor to greenhouse gas emissions, is experiencing a significant transformation as fossil fuels gradually lose market share due to the pressing need to meet the Paris Agreement targets. With nations worldwide pledging to cut GHG emissions and keep global warming well below 2 degrees Celsius, the demand for cleaner and renewable energy sources is rapidly increasing.
This transition poses considerable challenges and promising opportunities for the oil and gas industry, mandating a strategic and flexible approach to adapt to the changing energy landscape.

The diverse range of challenges faced by oil and gas companies is thoroughly examined in “The Energy Transition: Navigating the Shift Towards Renewables in the Oil and Gas Industry” by Ekrem Alagoz and Yaser Alghawi. They identify two major clusters of potential threats to the industry's stability: the increasing competition from renewable energy sources and the declining demand for fossil fuels. As renewable technologies become more accessible and cost-effective, they are gaining significant market share, accounting for over 70% of new power capacity additions in 2020 (Alagoz and Alghawi, 2023). Moreover, the sector's substantial environmental impact and its crucial role in the global economy have made it a focal point for policymakers and stakeholders

worldwide.[11] This growing awareness and sensitivity to climate change issues are driving consumers demand towards low-carbon energy options, thus narrowing the window for fossil fuel production.

Consequently, traditional oil and gas business models must undergo strategic changes to thrive in this evolving and pressured scenario. Nonetheless, Kienzler *et al.* (2023), argue that the industry's global scale, risk appetite, large balance sheet and long-standing relationships with energy customers and stakeholders make up for a promising outlook for oil and gas companies and their role in the energy transition.

Evidence shows that capital markets place higher value on firms structurally aligned with the energy transition. According to McKinsey's research (Kienzler *et al.*, 2023), major oil and gas companies realize this upside only when more than 40% of their total portfolios are low carbon. In addition to customer centricity, new energy management or risk exposure practices, and capital excellence and project capabilities, portfolio diversification (both geographic and financial)[12] will have the largest impact on risk exposure for oil and gas players entering new energy markets, with an observed rate of return improvement of 1.0 to 1.5 percentage points.[13]

"The Energy Transition: Navigating the Shift Towards Renewables in the Oil and Gas Industry" outlines three key strategies for industry players. Firstly, diversifying into renewable energy sources and low-carbon technologies can unlock new opportunities for growth and revenue generation while mitigating risks inherent in the traditional energy sector. This diversification is essential for maintaining competitive advantage as global energy demands evolve. Second, collaboration with other stakeholders, such as governments, technology firms, and academic institutions, is crucial. These partnerships facilitate the sharing of knowledge and expertise, fostering innovation and enabling the development of integrated solutions. Collaborative efforts can accelerate the adoption of renewable energy technologies and support a smoother transition. Finally, investing in research and development (R&D) is fundamental to overcoming technological barriers that hinder the widespread adoption of renewables. By prioritizing R&D, oil and gas

[11] ALAGOZ and ALGHAWI, *The Energy Transition: Navigating the Shift Towards Renewables in the Oil and Gas Industry*, 2023

[12] Geographic portfolio diversification refers to the practice of spreading investments across different regions or countries. Financial portfolio diversification involves spreading investments across various asset classes, sectors, and financial instruments to minimize risk and enhance the potential for stable returns.

[13] KIENZLER et. al., *How oil and gas companies can be successful in renewable power*, 2023

companies can develop cutting-edge technologies, position themselves as leaders in the energy transition, and set industry standards that align with future energy needs.
In exploring the solutions that oil and gas companies can adopt, McKinsey's report, "How Oil and Gas Companies Can Be Successful in Renewable Power," highlights that industry players can offer distinct value propositions in four areas of the transition:

- Offshore project development.
- Hydrogen production and transportation.
- EV charging.
- Decarbonization solutions.

When making these strategic choices, oil and gas companies must carefully consider the timing of investments, the relevant value chains and segments, and the appropriate operating models for their businesses.[14]

All the above strategies must consider the current state of a low-trust world. Geopolitics and energy have been deeply intertwined throughout the fossil fuel era, and recent crises have highlighted how geopolitical events can significantly impact the energy sector.[15] Following Russia's invasion of Ukraine, heightened tensions in the Middle East underscore the persistent risks to oil and gas supplies. In this low-trust environment, there may be a shift in favor of domestic available resources, which could present opportunities for clean energy while potentially prolonging coal's role in the energy mix (International Energy Agency, 2023). The delicate balance between importing and exporting countries is vulnerable to geopolitical disruptions, which could lead to significant consequences for both the energy sector and the broader economy. Therefore, the outlook for oil, gas, and coal depends not only on the transition pathways previously analyzed but also on political considerations and international relations.
Considering these challenges, oil and gas companies must remain flexible and responsive to both geopolitical and market changes. By incorporating geopolitical analysis into their strategic planning, industry players can better anticipate disruptions, manage risks, and capture emerging opportunities within the energy transition and the evolving global landscape.

[14] KIENZLER et. al., *How oil and gas companies can be successful in renewable power*, 2023
[15] IEA, *World Energy Outlook*, 2023

3 The Role of European Regulation in Driving the Energy Transition

The energy transition is one of the most significant challenges and opportunities of the 21st century. In this context, European regulation plays a pivotal role in guiding the transformation of the energy sector. This chapter examines how regulatory frameworks established by the European Union are driving the energy transition, responding to market trends and accelerating the shift toward a cleaner, more sustainable economic landscape.

The EU has positioned itself at the forefront of global efforts to combat climate change with a comprehensive set of legislative measures, including the Renewable Energy Directive (RED II), the Sustainable Finance Disclosure Regulation (SFDR) and the European Green Deal. The objectives established by this set of policy frameworks focus on reducing GHG emissions, enhancing energy efficiency and increasing the share of renewable energy in the overall European's overall energy mix. By setting clear targets and pathways for members states, these regulations ensure a coordinated approach to energy transition.

A crucial aspect of this developing regulatory landscape is its impact on well-established European industries. As the commitment to a low-carbon economy intensifies, fossil-fuel companies face increasing pressure from both transition and stranded assets risks. Carbon-intensive activities and assets will gradually lose their market dominance, facing significant devaluation, especially in sectors such as coal, oil and gas. Many financial institutions have indeed warned that the transition to a low-carbon economy could cause a major shock to fossil fuel valuation (Beyene, Delis and Ongena, 2022). The growing awareness of the economy's exposure to these financial risks is pressing companies and investors to reassess their portfolios and strategies, with a focus on sustainable and resilient energy investments.

3.1 Historical development of EU Energy Regulation

In response to the energy crisis, the European Union raised its clean energy ambitions, with almost USD 500 billion in enacted funding for clear energy investments (International Energy Agency, 2023). However, the EU's commitment to a low-carbon transition began almost 30 years ago, in the early 1990s, with significant policy developments accelerating in the 2000s and 2010s.

A pivotal moment in the advancing of EU's energy transition efforts was the endorsement by the Presidency of the European Council of the European Economic Recovery Plan. This initiative introduced the "20-20-20" targets: a 20% reduction in greenhouse gas emissions, a 20% increase in renewable energy, and a 20% improvement in energy efficiency by 2020, all compared to 1990 levels (European Council, 2008).
Another major regulatory milestone for the development of the current European framework was the publication in 2011 of the "Energy Roadmap 2050" by the European Commission. Highlighting the fact that the well-being of people, industry and economy depends on safe, secure, sustainable and affordable energy the Commission emphasized that the energy system at the time was unsustainable in how it produced, transformed, and consumed energy.[16] The publication general objective was to shape a vision and strategy of how the EU energy system can be decarbonized by 2050 putting forward an ambitious goal: the achievement of 80% domestic GHG reduction below 1990 in 2050 to limit global climate change to a temperature increase of 2° C compared to pre-industrial levels (European Commission, 2011).
These set of EU's long-term strategies were further solidified in 2015 with the adoption of the Paris Agreement, a landmark legally binding international treaty on climate change.

These strategic initiatives laid the foundation for the development of key regulatory frameworks that have since guided the EU's transition to a low-carbon economy. The following section will explore these frameworks in detail, examining their role in implementing the EU's energy goals and their impact on the energy landscape.

3.2 Key regulatory frameworks

The European Union has developed a comprehensive set of regulatory frameworks to translate its ambitious energy transition goals into actionable policies. Central to these efforts are key directives and mechanisms that address various aspects of the energy sector, ensuring a holistic approach to reducing emissions and increasing sustainability.

In 1991, Germany introduced the first feed-in-tarif for renewables, which initiated a legislative process that ultimately led to the enactment of the revised Renewable Energy

[16] EUROPEAN COMMISSION, *Energy Roadmap 2050*, 2011

Directive in 2023. The Renewable Energy Directive is the legal framework for the development of clean energy across all sectors of the EU economy. Since its introduction, the share of renewable sources in the Union's energy consumption has increased from 12.5% in 2010 to 23% in 2022 (European Commission, 2024). The directive, which requires an 18-month period to transpose into national law, sets an overall renewable energy target of at least 42.5% binding at EU level by 2030, but aiming for 45%.[17] The revised directive's increased target was deemed necessary following Russia's invasion of Ukraine, which highlighted the EU's urgent need to reduce dependency on fossil fuels given the current geopolitical landscape.

The 2023 Energy Efficiency Directive is a significant regulation that has had a profound impact on the European energy sector since its initial draft in 2012. The directive established a common framework of measures to promote energy efficiency within the Union boarders (Official Journal of the European Union, 2023). In doing so, it lays down rules designed to implement energy efficiency as a priority across all sectors, remove barriers in energy market and overcome market failures.[18] By eliminating energy waste, energy efficiency helps reduce overall energy consumption and is therefore central to achieving the EU's climate ambition (European Commission, 2024).

To combat the risk of "carbon leakage" – where companies based in the EU moving carbon-intensive production abroad to take advantage of laxer standards, or EU products being replaced by more carbon-intensive imports – the EU's Carbon Border Adjustment Mechanism (CBAM) was introduced in its transitional phase. The CBAM aims to assign a fair price to the carbon emitted during the production of carbon-intensive goods entering the EU (European Commission, 2024). With the definitive regime set to take effect in 2026, the CBAM will phase out the allocation of free allowances under the EU Emission Trading System, with the objective of decarbonizing the EU industry.[19] Consequently, EU importers will be required to declare the emissions embedded in their imports and surrender the corresponding number of certificates each year. The Carbon Broader

[17] EUROPEAN COMMISSION, *Renewable Energy Directive: targets and rules*, August 2024, https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en.
[18] EUROPEAN COMMISSION, Energy Roadmap 2050, 2011
[19] EUROPEAN COMMISSION, *Carbon Boarder Adjustment Mechanism*, August 2024, https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

Adjustment Mechanism is designed to support EU and global climate efforts by reducing global carbon emissions and advancing the goals of the Paris Agreement, while also creating incentives for emission reductions by operators in third countries.

These regulatory frameworks, while essential for achieving the EU's climate goals, pose significant challenges for European oil and gas companies. As the Renewable Energy Directive accelerates the shift towards renewable sources, and the Energy Efficiency Directive reduces overall energy demand, traditional fossil fuel-based companies face increasing pressure to decarbonize their operations or risk becoming obsolete. Additionally, the implementation of the CBAM will directly impact the competitiveness of European oil and gas firms by imposing stricter carbon costs on imports and potentially increasing operational expenses as they transition to lower-carbon technologies. Collectively, these regulations are driving the oil and gas sector to innovate and invest in cleaner alternatives, reshaping the industry's landscape in Europe and pushing it toward a more sustainable future.

3.3 Recent regulatory initiatives

The European regulatory framework for the energy sector and emissions reduction has been significantly enhanced by recent initiatives that adopt a more comprehensive approach to sustainability and economic development. These new regulations are poised to transform the ways in which industries, investors, governments, and society address the pressing challenges of climate change. By driving the European economic system toward a low-carbon and sustainable future, these initiatives play a crucial role in ensuring long-term environmental and economic resilience.

As a cornerstone of the EU's sustainable finance framework, the 2020 EU Taxonomy for sustainable activities has become a vital tool for enhancing market transparency (European Commission, 2024). The regulation establishes the criteria for determining whether an economic activity qualifies as environmentally sustainable for the purpose of establishing the degree to which an investment is environmentally sustainable.[20] The Taxonomy, with its detailed technical screening criteria, acts as a benchmark for market

[20] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088

participants, requiring companies to evaluate their activities against these standards to attract green investments and align with sustainability objectives. Additionally, by imposing disclosure requirements, the regulation mandates the assessment of both non-financial metrics (turnover, operating expenses, and capital expenditures) and financial metrics (Green Asset Ratio and Green Investment Ratio). This approach indirectly shapes the financial and industrial landscape by channeling investments toward sustainable projects and activities.

The Sustainable Finance Disclosure Regulation (SFDR) represents another significant foundation of European sustainable legislative process. As it shifts how banks, insurance companies, and investment funds report on sustainability, the regulation effectively pressures businesses seeking access to capital to continuously report and update their ESG metrics.
Under the SFDR, the environmental performance of banks will directly reflect the environmental performance of their entire investment portfolios. This regulation will become a critical and influential framework for firms, not by directly targeting them, but by affecting their access to capital. When firms seek financing, they will encounter requirements from capital providers to disclose their environmental impact. Consequently, firms will be incentivized to improve their environmental performance, as banks and other financial institutions will likely discontinue relationships with firms that do not meet ESG standards. Thus, banks will become indirect influencers of environmental practices within firms, redirecting capital flows toward more sustainable outcomes. This regulation marks a significant shift toward sustainable finance in the EU, influencing the behavior of financial market participants. As key players in the energy sector and major contributors to GHG emissions, oil and gas companies must be aware of these changes and adapt to meet the evolving expectations of investors who are increasingly focused on sustainability.

As the implementation framework for the European Green Deal, the "Fit for 55" package transforms the EU's climate goal of reducing emissions by at least 55% by 2030 into a binding legal obligation (European Council, 2024). This comprehensive policy is supported by key legislative frameworks, including the Renewable Energy Directive, the Energy Efficiency Directive, and the Carbon Border Adjustment Mechanism (International

Energy Agency, 2023). The "Fit for 55" package introduces a range of measures designed to strengthen carbon pricing, encourage the use of renewable energy, and improve energy efficiency across the European Union. Beyond aiming for a 55% reduction in net greenhouse gas emissions by 2030, the package of proposals also aims at providing a just and socially fair transition, strengthening innovation and competitiveness and underpinning EU's position as a leader in the global fight against climate change.[21]

Together, these regulatory initiatives form a cohesive and ambitious strategy to guide the European Union towards a sustainable and resilient future.
The combination of strict environmental standards and financial incentives foster an economic environment where sustainability becomes a key driver of growth and competitiveness. The ongoing implementation of these innovative regulatory frameworks is expected to drive innovation, enhance transparency, and reshape industry with the overall objective of aligning with global sustainability goals.
This proves to be particularly relevant for the oil and gas sector, which plays a crucial role in the energy industry and face substantial pressure to adapt.
The next chapter will explore how European oil and gas company are responding to these regulations, analyzing how they position themselves in the changing industry and economic landscape. The focus will be on how these companies are transforming their business model to thrive and be competitive in the energy transition.

[21] EUROPEAN COUNCIL, *Fit for 55*, August 2024, https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/

4 Data analysis

In this chapter, the strategies of European oil and gas companies in response to the energy transition will be analyzed. The goal is to provide insights into how the industry is adapting and developing within the evolving sustainability landscape.

First, a high-level analysis will focus on GHG emissions, energy intensity (the quantity of energy required per unit of output or activity), and GHG emissions intensity (the level of GHG emissions per unit of economic activity). Thereafter, narrowing the perspective, the chapter will touch upon the reasons behind changes in these metrics, exploring how companies' strategies are shaping their sustainable footprint. This second layer of analysis will examine companies' revenue structure, fossil fuel reserves and production, alignment with the EU Taxonomy and overall strategies for the energy transition.

The analysis relies on a combination of sources. Companies' annual and sustainability reports provide detailed financial and operational data including information on strategic initiatives. The Bloomberg Terminal offers comprehensive financial and sustainability data, including financial performance and comparable environmental impact metrics.

The collected data is analyzed using both qualitative and quantitative methods. This includes comparative analysis to identify patterns and trends across the selected companies. By focusing on the oil-gas-coal industry, a subset of 10 European companies have been selected to provide a in depth analysis of how these entities are navigating the changing European regulatory framework and hedging against transition and stranded asset risks.

Table 4 *Companies sampled*

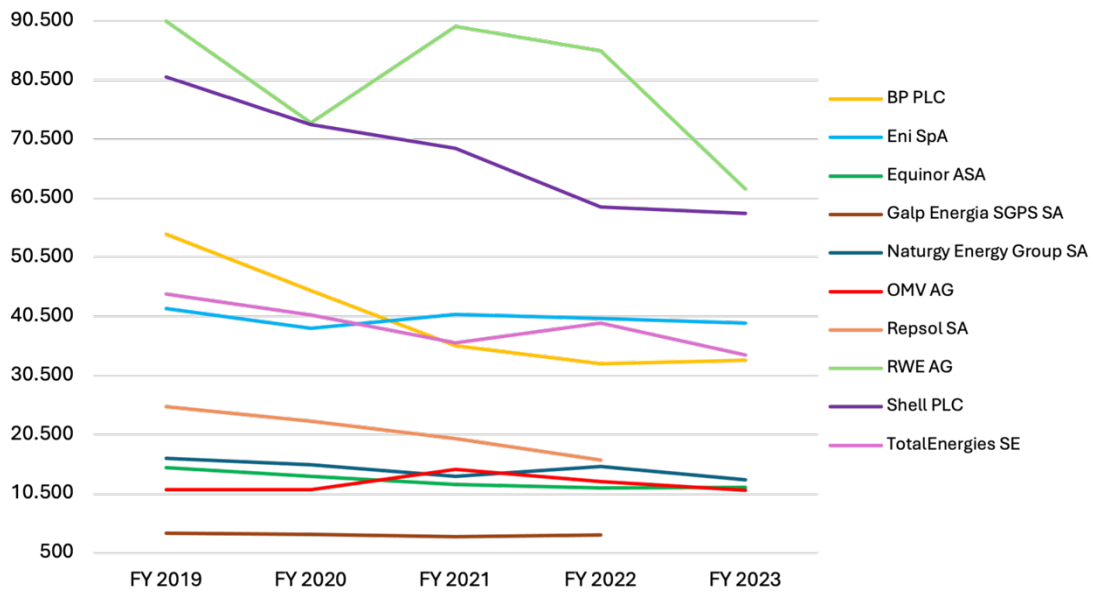
	Market Cap		***Enterprise Value***	
Company	*Current/LTM*	*2022*	*2023*	*Current/LTM*
BP PLC	90.462,60	144.148,20	144.352,30	135.506,00
Eni SpA	46.160,20	58.304,90	66.850,50	65.950,70
Equinor ASA	72.937,60	97.317,10	85.145,30	69.973,20
Galp Energia SGPS SA	14.572,60	14.031,60	14.400,90	17.930,60
Naturgy Energy Group SA	21.486,60	37.859,30	40.503,60	35.391,60
OMV AG	12.384,00	27.388,10	24.647,00	24.994,00
Repsol SA	15.400,10	26.963,80	24.700,00	25.409,10
RWE AG	23.438,40	30.999,00	34.589,40	32.151,40
Shell PLC	217.567,20	241.953,10	257.626,20	256.670,20
TotalEnergies SE	157.969,00	173.138,70	175.908,90	191.195,70

Adapted from Bloomberg

4.1 High-level analysis

Greenhouse gas emissions, along with energy and GHG intensity, are key measures in the legislative efforts to combat climate change. Lower levels of these intensities indicate higher efficiency, meaning less GHG emissions are produced, or energy is required for each economic activity or unit of output. Companies with high GHG and energy intensity might face stricter regulations, carbon taxes, higher operational costs or pressures from stakeholders to reduce their emissions. Thus, these metrics serve as primary indicators of a company's position in the energy transition.

Graph 1 *Total GHG emissions*



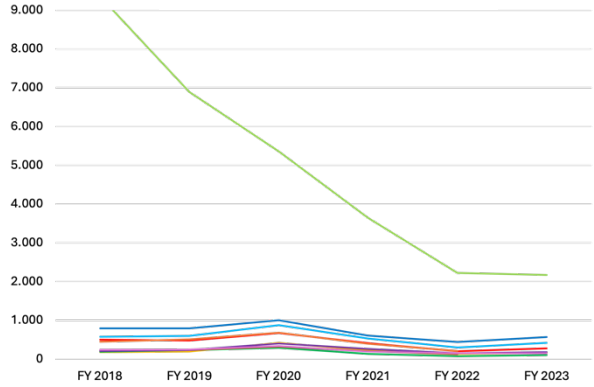
Adapted from Bloomberg

Graph 1 illustrates the total GHG emissions for the selected subset of EU companies over the past 5 years. The measure, as computed in Bloomberg's analysis, focuses on Scope 1 and Scope 2 emissions, with Scope 1 being the more significant contributor of the two. While the trend shows only a modest decline in emissions, three different clusters can be identified. First, high-emitting companies such as RWE AG and Shell PC both stand out for emitting around 60000 metric tons (mt) in 2023. The second cluster includes Eni SpA, TotalEnergies SE and BP PLC emitting ranging between 30500 and 40500 mt. Finally, the lower emitting companies positioning themselves between 20000 and 500 mt.

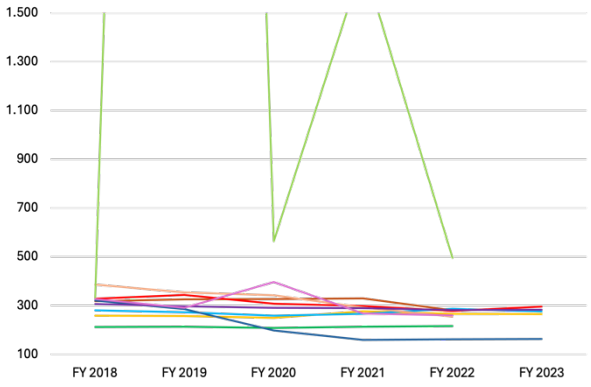
Remarkably, higher emitting companies have shown the most significant drop in emissions, possibly indicating a greater pressure from regulators and stakeholders to reduce their carbon footprint. However, total GHG emissions alone are not sufficient to understand a company's sustainability progress; variations in this level may highlight different approaches and strategies depending also on each company's business model.

A more granular analysis can be carried out by focusing on GHG intensities. Bloomberg's financial analysis provides for four types of distinct intensity metrics relevant to the companies under scrutiny: GHG intensity per sales, per assets, per barrel of oil equivalent (BOE) and per energy. These metrics provide a detailed view of how companies manage their carbon footprint.

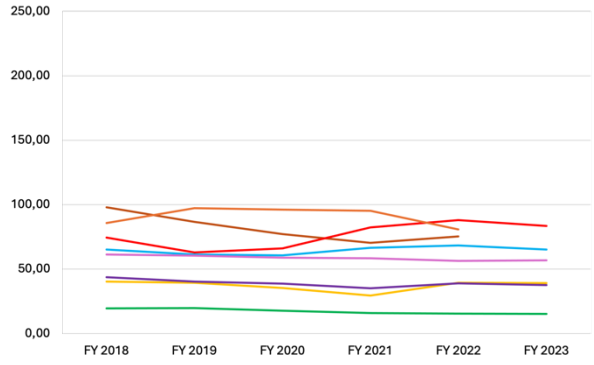
Graph 2 *GHG Intensity per Sales*



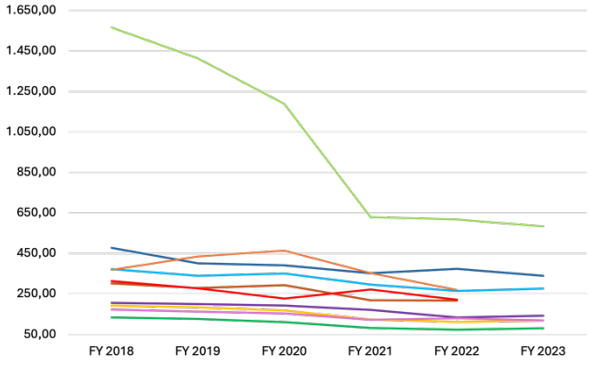
Graph 3 *GHG Intensity per Energy*



Graph 4 *GHG Intensity per BOE*



Graph 5 *GHG Intensity per Assets*



Adapted from Bloomberg

Overall, when comparing the four different metrics it is evident that most of companies' intensity levels are distributed within narrow ranges and follow similar pathways across each measure. On the other hand, RWE AG showcases significantly higher and more

variable intensity data, coherently it is the company with the higher level of total GHG emissions.

GHG intensity per sales measures the amount of greenhouse gas emissions produced per unit of revenue, it indicates how efficiently a company generates revenue relative to its carbon emissions. Except for RWE AG, the other companies in the sample show different levels but nearly identical trajectories, with a peak in 2020 and a slight increase in 2023 from the lowest levels of 2022. The 2020 peak is likely due to the impact of the COVID-19 pandemic. Indeed, the resulting economic disruption caused a significant decline in demand for many goods and services leading to reduced sales revenue for many companies. Nonetheless, many companies in the oil and gas industry continued to produce at similar levels, with fixed emissions that were not easily scalable tied to their operations.

Focusing on GHG intensity per unit of energy, although there is variation among different companies' values over the years, the overall trend shows declining or stable values for all entities. Notably, RWE AG displays a significant decrease but still maintains higher-than-average levels.

GHG intensity per BOE measures the emissions produced per unit of energy production. While data for RWE AG are lacking, companies with lower levels of this metric – such as BP PLC, Eni SpA, Equinor ASA, Shell PLC and TotalEnergies SE – display a relative stable trajectory with few minor variations over the years. Conversely, Galp Energia SGPS SA, Repsol SE and OMV AG present higher intensity levels with slightly more variation through the years. This measure is crucial for companies in the oil and gas sector as it directly relates to the efficiency their operations. GHG intensity per BOE reflects the ability to produce energy in a more environmentally sustainable manner, with companies projecting lower levels being more aligned with global decarbonization goals.

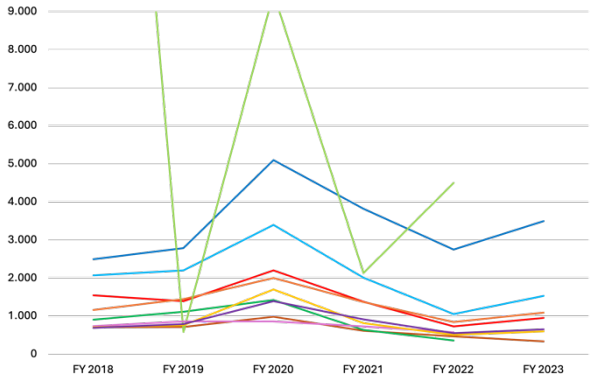
Finally, GHG emissions produced per unit of company’s assets can be considered. Like the first two metrics analyzed, GHG intensity per assets is significantly higher for RWE AG than the other companies studied. The graph shows a slightly downward trend for companies with lower levels of intensity, indicating increasing efficiency in how companies use their physical and financial resources in relation to its carbon emissions.

The analysis of the metrics clearly shows that RWE AG's high total carbon emissions are influenced by the company's low efficiency in generating revenue, utilizing assets, and consuming energy relative to its emissions. Nonetheless, Shell PLC – the other high-

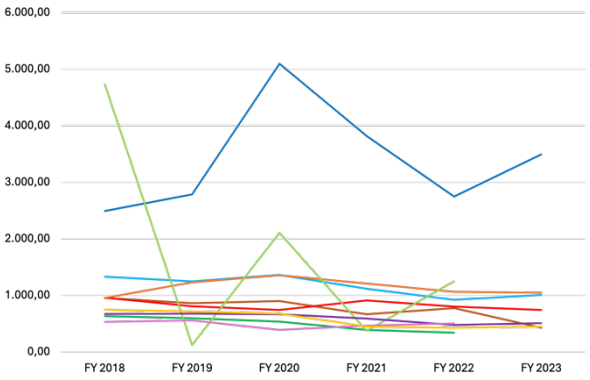
emitting company – aligns with the average trend for all the metrics analyzed, indicating the need for a more granular analysis of its structure and business model investigating what are the drivers of the companies GHG emissions.

For RWE AG, Shell PLC, as well as the lower-emitting companies, further analysis is essential to assess their exposure to the energy sector's transition. This should include an in-depth look at their strategies and business models, as total GHG emissions and GHG intensity levels alone are insufficient to provide a detailed and comprehensive understanding of the evolving landscape.

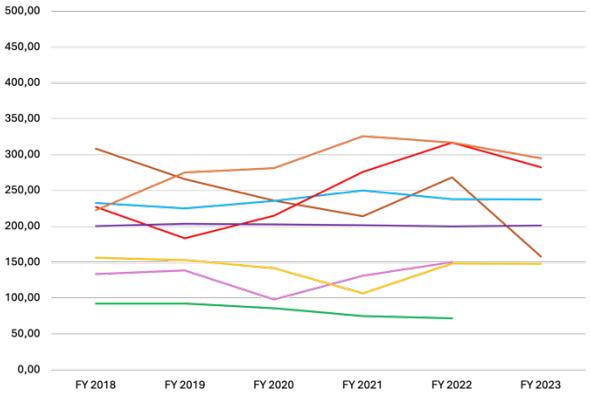
Graph 6 *Energy Intensity per Sales*



Graph 7 *Energy Intensity per Assets*



Graph 8 *Energy Intensity per BOE*



Adapted from Bloomberg

We now shift from GHG intensity to an analysis of energy intensity, focusing specifically on energy intensity per sales, per assets, and per BOE.

Energy intensity per sales measures the amount of energy used relative to the revenue generated. RWE AG, as for the previously examined metrics, shows higher-than-average values with substantial fluctuations over the years possibly indicating changes in market

conditions and shifts in energy sources (such as 2020 values inflated by COVID-19). The intensity pathways showcased by the other companies display similar trends with significant increase observed in 2020 – likely driven by the pandemic – followed by the lowest values in 2022 and a subsequent slight increase in 2023.

Measuring energy use relative to the company's total assets, decreasing energy intensity per assets might indicate more efficient assets utilization. Evidence shows that Naturgy Energy Group SA, a group dedicated to the generation, distribution and commercialization of energy and services, is the most asset-intensive companies in the sample. RWE AG, while still exhibiting high variability compared to other companies, appears to have efficiently implemented strategies to improve asset utilization and operational efficiency. As for the other companies, they share the same overall trends of slight decreasing values. Finally, energy intensity per BOE – which measures the amount of energy used to produce each barrel of oil equivalent – does not display a consistent trend across companies. However, the values range is narrower than for the other metrics considered, possibly indicating a relative limited scope for improvement and signifying that a fixed amount of energy may be necessary for extraction and production processes.

4.2 Revenue streams analysis

Revenue streams are a critical component of company analysis, offering insights into a company's business model, diversification, profitability, market positioning, and risk profile.

The revenue streams of selected European companies should be analyzed by considering both traditional sources and emerging "transition" revenues. Conventional sources for oil and gas companies include exploration, production, transportation, storage, refining, and petrochemicals, while emerging sources – driven by the new sustainable paradigm – comprehend renewables, low-carbon technologies and energy services.

Table 5 presents the revenue streams for the selected sample of oil and gas companies over several fiscal years (2017–2023). The table encompasses various categories of revenue sources that differ across companies but can generally be categorized into traditional revenue streams and emerging 'transition' revenue sources. The following analysis examines the revenue trends for each company in the sample, highlighting the shifts between these two streams and each company's position in the transition.

UK energy company BP PLC is transitioning from its traditional oil and gas-centric revenue streams toward more diversified and sustainable sources. Although “Customer and Products” consistently represents the largest portion of the company’s revenue – including its core oil and gas products – “Gas & Low Carbon Energy” shows notable growth, highlighting BP’s effort to align with global trends toward embracing renewable energy. As of 2020, the company reclassified its revenue streams, likely reflecting a shift in its business model to align with long-term sustainability goals, as evidenced by the elimination of the 'Downstream' and 'Upstream' categories.

Eni SpA’s revenue distribution remains relatively constant throughout the timeframe considered, with minor variations across the years possibly reflecting shifts in market and economic conditions. Starting in 2019, the “Gas and Power” segment was divided into “Global Gas & LNG Portfolio” and “EGL, Power, and Renewables”, likely emphasizing the company's commitment to a more sustainable, renewable-centered business. The only segment with notable growth is 'Sustainable Mobility, Refining & Chemistry,' which may indicate a shift of the company toward increasing the revenue share from emerging and transition segments.

The data from Equinor ASA's financial analysis indicates that the company remains heavily reliant on traditional oil and gas operations. In particular, “MMP” (Marketing, Midstream, and Processing) continues to be the dominant revenue stream, increasing to 98.60% in 2023. Exploration and production, on the other hand, shows a fluctuating but generally declining trend. In 2020, “Renewables” appears as a new segment in the company’s revenue sources, contributing only minimally, suggesting that the company is in the early stages of its energy transition.

For Galp Energia SGPS SA, traditional revenue sources such as “Refining and Marketing” and “Gas and Power” dominated until 2018, accounting for nearly all of the company’s revenue. However, starting in 2019, new revenue channels emerged, with “Industrial and Midstream” and “Upstream” gradually losing their share to “Commercial” and “Renewables & New Business” operations. The overall trend indicates a visible, albeit small, shift toward renewable energy and new business segments. “Commercial” has

become the main revenue source for the company, though it remains unclear whether this segment is traditional, or transition related.

Spanish company Naturgy Energy Group SA also demonstrates a change in its accounting method for revenue streams. Until 2018, “Networks” and “Energy Management – Gas & Power” were distinct revenue sources and the only contributors to the company’s operations. However, in 2019, these were consolidated into a single segment, with the emergence of the “Energy Market” segment encompassing various energy-related activities. Traditional revenue streams, such as “Supply” and “Thermal generation” contribute differently contribute differently within the broader “Energy Markets” category, with the former accounting for 33,40% and the latter for 8,40% in 2023. The renewable segment remains relative stable at around 1–2%, reflecting a gradual incorporation in the company’s business model. Overall, the Group continues to rely on traditional revenue streams while slowly expanding its renewable business.

OMV AG’s revenue streams from 2017 to 2023 reflects a shift in its business model towards diversification and a broader focus on energy. “Downstream” segment, despite being the dominant one contributing around 90% of total revenue, has seen significant decreases in its share across the years. Post-2019, OMV appears to have consolidated this category, possibly into broader segments like “Refining and Markets” and “Fuels & Feedstock”. The business model shift is more evident 2022 and 2023 with the bulk of revenue streams coming from “Fuels & Feedstock”, “Energy” and “Chemicals & Materials”. The emergence of the “Energy” segment along with the increasing relevance of the “Chemicals & Materials” segment indicates a more comprehensive energy portfolio, possibly including a stronger focus on sustainability. This shift is gradual but reflects a clear intent to align with the evolving energy landscape.

Repsol SA’s total revenue in 2017 and 2018 was derived from two revenue streams: “Upstream” and “Downstream”, with the latter contributing nearly 90% of the total. In 2019, new segments emerged such as “Industrial” and “Commercial & Renewables”, the latter of which representing a new sustainability focus, with a share oscillating around 30–35%. Despite this shift, “Industrial” kept being the most relevant segment, peaking at 61848 million (82.20%) in 2022, showing that Repsol continues to heavily rely on its

traditional operations. This suggests that the company is clearly reorganizing its business structure to better align with strategic priorities while still depending on its core business.

RWE AG's evolving revenue streams indicate a gradual, albeit not significant, shift in its core business. Throughout the years considered, "Supply & Trading" remains the largest revenue generator. However, starting from 2019, new revenue streams such as "Onshore Wind/Solar" and "Hydro/Biomass/Gas" emerged, reflecting RWE's growing focus on renewables and exploration of broader energy sources. Despite these developments, the company's revenues remain heavily reliant on its traditional operations, reflecting cautious approach to altering its business model.

Table 5 *Revenue Streams*

	FY 2017		FY 2018		FY 2019		FY 2020		FY 2021		FY 2022		FY 2023	
BP PLC														
Revenue	**240.208,00**	**100,00%**	**298.756,00**	**100,00%**	**278.397,00**	**100,00%**	**105.944,00**	**100,00%**	**157.739,00**	**100,00%**	**241.392,00**	**100,00%**	**210.130,00**	**100,00%**
Customers & Products	—		—		—		90.586,00	85,90%	128.869,00	81,90%	187.205,00	77,90%	159.848,00	76,30%
Gas & Low Carbon Energy	—		—		—		13.567,00	12,90%	26.277,00	16,70%	50.342,00	20,90%	48.489,00	23,10%
Oil Production & Operations	—		—		—		1.355,00	1,30%	2.111,00	1,30%	2.899,00	1,20%	1.196,00	0,60%
Other Businesses & Corporate Adjustment	894		807		1.006,00		436		482		946		597	
Upstream	21.261,00	8,90%	27.834,00	9,30%	27.467,00	9,90%	—		—		—		—	
Downstream	218.053,00	91,10%	270.115,00	90,70%	249.924,00	90,10%	—		—		—		—	
Eni SpA														
Revenue	**66.919,00**	**100,00%**	**75.822,00**	**100,00%**	**69.881,00**	**100,00%**	**43.987,00**	**100,00%**	**76.575,00**	**100,00%**	**132.512,00**	**100,00%**	**93.717,00**	**100,00%**
Sustainable Mobility, Refining & Chemistry	22.107,00	24,00%	25.216,00	23,60%	42.360,00	49,20%	25.340,00	47,30%	40.374,00	42,90%	59.178,00	37,00%	52.558,00	47,40%
Refining & Marketing	17.688,00	19,20%	20.646,00	19,40%	39.836,00	46,20%	22.965,00	42,90%	36.501,00	38,80%	54.675,00	34,20%	49.340,00	44,50%
Chemicals	4.851,00	5,30%	5.123,00	4,80%	4.123,00	4,80%	3.387,00	6,30%	5.590,00	5,90%	6.215,00	3,90%	4.236,00	3,80%
Intersegment Eliminations	-432	-0,50%	-553	-0,50%	—		—		—		—		—	
Exploration & Production	19.525,00	21,20%	25.744,00	24,10%	23.572,00	27,40%	13.590,00	25,40%	21.742,00	23,10%	31.200,00	19,50%	23.903,00	21,60%
Global Gas & LNG Portfolio	—		—		11.779,00	13,70%	7.051,00	13,20%	20.843,00	22,10%	48.586,00	30,40%	20.139,00	18,20%
EGL, Power & Renewables	—		—		8.448,00	9,80%	7.536,00	14,10%	11.187,00	11,90%	20.883,00	13,10%	14.256,00	12,90%
Corporate & Other Activities	1.462,00		1.589,00		1.676,00		1.559,00		1.698,00		1.879,00		1.972,00	
Consolidation Adjustments	-26.798,00		-32.417,00		-17.954,00		-11.089,00		-19.269,00		-29.214,00		-19.111,00	
Gas & Power	50.623,00	54,90%	55.690,00	52,20%	—		—		—		—		—	
Equinor ASA														
Revenue	**60.971,00**	**100,00%**	**78.555,00**	**100,00%**	**62.911,00**	**100,00%**	**45.753,00**	**100,00%**	**88.744,00**	**100,00%**	**149.004,00**	**100,00%**	**106.847,00**	**100,00%**
MMP	58.935,00	96,80%	75.487,00	95,20%	60.491,00	95,00%	44.623,00	97,70%	87.050,00	96,30%	147.173,00	98,10%	105.242,00	98,60%
Exploration & Production	1.961,00	3,20%	3.769,00	4,80%	3.174,00	5,00%	1.035,00	2,30%	1.912,00	2,10%	2.738,00	1,80%	1.500,00	1,40%
E&P International	1.984,00	3,30%	3.181,00	4,00%	1.685,00	2,60%	452	1,00%	1.121,00	1,20%	1.134,00	0,80%	993	0,90%
E&P USA	—		—		441	0,70%	368	0,80%	377	0,40%	305	0,20%	277	0,30%
E&P Norway	-23	0,00%	588	0,70%	1.048,00	1,60%	215	0,50%	414	0,50%	1.299,00	0,90%	230	0,20%
Other	102		45		527		88		307		149		85	
Renewables (REN)	—		—		—		18	0,00%	1.394,00	1,50%	127	0,10%	20	0,00%
Reconciliation	-27		-746		-1.281,00		-11		-1.919,00		-1.183,00		0	
Galp Energia SGPS SA														
Revenue	**15.202,00**	**100,00%**	**17.182,00**	**100,00%**	**16.571,00**	**100,00%**	**11.381,00**	**100,00%**	**16.117,00**	**100,00%**	**26.840,00**	**100,00%**	**20.769,00**	**100,00%**
Reconciliation	—		-312		-1.153,00		-1.000,00		-1.290,00		-2.320,00		20.292,70	
Corporate & Subsidiaries	134		142		147		205		84		159		293	
Renewables & New Business	—		—		25	0,10%	33	0,30%	50	0,30%	190	0,70%	161	87,80%
Commercial	—		—		8.892,00	50,60%	5.922,00	48,60%	7.917,00	45,70%	13.410,00	46,20%	10,3	5,60%
Industrial & Midstream	—		—		6.185,00	35,20%	4.453,00	36,60%	6.298,00	36,40%	11.000,00	37,90%	8,3	4,50%
Upstream	1.044,00	6,90%	1.687,00	9,70%	2.475,00	14,10%	1.768,00	14,50%	3.058,00	17,70%	4.401,00	15,20%	3,7	2,00%
Gas & Power	2.302,00	15,30%	2.885,00	16,60%	—		—		—		—		—	
Refining & Marketing	11.722,00	77,80%	12.780,00	73,70%	—		—		—		—		—	
Naturgy Energy Group SA														
Revenue	**23.207,00**	**100,00%**	**24.339,00**	**100,00%**	**20.761,00**	**100,00%**	**15.345,00**	**100,00%**	**22.140,00**	**100,00%**	**33.965,00**	**100,00%**	**22.617,00**	**100,00%**
Energy Markets	—		—		—		—		—		—		16.218,00	71,70%
Supply	—		—		8.691,00	30,20%	6.302,00	29,70%	6.457,00	29,20%	9.349,00	27,50%	7.561,00	33,40%
Energy Management	—		—		6.895,00	24,00%	4.222,00	19,90%	3.681,00	16,60%	6.748,00	19,90%	6.468,00	28,60%
Thermal Generation	—		—		—		—		—		—		1.904,00	8,40%
Renewable Generation	—		—		619	2,20%	640	3,00%	290	1,30%	371	1,10%	236	1,00%
Holding	—		—		—		—		—		—		49	0,20%
Renewable Gases	—		—		—		—		—		—		0	
Distribution Networks	—		—		—		—		—		—		6.398,00	28,30%
Rest	—		—		—		—		—		—		1	0,00%
Holding	—		—		—		—		—		—		0	
Energy Management & Networks	—		—		19.460,00	67,60%	14.290,00	67,30%	15.392,00	69,50%	24.243,00	71,40%	—	
Other	80		55		135		175		1		2		—	
Reconciliation	—		—		-8.144,00		-6.062,00		—		—		—	
Networks	8.933,00	38,60%	8.412,00	34,60%	—		—		—		—		—	
Energy Management - Gas & Power	14.194,00	61,40%	15.872,00	65,40%	—		—		—		—		—	

	FY 2017		FY 2018		FY 2019		FY 2020		FY 2021		FY 2022		FY 2023	
OMV AG														
Revenue	**20.222,00**	**100,00%**	**22.930,00**	**100,00%**	**23.460,00**	**100,00%**	**16.551,00**	**100,00%**	**35.555,00**	**100,00%**	**62.298,00**	**100,00%**	**39.462,00**	**100,00%**
Fuels & Feedstock	—		—		—		—		—		19.857,00	31,90%	17.753,00	45,00%
Energy	—		—		—		—		—		30.155,00	48,40%	13.344,00	33,80%
Chemicals & Materials	—		—		—		2.368,00	14,30%	10.509,00	29,60%	12.269,00	19,70%	8.345,00	21,20%
Corporate & Other	6		4		3		5		14		17		20	
Refining & Marketing	—		—		—		12.651,00	76,50%	23.148,00	65,10%	—		—	
Downstream	18.887,00	93,40%	20.756,00	90,50%	20.874,00	89,00%	—		—		—		—	
Gas	4.822,00	23,90%	6.049,00	26,40%	5.835,00	24,90%	—		—		—		—	
Gas and Power	—		—		—		—		—		—		—	
Oil	14.065,00	69,60%	14.707,00	64,10%	15.039,00	64,10%	—		—		—		—	
Exploration & Production	1.329,00	6,60%	2.170,00	9,50%	2.583,00	11,00%	1.527,00	9,20%	1.884,00	5,30%	—		—	
Repsol SA														
Revenue	**43.938,00**	**100,00%**	**49.873,00**	**100,00%**	**49.328,00**	**100,00%**	**33.282,00**	**100,00%**	**49.745,00**	**100,00%**	**75.153,00**	**100,00%**	**58.948,00**	**100,00%**
Industrial	—		—		38.524,00	55,50%	25.384,00	55,10%	39.956,00	58,20%	61.848,00	57,90%	46.676,00	56,50%
Customer	—		—		—		—		—		—		27.315,00	33,10%
Upstream	4.719,00	10,70%	5.699,00	10,80%	6.904,00	9,90%	4.228,00	9,20%	6.809,00	9,90%	10.712,00	10,00%	7.576,00	9,20%
Low-Carbon Generation	—		—		—		—		—		—		1.003,00	1,20%
Reconciliation	—		-2.834,00		-2.705,00		-1.681,00		-2.385,00		-31.600,00		-2.605,00	
Corporate & Others	1		1		-17.359,00		-11.138,00		-16.526,00		8		-21.017,00	
Commercial & Renewables	—		—		23.964,00	34,50%	16.489,00	35,80%	21.891,00	31,90%	34.185,00	32,00%	—	
Downstream	39.218,00	89,30%	47.007,00	89,20%	—		—		—		—		—	
RWE AG														
Revenue	**13.822,00**	**100,00%**	**13.406,00**	**100,00%**	**13.125,00**	**100,00%**	**13.688,00**	**100,00%**	**24.526,00**	**100,00%**	**38.415,00**	**100,00%**	**28.724,00**	**100,00%**
Core Business	—		—		12.096,00	92,20%	12.834,00	93,80%	23.615,00	96,30%	37.462,00	97,50%	27.924,00	97,20%
Supply & Trading	10.632,00	76,40%	10.194,00	76,10%	9.537,00	72,70%	9.581,00	70,00%	19.283,00	78,60%	32.152,00	83,70%	23.147,00	80,60%
Onshore Wind / Solar	—		—		1.265,00	9,60%	1.855,00	13,60%	2.324,00	9,50%	2.233,00	5,80%	2.295,00	8,00%
Hydro / Biomass / Gas	—		—		1.202,00	9,20%	1.059,00	7,70%	1.316,00	5,40%	1.831,00	4,80%	1.280,00	4,50%
Offshore Wind	—		—		85	0,60%	332	2,40%	688	2,80%	1.449,00	3,80%	1.202,00	4,20%
Other, Consolidation	37		18		7		7		4		-203		0	
Coal / Nuclear	—		—		1.029,00	7,80%	854	6,20%	911	3,70%	953	2,50%	800	2,80%
Natural Gas Tax/Electricity Tax	-131		—		—		—		—		—		—	
Innogy	1.087,00	7,80%	1.124,00	8,40%	—		—		—		—		—	
Lignite & Nuclear	1.271,00	9,10%	1.144,00	8,50%	—		—		—		—		—	
European Power	926	6,70%	926	6,90%	—		—		—		—		—	
Shell PLC														
Revenue	**305.179,00**	**100,00%**	**388.379,00**	**100,00%**	**344.877,00**	**100,00%**	**180.543,00**	**100,00%**	**261.504,00**	**100,00%**	**381.314,00**	**100,00%**	**316.620,00**	**100,00%**
Chemicals & Products	—		—		—		—		116.448,00	44,50%	144.342,00	37,90%	118.781,00	37,50%
Marketing	—		—		—		—		83.494,00	31,90%	120.638,00	31,60%	108.858,00	34,40%
Renewables & Energy Solutions	—		—		—		—		22.415,00	8,60%	53.190,00	14,00%	44.819,00	14,20%
Integrated Gas	32.674,00	10,70%	43.764,00	11,30%	41.323,00	12,00%	33.287,00	18,40%	29.922,00	11,40%	54.751,00	14,40%	37.645,00	11,90%
Upstream	7.723,00	2,50%	9.892,00	2,50%	9.482,00	2,70%	6.767,00	3,70%	9.182,00	3,50%	8.352,00	2,20%	6.475,00	2,00%
Corporate	51		43		44		51		43		41		42	
Chemicals	—		—		13.568,00	3,90%	11.721,00	6,50%	—		—		—	
Oil Products	—		—		280.460,00	81,30%	128.717,00	71,30%	—		—		—	
Downstream	264.731,00	86,80%	334.680,00	86,20%	—		—		—		—		—	
TotalEnergies SE														
Revenue	**201.191,00**	**100,00%**	**184.106,00**	**100,00%**	**176.249,00**	**100,00%**	**140.685,00**	**100,00%**	**184.634,00**	**100,00%**	**263.310,00**	**100,00%**	**218.945,00**	**100,00%**
Refining & Chemicals	99.341,00	49,50%	88.666,00	48,20%	84.583,00	48,00%	56.615,00	40,20%	87.600,00	42,60%	121.618,00	43,30%	101.203,00	42,70%
Marketing & Services	56.105,00	27,90%	68.308,00	37,10%	66.228,00	37,60%	63.451,00	45,10%	80.288,00	39,00%	100.661,00	35,80%	89.909,00	37,90%
Integrated Power	—		—		—		—		—		—		27.337,00	11,50%
Integrated LNG	—		—		—		—		—		—		12.086,00	5,10%
Exploration & Production	31.314,00	15,60%	9.889,00	5,40%	7.261,00	4,10%	4.973,00	3,50%	7.246,00	3,50%	9.942,00	3,50%	6.561,00	2,80%
Corporate	397		7		10		17		-21.204,00		25		32	
Adjustment	—		—		—		—		—		-17.689,00		-18.183,00	
Integrated Gas, Renewables & Power	14.034,00	7,00%	17.236,00	9,40%	18.167,00	10,30%	15.629,00	11,10%	30.704,00	14,90%	48.753,00	17,40%	—	

Adapted from Bloomberg

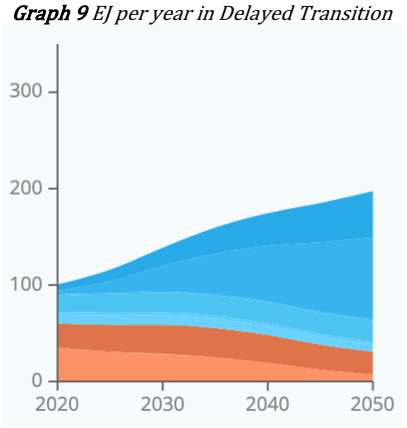
As with other previously analyzed companies, Shell PLC has reclassified its revenue streams from “Downstream” and “Upstream” to a more granular and detailed representation. Traditional revenue sources such as “Integrated Gas” and “Upstream” have shown a consistent trend of small contributions over the years. In contrast, “Chemical & Products” has been the major contributor to the company's total revenue, though its share decreased from 44,50% in 2021 to 37,50% in 2023, losing ground to other segments. Notably, “Renewables & Energy Solutions” segment, which emerged in 2021, shows an upward trend. This indicates that starting in 2021, Shell has begun diversifying into a boarder energy market and gradually shifting its focus toward renewable solutions.

TotalEnergies SE's revenue structure from 2017 to 2023 remains based on the same segments, indicating that no major shifts in the company's business model have occurred. Nonetheless, a changing strategic approach is evident. In fact, the two traditional revenue streams are those showing declining shares. "Refining & Chemicals" gradually loses relevance but still maintains a dominant percentage of 42,70%, while "Exploration & Production" share decreases to a marginally contributing value of 2,80%. Conversely, "Marketing & Services" display an increasing trend, along with "Integrated Gas, Renewables & Power" underlying the company's growing commitment to succeeding in the energy transition.

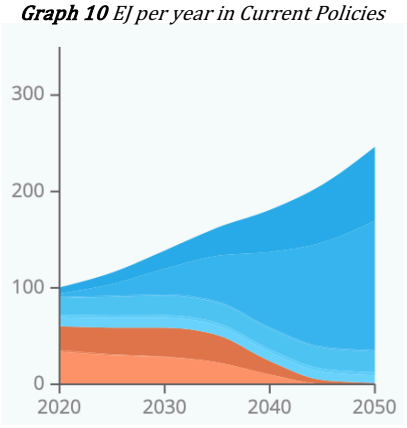
4.3 Fossil fuel reserves and production analysis

Considering climate mitigation scenarios developed by the Network for Greening the Financial System, in collaboration with the process-based IAM community, trajectories for individual energy sources can be projected. Moving from "Current Policy" to various mitigation scenarios, each energy source shows a consistent trend of either increasing or decreasing energy output.

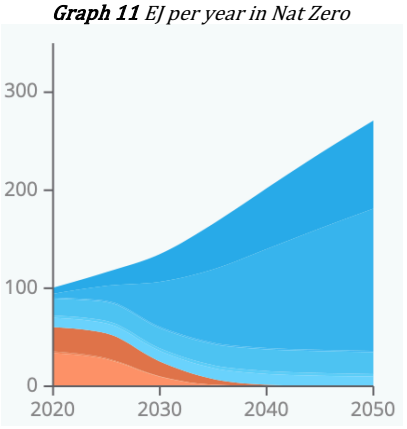
Graph 9 *EJ per year in Delayed Transition*



Graph 10 *EJ per year in Current Policies*



Graph 11 *EJ per year in Nat Zero*



Source: *NGFS Scenarios Portal*

While output for renewable energy sources like solar and wind increases significantly across all scenarios, including the 'Current Policies' and 'Low Demand' scenarios (which assume significant behavioral changes to reduce energy demand), the same trend does not apply to fossil fuels. Despite minor variations across scenarios, coal's electricity output is projected to reach zero at the latest (according to the Current Policies scenario)

by 2045, anticipated by oil which is expected to be completely reduced by 2035. Gas shows a slightly less immediate decline, with complete reduction in output forecasted by 2060 in only a few more stringent scenarios, possibly due to its significantly higher current electricity output. [22]

According to Battiston *et. al.*, "CLIMAFIN handbook: pricing forward-looking climate risks under uncertainty" shocks of NGFS trajectories by sector can be translated into equity shocks.

Recalling the equation for equity shock:

$$U_{P,j}^{equity} = \frac{\sum_{t=t_0}^{t_{max}^{equity}} \frac{O_{P,j,t}}{(1+r)^{t-t_0}} - \sum_{t=t_0}^{t_{max}^{equity}} \frac{O_{B,j,t}}{(1+r)^{t-t_0}}}{\sum_{t=t_0}^{t_{max}^{equity}} \frac{O_{B,j,t}}{(1+r)^{t-t_0}}}$$

With:

- $O_{P,j,t}$ = output in sector X under X mitigation scenario
- $O_{B,j,t}$ = output in sector X under baseline scenario
- $(1+r)^{t-t_0}$ = discount rate in year x to 2020

In a simplified setting, equity value in the electricity sector is proportional to its output, i.e. a 30% drop in total future output discounted to present leads to a 30% drop on present value. Using this assumption, equity shocks to financial assets can be calculated for different sectors under various climate mitigation scenarios, compared to the baseline scenario ("Current Policies").

Consistent with the trends in fossil fuel electricity outputs, the valuation adjustment – which is also the result of the shape of the scenarios trajectories – is negative for both coal and gas, with coal experiencing a considerably larger adjustment due to a greater reduction in overall output over time. Oil's outlook is peculiar, showing no equity shocks, as all NGFS scenarios project identical trajectories and values for this fossil fuel's electricity output.

Conversely, shocks for renewable energy sources are significantly positive. Higher projected future output and demand lead to positive adjustments for companies

[22] NGFS, *Scenarios Portal*, August 2024, https://www.ngfs.net/ngfs-scenarios-portal/

operating in these alternative energy sectors. The only scenario in which solar and wind equity shocks are negative is "Low Demand", highlighting the critical role of demand in determining the performance of the energy sector regardless of whether the sources are carbon-based or renewables.

Table 6 *Equity shocks*

Scenario	*Shock on equity*
Coal	
Current Policies	0,00%
Below 2°C	-16,16%
Delayed transition	-5,98%
Fragmented World	-5,36%
Low demand	-20,20%
Nationally Determined Contributions (NDCs)	-20,18%
Net Zero 2050	-20,22%
Gas	
Current Policies	0,00%
Below 2°C	-22,47%
Delayed transition	-38,75%
Fragmented World	-6,95%
Low demand	-39,46%
Nationally Determined Contributions (NDCs)	-28,99%
Net Zero 2050	-38,75%
Oil	
Current Policies	0,00%
Below 2°C	0,00%
Delayed transition	0,00%
Fragmented World	0,00%
Low demand	0,00%
Nationally Determined Contributions (NDCs)	0,00%
Net Zero 2050	0,00%

Scenario	*Shock on equity*
Solar	
Current Policies	0,00%
Below 2°C	44,46%
Delayed transition	44,98%
Fragmented World	24,17%
Low demand	-3,95%
Nationally Determined Contributions (NDCs)	43,21%
Net Zero 2050	44,98%
Wind	
Current Policies	0,00%
Below 2°C	31,41%
Delayed transition	35,27%
Fragmented World	25,49%
Low demand	-10,86%
Nationally Determined Contributions (NDCs)	34,72%
Net Zero 2050	35,27%

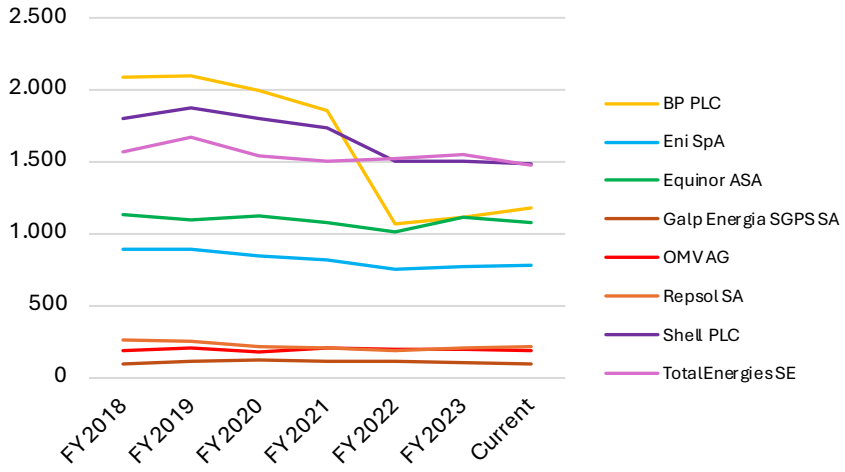
Author's own elaboration

This initial analysis highlights the significant exposure of oil and gas companies to the energy transition. It is evident that companies heavily reliant on fossil fuel production will face the greatest challenges if they fail to grasp the market opportunity of shifting their business models toward renewables. Embracing sustainable energy sources could lead to a compensating valuation effect, mitigating the downsides of prolonged oil, gas, and coal production.

Nonetheless, a more detailed analysis of each company's fossil fuels production and reserves is essential to fully understand their exposure to transition and stranded asset risks. It's also important to note that these results should not be taken at face value, as they are based on simplifying assumptions. A company's equity value and business structure are more complex than what the formula accounts for.

Data gathered from The Bloomberg Terminal allows us to compare fossil fuel production trend for 8 out of the 10 European companies selected. Naturgy Energy Group SA an RWE AG data are lacking. Naturgy will not be present in this analysis as its core business is not focused on fossil fuels production, therefore data on this specific topic are not disclosed. Lignite, hard coal and gas are among the conventional energy sources in RWE's portfolio, but production data are not present in Bloomberg's financial analysis.

Graph 12 *Oil (MBBL/Day)*

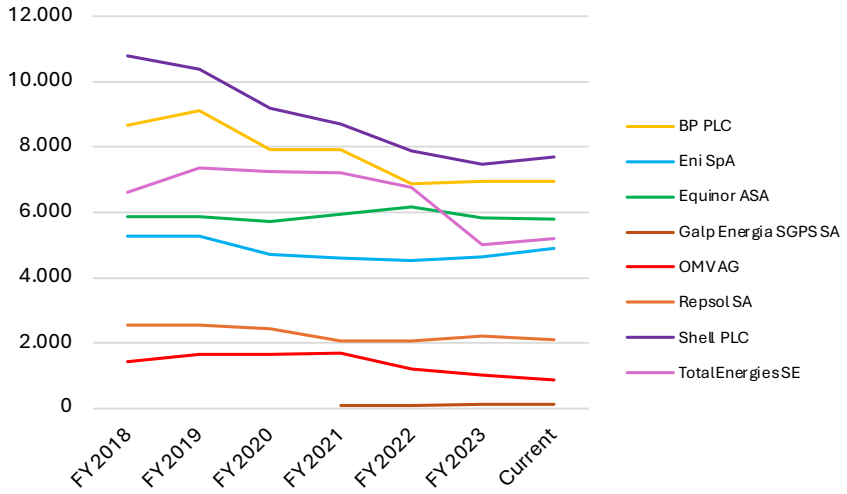


Adapted from Bloomberg

Focusing first on oil production, we can find only three companies with significant output reduction over the years. BP PLC has shown a steep decline in production from 2021, yet it remains one of the largest producers, alongside Shell PLC and TotalEnergies SE. The latter two companies also exhibit relevant declines in production, possibly indicating that pressure has been put by regulators and investors to reduce the environmental footprint of major producers. Eni SpA and Equinor ASA are positioned as mid-level producer with relatively slightly declining outputs. The three lower producing companies – OMV AG, Repsol SA and Galp Energia SGPS SA – display rather stable outputs.

A similar trend can be observed in gas output trajectories. The highest producing companies – Shell PLCA, BP PLC and TotalEnergies SA – are the same as those for oil production and they as well show the higher rates of output decline. The other companies follow as well similar patterns as for oil production, with the exception of Galp Energia SGPS SA, which appears to have started gas production only in 2021 and at a nearly unimportant level.

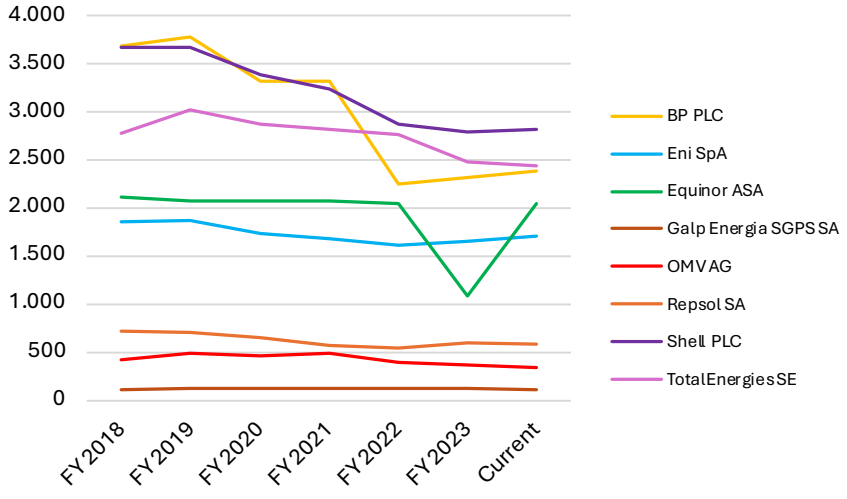
Graph 13 *Gas (MMCF/Day)*



Adapted from Bloomberg

Production, generally measured in MBOE per day, is consistent with the analysis of oil and gas production, revealing the same three cluster of high, mid and low producing companies, as well as an aligned overall output trend.

Graph 14 *Production (MBOE/Day)*



Adapted from Bloomberg

This second level of analysis reveals that only the major fossil fuels producers are reducing their oil and gas production. The other companies sampled are not significantly changing their production, indicating either a low incentive or a lack of willingness to fundamentally change their business model. It appears that this companies rather than shifting to more sustainable energy sources, gradually abandoning fossil fuels, might be investing in lowering GHG and energy intensity measures to limit their carbon footprint. This could be happening also because transition and stranded asset risks are currently

not fully priced into markets, allowing for the overvaluation of carbon-reliant companies and sectors.

As already pointed out in the energy transition fossil fuels reserves can remain untapped leading to financial losses. Therefore the last level of this paragraph's analysis will focus on reserves data.
Three main measures will be observed:

- Reserves developed: reserves expected to be recovered from existing wells including reserves behind pipe. Improved recovery reserves are considered developed only after the necessary equipment has been installed, or when the costs to do so are relatively minor. Developed reserves may be subcategorized as producing or non-producing. [23]
- Reserve production ratio: remaining amount of a nonrenewable resource that is known to be extractable at current economic conditions, expressed in years.
- Reserves growth: typical increases / decreases of estimated ultimate recovery that occur as oil & gas fields are developed and produced.

The percentage of total developed reserves gives insight about how a company is approaching the development of its fossil fuels business. Companies like Shell PLC, Repsol SA and OMV AG show a generally decreasing trend to this metric over the years. This downward trend indicates that a smaller proportion of the total reserves owned by these companies is converted into developed reserves over time. The reasons behind this trend can be varied and could have diverse implications. Companies might be facing challenges in bringing new reserves online due to technological and operational difficulties, increased environmental regulation, and economic unviability. Focusing more on the energy transition landscape, this trend could be a sign of companies strategically shifting their business away from developing new reserves and aligning with ESG goals. It is likely that a combination of these factors is contributing to the observed gradual decrease, which can be considered overall a good indicator considering *Table 2*'s required levels of unextracted fossil fuels.

[23] Society of Petroleum Engenieer, August 2024, https://www.spe.org/en/industry/petroleum-reserves-definitions/#:~:text=Reserve%20Status%20Categories&text=Developed%3A%20Developed%20reserves%20are%20expected,do%20so%20are%20relatively%20minor

For the other companies considered, the percentage of reserves developed has been relatively stable over the years showing a slightly downward trend, except for Galp Energia SGPS SA which shows a growing trend, yet still having lower-than-average values.

Table 7 *Reserves data*

	FY 2017	*FY 2018*	*FY 2019*	*FY 2020*	*FY 2021*	*FY 2022*	*FY 2023*
BP PLC							
% Reserves Developed	56,29	55,34	57,85	56,23	57,45	93,57	62,14
Reserve Production Ratio	14,23	21,20	19,87	14,97	15,54	36,53	36,67
Reserves Growth	3,54	8,16	-3,03	-7,02	-5,72	-57,63	-5,89
Eni SpA							
% Reserves Developed	62,39	67,72	70,91	70,96	69,52	63,37	62,29
Reserve Production Ratio	10,55	10,59	10,64	10,89	10,80	11,25	10,62
Reserves Growth	-6,68	2,33	1,61	-4,99	-4,01	-0,21	-3,02
Equinor ASA							
% Reserves Developed	62,27	60,45	61,28	61,25	71,28	70,74	66,34
Reserve Production Ratio	7,07	10,64	-	-	-	-	-
Reserves Growth	7,06	15,05	-2,77	-12,39	1,83	-3,08	0,44
Galp Energia SGPS SA							
% Reserves Developed	22,93	32,79	34,95	39,13	46,49	54,00	47,75
Reserve Production Ratio	16,51	11,08	11,23	9,92	9,08	8,08	8,87
Reserves Growth	18,76	-0,67	39,65	1,55	3,90	-4,77	6,63
OMV AG							
% Reserves Developed	86,16	83,04	79,76	79,44	78,47	81,46	68,79
Reserve Production Ratio	9,02	8,15	7,49	7,89	7,30	7,25	8,55
Reserves Growth	11,26	10,82	4,88	0,38	-3,14	-19,92	9,55
Repsol SA							
% Reserves Developed	65,22	67,76	70,78	70,36	62,04	57,99	59,59
Reserve Production Ratio	9,28	8,96	8,27	7,81	9,17	9,51	8,42
Reserves Growth	-1,09	-0,68	-8,55	-13,42	3,40	-0,31	-3,56
Shell PLC							
% Reserves Developed	82,17	79,36	79,39	85,18	83,47	71,34	69,83
Reserve Production Ratio	8,97	8,50	8,15	7,24	7,79	9,01	9,44
Reserves Growth	-7,79	-5,23	-4,15	-17,68	2,58	2,28	2,14
TotalEnergies SE							
% Reserves Developed	61,09	69,71	54,22	54,36	66,16	68,60	64,70
Reserve Production Ratio	12,25	5,36	4,83	-	-	-	-
Reserves Growth	-0,37	5,01	5,24	-2,78	-2,16	-15,52	3,67

Adapted from Bloomberg

Reserves Production Ratios, despite some fluctuations, display an overall trend of stability. BP PLC stands out as the company with the highest ratios, possibly linked to the decreasing production levels discussed earlier. The rest of the companies show similar levels of the analyzed measure. Overall, the upward/downward fluctuations could reflect lower/higher production rates or increased/decreased reserves.

Most companies exhibit significant volatility in reserves growth. Thus, an overall trend cannot be identified for this metric. This significant volatility suggests that companies are facing numerous challenges in maintaining or increasing their reserves. Negative reserves growth could stem from a lack of new reserves that replace what has been produced by the company, market conditions, commodity prices and geopolitical issues. Overall this volatility could be a pointer to long-term uncertainty in the industry, especially in the current geopolitical and sustainable-energy landscape.

4.4 Regulation alignment and sustainability analysis

Discussing a company's sustainability commitment can highlight potential discrepancies between its declarations and the actions it has actually implemented. Before analyzing each entity's sustainability reports, it may be insightful to first observe their alignment with the EU Taxonomy, as this can provide a clearer indication of their real commitment to transforming their businesses toward a more sustainable model.

Three climate-related KPIs – revenue, Capex and Opex – based on the framework established by EU Taxonomy Regulation, are collected by The Bloomberg Portal.

KPIs such as capital expenditures and operating expenditures are defined are defined with two components: a denominator that includes all of a firm's Capex/Opex, and a numerator that consists of the portion of the denominator that meets any of the following[24]:

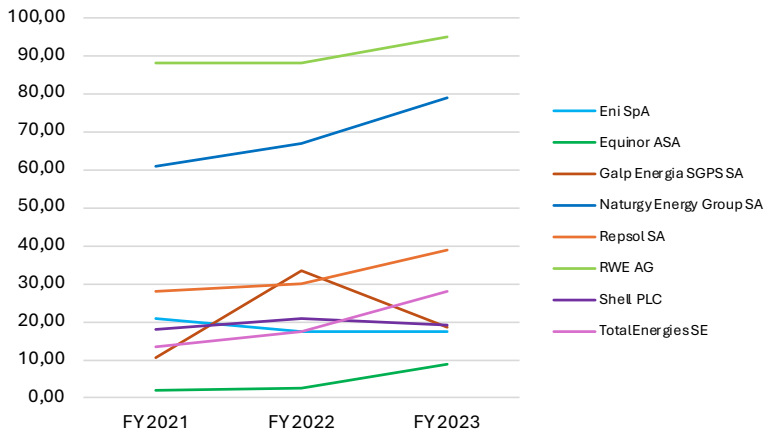
a. Related to assets or processes that are associated with Taxonomy-aligned or eligible economic activities.
b. Part of a plan to expand Taxonomy-aligned or eligible economic activities and individual measures enabling the target activities to become low-carbon or to lead to greenhouse gas reductions.

EU Taxonomy eligible Capex data varies significantly across companies. As depicted in *Graph 15*, two companies exhibit higher-than-average percentage of eligible Capex and along with an upward trend: Naturgy Energy Group SA and RWE AG. Coherently these companies' core businesses are more focused on new energy sources and less reliant on fossil fuels. In contrast, Equinor ASA is the worst-performing company by this metric.

[24] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088

While only TotalEnergies SE and Repsol SA show an increasing trend, the other companies in the sample display much more volatility in their percentages of eligible Capex.

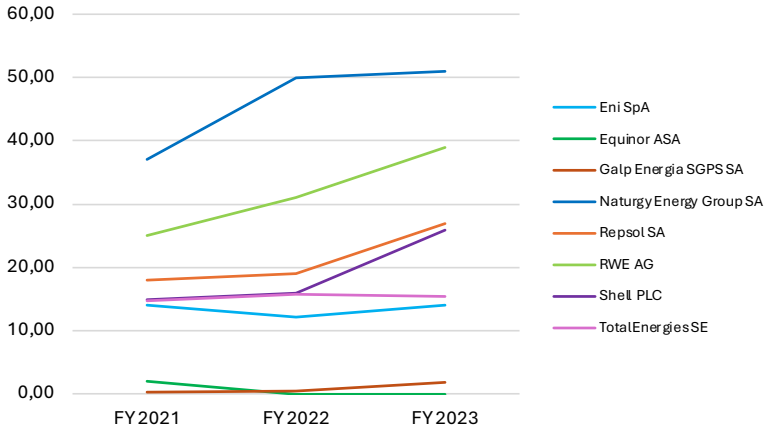
Graph 15 *EU Taxonomy eligible Capex percentage*



Adapted from Bloomberg

Regarding the percentage of EU Taxonomy-eligible Opex, RWE AG and Naturgy Energy Group SA still outperform all other analyzed oil and gas companies. However, the values for this metric are considerably lower (just above 50%) compared to the previously observed Capex KPI. Most of the other selected companies show increasing percentages of eligible operating expenditures, with less variability across the years and a more consistent overall trend, yet values are lower than the Capex ones.

Graph 16 *EU Taxonomy Eligible Opex Percent*

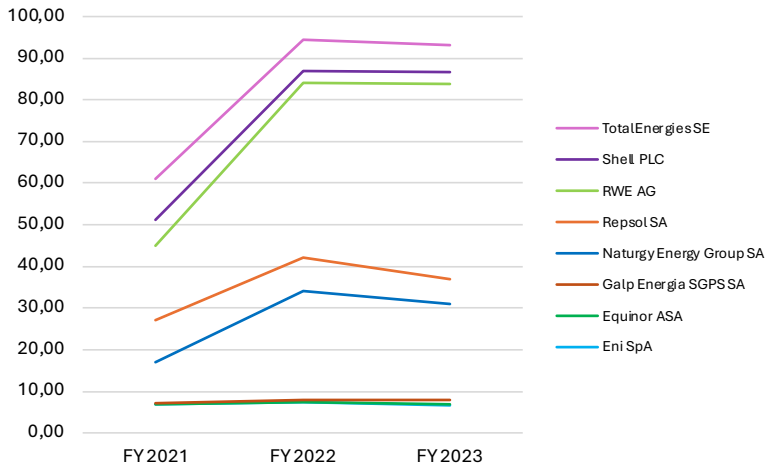


Adapted from Bloomberg

EU Taxonomy Eligible Revenue Percentages show a different trend compared to the other two metrics. TotalEnergies, Shell and RWE are the companies with the highest percentage

of revenue eligible according to EU Taxonomy's definition of sustainability, with significant increases from 2021 to 2022, followed by stabilization in 2023. These values prove to be coherent with the revenue streams analysis previously carried out. Conversely, Repsol SA and Naturgy Energy Group SA display a declining trend, but with percentages higher than Equinor and Galp Energia: the worst-performing companies.

Graph 17 *EU Taxonomy Eligible Revenue Percent*



Adapted from Bloomberg

Overall, the analysis of EU taxonomy eligible Capex, Opex and revenue percentages reveals different levels of alignment with sustainability criteria. While companies like RWE AG, Naturgy Energy Group SA, and TotalEnergies have demonstrated stronger performance in at least one of these metrics, their consistency across all three metrics varies. The observed data suggest a more proactive approach to integrating sustainability practices into their core operations. However, the observed data volatility underscore the ongoing challenges in aligning traditional oil and gas businesses with the Regulation's stringent requirements.

Each of these companies outlines its commitment to sustainability through a diverse yet sustainability-centered set of purpose and mission statements. Repsol's missions, for example, is to be an energy company committed to a sustainable world, while Equinor define itself as an international energy company committed to long-term value creation in a low-carbon future. The total of the companies sampled pledge to reduce their CO2

emissions in line with the 1.5-degree reduction pathway and share the commitment to achieve carbon neutrality by 2050.

Most of the companies' sustainability reports emphasize an increasing commitment to investments in non-oil and gas businesses. Overall, there is a clear trend among the majority of these companies toward increasing both installed renewable capacity and electricity generated from renewable sources. Although fewer companies are investing in sustainable products, those that do – BP PLC, Eni SpA, Equinor ASA, Repsol SA and Shell PLC – have been accelerating their investments over the years, possibly signaling a long-term commitment.

Nonetheless, each company's sustainability statement appears to be overreaching and may not fully align with the actual data presented in their annual reports and financial analyses.

Practical implications and research limitations

In the context of the European Union's shift toward a low-carbon economy, the oil and gas sector is facing increasing pressure from both regulators and stakeholders to meet sustainability targets. As outlined throughout this thesis, key EU policies are driving a transformation in corporate strategies. Companies must navigate changing market dynamics, stricter regulations, and rapid technological advancements, exposing them to substantial transition risks and the growing threat of stranded assets due to rising carbon pricing and the expansion of renewable energy. Building on the analysis conducted, practical implications for the EU's fossil fuel industry are drawn.

The significant negative equity value shocks observed for fossil fuel financial assets, alongside the positive shocks detected for renewable energy assets, highlight the financial opportunities of transitioning to cleaner energy. These trends also emphasize the growing exposure of oil and gas companies to transition risk. However, the critical role of energy demand underscores the dependence of corporate performance on market conditions. Projections suggest that the resilience of the fossil fuel industry will depend on the ability of oil and gas companies to capitalize on the growing demand for renewables while managing a reduction in their traditional revenue streams.

Despite the evidence, the sample's sustainability practices were inconsistent with the current transitioning landscape, highlighting the challenges traditional oil and gas businesses face in meeting stringent sustainability regulations. All the selected companies showed a reclassification of their revenue streams, reflecting the broader industry shift towards sustainability, with gradual diversification into renewable energy and other sustainable sources. While this suggests a small but steady restructuring of business models, most companies remain heavily dependent on fossil fuel operations, indicating only a superficial commitment to sustainability. Only major fossil fuels producers are significantly reducing their oil and gas outputs aligning with smaller producers who have not substantially altered production, indicating a lower incentive or unwillingness to fundamentally shift their business model. Declining reserves data potentially signals a strategic shift away from exploring new fossil fuel reserves in favor of aligning with ESG considerations. However, this is not a universal trend, as some companies have maintained relatively stable reserves, underscoring the ongoing uncertainties around

how they plan to navigate the energy transition. The energy sector faces long-term instability, exacerbated by fluctuating commodity prices and the geopolitical context affecting supply chains and resource availability, making it increasingly complex to align with sustainability standards.

Notably, high-emitting and high-producing companies are the ones showing the most significant reductions in GHG emissions and fossil fuel output, suggesting that regulatory and stakeholder pressure is a key driver in pushing these companies toward a more sustainable trajectory. Nonetheless, the industry as a whole does not show a firm commitment to abandoning traditional operations in favor of low-carbon alternatives. This suggests that, rather than committing to a widespread transition to renewables, many companies are focusing on reducing GHG emissions by improving intensity and efficiency measures to mitigate their environmental impact, without making long-term commitments to renewable energy. This reflects significant resistance to the energy transition.

Consequently, EU oil and gas companies remain highly exposed to both transition risks and stranded asset risks. The sector's gradual shift towards sustainability, while notable in some areas, is not enough to mitigate these risks fully. Continued reliance on fossil fuel operations, coupled with slow progress in embracing renewable energy, heightens the vulnerability of these companies in a rapidly changing regulatory and market landscape. A more decisive and widespread commitment to transitioning toward renewable energy and sustainable practices will be essential to mitigating these risks and ensuring long-term resilience in the low-carbon era.

Despite the valuable insights provided by this research, several limitations must be acknowledged. One of the primary limitations of this study is the variability and availability of data, different companies report data with varying levels of transparency and detail, making a direct and comprehensive comparison challenging. Furthermore, the research relies on certain assumption about future market demand, regulatory changes and technological advancements. These assumptions involve significant uncertainty, especially in predicting long-term outcomes. Finally, volatile commodity prices and geopolitical shifts create a constantly changing environment for oil and gas companies. The analysis does not fully capture the impact of sudden changes in market conditions or

external factors such as supply chain disruptions, which could drastically affect the financial implications of the energy transition.

These practical implications and limitations outline the complex landscape of the energy transition for EU oil and gas companies, stressing the need for continued adaptation and regulatory support.

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