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The decline of an economy based on cheap oil

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Abstract:

This article analyses the paradox between the perception of oil abundance in international markets and the structural trend towards the physical and geopolitical scarcity of conventional energy resources. Drawing on the distinction between geological and commercial viability, it explores the decline rates of oil and gas fields, the concentration of the global supply, and the material constraints of the energy transition. It also considers the economic implications of these issues and the associated geopolitical tensions. The article argues that the challenge lies not only in replacing fossil fuels with alternative technologies to address the climate crisis, but also in driving a profound economic transformation in the face of the progressive depletion of cheap oil, which has been the foundation of global growth. It describes the technical and material limits of electrification and other energy sources in replacing the economic structure built on hydrocarbons, and highlights that, currently, renewable energies represent more of an addition than a replacement.
The article concludes that the central risk is being underestimated: namely, that the availability and cost of energy derived from oil and gas could pose a significant economic challenge before the end of the decade.

Keywords:

Energy economics, oil scarcity, energy transition, critical minerals, energy geopolitics.

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Introduction: the illusion of abundance versus structural irreversibility

In a context dominated by headlines about excess supply, saturated inventories and the expansion of production in certain regions, speaking today of oil scarcity may appear contradictory. However, this perception of abundance coexists with a deeper structural reality: the increasing challenge of discovering, developing, and bringing geologically accessible and commercially viable new fossil energy resources to market.

This article proposes an analytical framework that distinguishes between the physical existence of resources and their capacity to be effectively transformed into a stable supply. The contemporary energy issue cannot be reduced to a debate about prices or market cycles, but must instead be understood as a structural problem affecting the foundations of economic growth.

The world is undergoing an economic transformation driven by the gradual disappearance of cheap oil. This process overlaps with the climate challenge, but cannot be explained solely by it. In this context, the real threat to our society lies not so much in contemporary political volatility, but in the gradual erosion of the economic conditions that originally sustained it[1]. In other words, an economy based on access to abundant and inexpensive energy[2].

Energy as the foundation of the economy

Following Hagens' approach[2], many of the processes described below can be interpreted as resulting from the economy's structural dependence on energy.

The modern economy is a process that transforms energy and materials. All productive activity, ranging from microchip manufacturing to agriculture and transporting goods, relies on energy flows that augment human labour. Although money functions as a medium of exchange and a measure of value, the underlying material value is determined by the energy mobilised during production.

The extraordinary economic growth experienced during the twentieth century was closely

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[1] BURN-MURDOCH, J. «Is liberal democracy in terminal decline?», *Financial Times*. 2024. Available at: https://www.ft.com/content/b4d2c7a3-587d-440f-a7a9-7e5e85b93a88?syn-25a6b1a6=1
[2] HAGENS, N. J. «Economics for the future: Beyond the superorganism», *Ecological Economics*, vol. 169. 2020. Available at: https://doi.org/10.1016/j.ecolecon.2019.106520

linked to the availability of high energy density fossil fuels. Among these, oil played a particularly significant role due to its high energy concentration, ease of transport, versatility of use and cost. Various authors have highlighted that the energy contained in a barrel of oil is equivalent to several years of human physical labour. Such comparisons illustrate the magnitude of the energy contribution that fossil fuels have provided to modern industrial economies[3,4,5,6].

However, the major challenge is that the current financial system developed under the implicit assumption of a continuously expanding supply of fossil energy. Growth associated with a phase of abundant resources enabled the consolidation of a credit system based on the expectation of future energy[3]. In this sense, debt functions as an anticipation of future work: a present commitment whose solvency depends on society having, in the future, the necessary energy base in the future to generate that wealth; that is, sufficient available energy, in terms of calorific value, volume and cost comparable to or lower than that of the past.

When this assumption ceases to hold, because energy returns decline or access to energy becomes more costly and volatile, the relationship between credit, growth and economic stability weakens. In such contexts, monetary expansion loses effectiveness in sustaining productive activity, as the constraint ceases to be financial and becomes physical: the availability of energy and materials.

This erosion of the material base increases economic fragility and social uncertainty. It affects the capacity of states to sustain public expenditure, companies to plan long-term investments, and households to maintain stable levels of consumption. Thus, the decline in energy returns and the unpredictability of energy sources intensifies competition for resources among societies that are no longer growing as they used to. This weakens institutional trust and generates doubts about political systems, the media and scientific knowledge. This favours social polarisation and the proliferation of oversimplified

[3] HAGENS, N. J. «Economics for the future: Beyond the superorganism», *Ecological Economics*, vol. 169. 2020. Available at: https://doi.org/10.1016/j.ecolecon.2019.106520
[4] SMIL, V. *Energy and Civilization: A History*. MIT Press, 2017. Available at: https://mitpress.mit.edu/9780262536165/energy-and-civilization/
[5] AYRES, R. U. and WARR, B. *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Edward Elgar Publishing, 2009. Available at: https://www.e-elgar.com/shop/gbp/the-economic-growth-engine-9781848441828.html
[6] MORGAN, T. *Life After Growth: How the Global Economy Really Works and Why It Matters*. Harriman House, 2016. Available at: https://harriman-house.com/lifeaftergrowth

responses to structural problems.

Finally, this model faces additional limits related to the capacity of ecosystems to act as sinks for the waste generated by the current economy, which natural systems must absorb[7].

The climate crisis and the paradox of the energy transition: substitution or addition?

The energy transition is driven by two interrelated pressures: the climate crisis and the security (or scarcity) of energy and mineral resources. The climate crisis constitutes the primary driver of the contemporary discourse on the energy transition. The world is experiencing a sustained increase in extreme climatic events, with global temperatures approaching the threshold of 1.5 °C above pre-industrial levels[8], and atmospheric CO_2 concentrations exceeding approximately 427–430 ppm[9], values not observed for several million years, before the existence of humanity.

This scenario comes as no surprise, as fossil fuel consumption continues to rise with no sign of slowing down. Furthermore, the International Energy Agency (IEA) [10,11], projects that by 2050 demand for liquid fuels will stand at 113 mb/d, to which dry gas[12] must be added, and fossil fuels will continue to account for around 75% of the energy mix. This is because, although energy generation from renewable sources has increased, its contribution remains primarily additive rather than substitutive, meeting additional energy demand rather than effectively displacing fossil fuels.

[7] HAGENS, N. J. «Economics for the future: Beyond the superorganism», *Ecological Economics*, vol. 169. 2020. Available at: https://doi.org/10.1016/j.ecolecon.2019.106520
[8] WORLD METEOROLOGICAL ORGANIZATION (WMO). «WMO confirms 2024 as warmest year on record at about 1.55 °C above pre-industrial level», *Press release.* 10 January 2025. Available at: WMO confirms 2024 as warmest year on record at about 1.55°C above pre-industrial level
[9] LINDSEY, R. «Climate change: Atmospheric carbon dioxide trends», *NOAA Climate.gov*. May 21 2025. Available at: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide
[10] INTERNATIONAL ENERGY AGENCY (IEA)*World Energy Outlook 2025*. IEA Publications, 2025. Available at: https://www.iea.org/reports/world-energy-outlook-2025
[11] All magnitudes in this article follow the reporting standards of the INTERNATIONAL ENERGY AGENCY (IEA).
[12] Dry gas consists almost exclusively of methane. Liquid fuels comprise crude oil, condensates and Natural Gas Liquids (NGLs) (such as ethane, propane or butane), characterised by their high energy density and their liquid state under ambient conditions or through basic processing.

Scarcity driven by geology and commercial viability

Beyond the climate crisis, the discussion on the energy transition must incorporate the scarcity of fossil fuels driven by geological, commercial and geopolitical factors.

Let us begin with geology. During much of the twentieth century, the oil industry benefited from large conventional discoveries: onshore and shallow offshore fields, with high natural pressure, good permeability and relatively straightforward access. Many of these fields continue to contribute a substantial share of global production. However, most of these resources were discovered decades ago and, since the mid-2000s, large conventional oil discoveries have become increasingly scarce.

Between 2005 and 2008, the production of this type of crude, which forms the basis for diesel, kerosene, petrol and petrochemical feedstocks, began to stabilise or decline slightly, despite advances in secondary and tertiary recovery[13]. This reflects the depletion of large conventional fields. Among the last discoveries of global relevance are the Brazilian pre-salt (2006) and the offshore fields of Guyana (2015). Since then, exploration has increasingly identified smaller resources, located at greater depths or in more remote and technically complex areas.

The stagnation of conventional oil has been partially offset by the development of unconventional resources[14], such as shale oil and shale gas in the United States and Argentina, as well as heavy oils in Canada and Venezuela. However, these resources present critical limitations.

- First, they exhibit faster decline rates than conventional fields: a shale well loses between 70% and 90% of its production within just three years, which requires continuous drilling to maintain stable output levels.
- Second, they require high capital intensity, as they depend on constant investment cycles in horizontal drilling, hydraulic fracturing and maintenance.
- In addition, they have a lower net energy return, which makes them more sensitive to market prices and requires high prices to justify continued investment.

[13] Secondary and tertiary recovery refer to advanced techniques used in resource extraction (such as oil) that increase the amount recovered beyond primary methods, through the injection of fluids or gases, or the use of chemical and thermal processes.
[14] Conventional reservoirs flow naturally from porous and permeable rocks. Unconventional resources (such as shale) are trapped in impermeable rock formations and require advanced stimulation techniques (such as hydraulic fracturing) for extraction.

These dynamics have direct effects on key sectors of the economy. Diesel, the backbone of the current economy, has experienced sustained price increases, with visible industrial impacts, including in Europe, where rising energy costs have affected the competitiveness of the productive base, particularly in economies such as Germany[15]. As the contemporary global economy remains heavily dependent on access to cheap oil, an increase in oil prices can lead to industrial collapse and economic crises.

Let us now turn to commercial viability and economic feasibility: the discovery of hydrocarbons does not guarantee supply. It is essential to distinguish between the physical existence of a resource and its capacity to be transformed into commercial supply. The industry does not simply extract «oil», but rather extracts economic profitability based on favourable geological conditions that enable low-cost extraction. This distinction helps explain why, even in contexts of high prices and technological advances, supply may face structural limits.

The industry provides numerous examples of the gap between discovery and development (discovery-to-development gap). In East Africa, for example, large volumes of natural gas have been discovered which, in regions such as Europe, would supply major markets. However, the absence of pipeline networks and the need to liquefy the gas for export as LNG (Liquefied Natural Gas) increase costs to the point of undermining the profitability of projects with reserves below 20 Tcf (trillion cubic feet)[16].

A similar situation occurs in the Brazilian pre-salt region, where large oil fields have been discovered that do not always justify the investment required for offshore infrastructure in ultra-deep waters. The economic breakeven point for such infrastructure typically lies between 0.5 and 1 billion barrels of oil equivalent (Bboe)[17,18].

Recent announcements of large discoveries in Namibia have generated new expectations, although part of these findings remains at a theoretical stage. Companies such as Shell and TotalEnergies have pointed out significant economic and technical

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[15] TURIEL, A. *Petrocalipsis: Crisis energética global y cómo la vamos a solucionar*. Editorial Alfabeto, 2020. Avaliable at: [Petrocalipsis - Editorial Alfabeto]
[16] INTERNATIONAL ENERGY AGENCY (IEA). *Africa Energy Outlook 2022: Final Investment Decisions and Natural Gas Infrastructure*. IEA Publications, 2022. Available at: https://www.iea.org/reports/africa-energy-outlook-2022
[17] PETROBRAS. «Strategic Plan 2024-2028: Pre-salt Exploration and Production Breakeven Analysis», *Petrobras Investor Relations*. 2024. Available at: https://docs.publicnow.com/viewDoc?hash_primary=84228F494115D8351137568F21C8DB884FB008FC
[18] RYSTAD ENERGY. «Deepwater Brazil: Analyzing Resource Thresholds and FPSO Deployment», *Rystad Energy Upstream Analysis*. 2025. Available at: https://www.rystadenergy.com/services/upstream-solution

limitations, and the Chief Executive Officer of Total has indicated that these developments would only be viable through clustered production schemes[19,20]. Shell, for its part, at the beginning of 2024, wrote down its exploration assets in Namibia after determining that its discoveries did not reach the threshold of commercial profitability under the current development model[21]. The combination of complex geology, high-risk technologies, remote locations and lack of infrastructure illustrates a fundamental principle: in the oil industry, finding hydrocarbons does not necessarily equate to generating economic value.

Commercial viability acts as a filter between geology and the market. The easiest fields to exploit are largely depleted, and the remaining resources tend to be smaller, more remote, more complex and more costly (figure 1)[22]. It can therefore be concluded that, in many regions, large volumes of discovered oil and gas will remain underground because the cost of bringing them to market is prohibitive. There are also resources yet to be discovered, but their exploration and development depend on expected economic returns. This logic explains why oil companies, even in contexts of high profits, do not increase exploration investment: decisions are governed by profitability and risk criteria.

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[19] Cluster production schemes consist of grouping several nearby projects or fields in order to share infrastructure, reduce operating costs and improve the economic efficiency of developments.

[20] TOTALENERGIES. «2023 Results & 2024 Objectives», *Strategic Update*. 2024. Available at: https://totalenergies.com/sites/g/files/nytnzq121/files/documents/2024-02/TotalEnergies_2023_Results_and_2024_Objectives_Transcript.pdf

[21] SHELL PLC. *First Quarter 2024 Results Update*. Shell Investor Relations, 2024. Available at: : https://shell.gcs-web.com/node/25051/pdf

[22] ATKINSON, N. y SIEMINSKI, A. *The Return of Realism in Global Oil Forecasts: A Critique of the INTERNATIONAL ENERGY AGENCY (IEA) World Energy Outlook 2025*. Energy Analytics, 2026. Available at: https://energyanalytics.org/the-return-of-realism-in-global-oil-forecasts/

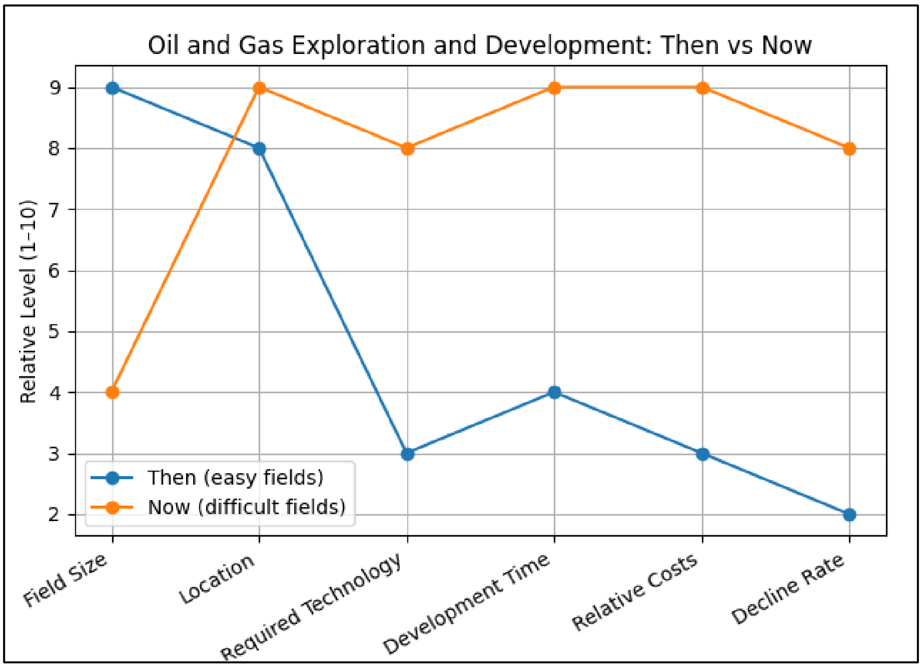

Figure 1 - Comparative exploration and development of oil and gas in the XX and XXI centuries. Economic viability depends on factors such as location, depth, access to infrastructure, development costs and market conditions. Source: own elaboration with data from International Energy Agency (EIA) [23].

Oil can be extracted and produced at high cost, but it cannot be paid at any price; historical data suggest that when a nation's energy expenditure exceeds 10% of its GDP, the risk of recession increases critically[24]. In the oil market, this affordability threshold has historically been associated with crude prices above 100 USD per barrel[25]. This correlation was confirmed by the IEA[26] following the 2022 crisis, validating that any project with breakeven costs close to this threshold lacks commercial viability in the face of the inevitable slowdown in demand.

Decline rates and energy security

Decline rates constitute one of the least understood factors in the public debate on

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[23] INTERNATIONAL ENERGY AGENCY (IEA) *World Energy Outlook 2025*. IEA Publications, 2025. Available at: https://www.iea.org/reports/world-energy-outlook-2025

[24] HAMILTON, J. D. *Causes and Consequences of the Oil Shock of 2007-08*. National Bureau of Economic Research, 2009. Available at: https://www.nber.org/papers/w15035

[25] KOPITS, S. *Oil and Economic Growth: A Supply-Constrained View*. Center on Global Energy Policy, Columbia University, 2014. Available at: https://www.energypolicy.columbia.edu/sites/default/files/energy/Kopits%20-%20Oil%20and%20Economic%20Growth%20(SIPA,%202014)%20-%20Presentation%20Version[1].pdf

[26] INTERNATIONAL ENERGY AGENCY (IEA) *World Energy Outlook 2023*. IEA Publications, 24 oct. 2023. Available at: https://www.iea.org/reports/world-energy-outlook-2023

energy, despite their critical relevance for security of supply. Decline is irreversible: once a field reaches its peak production, extraction naturally decreases, even with investment and advanced technology. According to the *World Energy Outlook 2025* of the IEA, these rates are accelerating globally, particularly in unconventional resources, deep offshore fields and smaller-scale fields.

At present, nearly 90% of upstream investment is allocated to compensating for the natural decline of existing assets rather than meeting new demand. To stabilise production towards 2050, it would be necessary to bring online 45 mb/d of new conventional oil capacity and approximately 2,000 bcm (billion cubic metres) of natural gas, unless there is a drastic contraction in consumption. In contrast with decarbonisation targets, the IEA has revised its short-term projections upwards, anticipating an increase of nearly 4 mb/d in liquid consumption and growth of 6% and 2% for gas and coal, respectively.

Within this framework, a recurring conclusion is the need to revitalise exploration. However, the decline in exploration investment since 2015 is not merely cyclical, as occurred in 2020 with the COVID-19 pandemic, nor solely due to the climate crisis, but reflects a structural loss of economic viability. Despite global exploration investment reaching approximately 50 billion USD annually in 2023, discoveries continue to decline, demonstrating that increased capital flows do not guarantee significant findings[27]. Conventional discoveries reached historical peaks in the 1960s (~100 Bboe/year), whereas in the 2010s the average declined to 20 Bboe and, since 2020, has fallen further to 8 Bboe, reaching a minimum of ~5.5 Bboe in the period 2023–2025, despite sustained investment between 45 and 65 billion USD annually[28,29,30,31].

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[27] EUCI. *Global oil and gas exploration spending is up at $50 billion in 2023 but reserves are down*. 29 Aug. 2023. Available at: https://www.euci.com/global-oil-and-gas-exploration-spending-is-up-at-50-billion-in-2023-but-reserves-are-down/

[28] INTERNATIONAL ENERGY AGENCY (IEA) *World Energy Outlook 2025*. IEA Publications, 2025. Available at: https://www.iea.org/reports/world-energy-outlook-2025

[29] RYSTAD ENERGY. *Global Oil and Gas Discoveries and Exploration Trends*, 2025. Available at: https://www.rystadenergy.com/flagship-report-energy-scenarios-2025?gad_source=1&gad_campaignid=23032735115&gbraid=0AAAAADvuAFO6TtnFb7uPur2g7QtVZ5y4e&gclid=Cj0KCQjws83OBhD4ARIsACblj1_zXJMBRdJ5eb3AamnKcLT7sLiT3TjMjipiOszJg6f3xy6lDI80f5waAjAkEALw_wcB

[30] ENERGY INSTITUTE. *Statistical Review of World Energy 2024*. 2024. Available at: https://www.energyinst.org/statistical-review

[31] WOOD MACKENZIE. *Exploration quietly recovering: Oil and gas exploration spending to recover from historic lows*. 16 Aug. 2023. Available at: https://www.woodmac.com/reports/oil-and-gas-exploration-exploration-quietly-recovering-150147814/

The shale boom in the United States (2008–2015) partially compensated for conventional depletion, but since 2016 the declining trend has accelerated again (figure 2).

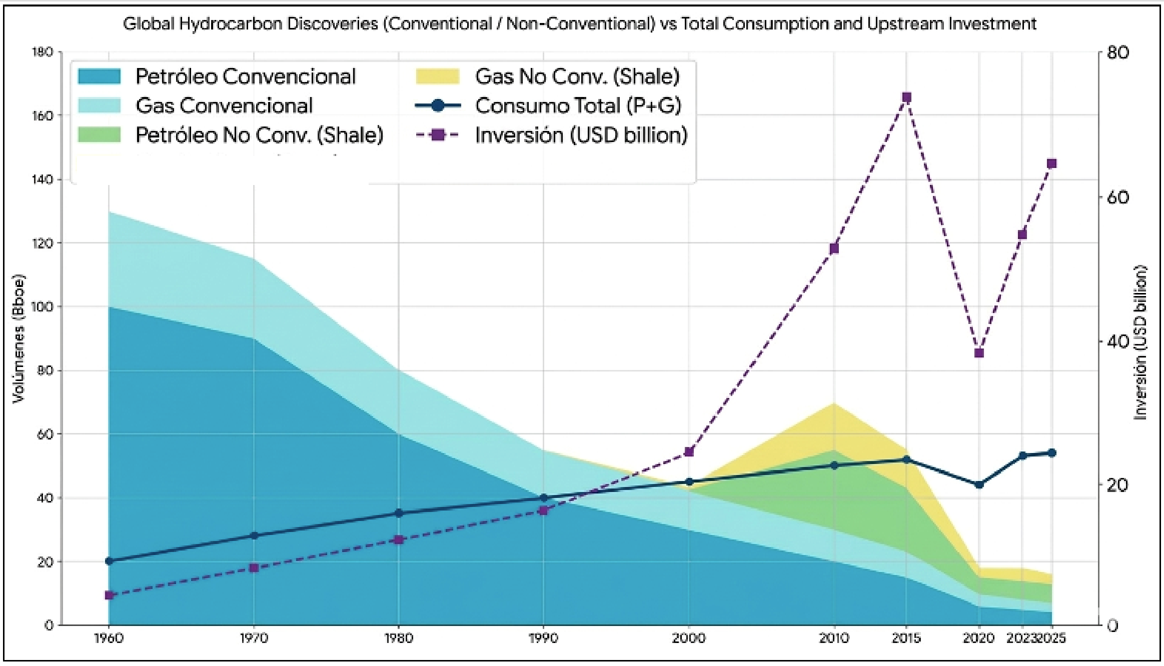

Figure 2 - Historical dynamics between discoveries (conventional/non-conventional), exploration investment and global consumption (1960–2025). The figure illustrates a critical disconnection in the global energy system: while total consumption maintains an upward trajectory that now exceeds 58 Bboe/year, the rate of conventional crude discoveries shows a terminal decline, reaching approximately 5.5 Bboe/year in the period 2023–2025. The introduction of unconventional resources (tight oil and shale) from 2000 mitigated the deficit, but geological productivity continued to decline even during the record investment cycle (2010–2014). This confirms the existence of a physical ceiling where capital no longer guarantees reserve replacement in mature basins. Source: own elaboration based on data from Rystad Energy 2025[32], IEA 2025[33], Energy Institute Statistical Review of World Energy 2024[34] and Wood Mackenzie 2023[35].

Since 2015, the absence of major discoveries, combined with global consumption that already exceeds 103 mb/d of liquid fuels and approximately 4,100 bcm of natural gas (corresponding to an annual consumption of ~58 Bboe)[36], has accelerated the erosion of proven reserves, as extracted volumes are not offset by new commercially viable

[32] RYSTAD ENERGY. *Global Oil and Gas Discoveries and Exploration Trends*, 2025. Available at: https://www.rystadenergy.com/flagship-report-energy-scenarios-2025?gad_source=1&gad_campaignid=23032735115&gbraid=0AAAAADvuAFO6TtnFb7uPur2g7QtVZ5y4e&gclid=Cj0KCQjws83OBhD4ARIsACblj1_zXJMBRdJ5eb3AamnKcLT7sLiT3TjMjipiOszJg6f3xy6lDI80f5waAjAkEALw_wcB
[33] INTERNATIONAL ENERGY AGENCY (IEA) *World Energy Outlook 2025*. IEA Publications, 2025. Available at: https://www.iea.org/reports/world-energy-outlook-2025
[34] ENERGY INSTITUTE. *Statistical Review of World Energy 2024*. 2024. Disponible en: https://www.energyinst.org/statistical-review
[35] WOOD MACKENZIE. *Exploration quietly recovering: Oil and gas exploration spending to recover from historic lows*. 16 Aug. 2023. Disponible en: https://www.woodmac.com/reports/oil-and-gas-exploration-exploration-quietly-recovering-150147814/
[36] 1 bcm = 6.11 mboe (million barrels of oil equivalent).

discoveries. At the current rate, the IEA indicates that discovered resources would have a lifespan of only 14 years, implying theoretical depletion around 2040.

Our calculations reinforce this trend: even under sustained investment generating discoveries of ~6 Bboe annually, a projected consumption of 60 Bboe per year would only shift depletion towards 2060.

Current exploration is limited to a few hotspots (Brazil, Guyana, Suriname, Namibia), which are insufficient to compensate for global consumption. The stagnation of discoveries between 4 and 8 Bboe annually, regardless of financial intensity, demonstrates that basin maturity constitutes an insurmountable physical limit (the industry is “investing more to discover less”). Reserve replacement increasingly relies on secondary and tertiary recovery techniques and in situ improvement[37]. Energy security therefore depends less on capital and more on the finite nature of resources.

With global consumption of ~58 Bboe per year compared to discoveries of only ~5 Bboe, the structural gap highlights the vulnerability of the current energy model and the urgency of considering the physical availability of energy as a central element of economic and political stability, reinforcing the need to diversify energy sources and to transform the model of production, distribution and consumption that underpins the current economy.

Scarcity due to geopolitics

The energy imbalance is not only geological or economic, but also geopolitical. The majority of global hydrocarbon reserves are concentrated in a limited number of regions, primarily the countries of the Middle East, Venezuela and Canada (figure 3).

[37] CONNAISSANCE DES ÉNERGIES. *The Implications of Oil and Gas Field Decline Rates*. 2024. Available at: https://www.connaissancedesenergies.org/sites/connaissancedesenergies.org/files/pdf-actualites/TheImplicationsofOilandGasFieldDeclineRates.pdf

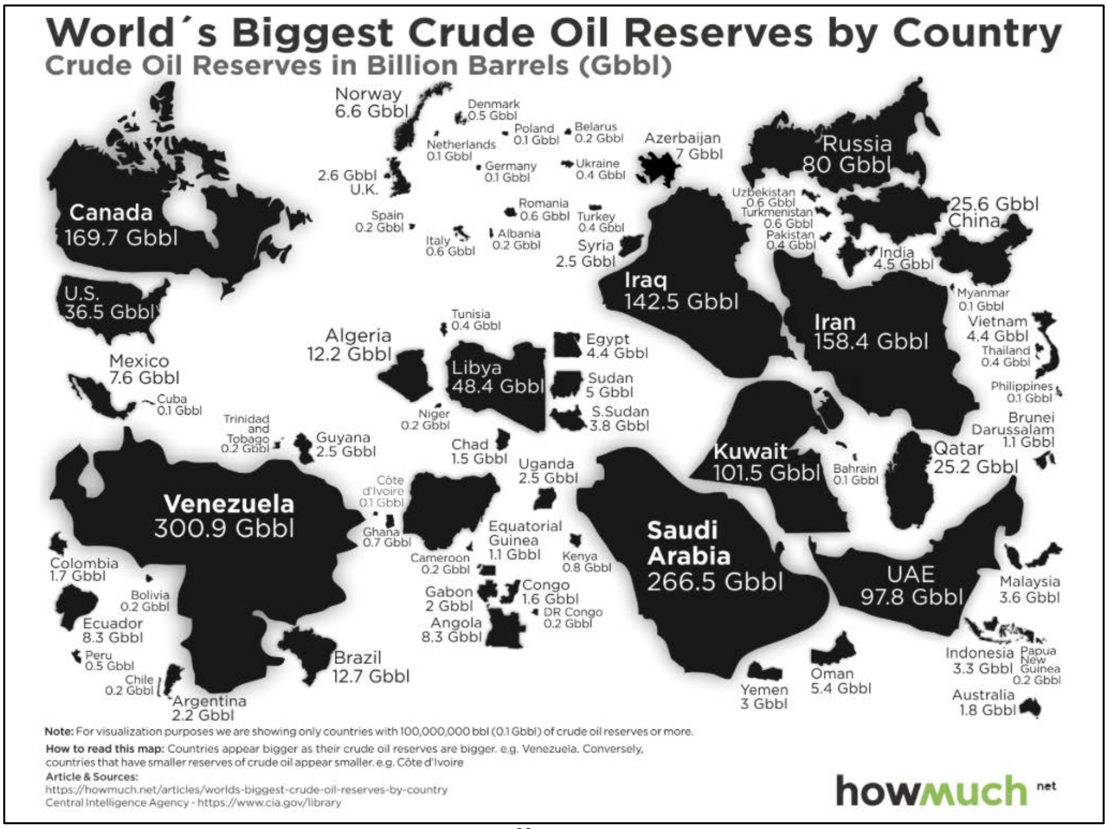

Figure 3 - Global crude oil reserves by country[38]. Source: Central Intelligence Agency. HowMuch.net

However, although the United States ranks lower in terms of total reserves, it has recently consolidated its position as the world's largest producer, driven by the expansion of shale oil following the conflict in Ukraine (figure 4). Nevertheless, despite its production leadership, the country remains one of the largest importers of oil, reflecting a structural dependence on international flows.

[38] HOWMUCH.NET. *Mapping crude oil reserves around the world*. 25 de marzo de 2019. Available at: https://howmuch.net/articles/worlds-biggest-crude-oil-reserves-by-country

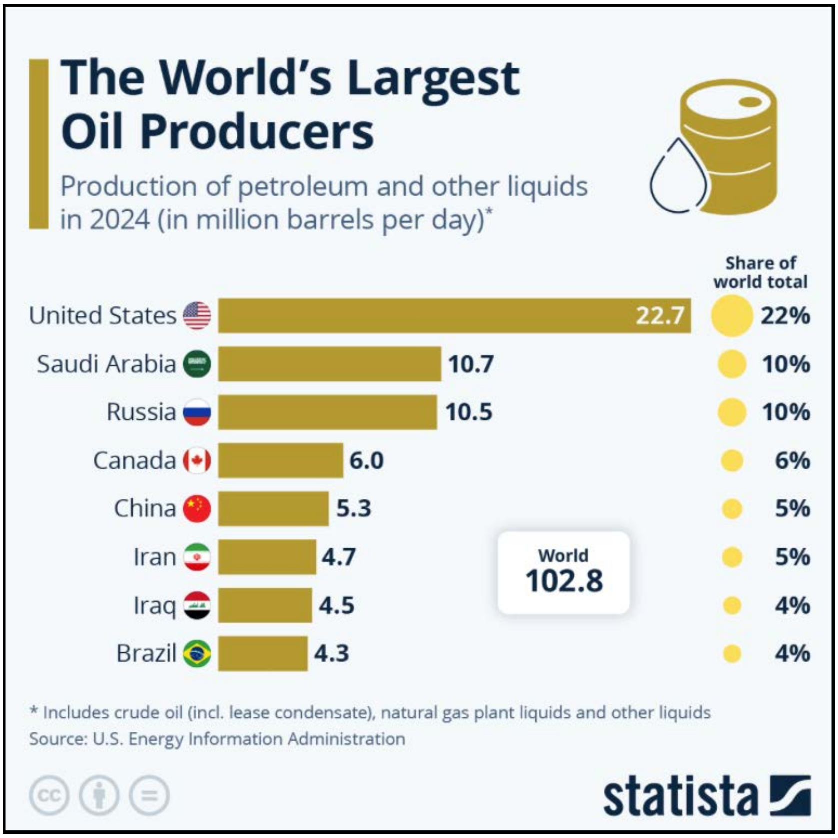

Figure 4 - Largest global producers 2026[39]. Source: U. S. Energy Information Administration. Statista

The paradox of temporary oversupply

The rise of shale oil in the United States, driven by prices above 90 dollars per barrel, made the exploitation of unconventional reservoirs profitable. This revived production, which had stagnated prior to the war in Ukraine. However, the rapid expansion also generated an oversupply, causing tensions with traditional producers such as Saudi Arabia and Russia. These countries have been forced to withdraw barrels from the market in order to sustain prices. Without these restrictions, crude prices would fall to levels at which much of the shale oil production would no longer be commercially viable.

In this regard, experts such as Berman[40] warn that the growth potential of shale gas in

[39] STATISTA. *The world's largest oil producers.* Fuente: U. S. Energy Information Administration. 9 de marzo 2026. Available at: https://www.statista.com/chart/16274/oil-producing-countries/
[40] BERMAN, A. *Complexity's Revenge: Electric Power and AI*. Art Berman Energy Analysis. 2026. Available at: https://www.artberman.com/blog/complexitys-revenge-electric-power-and-ai/

the Appalachian region (Marcellus) and the Permian Basin is already showing structural limits. The most plausible scenarios indicate that these resources will reach a production plateau in the first half of the 2030s, followed by a progressive decline.

Sanctions, conflicts and the new energy order

The sanctions imposed on Russia by the OECD (Organisation for Economic Co-operation and Development) following the invasion of Ukraine have produced an adverse effect: rather than weakening only the Russian economy, they have affected global stability. Europe's capture of gas supplies from Qatar and the United States left other countries without access to supply, a situation that Russia exploited by redirecting its flows and offering hydrocarbons at competitive and stable prices. From this point onwards, a reconfiguration of the market has been driven, giving rise to a new global order that brings together countries dissatisfied with what is termed "Western dominance", consolidating a Eurasian bloc that actively seeks alternatives to the petrodollar, and which is now further reinforced by the Iran war.

The member countries of OPEC account for around 80% of the world's proven oil reserves[41,42], reflecting a high geographical concentration of resources. Through the expanded OPEC+ cooperation framework, which includes major producers such as Russia and Kazakhstan, this group exerts significant influence over the global crude oil supply, and therefore over the energy security of major importing economies such as Europe, Japan, China and the United States.

Europe's vulnerability and the gas crisis

The European Union faces an existential risk following the breakdown of its energy relationship with Russia. The replacement of low-cost pipeline gas with expensive LNG (liquefied natural gas) from the United States, together with high diesel prices, has led to a process of silent deindustrialisation in major economies such as Germany. The European chemical and metallurgical industries are unable to compete with regions

[41] INTERNATIONAL ENERGY AGENCY (IEA). *World Energy Outlook 2025*. IEA Publications, 2025. Available at: https://www.iea.org/reports/world-energy-outlook-2025
[42] OPEC. *Annual Statistical Bulletin 2025*. OPEC Publications, 2025. Available at: https://asb.opec.org/

where energy is three to four times cheaper. By 2030, the EU could depend on the United States for up to 80% of its LNG supply[43], leaving it exposed to the domestic policy and demand conditions of that country.

Material and technological limits of the energy transition

Despite the rapid growth of renewable energies, their share in the global energy balance remains limited. Only around 20% of global energy consumption corresponds to electricity and, of this, approximately 30% is generated from renewable sources (mainly solar, wind and hydroelectric), while the remainder comes primarily from fossil fuels and nuclear energy. Consequently, around 80% of global energy consumption still depends on fossil fuels, namely oil, gas and coal. Although there is significant potential for electrification, certain sectors, such as aviation or energy-intensive industries such as petrochemicals, require energy densities for which no competitive large-scale alternatives currently exist.

The energy transition faces challenges that are often underestimated in more optimistic projections. Studies modelling the complete substitution of the fossil-based system[44], while maintaining projected consumption levels, indicate the need for an exponential expansion of renewable energy, not only in photovoltaic and wind capacity, but also in hydrogen production and the manufacturing of electric vehicles. However, the deployment of renewable energy alone would not be sufficient. Meeting demand would require doubling global hydroelectric and nuclear capacity, which would entail significant pressure on the industrial ecosystem, enormous capital requirements and increased dependence on uranium, a resource concentrated in a limited number of countries, as well as intensifying the challenges associated with the long-term management of radioactive waste.

Even with this level of deployment, it would still not be sufficient; the system would also require biofuels for aviation and heavy transport[44], which compete with food security, the availability of arable land and water resource consumption.

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[43] INSTITUTE FOR ENERGY ECONOMICS AND FINANCIAL ANALYSIS (IEEFA). *Global LNG Outlook*. 2024. Available at: [Global LNG Outlook 2024-2028 | IEEFA]

[44] MICHAUX, S. *Assessment of the Extra Capacity Required of Alternative Energy Electrical Power Systems to Completely Replace Fossil Fuels*. Geological Survey of Finland, 2021. Available at: https://tupa.gtk.fi/raportti/arkisto/42_2021.pdf

Furthermore, the deployment of clean technologies requires a massive expansion in the production of critical minerals such as copper, lithium, nickel, cobalt, graphite and rare earth elements, necessary to meet projected demand, which would imply multiplying current production by between seven and ten times. These minerals are essential not only for the energy transition, but also for digital technologies, computing and the military industry. The convergence of these expanding sectors increases structural vulnerabilities associated with the limited availability of resources and their high territorial concentration.

In terms of distribution, the map of major deposits shows a high degree of geographical concentration: China, for example, dominates the production of rare earth elements and graphite, while Chile leads in lithium production, although the most decisive control lies in processing and in the global value chain (figure 5)[45].

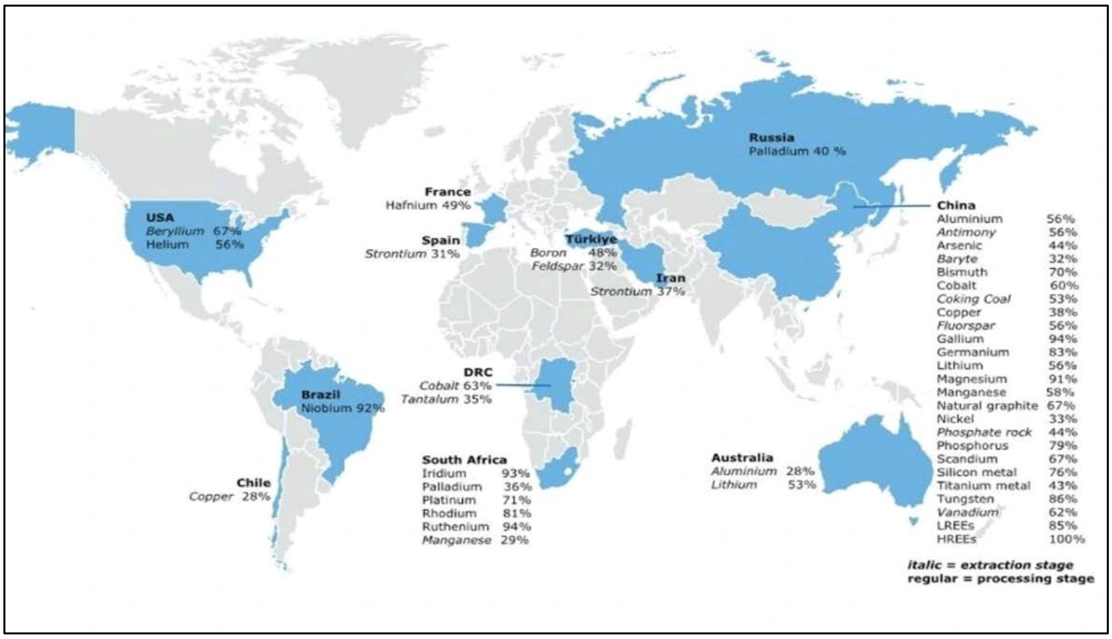

Figure 5 - Countries with the largest share of production of critical raw materials. Source: United States Geological Survey, USGS 2024.

Since 2000, China, aware of its dependence on fossil fuels, has developed a long-term strategy covering everything from geology to processing technologies across the entire value chain of critical minerals, which has enabled it to concentrate nearly half of global renewable capacity. Its competitiveness is not based solely on low wages, but on innovation and automation. China has replicated the model that the United States applied

[45] UNITED STATES GEOLOGICAL SURVEY (USGS). *Mineral Commodity Summaries 2025*. 2025. Available at: https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries

to oil in the twentieth century: not only controlling the resource, but also the associated industrial and technological ecosystem.

Finally, and as is also the case with oil, the extraction of critical minerals poses serious ethical and environmental challenges, including deforestation, water stress, labour exploitation and the displacement of communities. These impacts are observed in various regions of the world, such as the Amazon, Indonesia and the Philippines[46], the Democratic Republic of Congo[47], the lithium triangle (Argentina, Chile, Bolivia), Australia and Madagascar.

In summary, the energy transition faces technological, material, geopolitical and socio-environmental challenges that call into question the feasibility of optimistic theoretical scenarios of accelerated deployment. Sustaining unlimited growth through simple technological substitution is not viable[48].

Unequal distribution of resources, impact on global conflicts and the global landscape

There are currently more than 50 active armed conflicts in the world[49], most of them linked to the control of energy and raw materials. This "war for resources" is concentrated along several axes, including:

- Russia–Ukraine: The dispute centres on hydrocarbons, strategic minerals and agricultural capacity. In the face of foreseeable food crises in an agriculture dependent on fossil fuels (fertilisers and machinery), sovereignty over arable land constitutes a competitive advantage[50].
- Middle East: The United States, Israel, Saudi Arabia and Iran are leading the

[46] AMNISTÍA INTERNACIONAL (AI). *Powering Change: Principles for Businesses and Governments in the Battery Value Chain*, 2022.Available at: https://www.amnesty.org/es/documents/act30/3544/2021/es/
[47] AMNISTÍA INTERNACIONAL (AI). *República Democrática del Congo: La minería industrial de cobalto y cobre para baterías recargables está dando lugar a graves abusos*. 2023. Available at: https://www.amnesty.org/es/latest/news/2023/09/drc-cobalt-and-copper-mining-for-batteries-leading-to-human-rights-abuses/
[48] BERMAN, Art. «The Race to the Bottom». 15 Jan. 2026. Available at: https://www.artberman.com/blog/the-race-to-the-bottom/
[49] ORGANIZACIÓN MUNDIAL POR LA PAZ (OMPP). *Mapa global de conflictos: Guerras por recursos y materias primas*. 2026. Available at: https://worldpeaceorganization.org/
[50] TURIEL, A. *¿El final de las estaciones?*, 2024. Disponible en: https://viruseditorial.net/libreria/el-final-de-las-estaciones/

struggle for oil, gas, uranium and other raw materials. Israel acts as a key strategic ally for the United States in a region that holds the largest remaining hydrocarbon reserves, making it a vital area for securing access to oil, gas and mineral supplies, particularly given the decline or insufficiency of US domestic reserves. Against this backdrop, conflict in the region is expected to persist, in one form or another, with no end in sight [51].

- Sub-Saharan Africa: Competition for coltan (Democratic Republic of the Congo), uranium and gold (Niger, Burkina Faso, Mali) and gold and oil infrastructure (Sudan), among others, generates instability and endemic poverty. The limited effectiveness of European diplomacy and asymmetric pricing have favoured the influence of Russia and China, increasing the presence of para-state actors[52] [53] [54].
- Venezuela: The United States requires heavy crude to maintain the operation of its refineries and petrochemical industries.

Global security depends on managing scarcity, with major powers adopting different strategies. As an «electrostate», China is moving towards a clean structural transformation while securing long-term, competitive and diversified contracts for fossil fuels to sustain its energy transition. Russia bases its influence on territorial control of energy, minerals and land, and positions itself as an alternative supplier to the Western bloc by redirecting flows towards the East and the Global South. The United States maintains a «petrostate» model, with an economy anchored in hydrocarbons and interventionist policies aimed at securing strategic resources. Meanwhile, the European Union is pursuing electrification without achieving resource sovereignty. It is highly dependent on critical minerals and renewable energies that complement, but do not replace, fossil fuels, on which it continues to rely despite lacking them domestically.

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[51] Author's opinion.
[52] UK PARLIAMENT, RESEARCH BRIEFINGS. *Conflict Minerals and Africa's Resource Curse*. 2024. Available at: https://researchbriefings.files.parliament.uk/documents/CBP-10089/CBP-10089.pdf
[53] ATLANTIC COUNCIL. *Illicit Mineral Supply Chains Fuel the DRC's M23 Insurgency*. 2024. Available at: https://www.atlanticcouncil.org/blogs/energysource/illicit-mineral-supply-chains-fuel-the-drcs-m23-insurgency/
[54] DEUTSCHE WELLE. *Critical Minerals Contribute to Instability in Africa*. 2025. Available at: https://www.dw.com/en/africa-critical-minerals-mining-instability-drc-rwanda-m23-conflict-graphics-v2/a-73876380

Conclusions: the end of cheap energy

Geological and geopolitical evidence indicates that the central challenge facing our societies is not only the climate crisis or technological change, but the management of a scarcity of high energy density and low-cost energy.

The era of cheap oil drove the economic model of growth and the continuous increase in energy consumption, but hydrocarbons are showing signs of decline and there is no source with the calorific power and versatility of fossil fuels capable of fully replacing them, which sets limits to the current model.

Renewable energies add capacity, but do not replace fossil fuels. It is the economic model itself, based on increasing energy demand and unlimited growth, that prevents the abandonment of hydrocarbons and reproduces, for new energies, a centralised system that maintains dependence on global supply chains, reduces local energy sovereignty and exacerbates the biodiversity crisis.

The concentration of fossil resources and critical minerals required for renewable, digital and military transformations redefines the map of power and is the origin of most armed conflicts and growing inequalities. In addition, climate inaction entails costs for countries and governments: extreme environmental events, deterioration of health due to air and water pollution, extreme heat and risks to energy and food security.

In this context, the energy transition cannot be limited to a simple change of sources. The idea of maintaining a growth model based on unlimited consumption through a simple substitution of energy sources is physically unviable. It is also underestimated that the availability and cost of energy derived from oil and gas may become a significant economic constraint before the end of the decade, particularly affecting regions dependent on imports such as Europe.

An effective transition will only occur through a realistic adaptation to a context of finite resources and lower energy availability. Accelerating renewables and innovation is necessary, but it is equally necessary to rethink how energy is used and how prosperous and just societies can be sustained within this new scenario.

With an orderly but inevitable transition away from fossil fuels, the transformation will only be possible if an economic model that wastes energy is left behind and patterns of production, consumption and distribution are redefined. Along this path, it will be possible to regain control over our energy and our lives, with cleaner air, improved health and a fairer future. Preparing from now is essential; otherwise, the system will not be viable for anyone, and scarcity will further deepen inequalities.

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