Paper 16 • December 2024 • catavento.biz

CATAVENTO

RETHINKING TRANSITIONING AWAY FROM OIL AND GAS IN A JUST, ORDERLY, AND EQUITABLE MANNER

Clarissa Lins, Guilherme Ferreira, Leonardo Bastos and Bernardo Corrêa

Photo by Zachary Theodore via Unsplash

ABOUT THE PROJECT

Following the COP28 commitment of transitioning away from fossil fuels, countries now face a complex challenge of reducing both the supply and demand of these energy sources in order to stay within reach of the 1.5 °C temperature rise limit. This ambitious goal sets an unprecedented pace of change and implies complex trade-offs, which will require deep discussions with a wide range of stakeholders to develop a feasible action plan for COP29 and especially for COP30 in Brazil.

To facilitate this discussion, Catavento — supported by the Institute of Climate and Society (ICS) and the Brazilian Petroleum and Gas Institute (IBP) — has conducted extensive desk research, expert interviews, and a roundtable with international energy specialists, including members of the public and private sectors, as well as academia. The focus of this work is to acknowledge our starting point as a global society, as well as to propose criteria that inform the decision-making process of transitioning away from O&G, in line with the commitment established at COP28. Note that coal has not been included in the analysis.

In this context, eleven countries from seven different regions and with distinct characteristics were selected based on their relevance to O&G supply (annual production and proved reserves) and demand (annual consumption). These countries were analyzed across five categories of criteria to offer a broader perspective on the interplay of various dimensions that are expected to be considered.[1]

1. The authors would like to thank the experts and executives that participated in the roundtable and interviews.

This study was supported by

BOUNDARY CONDITIONS AND LIMITATIONS

This study focuses exclusively on the oil and gas (O&G) industry, excluding coal from its scope. This exclusion allows for a more detailed and insightful examination of the dynamics surrounding the transition away from O&G within the analyzed dimensions. However, it also limits the comprehensiveness of the findings, particularly when addressing challenges faced by coal-dependent countries.

The study does not account for all relevant countries in terms of oil production and consumption. Nonetheless, efforts were made to mitigate this limitation by selecting a diverse range of countries—based on specific criteria—that can serve as proxies for nations with similar key characteristics.

The selection of countries analyzed was further constrained by the availability of publicly accessible data from internationally recognized sources with credible and consistent track records.

The three cluster categories identified in this study — front-runners, movers, and adapters — do not suggest that the countries within each category face identical challenges or possess equivalent capabilities and resources to advance their domestic energy transitions. Instead, these categories represent groupings of countries that, for varying reasons, are either better or worse positioned to transition away from O&G.

Reducing both O&G supply and demand simultaneously is essential to avoid economic disruptions and the loss of societal support. At the same time, the costs of climate inaction far exceed those of any energy transition pathway. Therefore, it is imperative for all countries to progress with their transitions from O&G, in alignment with their respective capacities and pace.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

- **The cost of climate inaction can be illustrated by the increased frequency, intensity, and unpredictability of extreme weather events.** From 2010 to 2019, weather-related natural disasters were responsible for over US$ 1.4 trillion in global economic losses — approximately eight times the amount recorded in the 1970s. In 2023 alone, these costs surpassed US$ 280 billion, with 60% of them remaining uninsured.

- **The burning of fossil fuels is one of the main factors behind the increase in the global average temperature.** Between 1990 and 2023, greenhouse gas (GHG) emissions grew by more than 51%, reaching 57.1 $GtCO_2e$. Of this total, approximately 68% is related to emissions from the way the world produces and consumes energy, notably from oil and gas (O&G). If current emission levels are maintained, the carbon budget necessary to limit the temperature increase to 1.5 °C, as recommended by science, will be exhausted in just 5 years. Meanwhile, current policies would lead to an increase of at least 2.4 °C by 2100.

- **At COP28, almost 200 countries committed to promoting a significant reduction in GHG emissions in line with a 1.5 °C trajectory.** To achieve this ambition, different targets were established, including tripling global renewable power capacity and doubling the global rate of energy efficiency improvements by 2030. Additionally, it was agreed to 'transition away from fossil fuels in energy systems in a just, orderly, and equitable manner, accelerating action in this critical decade to achieve net zero by 2050, in line with scientific guidance.' The full implementation of these commitments is expected to lead to profound transformations in the energy sector, including a 20% reduction in demand for O&G by the end of the decade.

- **Promoting the necessary transformations is challenging and complex, as the O&G industry provides secure, reliable, and affordable energy, which has significantly contributed to the development of modern society and current levels of welfare.** Additionally, the sector plays a crucial socioeconomic role in major producing countries, influencing GDP, exports, tax revenues, and job creation. It is estimated that approximately 50% of the revenues generated by the sector between 2018 and 2022, equivalent to US$ 8.5 trillion, were directed to governments, primarily in the form of taxes. Furthermore, the industry is responsible for over 11.7 million direct jobs, accounting for 47% of employment in the energy sector in 2022.

- **In this context, considering the current energy and climate landscape, the commitment to transition away will only be achieved if supply and demand are addressed simultaneously.** An abrupt disruption in the supply of O&G could lead to significant impacts on the global energy system, leading to price volatility and potential economic shocks. Moreover, instabilities in energy markets may diminish public support for the energy transition, especially in democratic nations, and slow the progress towards decarbonization.

- **This study aims to contribute to the decision-making process by proposing a set of criteria to identify countries best positioned to 'transition away from O&G'.** In this regard, 11 countries from different regions were selected among the most relevant O&G producers and consumers: the US, Canada, Russia, China, India, Saudi Arabia, the United Arab Emirates, Norway, Germany, Brazil, and Nigeria. For the analysis, a set of key indicators was identified and grouped into the following five categories: (i) O&G relevance; (ii) O&G competitiveness; (iii) energy security and transition readiness; (iv) emissions profile; and (v) social and institutional aspects.

- **O&G relevance — Transitioning away from O&G is expected to impact countries differently. Those where the sector holds significant economic relevance — whether through its contribution to GDP or exports — and has extensive infrastructure dedicated to these activities, are likely to be more heavily affected in a context of increasing restrictions on O&G supply and demand.** Germany – led by its highly diversified economy (oil rents < 1% of GDP)[2], limited O&G production (oil: < 1.4 mb/d), reserves (oil: < 4 bn barrels) and assets, and high reliance on O&G imports – was classified as having low dependence on O&G revenues. China shares similar characteristics with Germany, except for its moderate production (oil: 1.4 – 4.3 mb/d) and reserves (oil: 4 – 30 bn barrels), resulting in a classification of moderate dependence. The US also has a highly diversified economy and, despite its high production (oil: > 4.3 mb/d) and reserves (oil: > 30 bn barrels), faces only moderate exposure to stranded asset impacts (2% - 5% of GDP). Therefore, exclusively considering this category, Germany, China and the US would be better positioned to transition away from O&G, as the sector plays a relatively smaller role in their economies compared to the rest of the sample.

2 The numbers presented in this executive summary as references were established based on the sample considered

- **O&G competitiveness — Countries unable to hold competitive O&G production — both in terms of costs and emissions intensity — are not well-positioned in the future O&G market, which is expected to face declining demand, lower commodity prices, and higher carbon costs.** When it comes to cost-competitiveness, Canada, China, and Nigeria exhibit the highest break-even costs (break-even > US$ 47/barrel of new crude oil supply in 2040) compared to other onshore and offshore provinces. From an emissions intensity standpoint, Russia, Nigeria, and China were identified as the least competitive in both O&G (scope 1 and 2)[3] (oil: > 91 kg/boe; gas: > 59 kg/boe), influenced by high methane and operational emissions. These countries would be prioritized to transition away from O&G if production competitiveness had been the main criterion.

- **Energy security and transition readiness — Countries with a greater capacity to replace, in an orderly and secure way, O&G with low-carbon sources – referred to in this study as transition readiness – are better positioned to lead the transition away from O&G.** Considering the relevance of O&G to a country's energy mix —identified in this study as a potential barrier to a secure transition away — every country analyzed faces severe (> 60% of O&G in the energy mix) or serious (30% - 60%) obstacles. China and India are better positioned than the other countries in the sample, but only if transitioning from coal is not taken into consideration. Their advantages stem from lower reliance on O&G in their energy mix (<30%), their status as net importers of O&G, and moderate to low per capita primary energy consumption (<25 MWh/person). In addition, the US, Canada, Norway, and Germany stood out for their advanced transition readiness, given their high GDP per capita (> US$ 20k), low capital costs for financing the transition (sovereign ratings ranging from AAA to AA+), relatively competitive renewable energy sources, and integration into low-carbon value chains. Additionally, China's dominance of global supply chains for critical mineral processing and clean energy technology manufacturing, as well as its crucial role in energy transition investments, have led to its inclusion among the leaders of the transition readiness category.

- **Emissions profile — Responsibility for addressing the climate challenge is shared, but it should be differentiated among countries based on their historical and current contributions to emissions.** The US, China, and Russia are the largest contributors to global GHG emissions from energy and industry, both in absolute terms (> 2 $GtCO_2e$) and relative terms (> 10 tCO_2e/person; > 550 tCO_2e/US$ million of GDP), and from a historical perspective (> 70 $GtCO_2e$). Germany has also contributed significantly to historical emissions, despite having relatively lower current emission levels compared to the rest of the sample. As a result, from a climactic perspective, the US, China, Russia and Germany should lead the transition away from O&G, given their outsized emissions contributions.

- **Institutional and social resilience — A country's ability to achieve an orderly energy transition depends on robust institutional and social capacity to absorb the structural economic shifts associated with the replacement of fossil fuels by low-carbon energy sources.** In this context, Norway, Germany, Canada, and the US exhibit high state resilience scores (> 7.3), an indicator that measures factors including state and individual capacities, social cohesion, and civic space. They also boast high human development index scores (> 0.82), reflecting their advanced standards of living and high income. The United Arab Emirates (UAE) is also well-positioned, with a moderate state resilience measure (score: between 5.3 and 7.3) and a high human development index level. Therefore, these countries are better equipped to conduct the transition away, as they possess a stronger ability to deal with the potential disruptions that come with this transformation.

- Based on the five dimensions considered, the study has proposed a categorization of countries into three distinct groups: **(i) front-runners,** including Germany, China, the US, and Canada; **(ii) movers,** comprising Brazil, Russia, Norway, and the UAE; and **(iii) adapters,** which includes India, Saudi Arabia, and Nigeria. The main objective of this categorization is to reflect the varying degrees to which each country is exposed to the O&G industry - both economically and in terms of energy dependency - as well as its capacity to lead a secure and orderly energy transition. **The category names were chosen to broadly represent the unique conditions to gradually transition away from O&G faced by the three groups of countries, although it remains imperative for all to advance toward this goal, addressing both supply and demand for energy.**

3 Emissions from oil and gas extraction, processing, refining, and transport; methane, venting, and flaring

1. INTRODUCTION

Climate change leads to a worsening of extreme weather events. The current 10-year global average temperature is approximately 1.2 °C above the 1850-1900 period[4], making it the hottest decade on record. At the same time, 2023 was the warmest year ever registered, reaching 1.45 °C above pre-industrial levels[5]. Higher temperatures are leading to more frequent, intense and costly extreme weather events. During the 2010s, weather-related natural disasters caused over US$ 1.4 tn in economic losses, an eightfold increase compared to the 1970s[6]. Moreover, in 2023 alone, losses reached over US$ 280 bn, of which 60% were uninsured[7].

The increase in global average temperature is directly linked to anthropogenic GHG emissions. Since 1990, they have grown by 51%, reaching 57.1 $GtCO_2e$ in 2023, with around 68% attributable to the energy sector[8]. If emissions continue their current trajectory, the world's carbon budget to limit the temperature increase to 1.5 °C, as indicated by the science, will be exhausted in up to 5 years. Current policies are projected to result in at least 2.4 °C of warming by 2100[9], which would lead to severe and irreversible damage to society and its economic activities.

In this context, the O&G industry is at the forefront of global discussions about the future of energy, since it accounts for approximately 55% of energy-related emissions (15% associated with its production and 40% with its use)[10]. At COP28, nearly 200 countries acknowledged the need for "deep, rapid and sustained reductions in GHG emissions in line with 1.5 °C pathways", committing to "transitioning away from fossil fuels in energy systems, in a just, orderly, and equitable manner, accelerating action in this critical decade, in order to achieve net zero by 2050, in keeping with the science."

According to the International Energy Agency (IEA)[11], the implementation of COP28 commitments will lead to profound transformations, including lower O&G demand, increased renewable power, and greater energy efficiency. In terms of achieving a "just, orderly and equitable" transition, the IEA states that policies are crucial to ensure a stable retirement or repurposing of existing infrastructure, provide clear demand signals from consumers to producers to avoid disruptions, and ensure support to producing countries to manage reductions in fiscal revenues and income.

Therefore, the commitment of "transitioning away" requires an honest debate, as it implies trade-offs and dilemmas that are complex in nature and must be handled appropriately. There is still a weak understanding about the potential implications of transitioning away from O&G for both producers and consumers, which raises concerns around energy security and affordability. If society is to advance and fulfill the commitments made at COP28, policy makers cannot ignore the potential disruption that a mismatch of supply and demand could have and cannot risk losing societal support for the energy transition. This underpins the need to adopt a comprehensive perspective of the risks and opportunities at stake, while preparing all stakeholders to a new energy system.

This study provides an overview of the current state of the O&G industry and its importance to the global economy. Subsequently, different energy transition scenarios are analyzed, highlighting the extent to which they are aligned to the COP28 commitments. Finally, different criteria for transitioning away are explored, along with their implications for the selected countries.

4 WMO. State of the global climate 2023. 2024
5 WMO. Global temperature is likely to exceed 1.5 °C above pre-industrial level temporarily in next 5 years. 2024
6 WMO. Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019). 2021
7 AON. Climate and Catastrophe Insight. 2024
8 UNEP. Emissions Gap Report. 2024
9 IEA. World Energy Outlook. 2024
10 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
11 IEA. From taking stock to taking action. 2024

2. THE CURRENT STATE OF THE O&G INDUSTRY – SUPPLY AND DEMAND

Photo from Shutterstock (474102874)

2.1 OVERVIEW

Energy has been crucial in driving the socioeconomic development witnessed throughout history, becoming a critical pillar of modern society[12]. Countries that have managed to achieve higher levels of energy consumption generally perform better on key welfare indicators, such as health, education, and quality of life[13], not to mention on relevant economic indicators, such as GDP per capita. Developed economies like the US (77 MWh/person), Japan (39 MWh/person), and Germany (38 MWh/person), have above the average energy consumption per capita (21 MWh/capita in 2023)[14].

In this context, the adoption of fossil fuels, particularly after the Industrial Revolution, was central in promoting significant productivity gains, driving industrialization, urbanization, and socioeconomic development[15]. Fossil fuels quickly gained widespread use due to their competitive advantages, being more reliable and affordable than the alternatives available at the time, shaping global energy systems, value chains, and the existing infrastructure[16]. Today, the energy sector is largely dominated by these sources. In 2023, O&G accounted for approximately 51% of the global energy mix (vs. 12% for renewables) and around 60% of global electricity generation (vs. 30% for renewables)[17].

However, this came at a cost of increased GHG emissions as mentioned in the introduction. Therefore, global energy systems must be able to provide energy needs while simultaneously dealing with related emissions. Given the magnitude of the challenge, it is crucial to promote an orderly transition, addressing fossil fuels supply and demand in tandem[18]. Abrupt disruptions can trigger economic shocks, price volatility, and a decline in public support, notably in democratic countries[19]. The recent energy crisis of 2021-2022, driven by the conflict in Ukraine, emphasized the extent to which a sudden supply shock in O&G, even in a specific region, can have profound global consequences.

12 Vaclav Smil. World History and Energy. 2004
13 Vaclav Smil. World History and Energy. 2004
14 Our world on data. Primary energy consumption per capita. 2023
15 Vaclav Smil. World History and Energy. 2004
16 IEA. World Energy Outlook. 2024
17 IEA. World Energy Outlook. 2024
18 E3G. An orderly and equitable global transition away from fossil fuels. 2024
19 E3G. An orderly and equitable global transition away from fossil fuels. 2024

2.2 SUPPLY OF O&G

Despite the challenges posed by climate change, O&G production has increased in recent years, driven by economic and population growth. Between 2010 and 2023, oil production rose by 16%, from 85.1 million barrels per day (mb/d) to 99.2 mb/d[20]. Similarly, natural gas production increased from 3,286 billion cubic meters (bcm) to 4,218 bcm over the same period, reflecting an even greater growth of 28%[21].

O&G production is concentrated in a few countries and regions, which holds significant influence over global energy markets and price conditions. According to data from the Energy Institute (2024)[22], considering only crude oil (83 mb/d in 2023)[23], the top 10 oil-producing countries account for approximately 72% of the total production, led by the US (12.9 mb/d), Russia (10.1 mb/d), and Saudi Arabia (9.6 mb/d) **[Fig. 1]** [24]. This concentration is also evident in the natural gas market, where the top 10 producers hold about 73% of global production (2,963 bcm), with the US (1,035 bcm), Russia (586 bcm), and Iran (252 bcm) leading the way.

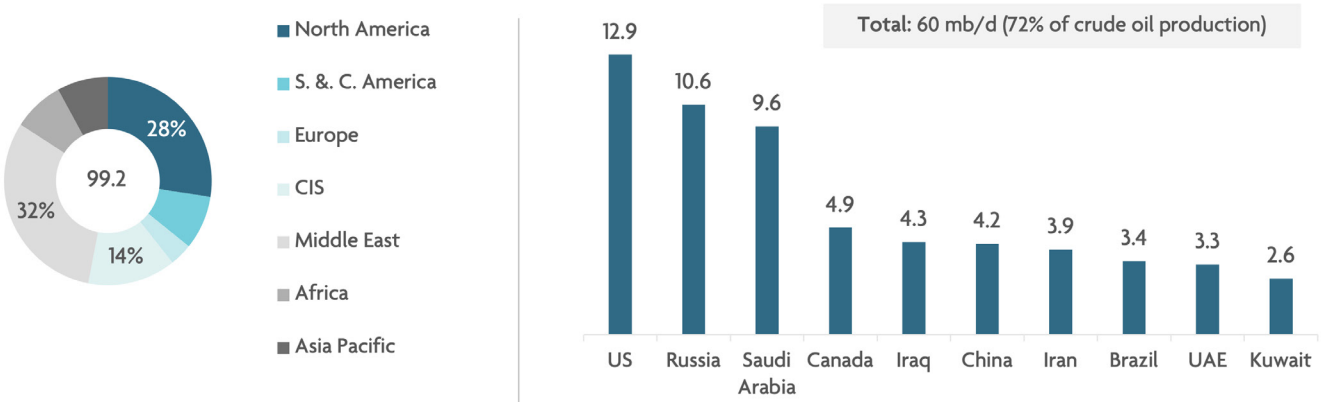
The O&G industry plays a significant economic role in producing countries. According to the IEA, between 2018 and 2022, approximately 50% of the revenues generated by the industry (US$ 8.5 bn) went to governments, mostly in the form of taxes, while 40% was allocated to CAPEX and OPEX and 10% went to shareholders and debt[25].

In particular, the industry makes a substantial contribution to the GDP of producing countries, especially those with high production levels and low economic diversification. For example, based on 2021 data, Iraq (40%), Saudi Arabia (38%), and Russia (8.5%) exhibit high oil rents as a share of GDP, compared to a global average of 1.3%. In terms of trade, O&G contributes significantly to exports in major producing countries. Considering other relevant producers, Nigeria (90%), Qatar (87%), and Norway (79%) have very elevated shares of fuel exports relative to total exports. A condition that can also be observed, though with less significance, in more diversified economies like the US (21%) and Brazil (16%).

At the same time, the O&G industry is a major driver of job creation. In 2023, O&G supply employment grew by 5%, reaching approximately 12.4 mn people (18% of the energy sector), with around 8.2 mn in oil and 4.2 mn in natural gas[26]. It is also worth noting that the industry offers higher average wages compared to other segments of the energy sector. In the US, for example, the average annual salary of permanent energy workers in the O&G industry is 29% higher than in renewables and 34% higher than in petrochemicals. This trend is also observed in other regions, such as Asia, Africa, Europe, and the Middle East.

FIGURE 1 – GLOBAL OIL PRODUCTION BY REGION AND CRUDE OIL PRODUCTION BY COUNTRY (mb/d, 2023)

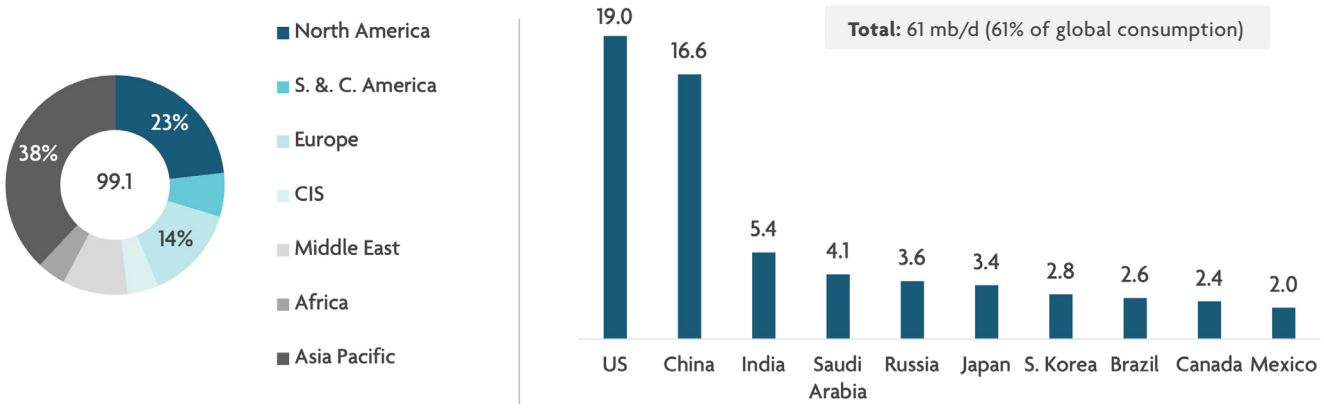
Source: IEA. World Energy Outlook. 2024; Energy Institute. Statistical Review of World Energy. 2024



20 IEA. World Energy Outlook. 2024
21 IEA. World Energy Outlook. 2024
22 Energy Institute. Statistical Review of World Energy. 2024
23 Energy Institute. Statistical Review of World Energy. 2024
24 Energy Institute. Statistical Review of World Energy. 2024
25 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
26 IEA. World Energy Employment. 2024

FIGURE 2 – GLOBAL OIL DEMAND BY REGION AND COUNTRY (mb/d, 2023)

Source: IEA. World Energy Outlook. 2024; Energy Institute. Statistical Review of World Energy. 2024



2.3 DEMAND FOR O&G

Similarly to production, demand for O&G is concentrated in a few countries and regions, which will play a key role in determining the pace of the energy transition[27]. Global oil demand reached approximately 99.1 mb/d in 2023, growing by 14% since 2010 (87.2 mb/d)[28]. The top 10 oil-consuming countries accounted for roughly 61% of total global demand (61 mb/d), led by the US (19 mb/d), China (16.6 mb/d), and India (5.4 mb/d) **[Fig. 2].** When it comes to natural gas, the total demand reached approximately 4,186 bcm in 2023, up from 3,312 bcm in 2010, representing a 26% increase[29]. According to data from the Energy Institute (2024)[30], about 61% of global demand (2,557 bcm) was concentrated in just 10 countries in 2023. The main consuming countries are the US (886 bcm), Russia (453 bcm), and China (405 bcm).

O&G demand is also focused on a few sectors which are typically energy-intensive, where the characteristics of fossil fuels, such as energy density and reliability, are highly valued. When it comes to oil, demand is primarily driven by transportation (55%), notably road transport (43%), and industry (21%). On the other hand, gas consumption is mainly linked to power generation (39%), buildings (21%), and industry (21%). Decarbonizing these sectors by reducing or replacing fossil fuels is essential in the context of transitioning away from O&G. While the number of sectors is limited, demand is dispersed across various companies and even individuals, resulting in diverse decarbonization pathways and ambitions.

The challenges of decarbonization are particularly significant in hard-to-abate sectors, such as shipping, aviation, petrochemicals, and steel. These sectors encounter significant technical challenges in adopting decarbonization technologies or promoting electrification based on renewable energy sources[31]. Therefore, it is crucial to accelerate the transition in other sectors where these barriers are less pronounced, while technological solutions for hard-to-abate sectors become more competitive and viable.

Finally, it is important to underline that one of the obstacles to reducing or replacing O&G consumption is related to price signals. In response to the 2022 energy crisis, O&G subsidies aimed at consumers and end-users reached record levels of US$ 841 bn (compared to US$ 384 bn in 2021)[32]. These subsidies were intended to protect consumers by keeping energy prices affordable. However, they are often poorly targeted, as they disproportionately benefit higher-income households[33], create fiscal pressures, and hinder the efficient allocation of resources. In this context, it is essential to phase out and reduce inefficient subsidies to make clean technologies more competitive, while also addressing negative externalities by putting a price on carbon.

27 Energy Institute. Statistical Review of World Energy. 2024
28 IEA. World Energy Outlook. 2024
29 IEA. World Energy Outlook. 2024
30 Energy Institute. Statistical Review of World Energy. 2024
31 IEA. World Energy Outlook. 2024
32 OECD. OECD Inventory of Support Measures for Fossil Fuels. 2023; IEA. Tracking the impact of government support – fossil fuels. 2023
33 OECD. OECD Inventory of Support Measures for Fossil Fuels. 2023; IMF. Climate change: fossil fuel subsidies. 2023

3. ENERGY TRANSITION SCENARIOS

Photo by Adreas Gucklhorn via Unsplash

Scenario analysis is essential for navigating the many uncertainties surrounding the future of the energy sector. Some of the scenarios considered by decision-makers are those from the Organization of Petroleum Exporting Countries (OPEC), oil majors, and the IEA. As a result of various assumptions, including those related to technological development, consumer preferences, and the effectiveness of public policies, these scenarios present fundamentally diverse perspectives on the future of global energy supply and demand, particularly for O&G, as well as on the achievement of climate ambitions, including the commitments made at COP28.

The OPEC reference scenario projects that the energy sector will still be dominated by O&G by mid-century. The share of O&G in the global energy mix is expected to remain at current levels over the long term, at approximately 53% in 2050 (vs. 51% in 2023)[34]. Oil demand is projected to grow by around 20% between 2023 and 2050, reaching 120 mb/d (vs. 99.1 mb/d in 2023)[35]. In this scenario, the global average temperature increase would exceed 2 °C, as OPEC indicates that population and economic growth would prevent the decarbonization of the energy sector from happening in a safe manner[36].

In parallel, OPEC has developed an alternative scenario, named Technology-Driven, which is aligned with the trajectory of limiting the rise in global average temperatures to well below 2 °C, as outlined in the Paris Agreement. This scenario assumes accelerated energy efficiency gains across all sectors and large-scale implementation of carbon capture and removal technologies, such as direct air capture (DAC) and carbon capture, utilization and storage (CCUS). In this scenario, oil demand would reach 96 mb/d by 2050[37], representing only a 3% decrease compared to current levels. Estimates indicate that nearly US$ 3.7 tn per year[38] would be required for carbon removal technologies to sustain the current O&G production levels, potentially impacting the economic feasibility of new projects.

On the other hand, energy companies and institutions project a reduced role for O&G in the future of global energy systems, driven by technological development, regulatory progress, and changes in consumption patterns. Among European oil majors, bp and Shell can be cited as examples. In their reference scenarios[39], the companies signal peak oil demand during the 2020s (bp) and 2030s (Shell), while gas plays a more significant role through 2050. In addition, in their climate-aligned scenarios, both companies project a reduction in O&G demand by 2050 — Shell 45 mb/d[40] and bp 28 mb/d[41] by 2050.

34 OPEC. World Oil Outlook 2050. 2024
35 IEA. World Energy Outlook. 2024
36 OPEC. World Oil Outlook 2050. 2024
37 OPEC. World Oil Outlook 2050. 2024
38 IEA. World Energy Outlook. 2024
39 bp. Energy Outlook 2024. 2024
40 Shell. The Energy Security Scenarios. 2024
41 Shell. The Energy Security Scenarios. 2024

Given the range of perspectives and the degree of uncertainty, this study focuses on two IEA scenarios for deeper analysis: the Stated Policies Scenario (STEPS), which considers the energy, climate, and industrial policies that are in place or that have been announced, and the Net Zero Scenario by 2050 (NZE), which outlines the necessary transformations to achieve net zero energy-related emissions by 2050[42]. According to the IEA[43], the full implementation of the COP28 commitments, including "transitioning away," would set the sector on a medium-term path consistent with the NZE. The comparison between scenarios illustrates the gap between the current trajectory of the energy system (STEPS) and what would be required for a 1.5 °C scenario (NZE).

Both scenarios project a decline in O&G demand, in absolute and relative terms, by 2050. In the STEPS scenario, O&G's share in the global energy mix would drop from 51% in 2023 to 50% in 2030 and 44% in 2050. This scenario considers a peak in O&G demand before the end of the decade, followed by a slight decline by mid-century, with oil demand reaching 93.1 mb/d and natural gas 4,377 bcm by 2050. In the NZE scenario, the changes are more significant. O&G's share in the energy mix would need to fall to 45% by 2030 and 11% by 2050[44], implying oil demand of 23 mb/d in 2050 and natural gas demand of 882 bcm.

Significant shifts in energy sector investments are required if the world is to be aligned with the NZE scenario. Since 2019, investments in low-carbon technologies have grown by approximately 64% and are expected to reach around US$ 2 tn in 2024[45]. Meanwhile, investments in fossil fuels have remained relatively stable over the past six years, averaging US$ 1 tn per year. As a result, the ratio of clean technology investments to fossil fuel investments has shifted from 1:1 in 2019 to 1:2 in 2024.

However, it remains critical to further scale up clean energy investments over the coming decades. In STEPS, they are expected to rise from US$ 2 tn per year to US$ 2.4 tn by 2030, but in the NZE scenario they would need to increase to US$ 4.1 tn by the end of the decade[46]. At the same time, investments in fossil fuels are projected to decrease from US$ 1 tn to US$ 0.9 tn (STEPS) but further to US$ 0.4 tn (NZE) over the same period. According to the IEA, under the NZE scenario, no further investment in new long-lead time upstream O&G projects would be needed[47]. Having said that, investments in operational assets and already-approved projects will be crucial to mitigate risks of supply disruption and increased energy price volatility.

Additionally, investments must become increasingly geographically diversified. In 2024, a significant portion of clean technology investments occurred in advanced economies (53%) and China (32%), while emerging markets and developing economies (EMDEs) accounted for only 15% of the total. Under the NZE scenario, clean technology investments in EMDEs grows by 4 to 6 times by 2030, rising from US$ 0.32 tn per year to US$ 1.4–1.9 tn[48], and approximately 90% of these investments are already in the commercial viability or development stages[49].

42 IEA. From Taking Stock to Taking Action. 2024
43 IEA. From Taking Stock to Taking Action. 2024
44 IEA. World Energy Outlook. 2024
45 IEA. World Energy Investment. 2024
46 IEA. World Energy Investment. 2024
47 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
48 IEA. Scaling up private finance for clean energy in emerging and developing economies. 2023
49 IEA. Scaling up private finance for clean energy in emerging and developing economies. 2023

4. IMPLICATIONS FOR PRODUCING COUNTRIES AND O&G COMPANIES

Photo by Maria Lupan via Unsplash

4.1 EMERGING RISKS

Producing countries and O&G companies are increasingly exposed to climate risks, which can be categorized as either physical or transition risks[50]. Physical risks are associated to the increased frequency and intensity of extreme weather events, including higher temperatures, sea-level rise, flooding, storms, and droughts. These events can impact or disrupt O&G operations and, in severe cases, lead to damages to assets. According to the UN[51], approximately 40% of global O&G reserves are currently threatened by physical risks, a percentage that could increase with the worsening effects of climate change. In this sense, actions for mitigation, adaptation, and response planning are required.

Transition risks, on the other hand, are associated with new public policies, emerging technologies, as well as evolving market behavior and consumer preferences within the context of the transition to a low-carbon economy[52]. In this regard, several risks can be identified, including those related to stranded assets, climate litigation, and carbon markets.

The reduction in production and potential decline in O&G prices due to more restrictive climate policies and shifting demand profiles could lead to stranded assets — whether in terms of volume (unexploited reserves), capital (unrecovered infrastructure investments), or value (loss of future revenue)[53]. Both national oil companies (NOCs), along with governments, and private companies are exposed to this risk. According to the IEA, the value of the O&G industry diminishes with increased climate ambition. For example, the net present value of upstream O&G production could decrease by up to 60% from the STEPS to the NZE scenario[54].

Moreover, O&G companies are increasingly subject to climate litigation, and its disruptive potential —whether financial, regulatory, or judicial — remains uncertain. According to the London School of Economics (LSE), over 230 climate litigation cases have been filed against companies since 2015, with a growing focus on O&G firms[55]. A notable recent example is the State of California's lawsuit against oil majors and an industry trade association, alleging

50 Task Force on Climate-related Financial Disclosure. Climate risks. 2024
51 UN Environment Programme. Sectoral Risk Briefings. Insights for financial institutions. 2023
52 Task Force on Climate-related Financial Disclosure. Climate risks. 2024
53 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
54 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
55 London School of Economics. Global trends in climate change litigation: 2024 snapshot. 2024

that these actors were aware of the harmful impacts of GHG emissions from burning fossil fuels to the climate, but suppressed the information from the public[56].

Finally, carbon pricing mechanisms are expected to play an increasingly significant role in addressing negative externalities, either by expanding emissions coverage or through rising prices. According to the World Bank[57], there are nearly 75 carbon pricing mechanisms — either taxes or emissions trading schemes — operating globally, covering approximately 24% of global emissions, with varying price levels. These mechanisms are expected to gain increasing relevance in the coming years, driven by advancements in the Article 6 of the Paris Agreement[58], expanded coverage in critical regions such as China — which plans to include steel, aluminum, and cement in its carbon market by the end of 2024[59] —, and the progress of similar regulations in different countries, such as Brazil, where a Bill was recently approved[60].

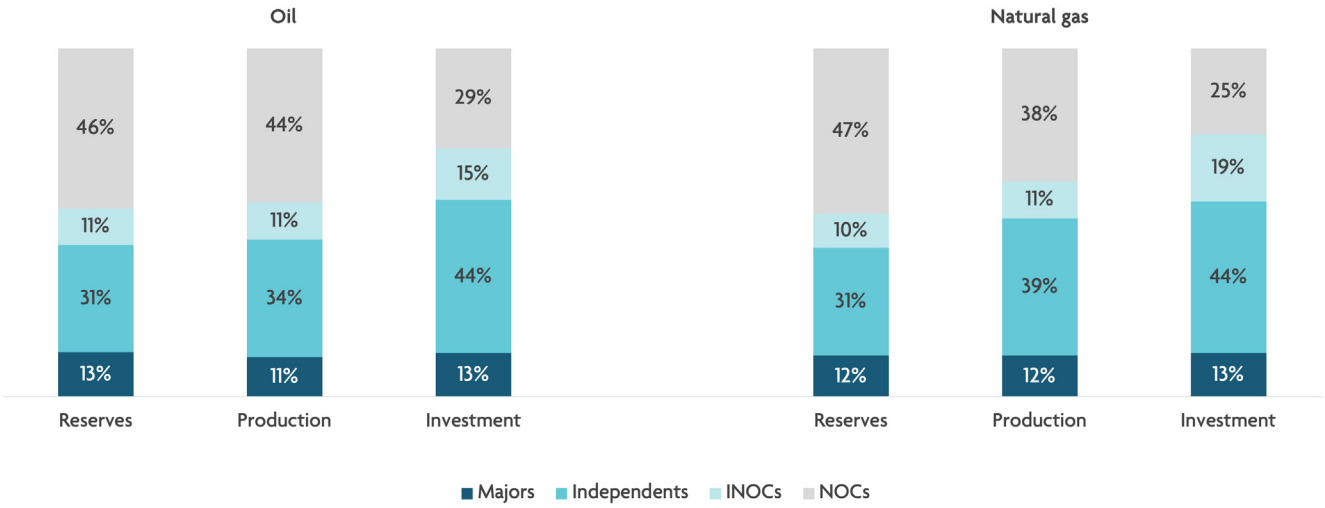
4.2 DECARBONIZATION STRATEGIES

Countries and companies that can produce O&G with lower carbon intensity are likely to be better positioned in the context of reduced demand and stricter climate regulations. In this sense, O&G companies — including oil majors[61], independents[62], and NOCs[63] — are developing different decarbonization strategies.

Although oil majors are at the center of most climate discussions, it is crucial to understand how reserves, production, and investments are distributed across the various categories of companies in the sector **[Fig. 3]**. According to the IEA, NOCs account for more than 40% of global O&G reserves and production, while oil majors — such as ExxonMobil, Chevron, TotalEnergies, Shell, and bp — are responsible for near 13% of reserves and 12% of production[64].

FIGURE 3 – OWNERSHIP OF O&G RESERVES, PRODUCTION, AND UPSTREAM INVESTMENT (%, 2022)

Source: IEA. The Oil and Gas Industry in Net Zero Transitions. 2023



56 Financial Times. California accuses Big Oil of covering up climate change risks in lawsuit. 2023
57 World Bank. State and Trends of Carbon Pricing. 2024
58 Article 6 pertains to the establishment of international compliance carbon markets governed by the rules of the Paris Agreement where countries can trade carbon credits – World Bank. What You Need to Know About Article 6 of the Paris Agreement. 2024
59 Carbon Brief. Explainer: China's carbon market to cover steel, aluminium and cement in 2024. 2024
60 Câmara dos Deputados. Câmara aprova projeto que regulamenta o mercado de carbono no Brasil; texto segue para sanção. 2024

61 Large companies listed on stock markets in the US and Europe
62 Smaller fully integrated companies or independent upstream operators
63 Given mandates by their home Governments to exploit national resources and have a legally defined role in upstream development
64 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023

As previously mentioned, both supply and demand of O&G are highly relevant to energy-related GHG emissions, contributing 18.7 $GtCO_2e$ (55% of the total energy-related emissions). While over 70% of total O&G emissions are related to scope 3 (i.e., consumption), 30% are associated with scope 1 and 2 emissions (i.e., operational emissions), totaling 5.1 $GtCO_2e$[65]. According to the IEA, operational emissions must decrease by 63% (NZE) between 2022 and 2030, reaching near zero by 2050[66].

Five key levers have been mapped to reduce the industry's operational emissions[67]: addressing methane emissions, eliminating all non-emergency flaring, electrifying upstream facilities, equipping O&G processes with CCUS, and expanding the use of low-emission electrolytic hydrogen in refineries. Estimates suggest that approximately US$ 600 bn would need to be invested in these strategies by 2030 to enable the necessary emissions reductions in line with the more restrictive NZE scenario[68].

Reducing methane emissions would have the greatest impact by the end of the decade. Methane is considered the most impactful GHG, responsible for about 30% of the global temperature increase from pre-industrial levels[69]. The technologies and measures to mitigate and prevent methane emissions are well-known and have already been commercially applied in various locations. Examples include the installation of control and detection devices and the replacement of components. Estimates indicate that most available solutions have abatement costs below US$ 20/tCO_2e[70].

At the same time, eliminating non-emergency natural gas flaring by 2030 could avoid approximately 365 $MtCO_2e$ per year. Several alternatives can be considered, such as reinjecting gas to improve reservoir recovery, converting natural gas into LNG, or even using it to power CCUS equipment[71]. Although abatement costs vary depending on the measure chosen, an estimated US$ 70 bn in investments would be needed by 2030 to reduce flaring emissions by 95%[72].

Electrification of operations is also considered a high-potential emissions reduction measure. Electrification could reduce carbon emissions from energy use by up to 50% by 2030[73]. Currently, most of the energy required for O&G operations is used to generate electricity for equipment, which is predominantly produced on-site using small natural gas generators. According to the IEA, approximately 50% of global O&G production is located less than 10 km from grids, and 75% of production is situated in areas with potential for solar and wind generation. Despite these factors, electrification options will still be uncompetitive by 2030, resulting in additional costs for operators, even with efficiency gains.

CCUS and hydrogen are relevant technological options, despite their limited potential until 2030. In 2022, the O&G industry was involved in approximately 90% of the global operating CCUS capacity. Additionally, more than 40% of investments made since 2010 in this technology were by companies in the sector[74]. In the NZE scenario, carbon capture capacity applied in the O&G value chain needs to grow more than six times by 2030, reaching 160 $MtCO_2$ (vs. 25 $MtCO_2$ in 2022). Meanwhile, the use of low-carbon hydrogen, though limited in the medium term, could contribute to significant reductions after 2030, particularly in refineries.

In addition to initiatives aimed at decarbonizing operations, O&G companies are increasingly being called upon to address their scope 3 emissions, which represent the bulk of their total emissions. Different strategies are being implemented by companies, particularly oil majors, to diversify portfolios and promote low-carbon technologies. In 2022, O&G companies invested approximately US$ 20 bn in clean technologies, including batteries[75], CCUS, bioenergy, solar, and wind. This amount is 20% higher than in 2021 and about 10 times higher than in 2015. Despite this progress, the industry still invests relatively little in clean technologies. These investments account for only 2.7% of the sector's total CAPEX and represent just 1.2% of global investments in clean technologies[76].

65 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
66 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
67 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
68 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
69 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
70 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
71 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
72 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
73 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
74 IEA. Emissions from O&G Operations in Net Zero Transitions. 2023
75 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023
76 IEA. The Oil and Gas Industry in Net Zero Transitions. 2023

5. PERSPECTIVES AND CRITERIA TO BE CONSIDERED IN THE "TRANSITIONING AWAY"

Photo by Support Offshore Wind

This work aims to provide insights to the complex and challenging debate on transitioning away from O&G in a "just, orderly, and equitable manner", by analyzing a selected group of countries that play a significant role in the supply and demand of O&G. The selection process ranked the most relevant O&G countries into two groups: (i) producers, based on annual O&G production and proven reserves, and (ii) consumers, based on annual O&G consumption. The top ten countries from each group were merged into a single list of eleven countries, aiming to ensure diversity in geographic representation **[Fig. 4].** Brazil was included among the 11 countries, standing out as the 9th largest producer and the 8th largest consumer of oil, as well as being the host country of the institutions responsible for conducting this study.

A set of indicators to support decision-makers in the transitioning away from O&G context was identified. These indicators were grouped into five main categories: (i) O&G relevance, (ii) O&G competitiveness, (iii) energy security and transition readiness, (iv) emissions profile, and (v) institutional and social resilience. The analysis of these selected categories highlights the trade-offs and dilemmas across different dimensions and underscores the potential implications of decisions that prioritize one category over the others.

5.1 O&G RELEVANCE

This category focuses on a country's dependence on the O&G sector for its development, encompassing indicators that measure its economic relevance. The objective is to determine the degree of economic dependency on O&G activities to assess each country's level of vulnerability in an energy transition context. To that end, six critical indicators were analyzed **[Tab. 1]**.

Reducing O&G production will be challenging everywhere, but the difficulties grow in direct relation to a country's economic dependency on the O&G sector **[Fig. 5]**. Net-exporting countries with established O&G infrastructure and less diversified economies often rely heavily on revenues from the sector's activities. As a result, fluctuations in export revenues can directly affect the country's current account. Likewise, shifts in foreign investment in the O&G sector, prompted by investors' anticipation of decreasing global oil demand, will impact the inflows in the financial account.

Reduced demand for O&G could lead to a decline in export revenues and investments for producing countries. This decline may trigger fiscal imbalances, slow GDP growth, increase inflation, and

FIGURE 4 – COUNTRIES SELECTED FOR THE STUDY

Source: Catavento analysis based on Energy Institute. Statistical Review of World Energy. 2024

Group 01 – Top 10 O&G producers

Country	Region
US	North America
Saudi Arabia	Middle East
Russia	CIS
Canada	North America
Iran	Middle East
UAE	Middle East
China	Asia Pacific
Qatar	Middle East
Norway	Europe
Nigeria	Africa

Group 02 – Top 10 O&G consumers

Country	Region
US	North America
China	Asia Pacific
India	Asia Pacific
Saudi Arabia	Middle East
Russia	CIS
Japan	Asia Pacific
South Korea	Asia Pacific
Canada	North America
Mexico	North America
Germany	Europe

Final group – most relevant countries

Country	Region
US	North America
Canada	North America
Russia	CIS
China	Asia Pacific
India	Asia Pacific
Saudi Arabia	Middle East
UAE	Middle East
Norway	Europe
Germany	Europe
Brazil	S. & C. America
Nigeria	Africa

11 countries selected based on global O&G significance and geopolitical diversity

TABLE 1 – INDICATORS OF O&G RELEVANCE

INDICATOR	UNIT	DEFINITION
Oil production	Mb/d	Total amount of oil produced by the country
Oil reserves	bn barrels	Total proved oil reserves of the country
Oil rents	% of GDP	Difference between the value of crude oil production at regional prices and total costs of production
Fuel exports	% of exports	Total share of fuels (mineral fuels, lubricants and related materials) in merchandise exports
Stranded assets	total US$ and % of GDP	The financial impact of a change in expectations on the present value of discounted future profit streams from O&G

affect the financial sector — especially if the downturn in the O&G industry extends to related sectors, such as fertilizers and petrochemicals, with potential multiplier effects throughout the economy. These ripple effects could also have a more severe impact on the broader tax base and alter the composition of public spending.

Generally, the larger a country's oil production and reserves are, the more exposed it is to the impacts of a global transition away from O&G [Fig. 6]. Countries with large reserves but low production may struggle to fully capitalize on these assets in an energy transition trajectory compatible with the NZE scenario, especially those with less competitive production costs and emissions levels.

Based on our analysis, three main categories of countries can be identified when it comes to economic dependence on O&G [Tab. 2].

FIGURE 5 – OIL RENTS AND FUEL EXPORTS IMPORTANCE

Source: Catavento analysis based on World Bank. Open Data. 2021, 2022, 2023

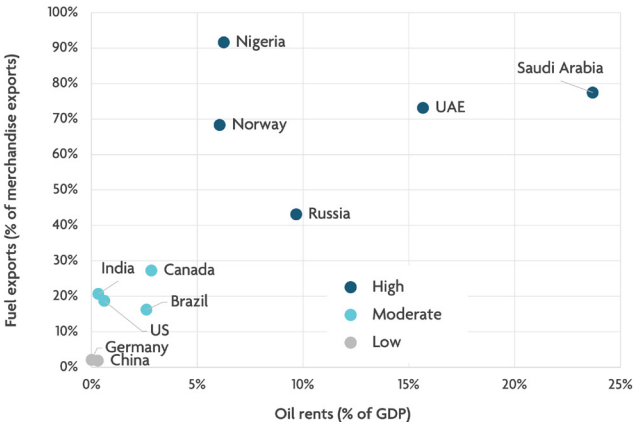
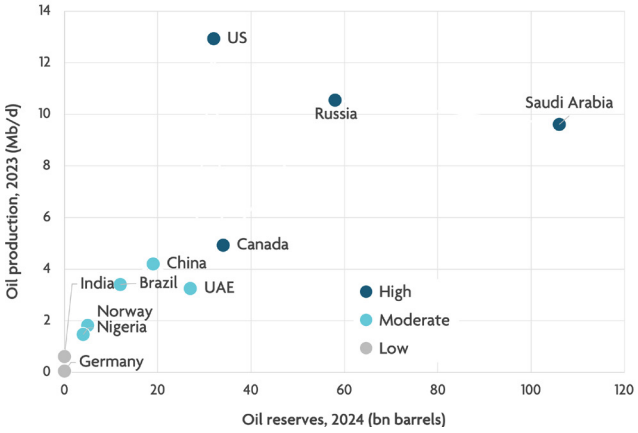


FIGURE 6 – OIL RESERVES[77] AND OIL PRODUCTION RELEVANCE

Source: Catavento analysis based on Energy Institute. Statistical Review of World Energy. 2024



77 Proved reserves

TABLE 2 – ECONOMIC RELEVANCE OF O&G

CATEGORY	OIL RENTS RANGE	FUEL EXPORTS RANGE	OIL PRODUCTION	OIL RESERVES
High	> 5% of GDP	> 30% of total exports	> 4.3 Mb/d	> 30 bn barrels
Moderate	1% - 5% of GDP	10% - 30% of total exports	1.4 – 4.3 Mb/d	4 – 30 bn barrels
Low	< 1% of GDP	< 10 % of total exports	< 1.4 Mb/d	< 4 bn barrels

- **High relevance:** Middle Eastern countries — such as Saudi Arabia and the UAE — are highly dependent on both oil rents, which represent more than 15% of GDP, and on fuel exports, which account for more than 70% of their total merchandise exports. Nigeria, Norway, and Russia are less dependent on oil rents (between 5% and 10% of GDP), but rely on fuels for more than 40% of their merchandise exports, making the O&G sector a very important economic actor. Additionally, Saudi Arabia and Russia hold high levels of oil production and reserves, amplifying the potential significance of O&G in their economies.
- **Moderate relevance:** In Canada, the US, and Brazil, the O&G sector is a relevant economic driver, but these countries' economies are less dependent on oil rents and fuel exports. However, the US and Canada possess substantial oil production and reserves, increasing the potential significance of O&G to their economies. China also has a large O&G sector with moderate level of production and reserves; however, its weight is relatively small considering the robust size of its diversified economy and exports. In India, oil rents, oil production, and oil reserves are not as relevant, but O&G derived fuels alone account for more than 20% of total exports.
- **Low relevance:** In countries such as Germany, O&G production and reserves are minimal, rendering the sector's revenues negligible in comparison to the overall economy.

O&G assets[78] face the risk of becoming stranded due to lower demand and changing price levels, as mentioned in section 4.1. The largest O&G-producing nations are likely to incur the greatest losses because of shifting expectations regarding the present value of discounted future profit streams **[Fig. 7]**. However, when assessing losses in relation to GDP, countries that are highly dependent on O&G investments and cannot maintain profitable production sites will experience the most significant proportional impact **[Fig. 8]**. Companies operating in low-cost Middle Eastern fields might increase their market share as global O&G demand peaks and then declines, with these producers competing to capture the shrinking market.

Based on our analysis, three main categories of countries can be identified when it comes to stranded assets impact **[Tab. 3]**.

FIGURE 7 – STRANDED ASSETS LOSS (US$ tn)[79]

Source: Catavento analysis based on Nature Climate Change. Stranded fossil-fuel assets translate to major losses for investors in advanced economies. 2022

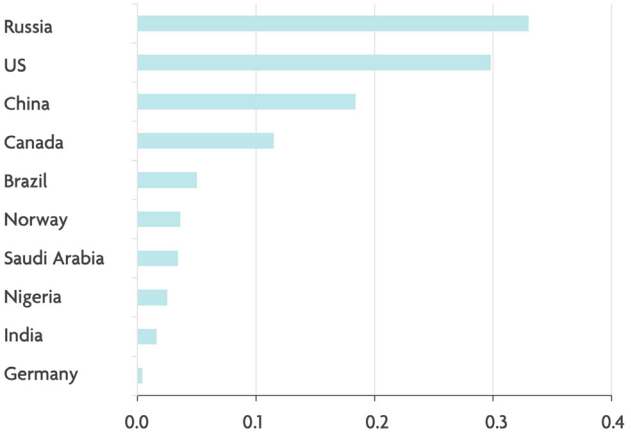


FIGURE 8 – STRANDED ASSETS AS SHARE OF GDP (%)[79]

Source: Catavento analysis based on Nature Climate Change. Stranded fossil-fuel assets translate to major losses for investors in advanced economies. 2022

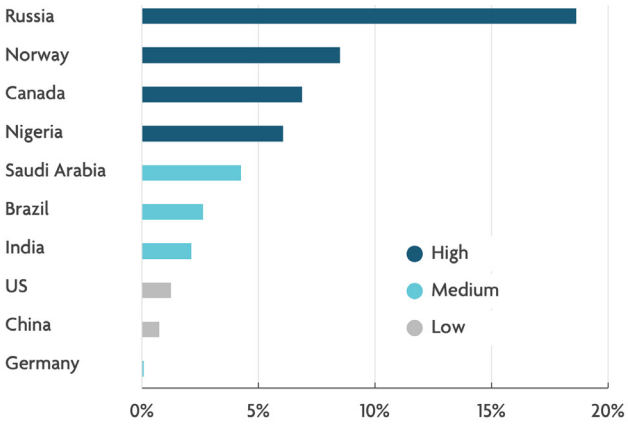


TABLE 3 – STRANDED ASSET IMPACT

CATEGORY	STRANDED ASSETS (% OF GDP)
High	> 5% of GDP
Moderate	2% - 5% of GDP
Low	< 2 % of GDP

78 Based on O&G production sites worldwide—covering most current global production, reserves, and resources—asset stranding is attributed to the country where these sites are located. Stranded assets are estimated by comparing investor expectations of asset profitability under a baseline scenario to those under a policy scenario in 2022, over a 15-year profit horizon (Nature Climate Change.Stranded fossil-fuel assets translate to major losses for investors in advanced economies. 2022).

79 Data on the UAE's stranded asset risk/loss was unavailable in the considered scenario and was consolidated under the Rest of the World (ROW) category.

- **High impact:** Russia, Norway, Canada, and Nigeria face the highest risk of stranded assets in a global transition away from O&G, with a strong potential for ripple effects across other sectors.
- **Moderate impact:** Saudi Arabia, Brazil, and US would experience a significant impact from stranded O&G assets, though to a lesser extent. However, they also face considerable spillover effects across other sectors.
- **Low impact:** Germany, India, and China would be the least relatively impacted by losses in O&G investments and would also face minimal exposure to spillover effects in other sectors.

Key messages from O&G relevance

- Even in a moderate energy transition scenario (e.g., STEPS), the expected shift in expectations for future global O&G demand could have a significant impact on countries that are heavily dependent on O&G.
- The country's resilience during the energy transition—despite high levels of O&G production and reserves—depends in part on the diversification of its economy.
- Countries with high or medium economic dependence on O&G and significant stranded asset risks that cannot keep their remaining operations competitive, or repurpose these assets effectively, are the most vulnerable to the transition from an economic standpoint.
- Net O&G importers are less dependent on O&G revenues for economic development and face lower stranded asset risks, providing them with greater stimulus to transitioning away from O&G in their domestic energy demand.
- Countries with significant reserves but low production may find it challenging to fully leverage these assets in more restricted climate contexts.

5.2 O&G COMPETITIVENESS

This category seeks to assess a country's O&G production competitiveness in terms of cost and emissions [Tab. 4]. In a world undergoing an energy transition, the remaining O&G-producing countries must be resilient to both lower O&G prices and higher carbon prices. In this context, countries capable of producing at the lowest cost and with lower carbon intensity would be better positioned to meet future remaining demand.

TABLE 4 – INDICATORS OF O&G COMPETITIVENESS

INDICATOR	UNIT	DEFINITION
Breakeven prices of new crude oil supply	(US$/bbl)	The minimum oil price at which a new production project becomes economically viable – projections to 2040
Emissions per barrel	(kg CO_2-eq)	Total amount of kg CO_2-eq emitted on average for each barrel of oil equivalent (boe) produced

The Middle East's onshore production stands out for having the world's lowest average breakeven prices for new crude oil projects and the largest resource base **[Fig. 9]**. Offshore production, led by Brazil, comes in third in terms of breakeven prices and ranks second in resource potential. Norway, Russia, and the US—particularly in the Gulf of Mexico and the Permian Basin's tight oil—follow closely, positioning themselves competitively in the new crude oil supply landscape.

The tight oil sector benefits from significantly shorter payback times — just two years compared to roughly 10 years for other sources —and a higher average internal rate of return[80]. At the opposite end of the spectrum are oil sands, which have the lowest internal rate of return due to being the most expensive source of supply.

In this context, the study identifies three main categories of oil production competitiveness based on cost factors **[Tab. 5]**.

FIGURE 9 – COST CURVE OF NEW GLOBAL CRUDE OIL SUPPLY IN 2040

Source: S&P Global. Global crude oil cost curve shows 90% of projects through 2040 breaking even below US$ 50/bbl.

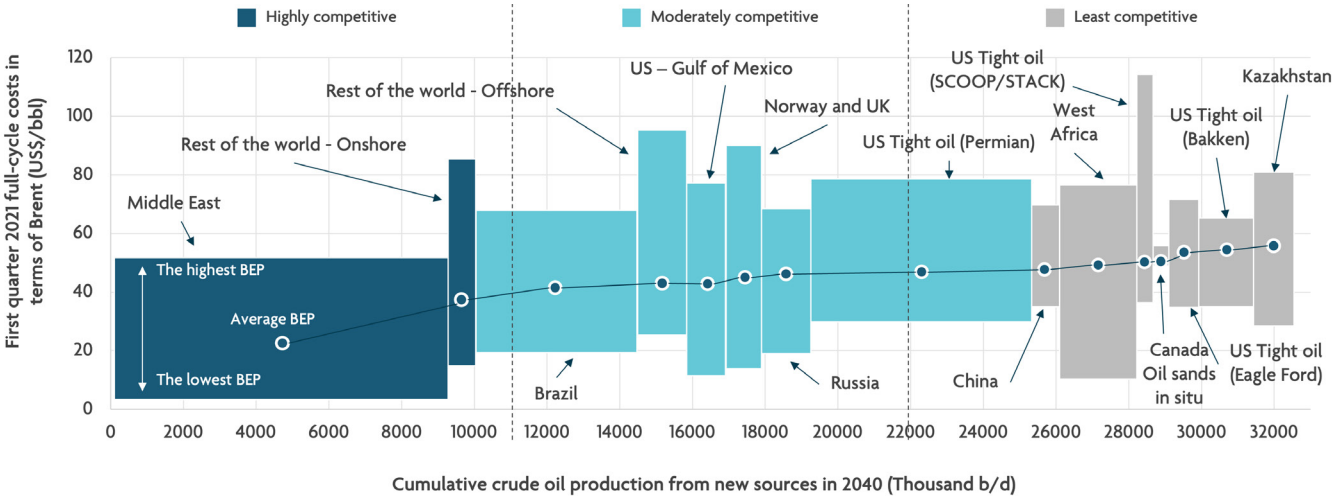


TABLE 5 – COST COMPETITIVENESS OF OIL

CATEGORY	BREAKEVEN PRICES OF NEW CRUDE OIL SUPPLY (APPROXIMATE VALUES)
Highly cost-competitive	< US$ 40 per barrel (the first third of cumulative oil production from new sources)
Moderately cost-competitive	US$ 40 - 47 per barrel (the second third of cumulative oil production from new sources)
Least cost-competitive	> US$ 47 per barrel (the last third of cumulative oil production from new sources)

- **Highly cost-competitive:** Middle Eastern countries, such as Saudi Arabia and the UAE, lead as the most competitive regions for new supply, followed by cost-effective onshore producers from other regions.
- **Moderately cost-competitive:** Brazil, other offshore cost-effective producers, Russia, Norway, and much of the new projects from the US compete for the second tier of cost-effectiveness for new supply.
- **Least cost-competitive:** : Canada, China, and Nigeria are lagging in terms of cost advantage for new supply.

80 Assuming a US$ 70 per barrel price. Rystad. Shale project economics still reign supreme as cost of new oil production rises further. 2024

Norway sets the benchmark for emissions intensity in the O&G sector [Fig. 10]. The emission intensity of O&G production exhibits a broad spectrum of life-cycle emissions, influenced by the methods of extraction, processing, refining, transportation, and usage. As a result, production emissions can vary significantly from one country to another.

Regions with lower emissions are typically those where oil is easier to extract, where refining takes place close to extraction sites, or where methane emissions are effectively controlled. Producers of light oils and natural gas liquids also have lower carbon intensity because they require less refining. In contrast, countries that export large volumes of natural gas as liquefied natural gas (LNG) or through long pipelines tend to have higher emissions due to the energy-intensive processes involved, such as LNG liquefaction.

In this context, the study identifies three main categories of oil production competitiveness based on emissions factors [Tab. 6].

FIGURE 10 – AVERAGE EMISSIONS INTENSITY OF O&G PRODUCING COUNTRIES, 2022 (kg CO_2-eq)

Source: IEA. The Oil and Gas Industry in Net Zero Transitions. 2023. No data available for Germany.

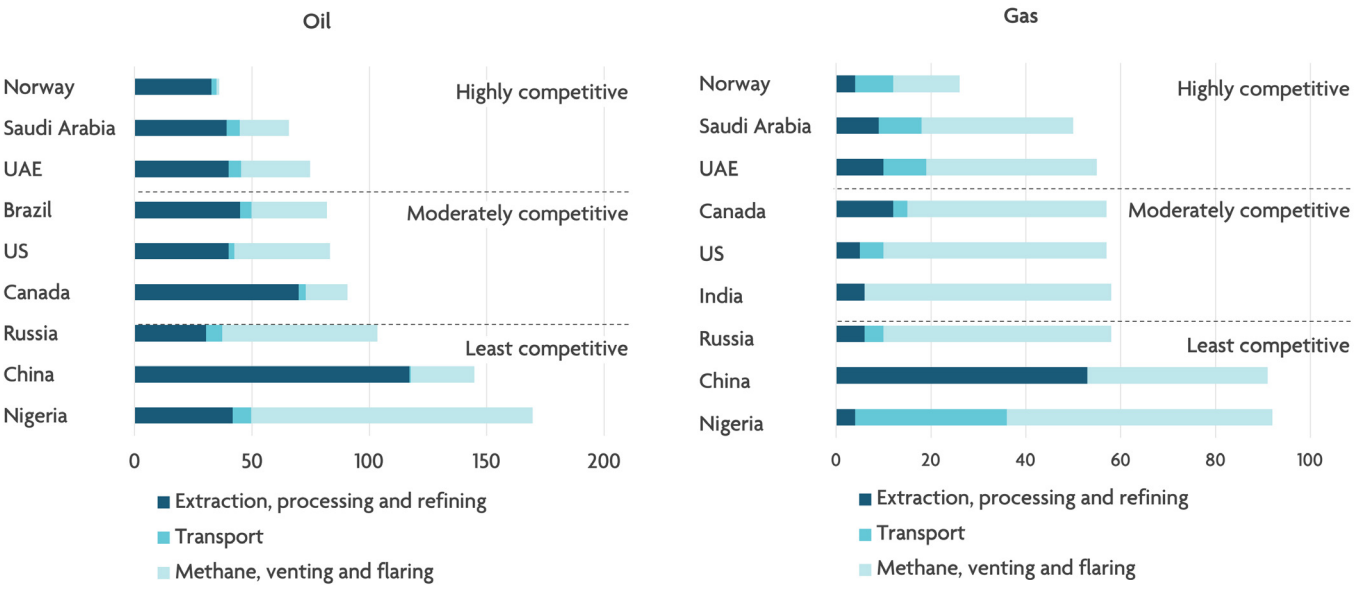


TABLE 6 – EMISSIONS COMPETITIVENESS OF O&G

CATEGORY	EMISSIONS PER BARREL (KG CO_2-eq)
Highly emissions-competitive	Oil: < 75 kg per boe Gas: < 56 kg per boe (the first third of countries)
Moderately emissions -competitive	Oil: 75 - 91 kg per boe Gas: 56 - 59 kg per boe (the second third of countries)
Least emissions-competitive	Oil: > 91 kg per boe Gas: > 59 kg per boe (the last third of countries)

- **Highly emissions-competitive:** Norway, Saudi Arabia, and the UAE lead due to low emissions from extraction, processing, and refining. Norway has the lowest methane emissions for both O&G.
- **Moderately emissions-competitive:** Brazil, the US, and Canada for oil; and the US, Canada, and India for gas. All countries, except Canada, could move up a tier with reduced methane intensity.
- **Least emissions-competitive:** Russia and Nigeria fall behind primarily due to very high methane emissions. China lags due to relatively high emissions from extraction, processing, and refining.

A country's success in emissions mitigation depends on the main sources of its emissions and the extent to which it can cost-effectively implement mitigation measures. Each nation's unique circumstances play a crucial role in determining the effectiveness of these strategies. A country, for instance, may encounter significant challenges in implementing low-emissions electrification for its upstream operations due to a lack of power grid infrastructure and limited renewable energy capacity. However, it could feasibly implement flaring avoidance mechanisms in a technical and cost-effective manner.

As mentioned in the chapter 4, controlling methane emissions is a game changer for the competitiveness of the O&G sector, especially as carbon pricing mechanisms gain traction. Reducing methane emissions stands out as the most impactful action companies can take to lower their emissions intensity. Russia and Nigeria could advance to the second tier of emission competitiveness in oil and to the first tier in gas by achieving significant reductions in methane emissions, given their relatively low emissions levels from extraction, processing, and refining.

The operational lifespan of O&G facilities plays a critical role in emissions intensity as time goes by. As reservoirs deplete and production volumes decline, companies often resort to newer recovery methods that require more energy and generate higher emissions. Thus, the way a country manages the O&G operational emissions can enhance (or undermine) its competitiveness in a transitioning energy landscape.

Decarbonizing O&G operations may compromise their cost competitiveness. Investments in operations aimed at curbing emissions might influence the cost curve of both non-producing (new supply) and producing fields (current supply), impacting the breakeven price and internal rate of return of these projects. Consequently, investments in the decarbonization of operations could affect a country's cost competitiveness in the O&G sector, particularly in an environment characterized by weak carbon pricing mechanisms.

Key messages from O&G competitiveness

- The viability of new O&G projects is subject to future declines in demand even in moderate scenarios.
- Future O&G competitiveness hinges on both cost-efficient and emissions-efficient production.
- Investments in decarbonizing technologies to lower emissions may impact countries unevenly in terms of cost competitiveness.
- Methane reductions could reshape the competitive landscape, particularly under an enforced carbon pricing regime.

5.3 ENERGY SECURITY AND ENERGY TRANSITION READINESS

Energy security encompasses the reliable availability of energy at affordable prices while minimizing the risk of supply disruptions. As the world transitions away from O&G, a delicate balance must be struck between ensuring dependable energy supplies and achieving climate objectives, all while safeguarding economic stability. In this context, a country's ability to move away from O&G is closely linked to its energy transition readiness, which reflects its preparedness to shift from a fossil fuel-based energy system to a low-carbon one. To accomplish this, seven key indicators must be considered [Tab. 7].

Generally, the larger the share of O&G in a country's energy mix, the less diversified that mix tends to be, making the country more vulnerable during the transition to a lower-carbon energy system [Fig. 11], leading to increased uncertainties about energy security. Despite the growing role of renewable technologies in enhancing energy sovereignty and security for many nations, a transition away from O&G sources could, in the short term, impact a

country's ability to secure a reliable and affordable energy supply, depending on the pace of the transition and its management capacity. Additionally, efforts to raise energy consumption per capita [Fig. 12] and increase energy access could further complicate the transition for O&G-dependent countries, particularly if they produce most of the O&G resources they rely on domestically.

TABLE 7 – INDICATORS OF ENERGY SECURITY AND ENERGY TRANSITION READINESS

INDICATOR		UNIT	DEFINITION
Energy security	Energy mix diversification (share of O&G in total energy supply)	%	Indicates the proportion of the total energy supplied to end users in the country that comes from O&G sources. It serves as a proxy for assessing the country's level of energy diversification and its dependency on O&G as primary energy sources
	O&G production and consumption ratio	%	Measures the relationship between the volume of O&G produced in a country or region and the volume consumed. This ratio serves as a key indicator of energy self-sufficiency, offering insights into a nation's reliance on O&G energy imports
	Primary energy consumption per capita	thousand kWh/person	Refers to the total amount of energy consumed per person, considering all energy sources before conversion to secondary forms like electricity
Energy transition readiness	GDP per capita	US$ - current prices	Sizes the average economic output per person, reflecting the standard of living and economic performance of a country
	Sovereign rating	Rating category	Assesses the country's creditworthiness or its ability and willingness to meet its financial obligations. It is typically assigned by credit rating agencies and reflects the risk level associated with investing in a country's sovereign debt
	Levelized cost of electricity (LCOE) for clean energy	US$/kWh	Estimates the average cost per unit of electricity generated over the lifetime of a power-generating asset. LCOE provides a standardized way to compare the cost-effectiveness of different energy generation technologies, including renewables and fossil fuel energy sources
	Access to clean energy supply chain	%	Assesses the role of a country in mining and processing critical minerals, as well as in manufacturing and distributing clean technology products, such as solar panels, wind turbines, batteries, electric vehicles, and other low-carbon solutions. A country's share in the mining or processing of critical minerals, or its share in manufacturing, serves as a proxy for this level of access in the clean tech supply chain

FIGURE 11 – SHARE OF O&G IN TOTAL ENERGY SUPPLY (%)

Source: Catavento analysis based on IEA. Countries and regions. 2024

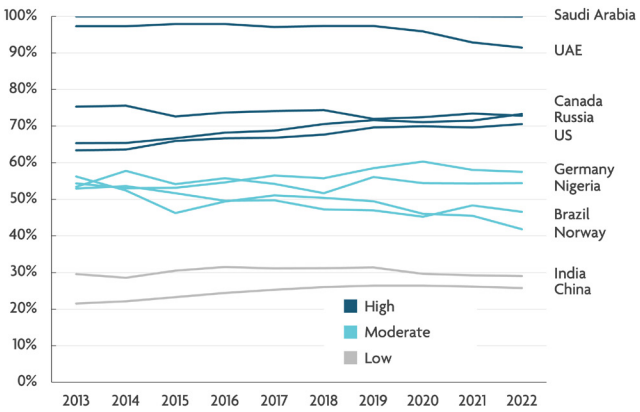
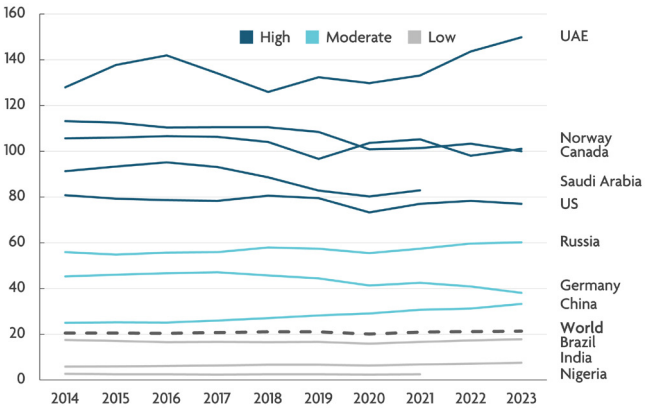


FIGURE 12 – PRIMARY ENERGY CONSUMPTION PER CAPITA (MWh/person)

Source: Catavento analysis based on Our World in Data. Primary energy consumption per capita. 2023



In 2022, the conflict between Russia and Ukraine sparked an energy crisis that has heightened governments' concerns about energy security worldwide. Trade patterns for O&G have shifted significantly as governments seek to bolster their energy security, making domestic energy alternatives more strategic in this context to mitigate supply uncertainties. O&G-producing countries like Saudi Arabia, the UAE, the US, Russia, and Canada may find it more challenging to transition away from O&G due to their high primary energy consumption per capita and the fact that over 70% of their energy mix relies on domestically supplied O&G sources **[Fig. 13]**. For developing countries like Nigeria, which is both a net O&G exporter and heavily dependent on O&G, the challenge lies in expanding domestic energy access. For this group of countries, transitioning away from O&G requires extra caution from an energy security standpoint.

O&G net importers face fewer exit barriers to shift toward clean energy alternatives. For countries like China, India, and Germany, which are highly dependent on O&G imports, accelerating the shift to clean energy sources could enhance reliability and resilience in their energy systems over the long term. Countries like Brazil and Norway also rely significantly on O&G but have more diversified energy mixes, making them less vulnerable to the risks associated with transitioning away from O&G, although they still face relevant challenges.

Based on our analysis, three main categories of countries can be identified in terms of energy security obstacles for the transition **[Tab. 8]**.

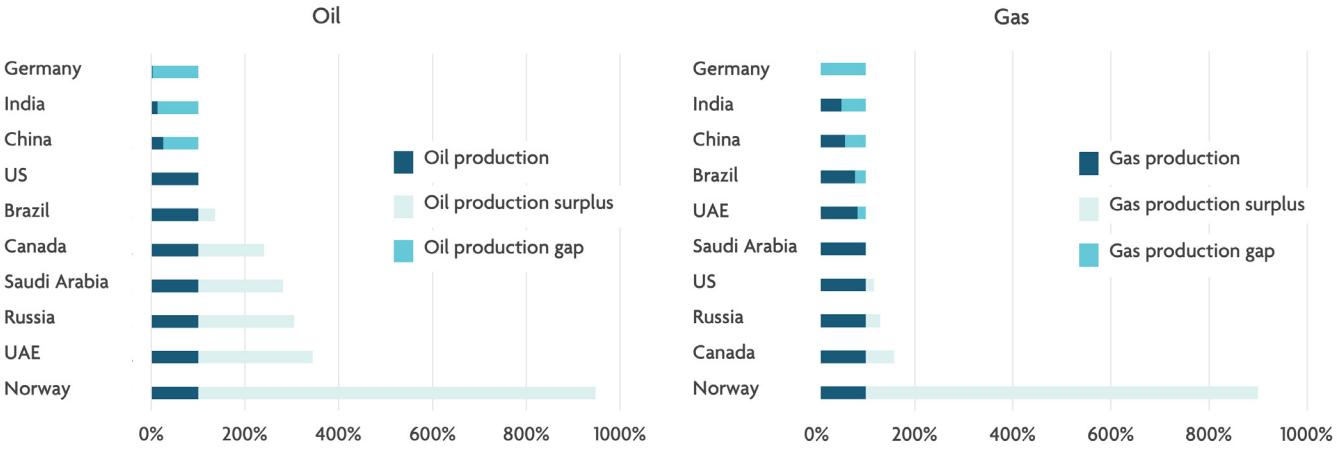
TABLE 8 – DIFFICULTY LEVEL OF TRANSITIONING WHILE ENSURING ENERGY SECURITY

CATEGORY	ENERGY MIX DIVERSIFICATION (SHARE OF O&G IN TOTAL ENERGY SUPPLY) (%)	O&G PRODUCTION AND CONSUMPTION RATIO (%)	PRIMARY ENERGY CONSUMPTION PER CAPITA (MWH/PERSON)
Severe obstacles	> 60% of O&G in energy mix	Net exporter	> 65
Serious obstacles	30% - 60% of O&G in energy mix	Net exporter	25 - 65
Moderate obstacles	< 30% of O&G in energy mix	Net importer	< 25

- **Severe obstacles:** The US, Saudi Arabia, the UAE, and Canada face the highest level of challenges due to their highly undiversified energy mix, heavy reliance on O&G, very high per capita energy consumption, and the reliance on domestic O&G supply.
- **Serious obstacles:** Brazil, Norway, Germany, Russia, and Nigeria face less severe challenges, albeit for different reasons. All these countries, except Germany, are net exporters of O&G. However, all countries except Russia have a more diversified energy mix, rely less on O&G, and apart from Norway, have moderate or low per capita energy consumption.
- **Moderate obstacles:** From an exclusive O&G perspective, China and India would face moderate obstacles in transitioning away due to their relatively low reliance on O&G to sustain their energy mix, high dependence on external sources for O&G supply, and moderate to low per capita primary energy consumption. Nevertheless, both countries are heavily reliant on coal to meet their energy demand, making the transition away from fossil fuels, including coal, much more challenging and complex.

FIGURE 13 – O&G PRODUCTION/CONSUMPTION RATIO (%), 2023[81]

Source: Catavento analysis based on Energy Institute. Statistical Review of World Energy. 2024



A country's ability to transition away from O&G without compromising its energy security largely depends on its energy transition readiness. This readiness ultimately determines the extent to which a country is prepared to shift from traditional O&G fuel-based energy systems to more renewable energy sources in a stable manner. This capacity hinges primarily on economic conditions such as economic growth and national wealth—both of which are critical for financing the transition and managing potential disruptions. Additionally, the ability to deploy clean energy cost-competitively and to access these supply chains is crucial, as they reflect the degree of a country's reliance on external sources for clean technologies and its capacity to replace O&G energy sources without facing price volatility.

A nation's GDP per capita and sovereign rating play critical roles in determining its capacity to undertake the transition from O&G. GDP per capita serves as a key proxy for both economic growth and a country's wealth **[Fig. 14]**. It provides a fundamental measure of the value of output generated per person, indirectly reflecting individual income levels and overall national wealth. A country's sovereign rating complements GDP per capita by indicating its ability to raise funds at favorable interest rates to support the shift towards a cleaner energy mix **[Fig. 15]**. A higher sovereign rating means lower borrowing costs, making it more affordable for a country to finance its energy transition.

FIGURE 14 – GDP PER CAPITA (US$ - CURRENT PRICES)

Source: Catavento analysis based on IMF. World Economic Outlook. 2024

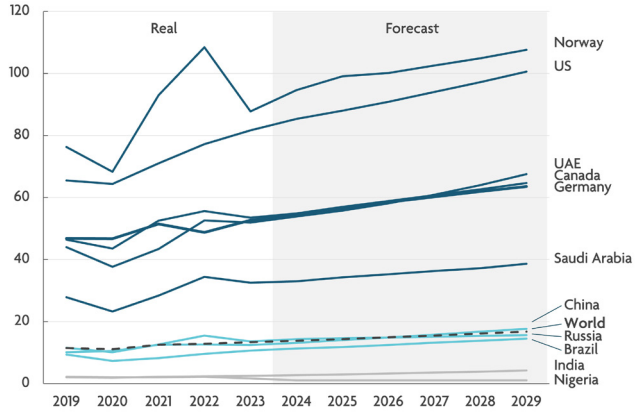


FIGURE 15 – SOVEREIGN RATING (S&P GLOBAL)

Source: Catavento analysis based on S&P Global Ratings.

Country	2019	2020	2021	2022	2023	2024	Capacity to meet financial commitments	
Canada	AAA	AAA	AAA	AAA	AAA	AAA	Extremely strong	Investment grade
Norway	AAA	AAA	AAA	AAA	AAA	AAA	Extremely strong	
Germany	AAA	AAA	AAA	AAA	AAA	AAA	Extremely strong	
US	AA+	AA+	AAA	AA+	AA+	AA+	Very strong	
UAE	AA	AA	AA	AA	AA	-	Very strong	
China	A+	A+	A+	A+	A+	A+	Strong	
Saudi Arabia	A-	A-	A-	A-	A	A	Strong	
India	BBB-	BBB-	BBB-	BBB-	BBB-	BBB-	Adequate	Speculative grade
Brazil	BB-	BB-	BB-	BB-	BB-	BB	Less vulnerable	
Nigeria	B	B-	B-	B-	B-	B-	More vulnerable	
Russia	BBB	BBB-	BBB-	SD	SD	SD	Selective Default	

81 Norway's total gas production was 3075% higher than the total country consumption. No data on O&G consumption was available for Nigeria.

Considering renewable generation, onshore wind and solar PV projects have surpassed fossil fuels in terms of cost competitiveness. The global weighted average LCOE for newly commissioned onshore wind and solar PV projects has remained below the lower range of fossil fuel costs in nearly all the countries analyzed **[Fig. 16 and Fig. 17]**. In onshore wind, China and Brazil have the most competitive LCOE, both below the global average for onshore wind generation. In solar PV, China and Saudi Arabia lead with the lowest LCOE among the countries.

Another critical pillar of energy readiness that supports a country's energy security during the transition away from O&G is the assurance of a reliable and cost-competitive supply of materials and technologies needed for clean energy generation. In this context, a country's share in one of the three key clean energy supply chains **[Fig. 18]** indicates its access to the materials and technologies essential for decarbonizing its energy matrix and securely transitioning from O&G.

China dominates critical minerals processing, as well as clean energy technology and component manufacturing. The reserves of critical minerals are heavily concentrated in a handful of countries in Africa, Asia-Pacific, and Central & South America. The production of materials from these critical minerals is in the Asia-Pacific and Central & South American regions, with China alone responsible for processing between 29% and 90% of all critical minerals. Other regions house up to 16% of production, offering limited domestic access to these intermediary products. China's dominance is even more pronounced in the manufacturing of clean technology consumer products and infrastructure components, where its market share ranges from 39% to 96%. While Europe and North America play an important role in certain components and products, their market share does not exceed 29%.

Current clean energy technology supply chains are more geographically concentrated than fossil fuel supply chains. As a result, most countries depend on external sources for clean energy products and components to meet the domestic demands of the ongoing energy transition. Key materials and components are sourced from a limited number of countries, raising concerns about supply security, especially when much of the supply comes from nations facing geopolitical risks and instability, unfair trade practices, or human rights violations, as noted by the IEA[82].

Based on our analysis, three main categories of countries can be identified in terms of transition readiness **[Tab. 9]**.

FIGURE 16 – WEIGHTED AVERAGE LCOE OF COMMISSIONED ONSHORE WIND (US$/kWh)

Source: IRENA. Renewable Power Generation Costs in 2023. 2024

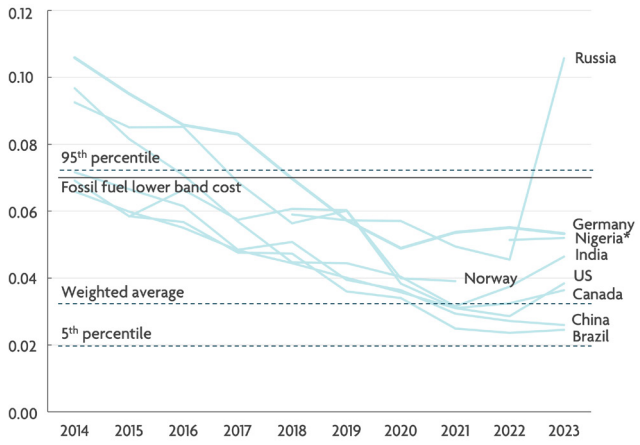
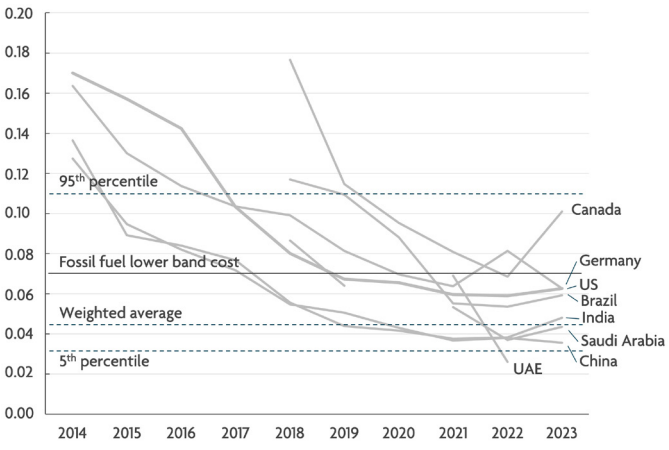


FIGURE 17 – WEIGHTED AVERAGE LCOE FOR UTILITY-SCALE SOLAR PV (US$/kWh)

Source: IRENA. Renewable Power Generation Costs in 2023. 2024



82 IEA. Global Critical Minerals Outlook.2024

FIGURE 18 – CRITICAL CLEAN ENERGY SUPPLY CHAINS

Source: IEA. Energy Technology Perspectives. 2023
*Measured in terms of production capacity. **Measured in terms of current production.

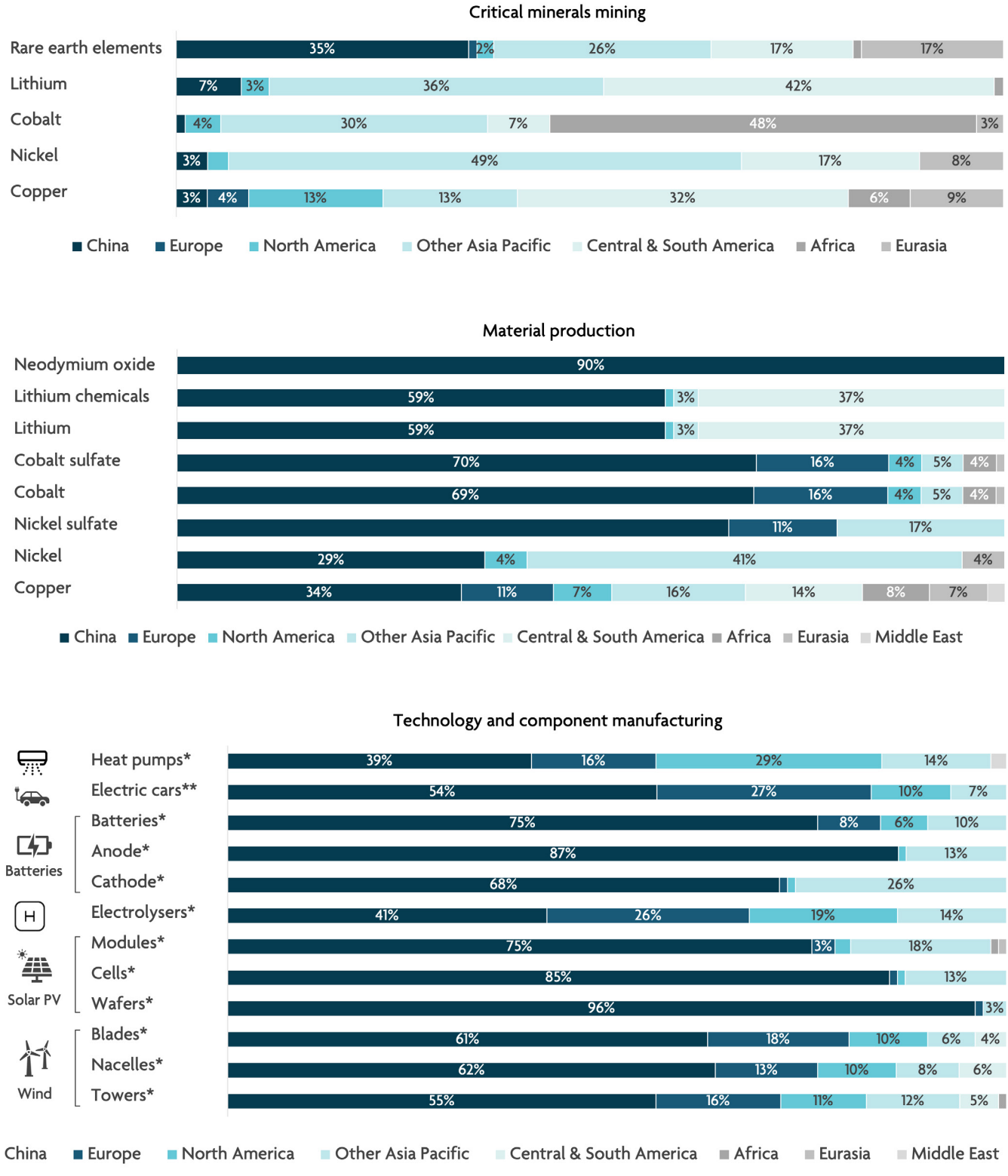


TABLE 9 – TRANSITION READINESS LEVEL

CATEGORY	GDP PER CAPITA (THOUSAND US$)	SOVEREIGN RATING	LCOE FOR CLEAN ENERGY	ACCESS TO CLEAN ENERGY SUPPLY CHAIN
Superior transition readiness	> 20	From AAA to AA+	Solar PV and onshore wind outcompete fossil fuel lower band cost	Part of a region with minimum share of 10% in more than 50% of supply chains
Moderate transition readiness	10 - 20	From AA to A-	Solar PV or onshore wind outcompete fossil fuel lower band cost	Part of a region with minimum share of 10% in 20% to 50% of the supply chains
Low transition readiness	< 10	Lower than A-	Neither solar PV nor onshore wind outcompete fossil fuel lower band cost	Part of a region with minimum share of 10% in less than 20% of the supply chains

- **Superior transition readiness:** The US, Canada, Norway, Germany, and China demonstrate the highest readiness for the energy transition. The European and North American nations benefit from high GDP per capita and a low cost of capital to fund the transition. They also enjoy a competitive LCOE in onshore wind and solar PV generation, along with moderate access to clean energy supply chains. China, while having a moderate GDP per capita and sovereign rating, boasts the best LCOE for onshore wind and the second-best for solar PV. Additionally, China dominates critical mineral processing and the manufacturing of clean energy technologies and components.
- **Moderate transition readiness:** Saudi Arabia, the UAE and Brazil show moderate readiness for the energy transition, but for different reasons. The Middle Eastern nations have high GDP per capita and highly competitive LCOE for solar PV. However, both countries face moderate sovereign ratings and very limited share in clean energy supply chains. Brazil, with a moderate GDP per capita and high cost of capital due to a low sovereign rating, has nevertheless very competitive LCOE for onshore wind and solar PV, and moderate access to clean energy supply chains.
- **Low transition readiness:** Russia, India, and Nigeria have the lowest level of readiness, primarily due to very high capital costs and low GDP per capita (moderate in Russia's case). These countries also have a minimal share in clean energy supply chains, further hindering their energy transition capabilities.

Key messages from energy security and energy transition readiness

- Countries with a high reliance on O&G in their energy mix, high per capita primary energy consumption, and strong O&G self-sufficiency often face greater inertia in transitioning away from O&G due to heightened energy security concerns.
- Clean energy sources like onshore wind and solar PV have out-competed fossil fuel generation in terms of cost, although highly concentrated supply chains may increase energy security risks during the transition.
- Nations with a moderately O&G-dependent energy mix but reliant on external sources, coupled with significant or moderate transition readiness, are better positioned to shift away from O&G.
- As clean technologies become more cost-competitive world-wide, GDP per capita and sovereign credit ratings play a crucial role in determining a nation's ability to finance the transition away from O&G.

5.4 EMISSIONS PROFILE

This category addresses the principle of "common but differentiated responsibilities" from the Paris Agreement, as well as the potential impact of reducing energy and industry emissions resulting from a country's transition away from O&G. It evaluates the emissions profiles of each nation based on the remaining carbon budget, which is the net amount of CO_2 that can be emitted without exceeding a predetermined global warming limit. In this context, the category includes indicators to measure both the current and historical emissions from each nation's energy and industrial sectors **[Tab. 10]**.

The US is the country that has profited the most from historical cumulative emissions in the energy and industry sectors, followed by China, Russia and Germany **[Fig. 19]**. Regions that industrialized earlier, such as North America and Europe, have had more time to benefit from the global carbon budget than those that began developing later. Additionally, nations that predominantly depend on fossil fuels for energy generation typically show higher cumulative emissions compared to those with a cleaner energy mix. Population dynamics are another key factor, as regions with larger populations, particularly those experiencing economic growth, face higher energy demand that often leads to increased emissions. Finally, countries reliant on carbon-intensive industries, such as fossil fuel extraction and energy-intensive manufacturing, tend to have higher cumulative emissions.

Most of the top historical emitters are still among the greatest annual emitters. Total annual GHG emissions reflect the amount emitted by each country in a given year, highlighting the geographical distribution of current emissions worldwide **[Fig. 20]**. Despite ongoing efforts to reduce emissions, global GHG levels continue to surpass the thresholds needed to avert the most severe consequences of climate change. As many historical top emitters continue to be significant contributors to current GHG emissions, the remaining carbon budget for emerging and developing economies is increasingly depleted by countries that have historically benefited from past emissions.

TABLE 10 – INDICATORS OF EMISSIONS PROFILE

INDICATOR		UNIT	DEFINITION
Current GHG emissions	Total annual energy and industry emissions	$GtCO_2e$	The total amount of GHG emitted by a country within a single year specifically from energy and industry sectors.
	Energy and industry emissions per capita	tCO_2e /person	A measure of the GHG emissions generated from a country's energy production and industrial activities on a per-person basis.
	Energy and industry emissions per GDP	tCO_2e /US$ mn of GDP	A measure of GHG emissions from a country's energy production and industrial activities relative to its economic output. This metric reveals the emissions intensity of an economy.
Historical GHG emissions	Total energy and industry cumulative emissions from 1850 to 2022	$GtCO_2e$	The aggregate amount of GHG emissions produced by the energy and industrial sectors of a country. It highlights a country's energy and industry sectors long-term contribution to global warming.

FIGURE 19 – TOTAL ENERGY AND INDUSTRY CUMULATIVE EMISSIONS FROM 1850 TO 2022 ($GtCO_2e$)

Source: Catavento analysis based on ClimateWatch and PIK PRIMAP-hist data.

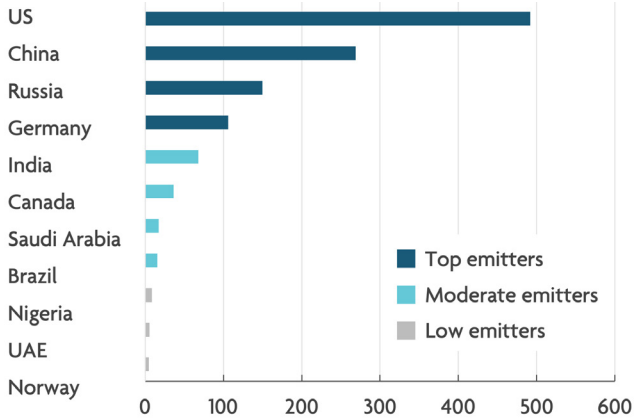
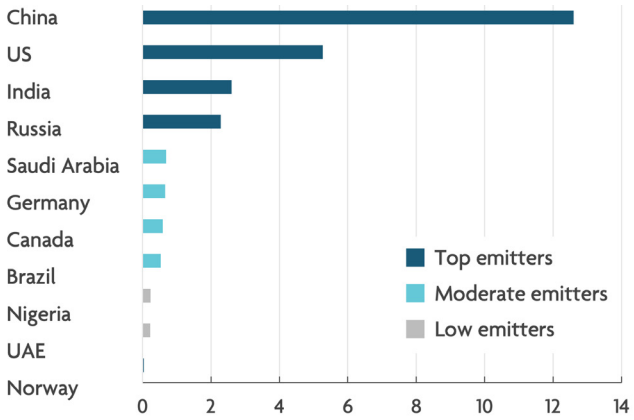


FIGURE 20 – TOTAL ANNUAL ENERGY AND INDUSTRY EMISSIONS ($GtCO_2e$, 2022)

Source: Catavento analysis based on ClimateWatch data.



Russia is, by far, the least emission-efficient economy in terms of intensity, followed by India, Saudi Arabia, and China **[Fig. 21]**. The emissions intensity of an economy sheds light on how effectively a country generates economic output concerning GHG emissions. A low emissions-per-GDP figure indicates a less carbon-intensive economy, while high emissions per GDP are often found in countries reliant on fossil fuels for energy or with a significant share of energy-intensive industries, such as steel, cement, or chemicals. All else being equal, countries with high energy and industry emissions per GDP would significantly impact the remaining carbon budget as they transition away from O&G.

The higher the energy emissions per capita, the higher the contribution of a country, on a per-person basis, to climate change. Per-capita CO_2 emissions are generally higher in more economically developed countries **[Fig. 22]**. These disparities in consumption-based emissions underscore the profound inequalities in income and wealth, as well as the differing consumption patterns among nations. However, emissions can also vary significantly Per-capita CO_2 emissions are generally higher in more economically based on a country's economic structure and energy system. Countries that heavily rely on carbon-intensive transportation methods, have a larger share of energy-intensive industries, or depend predominantly on fossil fuels for power generation will exhibit elevated emissions per capita. All else being equal, nations with higher per capita emissions would have a greater impact on the remaining carbon budget as they transition away from O&G.

Based on our analysis, we can identify three main categories of countries regarding their impact and responsibilities on energy and industry-related GHG emissions **[Tab. 11]**.

FIGURE 21 – ENERGY AND INDUSTRY EMISSIONS PER GDP (tCO_2e/mn US$ GDP)

Source: Catavento analysis based on ClimateWatch data.

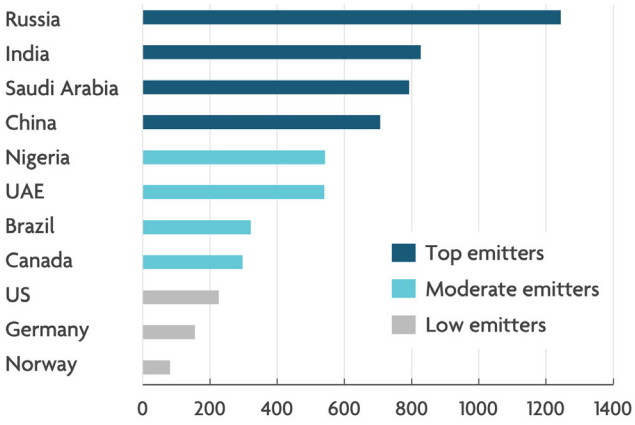


FIGURE 22 – ENERGY AND INDUSTRY EMISSIONS PER CAPITA (tCO_2e /person)

Source: Catavento analysis based on ClimateWatch data.

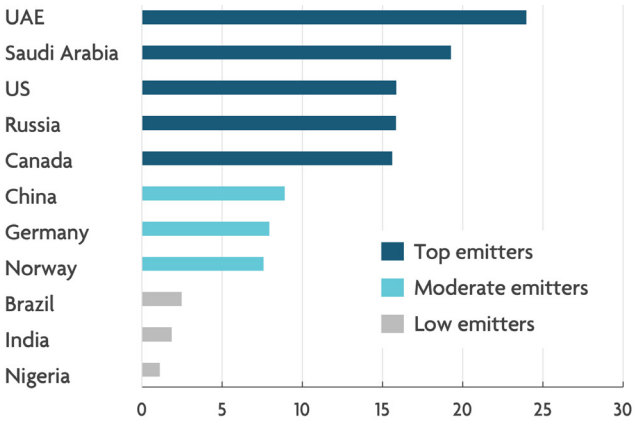


TABLE 11 – IMPACT AND RESPONSIBILITY LEVELS OF ENERGY AND INDUSTRY-RELATED GHG EMISSIONS

CATEGORY	CURRENT GHG EMISSIONS			HISTORICAL GHG EMISSIONS
	TOTAL ANNUAL ENERGY AND INDUSTRY EMISSIONS ($GtCO_2e$)	ENERGY AND INDUSTRY EMISSIONS PER CAPITA (tCO_2e/PERSON)	ENERGY AND INDUSTRY EMISSIONS PER GDP (tCO_2e/US$ MN)	TOTAL ENERGY AND INDUSTRY CUMULATIVE EMISSIONS FROM 1850 TO 2022 ($GtCO_2e$)
Top emitters	> 2	> 10	> 550	> 70
Moderate emitters	From 0.5 to 2	From 5 to 10	From 250 to 550	From 15 to 70
Low emitters	< 0.5	< 10	< 250	< 15

- **Top Emitters:** The US, China, and Russia rank among the top emitters in both historical and current terms. Germany, while in the past a major emitter, has reduced its footprint, due to its low emissions relative to GDP and moderate levels of per capita and total annual emissions. Transitioning away from O&G in these countries would significantly reduce global emissions, allowing the remaining carbon budget to be allocated more equitably and efficiently to nations that have benefited less historically.
- **Moderate Emitters:** This group includes Saudi Arabia and India, both of which are significant emitters in current terms but moderate in historical ones. Brazil and Canada also fall into this category, with moderate levels of both current and historical emissions. A shift from O&G to a cleaner energy mix among these countries would still have a meaningful impact on reducing global emissions.
- **Low emitters:** Despite its high per capita emissions and moderate emissions relative to GDP, the UAE's contribution to current and historical emissions remains low. While Nigeria has moderate emissions per GDP, and Norway shows moderate emissions per capita, both countries have low contributions to current and cumulative emissions, indicating a limited overall impact on global emissions.

Key messages from emissions profile

- The longer top emitters and countries that benefitted most from high emissions postpone their transition away from O&G, the greater the disparity in carbon budget distribution among nations will become.
- The sooner most current top-emitting countries transition away from O&G, the greater their impact will be on reducing global emissions in comparison to moderate and low-emitting nations.
- Countries with high energy and industry emissions per capita or per GDP generally have more substantial opportunities for improving energy and industry-related emissions efficiency than moderate and low-emitting nations.
- Top emitters must take the lead in adopting carbon removal technologies and mechanisms to reduce emissions (e.g. nature-based solutions; carbon capture and storage; enhanced oil recovery; direct air capture).

5.5 INSTITUTIONAL AND SOCIAL RESILIENCE

Transforming energy systems requires adaptation that goes beyond the availability of technologies, pricing competitiveness and financial resources. It involves broader social and institutional frameworks to deal with emerging patterns of energy production and consumption. In this context, transitioning away from O&G represents a complex socio-technological shift that demands resilience from countries to effectively navigate significant changes impacting diverse communities and businesses.

A country is more resilient if it is not overly dependent on one singular factor for its stability, whether in terms of revenue, trade, energy, and industry, for example. When geopolitical, economic or energy-related disruptions occur, they can trigger a cascade of setbacks, leading to potential turmoil and social unrest. In contrast, a resilient country can mitigate the intensity of a possible crisis, contain potential impacts and ensure a quicker return to stability.

TABLE 12 – INDICATORS OF INSTITUTIONAL AND SOCIAL RESILIENCE

INDICATOR	UNIT	DEFINITION
Human Development Index (HDI)	Scores range from 0 to 10	A composite index developed to assess the overall development and quality of life within a country.
State Resilience Index (SRI)	Scores range from 0 to 1	A measure developed to assess a country's ability to withstand, manage, and recover from social, economic, and environmental challenges and disruptions.

A country's capacity to transition away from O&G also relies on its ability to anticipate, manage, and recover from a disruption. This resilience perspective can be measured by human development achievements, such as a long and healthy life, being knowledgeable, and having a decent standard of living (measured by Human Development Index), as well as by a country's capabilities, including economic stability, institutional strength, social cohesion, and state capacity (measured by State Resilience Index) **[Fig. 23]**.

Based on our analysis, three main categories of countries can be identified in terms of institutional and social resilience levels **[Tab. 13]**.

FIGURE 23 – LEVEL OF INSTITUTIONAL AND SOCIAL RESILIENCE BY COUNTRY

Source: Catavento analysis based on UNDP. Human Development Index (HDI). 2022. Fund for Peace. State Resilience Index (SRI). 2022

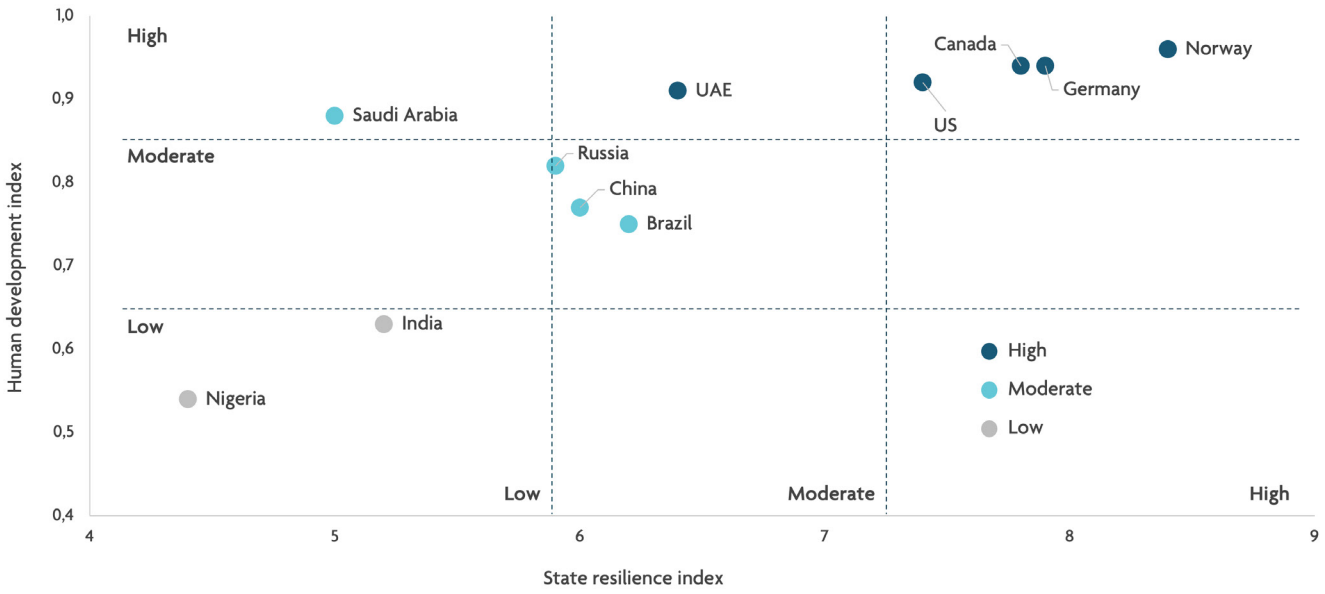


TABLE 13 – INSTITUTIONAL AND SOCIAL RESILIENCE LEVEL

CATEGORY	HUMAN DEVELOPMENT INDEX (HDI)	STATE RESILIENCE INDEX (SRI)
High	> 0.82	> 6.4
Moderate	From 0.82 to 0.64	From 6.4 to 5.9
Low	< 0.64	< 5.9

- **High:** countries with high level of human development and high or moderate level of state resilience such as US, Canada, Norway, Germany and UAE.
- **Moderate:** countries with high or moderate level of human development and moderate level of state resilience such as Russia, China, Brazil and Saudi Arabia.
- **Low:** countries with low level of both human development and state resilience such as India and Nigeria.

High-state resilient index countries often possess stronger, more diversified economies characterized by greater economic stability, well-established institutions, and governance frameworks that support long-term planning and crisis management. These institutions are better equipped to implement complex energy transition policies and adapt to challenges and disruptions, thereby enhancing resilience.

High-HDI countries often have well-structured social programs and a relatively high quality of life that help maintain social cohesion during periods of change. They also tend to have more comprehensive social welfare systems, which can mitigate the impacts of transitioning away from O&G, fostering public support and |social resilience. Additionally, these countries enjoy higher levels of education, which correlate with greater public awareness of environmental issues and a workforce skilled in Science, Technology, Engineering, and Mathematics (STEM) fields. This combination facilitates the adoption of new technologies and supports innovation, both of which are critical for resilient energy transitions.

Key messages from institutional and social resilience

- The energy system is deeply interconnected with social, economic, and ecological systems. Shifting away from O&G sources involves a profound transformation of the entire energy landscape for many countries, carrying substantial social, economic, and ecological impacts that ripple far beyond the energy sector itself.
- A country's capacity for transitioning away also relies on its ability to anticipate, manage, and recover from a disruption with minimal disturbance to society.
- From the standpoint of institutional and social resilience, O&G extraction should be reduced most rapidly where the social costs are lowest.
- Countries with low levels of institutional and social resilience face greater vulnerability in adapting to the social and economic demands of transitioning away from O&G.
- A lower level of institutional and social resilience can weaken a country's society perception of the urgency of transitioning from O&G, risking a loss of legitimacy for these efforts.

6. CHARTING THE PATH AHEAD: A FRAMEWORK FOR A JUST, ORDERLY, AND EQUITABLE TRANSITION FROM O&G

Photo by Zetong Li via Unsplash

The following analysis synthesizes the dimensions examined in this study to offer a perspective on how different country categories — based on their current characteristics in terms of O&G relevance, competitiveness, energy security, transition readiness, emissions profile, and social and institutional resilience — can help establish parameters for assessing a just, orderly, and equitable transition.

This perspective classifies countries into three categories according to their overall emissions impact and total capacity to transition away from O&G in terms of supply and demand: (i) front-runner, (ii) mover, and (iii) adapter. This classification is an attempt to identify a transition pathway that minimizes turbulence in a shift to a lower-carbon energy system while ensuring the legitimacy of the process, acknowledging that all countries will have to act.

TABLE 9 – TRANSITION READINESS LEVEL

	FRONT-RUNNER	MOVER	ADAPTER
O&G relevance	Low economic dependence on O&G revenues, with a low share of GDP tied to stranded assets and a low level of production and reserves. **Countries**: Germany.	Moderate economic dependence on O&G revenues, with a low to medium share of GDP tied to stranded assets and a moderate level of production and reserves. **Countries**: US, Brazil, China, India, and UAE.	High economic dependence on O&G revenues, with a medium or high share of GDP tied to stranded assets, with a moderate to high level of production and reserves. **Countries**: Nigeria, Russia, Norway, Saudi Arabia, and Canada.
O&G competitiveness	Low cost-effectiveness with low to moderate emission efficiency Moderate cost-effectiveness and low emission efficiency **Countries**: China, Russia, Canada, and Nigeria **Heavily O&G net importers** **Countries**: India and Germany	Moderate cost-effectiveness and moderate emission efficiency **Countries**: Brazil and the US	High or moderate cost-effectiveness and high emission efficiency **Countries**: Saudi Arabia, UAE, and Norway
Energy security and transition readiness	Superior readiness with severe to serious energy security obstacles **Countries**: China, Germany, the US, Canada, and Norway	Moderate readiness with severe to serious energy security obstacles **Countries**: Saudi Arabia, UAE, and Brazil	Low readiness with severe to moderate energy security obstacles **Countries**: Nigeria, India, and Russia
Emissions profile	Top emitters in both cumulative and current energy and industry emissions **Countries**: the US, China, Russia and Germany	Moderate emitters in both cumulative and current energy and industry emissions **Countries**: Saudi Arabia, India, Brazil and Canada	Low emitters in both cumulative and current energy and industry emissions **Countries**: Nigeria, Norway, and UAE
Institutional and social resilience	High level of human development and high to moderate level of state resilience Countries: the US, Norway, Canada, Germany, and UAE	High to moderate level of human development and moderate to low level of state resilience **Countries**: Brazil, Russia, China, Saudi Arabia	Low levels of human development and state resilience **Countries**: India and Nigeria
Synthesis	US, China, Germany, and Canada	Brazil, Russia, Norway, and UAE	India, Nigeria, and Saudi Arabia

Front-runner characteristics

- **O&G relevance:** Countries with high levels of economic diversification, along with moderate to high O&G production and reserves, find the O&G sector to be an important economic driver, even though their economies are not dependent on oil rents and fuel exports. They typically have a low impact from stranded assets in a scenario of declining demand for O&G. Some are net importers of O&G, heavily reliant on external sources (such as Germany);
- **O&G competitiveness:** Countries with low to moderate levels of competitiveness, as none produce the most cost-competitive or emissions-efficient oil;
- **Energy security and transition readiness:** The energy security aspect, defined by the importance of O&G in the energy mix, did not emerge as a key differentiator, as the countries face moderate to severe energy security challenges (ranging from lower to upper classifications). High readiness for the energy transition, backed by strong sovereign ratings, high GDP per capita, and competitive Levelized Costs of Energy (LCOE) in at least two key clean energy sources, such as onshore wind and solar PV. Many of these nations also play critical roles in global low-carbon energy supply chains;
- **Emissions profile:** Most of them are leading emitter countries with high current and cumulative emissions, among those who historically benefited most from cheap fossil fuels and the carbon budget for development and growth;
- **Institutional and social resilience:** Countries with robust institutional and social resilience, as well as a strong capacity to anticipate, manage, and recover from disruptive challenges, including those posed by the transition away from O&G.

Mover characteristics

- **O&G relevance:** Countries with moderate economic diversification that rely moderately to heavily on oil rents and exports, along with moderate to high levels of O&G production and reserves. These countries generally face a medium to high impact of stranded assets.
- **O&G competitiveness:** Countries with moderate to high levels of competitiveness regarding oil production costs and emissions advantages.
- **Energy security and transition readiness:** Typically, these are oil net-exporting countries facing serious to severe challenges in safeguarding energy security during the transition away from O&G. This is due to a moderate to high share of O&G in their energy mix and primary energy consumption per capita. They demonstrate moderate to high readiness, supported by a moderate to high GDP per capita and at least one competitive LCOE in key clean energy source, such as onshore wind or solar PV. Additionally, they play a secondary role in global low-carbon energy supply chains due to their limited share in these markets.
- **Emissions profile:** Generally, they demonstrate low to moderate levels of both current and cumulative emissions.
- **Institutional and social resilience:** Their moderate to high level of institutional and social resilience provides a reasonable capacity to anticipate, manage, and recover from shocks, including those posed by the transition away from O&G.

Adapters characteristics

- **O&G relevance:** Highly dependent on revenues and assets from the O&G sector for development, with moderate to high levels of O&G production and reserves. These countries also face a medium to high risk of stranded assets before a demand declining O&G scenario.
- **O&G competitiveness:** Typically, those countries have moderate to high levels of competitiveness for both oil production costs and emissions.
- **Energy security and transition readiness:** Energy security challenges range from moderate to severe across these countries, influenced by varying levels of energy mix diversification and per capita energy consumption. However, their overall readiness remains low, impacted by a low GDP per capita and weak sovereign rating, despite having a competitive LCOE in at least one key energy source, such as onshore wind or solar PV. Additionally, they have a minor role in global clean energy supply chains, with supply chains shares, when any, concentrated in critical minerals mining.
- **Emissions profile:** Low to moderate emitters in terms of both current and cumulative emissions.
- **Institutional and social resilience:** Their low institutional and social resilience provides a weak capacity to anticipate, manage, and recover from the serious potential turbulences posed by transitioning away from O&G.

FIGURE 24 – SUMMARY – COUNTRIES CATEGORIES

*Less competitive O&G countries should lead the transition away
** Countries with the highest contribution to emissions should lead the transition away

Countries	Relevance of O&G	O&G competitiveness (-)*	Energy security and energy transition readiness	Emissions profile (-)**	Institutional and social resilience	Synthesis
Germany	Front-runner	Front-runner	Front-runner	Front-runner	Front-runner	Front-runner
China	Mover	Front-runner	Front-runner	Front-runner	Mover	Front-runner
US	Mover	Mover	Front-runner	Front-runner	Front-runner	Front-runner
Canada	Adapter	Front-runner	Front-runner	Mover	Front-runner	Front-runner
Brazil	Mover	Mover	Mover	Mover	Mover	Mover
Russia	Adapter	Front-runner	Adapter	Front-runner	Mover	Mover
Norway	Adapter	Adapter	Front-runner	Adapter	Front-runner	Mover
UAE	Mover	Adapter	Mover	Adapter	Front-runner	Mover
India	Mover	Front-runner	Adapter	Mover	Adapter	Adapter
Saudi Arabia	Adapter	Adapter	Mover	Mover	Mover	Adapter
Nigeria	Adapter	Front-runner	Adapter	Adapter	Adapter	Adapter

7. CHALLENGES THAT MAY AFFECT THE PACE OF TRANSITIONING AWAY FROM O&G

Photo by Clyde Thomas via Unsplash

Geopolitical tensions pose a significant threat to a just, orderly and equitable transitioning away from O&G. The energy transition has been brought to the forefront of industrial policies and trade disputes as nations aim to reduce concentration and establish a foothold in emerging clean technology supply chains, raising concerns over growing protectionism. At the same time, an increasingly fractured global order is limiting the extent to which countries can find common ground and undermining the credibility and effectiveness of multilateral institutions to resolve conflicts. Therefore, given that the potential socioeconomic disruptions caused by the transition away from O&G make international cooperation a crucial tool, the lack of it could lead to a less just, orderly and equitable pathway, ultimately slowing it down.

In addition, major net importers of O&G like China and India face the combined challenge of transitioning away from O&G while also phasing out coal from their energy mix. This places significant additional pressure on their energy systems and poses heightened risks to domestic energy security, while also intensifying competition for financial resources. Managing both shifts adds considerable complexity, which could slow the overall pace of each country's energy transition. Therefore, any transition away from O&G must be managed in coordination with other energy sources to ensure a balanced and reliable pathway.

India must also address the challenge of providing sufficient and affordable energy to support its rapidly expanding economy, population, urbanization, and industrialization. These factors are projected to drive the largest increase in energy demand of any country by 2040, according to the IEA[83] and bp[84]. This high growth in energy demand further complicates India's capacity to transition away from fossil fuels and may also impact the speed at which it can reduce reliance on O&G.

83 IEA. World Energy Outlook. 2024
84 bp. bp Energy Outlook. 2024

At the same time, inefficient subsidies for O&G present substantial obstacles to the transition away from these energy sources. By artificially lowering the prices of O&G products, these subsidies distort markets in favor of carbon-intensive energy over cleaner alternatives. This practice not only drives up GHG emissions by encouraging O&G consumption but also deters investment in clean energy and delays shifts toward low-carbon infrastructure. Additionally, these subsidies tend to disproportionately benefit wealthier households and industries, rather than vulnerable populations[85]. For governments — especially in emerging and developing economies — these subsidies can impose considerable fiscal burdens and undermine carbon pricing initiatives, thus hindering efforts to accelerate the energy transition.

Finally, O&G producing countries—and, indirectly, O&G consumers—are increasingly vulnerable to climate risks that threaten the infrastructure and operational stability of production and distribution. These risks not only challenge existing operations but also require substantial investments in resilience and adaptation measures. This evolving landscape could impact the energy security and transition readiness of these countries, potentially diverting investments away from energy efficiency and the expansion of low-carbon energy initiatives.

85 IMF. Fossil Fuel Subsidies Surged to Record $7 Trillion. 2023

8. CONCLUDING REMARKS

Photo by Adrian Schwarz via Unsplash

Extreme weather events, which are increasingly frequent and costly, underscore the urgent need to reverse the current trajectory of GHG emissions. Achieving this requires a transformative shift in the way energy is produced and consumed globally, as the energy sector accounts for the majority of global emissions. In this context, it is essential to mobilize and redirect investments from fossil fuels toward decarbonized energy systems. While the costs of this transformation are significant, they represent only a fraction of the potential costs of inaction on climate change.

At COP28, held in the United Arab Emirates in 2023, many countries made substantial energy-related commitments. Among them was the global pledge to **'transition away from fossil fuels in energy systems in a just, orderly, and equitable manner, accelerating action in this critical decade to achieve net zero by 2050, in line with scientific guidance'.** Since then, institutions, research centers, and policymakers have worked to understand the implications of this commitment and the extent to which it can be effectively implemented, as outlined in the UAE consensus.

This study focuses on oil and natural gas, identifying that a managed yet urgent reduction in both supply and demand is critical. If supply is abruptly reduced without competitive, ready-to-scale alternatives to meet demand, energy systems may experience disruptions and price volatility, with direct consequences for global energy security and economies, running the risk of losing societal support.

To contribute to this discussion, a set of indicators was identified to guide policymakers in analyzing which countries are best positioned to succeed in the context of transitioning away from O&G. These indicators have been grouped into categories that capture various critical dimensions — economic, climatic, energy-related, social, and institutional—that must be considered in discussions on this topic.

Countries with lower economic and energy dependence on O&G, coupled with greater readiness to enable the transition to decarbonized energy systems, have been classified as **front-runners.** For these countries, the risks associated with the transition are less pronounced, while opportunities are more tangible, positioning them to lead the transition away from O&G.

In parallel, countries with high economic and energy dependence on O&G, and with fewer resources or institutional capacity to facilitate the energy transition, have been classified as **adapters**. For these nations, the transitioning away process must include careful mitigation of associated risks. Countries that fall between these two extremes have been classified as **movers**.

It is important to emphasize that this classification is not intended to rank countries but rather to reflect their intrinsic conditions for achieving the transitioning away goal, while acknowledging that it requires a multidimensional approach. Considering the climate emergency, all countries are expected to work toward replacing fossil fuels with low-carbon alternatives, driving the energy transformations needed to align with science and the UAE consensus.

The commitment of transitioning away from fossil fuels is expected to be a focal point of discussions at COP30, which will take place in Brazil in 2025. Climate negotiators are due to examine various aspects of this topic, including the indicators that should be considered as criteria for assessing priority countries in this context. However, it is crucial to recognize that weighing these indicators differently can lead to distinct global energy outcomes. Therefore, it is imperative to carefully analyze the trade-offs involved and ensure that potential risks are comprehensively and responsibly mitigated, in the context of increased uncertainty and geopolitical tension. Let's work to remain united in our common goal.

www.catavento.biz