

The Energy Transition and Global Warming Paradox: Implications for Algeria's Sovereign Energy Strategy

*Khris Fatiha**, MAA at Faculty of Economics, Business and Management Sciences, Mouloud Mammeri University, Tizi Ouzou, PhD Student, National School of Statistics and Applied Economics, (ENSSEA), (Algeria), fatiha.khris@ummt.o.dz
Mohamed Kolli, Ph.D. in Finance, M'hamed Bougara University, Faculty of Economics, Boumerdes, (Algeria), ORCID ID: 0000-0002-8486-0459, m.kolli@univ-boumerdes.dz.

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Abstract:

This article examines the conflation of the energy transition and the climate emergency, demonstrating that CO₂, whose role is primarily framed in terms of its greenhouse effect within the prevailing scientific and policy discourse, remains an essential atmospheric nutrient for the biosphere. It draws attention to the contradictions inherent in environmental policies that hinder development without effectively decarbonising the economy. For Algeria, a sovereign transition focused on its natural resources and geopolitical commitments, represents the most appropriate pragmatic choice. Drawing on a qualitative, documentary approach, the study cross-references academic, institutional, and statistical sources to test these claims against empirical evidence.

Keywords: Energy transition, Carbon dioxide, Climate change, renewable energy, Energy policy.

Jel Classification Codes: Q42, Q48, Q54, Q56.

* Corresponding author

1. INTRODUCTION:

Global energy systems must simultaneously ensure reliable access to affordable energy, support economic development and reduce environmental pressures. These objectives do not always converge in the short term, and the design of transition policies therefore requires careful attention to trade-offs, sequencing and distributional effects.

Hydrocarbon resources remain a major determinant of energy geopolitics, and their control shapes international relations and investment decisions (Hache, 2016).

The framing of energy and climate debates can privilege assumptions and policy narratives, and rigorous analysis must therefore engage transparently with competing evidence, methodological approaches and sources of uncertainty (Milot, 2019).

Recent policy debates emphasise the need to reduce greenhouse-gas emissions to limit global warming. Scientific assessments link observed warming to anthropogenic emissions, while also acknowledging uncertainty about the precise regional and sectoral scale of future impacts (IPCC, 2021).

Warnings from scientists, often unidentified, about rising global temperatures, rising sea levels, the melting of sea ice, and an increase in the frequency of extreme weather events, such as cyclones, tornadoes, floods, and heatwaves, have consistently pointed to CO₂ and greenhouse gases resulting from human activity, with rising sea levels said to create thousands of climate refugees (Zarzoso, Lehmann, & Paschoaleto, 2023).

Yves Roucaute*, in his book *L'obscurantisme vert* (Roucaute, 2022), traced the history of planet Earth through its various eras, showing that it has never been a long, tranquil river. From the Big Bang to the extinction of the dinosaurs, it experienced a succession of warm and glacial periods, volcanic eruptions and major earthquakes, all while humanity did not yet exist.

* **Yves Roucaute** is a qualified teacher of philosophy and political science, a university professor, holder of a doctorate, a lecturer and an epistemologist; he is the author of books acclaimed by the press and the reading public, including **La Puissance de la Liberté** and, more recently, **Le Bel Avenir de l'Humanité**

A further aspect concerns the increasing politicisation of climate discourse, which may, in some contexts, place greater emphasis on policy and societal considerations than on empirical analysis, highlighting the importance of maintaining a clear distinction between scientific evidence and broader normative debates (Millot, 2019).

Climate and energy debates are sometimes presented in polarised terms. This article therefore distinguishes between established scientific findings, disputed projections, normative choices and distributional effects, and uses this distinction to structure its analysis.

In this article, we examine the role of atmospheric carbon dioxide (CO₂) in global productivity and crop yields, with particular attention to its contribution to plant growth and agricultural production. We further seek to distinguish established scientific evidence from commonly held assumptions regarding the environmental effects attributed to CO₂, while critically examining the scientific basis of policies and regulatory measures associated with its emissions.

The aim of this work is to place the energy transition and global warming within its true context: the former in terms of its objective of energy security, the latter in terms of its ultimate purpose, the protection of the environment and the preservation of the planet. Both share a goal: the well-being and sustainability of human life on Earth under the best possible conditions. This analysis is grounded in concrete data. We highlight, as far as possible, the inconsistencies and complexity in the treatment of these two closely interrelated subjects.

To this end, we address the following question: **To what extent can current energy-transition policies reconcile greenhouse-gas mitigation with energy security and development, and what policy mix is most suitable for Algeria?**

Three sub-questions follow:

- a) What are the contradictions in the current global energy transition strategy?
- b) What is the actual role of CO₂ in the ecosystem? And
- c) What are the key features of Algeria's sovereign energy strategy?

1.1. Research Objectives

- To clarify the conceptual framework distinguishing the imperative of energy security from the restrictive excesses of climate policies.
- To analyse, quantitatively and scientifically, the impact of atmospheric CO₂ concentrations on plant biomass and global agricultural yields.
- To assess the methodological uncertainties associated with global climate projection models.
- To define the strategic pathway and optimal energy mix (by 2035) that will guarantee Algeria's economic and energy sovereignty.

1.2. Significance of the research

The significance of this study is threefold:

- **Theoretical significance:** It enriches the academic debate by offering a critical and balanced perspective on the paradox between the energy transition and global warming.
- **Practical significance:** It provides a pragmatic analytical framework for public decision-makers to develop sustainable energy policies.
- **Target audiences:** Government bodies (Ministries of Energy and the Environment), companies in the energy sector (Sonatrach, Sonelgaz), as well as the academic and research community.

1.3. Literature review and research gap

Although the transition to low-carbon systems has been the subject of numerous publications (Millot, 2019), (Gitelman & Kozhevnikov, 2023) etc., the Algerian academic literature still pays insufficient attention to the necessary distinction between the technical imperatives of energy security and climate policies. This research addresses this gap by critically assessing the impact of environmental policies on developing countries and proposing a model of sovereign transition tailored to the Algerian context.

The research gap lies in the limited integration of these strands within a single Algeria-specific framework. Existing work rarely brings together climate evidence, carbon-cycle evidence, energy security, distributional effects and the fiscal dependence of a hydrocarbon-exporting economy. This article addresses that gap through a balanced review and a policy-oriented synthesis.

1.4. Critical synthesis of literature

Institutional assessments advocate rapid decarbonisation to limit warming, drawing on isotopic, observational and physical evidence linking recent CO₂ increases to human activity (IPCC, 2021; IEA, 2024; IRENA, 2023). In contrast, critical authors discuss uncertainties in complex climate processes, while energy-geopolitics research cautions that renewable deployment may create new dependencies on critical materials and technologies (Allègre, 2010); (Gérondeau, 2021), (Gérondeau, 2022); (Gervais, 2020); (Roucaute, 2022); (Hache, 2016); (Genc & Kosempel, 2023).

1.5. Methodology

This article adopts a qualitative documentary research design based on a structured critical narrative review and a policy-oriented analysis of Algeria's energy system. In our view, a key question that remains insufficiently explored in the Algerian academic literature is whether the necessity of the energy transition can be distinguished from the broader political, institutional, and policy frameworks that have shaped its development. From an epistemological perspective, we adopt a **critical approach** to the prevailing discourse, drawing on a diverse body of scientific literature, including alternative perspectives, to assess empirical evidence in relation to existing theoretical models.

The documentary sources reviewed, are organized into **three** complementary categories: academic works from indexed journals and recognised scientific publications; institutional reports issued by international organisations (IPCC, IEA, IRENA, MEQV); and reference statistical data (BP Statistical Review, Global Carbon Project, NOAA), alongside works by authors known for their critical position towards the scientific consensus. The analysis cross-references these sources using a comparative and critical approach, aiming to identify the inconsistencies, paradoxes and limitations of current energy policy.

The qualitative nature of the approach adopted here means that the study does not claim to be quantitatively exhaustive; rather, it seeks to critically highlight a scientific and political debate that remains

insufficiently nuanced in dominant literature. A dedicated discussion of the limitations of this approach is provided before the conclusion.

To address this issue, two competing hypotheses are proposed, to be tested against the evidence developed in Sections I to IV:

Hypothesis 1: Greater reliance on low-carbon energy and energy-efficiency measures is associated with lower emissions intensity, if reliability and affordability constraints are managed.

Hypothesis 2: A diversified strategy combining renewable energy, efficiency, methane reduction and transitional use of hydrocarbons is more compatible with Algeria's energy-security and development objectives than an abrupt single-technology transition.

Four key areas structure the treatment of the two hypotheses:

Axis I: The energy transition

Axis II: The significance of CO₂ and greenhouse gases

Axis III: Global warming

Axis IV: Which energy transition path for Algeria?

2. The energy transition

2.1. A brief definition of the energy transition

Although the concept of energy transition has been used extensively in recent years, there is no established definition, and it remains a subject of discussion and debate.

As it is often defined by its intended objective, it is sometimes associated, rightly or wrongly, with the transition to a green economy or ecological transition, or the transition to a low-carbon economy, or even, in extreme cases, a zero-carbon economy (an implausible scenario).

In the report by Meadows (Meadows, et al., 1972), *The Limits to Growth* (or *Halte à la croissance* in French), as cited by (Millot, 2019), the concept of transition aims to warn against the depletion of resources caused by the prevailing model of economic growth. To achieve a state of equilibrium while avoiding systemic collapse, the authors advocate abandoning the growth-based economic model and thus initiating the transition.

The Brundtland report (Brundtland, 1987), upon its publication, linked the energy transition to the concept of ‘sustainable development,’ connecting socio-economic development and environmental protection. This was followed in 1997 by the Club of Rome's report, *Factor Four: Doubling Wealth, Halving Resource Use*[†], which set out the objective of reducing greenhouse gas (GHG) emissions by a factor of four by 2050, in the hope of limiting global warming to 2°C.

While the concept of energy transition is widely used in political and media circles, no single definition is universally accepted within the scientific community. It refers, among other things, to the shift from an energy system based on conventional, stock-based fossil fuels to a low-carbon system built on renewable and new, more environmentally friendly energy sources, through the gradual replacement of fossil fuels in the energy mix with renewable sources wherever possible. Changes to production processes (technical innovation), the institutional framework and energy policy will be necessary across all sectors of human activity (industry, buildings, transport, heating, lighting, etc.). The energy transition cannot be treated as a purely technical matter; it requires coordinated action across research disciplines, public institutions, and civil society (Gitelman & Kozhevnikov, 2023).

The main objectives and challenges of the energy transition are numerous and often contradictory:

- Reducing greenhouse gas emissions and the pollution caused by energy production and consumption, to combat global warming;
- Ensuring access to affordable and readily available energy to meet the demand of a growing population;
- Reducing energy consumption and improving energy efficiency to promote sustainable development;
- Turning to renewable and new energy sources, and rolling out technological innovation in the energy sector;
- Energy independence (for certain countries) and energy security.

[†] This report, like the Meadows report, is a Club of Rome report commissioned from the German Wuppertal Institute for Climate, Environment and Energy Research.

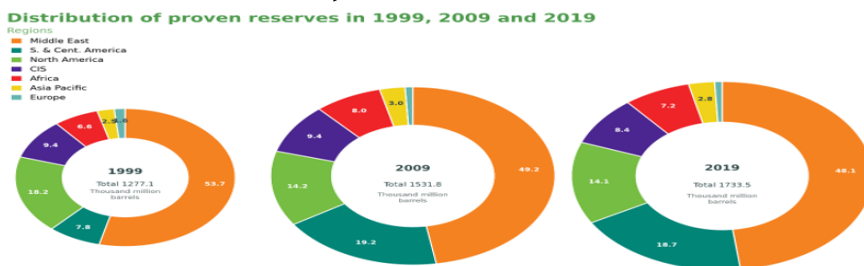
2.2. Energy reserves (fossil fuels)

Care should be taken to distinguish between resources, which comprise all the volumes of energy available in nature in various forms (initial, discovered-recoverable, and discovered-non-recoverable) (Khris, 2014), and global energy reserves, which comprise all known quantities of energy that are technically feasible to extract and economically viable; these volumes fluctuate in line with new discoveries and technical progress.

The notion of the depletion of fossil-fuel resources is often cited as justification for the energy transition. Yet the ratio of reserves (in tonnes) to annual production (in tonnes per year), known as the R/P ratio (proven reserves over production at the current rate), which indicates the number of years of remaining supply, has stayed fairly stable over recent decades, and has in some cases even increased.

The BP Statistical Review of World Energy (BP, 2020) is the most authoritative source for determining global energy reserves and the trend in the R/P ratio by energy source. Figure 1 below shows the distribution of proven oil reserves (in billions of barrels) in 1999, 2009 and 2019.

Figure 1: Distribution of proven oil reserves (in billions of barrels) in 1999, 2009 and 2019.



Source: BP Statistical Review of World Energy, 2020[‡].

This graph shows that proven oil reserves rose from 1,277.1 billion barrels (bb) in 1999 to 1,531.8 bb in 2009, and then to 1,730.9 bb in 2019 (BP, 2020). Gas reserves increased from 132.8 trillion cubic meters in 1999

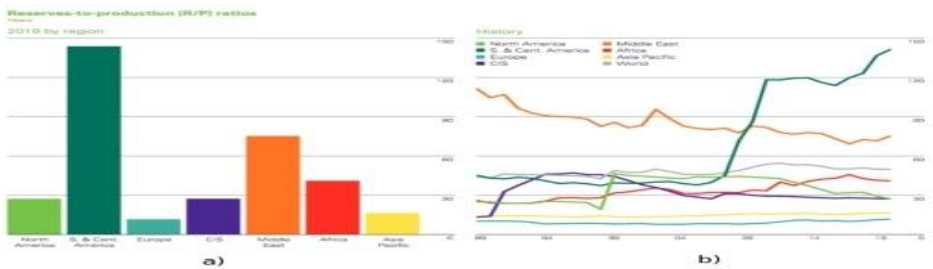
[‡] CIS: This stands for the *Commonwealth of Independent States* (CIS), which is an intergovernmental organisation comprising 10 of the 15 former Soviet republics. (Chareyron, Horsin-Moliaro and Multon, 2020)

to 170.5 trillion in 2009 and to 198.8 trillion in 2019; coal reserves remained broadly stable over the same period. These data describe accounting reserves at given prices and technologies; they do not constitute evidence that resources are unlimited, that extraction costs remain constant, or that climate constraints disappear.

Fossil fuels are, admittedly, finite, but advances in extraction techniques and innovation in the energy sector are making a significant contribution to the longevity of field operations and the replenishment of reserves, alongside major new discoveries around the world (Lebanon, Côte d'Ivoire, Algeria, Niger, Russia, Suriname, and others).

Figure 2 below illustrates the R/P ratio for oil; the global figure (the grey line) indicates an average of more than 50 years of production at the current rate, a level that has not changed significantly since 1989.

Figure 2: Representation of the R/P ratio in years for oil, by region, from 1989 to 2019.



a) R/P ratio for oil by region in 2019; **b)** historical trend from 1989 to 2019 (in years).

Source: BP Statistical Review of World Energy, 2020.

2.3. Energy security and the new geopolitics of renewable energy sources (RES)[§]

Energy security is every country's ultimate objective, and securing energy supply lies at the heart of international relations.

Ensuring a continuous flow of energy is essential for economic development and for the continuity of current ways of life. Whether energy-

[§] NRE: new and renewable energy, referring primarily to biofuels, wind power, solar photovoltaics and solar thermal energy.

independent or energy-dependent, states seek to diversify not only their energy sources (fossil and renewable) but also their sources of supply.

Fossil fuels are characterised by their concentration in specific geographical areas, which is not the case for renewable energy. This requires different strategies from the various stakeholders (states, major energy groups, producer and consumer countries, financial institutions) and tailored energy policies. Although renewable energy offers significant diversification within the energy mix, it has the disadvantage of storage limitations, due primarily to its intermittent nature and the limited development of storage technologies. In fact, decarbonising energy systems presents both urgency and paradox: the faster the transition proceeds, the more clearly its technical, financial, and institutional barriers emerge (Saini, 2026).

The deployment of renewable energy requires the large-scale rollout of patented technologies whose production involves rare materials known as rare earths or critical materials, which, like traditional resources, are highly concentrated geographically. These two factors have led to the emergence of new geopolitics of patents and new geopolitics of resources (Hache, 2016, pp. 42,44). These challenges call for a reassessment of relations between producers, consumers, and transit countries.

China remains the world leader in the renewable energy sector, accounting for around 67 per cent of photovoltaic modules in 2020, according to the Fraunhofer Institute for Solar Energy Systems. It supplies around 80 per cent of components used in wind-turbine production, and 97 per cent of silicon wafers, a component essential to the manufacture of solar panels, according to the same source^{**}. The same pattern holds for patents: only Germany and Japan can compete, but China has a clear advantage given its reserves of rare-earth elements, which creates a dependence on China within the renewable-energy technology sector. The global shift towards renewable energy is structurally necessary, yet it unfolds in a

^{**} Tidey Alice. (2022). *The EU needs renewable energy, and to achieve this, it depends on China*. Article from the Euronews online newspaper <https://fr.euronews.com/my-europe/2022/06/13/l-ue-a-besoin-des-energies-renouvelables-et-pour-cela-depend-de-la-chine>

context of geopolitical vulnerability that exposes the fragility of energy supply chains (Genc & Kosempel, 2023).

2.4. Energy transition and the energy crisis

What recent events have laid bare is a fundamental inconsistency at the heart of the energy transition: the very process designed to secure a stable climate future is, in its transitional phase, generating renewed tensions. The sabotage of the Nord Stream gas pipelines in 2022 illustrated this with exceptional clarity, in a context of acute geopolitical rivalry, European nations, endowed with far greater financial leverage than their counterparts in the Global South, moved swiftly to capture available LNG supplies, securing their own industrial reorientation at the expense of developing states already operating at the margins of global energy markets. This consolidation of power undermines the position of developing states, or so-called ‘peripheral’ nations, which find themselves excluded from supply networks due to soaring costs. For these already vulnerable states, energy scarcity is no longer merely an economic obstacle but an existential threat: the resulting failure of infrastructure and disruption to essential services directly jeopardise the sustainability, or even the very existence, of the state apparatus, placing them in a precarious position.

3. The importance of CO₂ and greenhouse gases (GHGs)

CO₂ is a greenhouse gas that is essential for trapping the heat emitted by the Earth. Without it and other GHGs, the Earth's temperature would be -18°C, making life impossible. This physical fact does not imply that additional anthropogenic greenhouse-gas emissions are harmless.

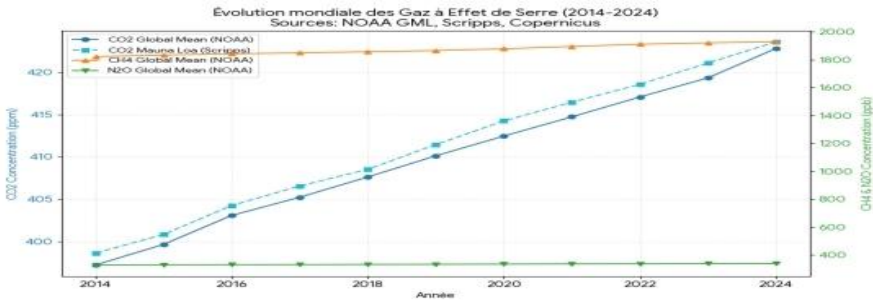
Beyond being an essential nutrient for plants, natural carbon cycles (oceans, soils, vegetation) regulate the concentration of CO₂ in the atmosphere and thus help to maintain a stable climate over thousands of years. These systems are not perfectly stable and respond to both natural and human drivers.

Atmospheric CO₂ levels are observed to be rising rapidly due to human activity (industry, deforestation, transport), which exacerbates the greenhouse effect and global warming, a causal relationship that, while

widely accepted, remains subject to ongoing scientific debate regarding its precise magnitude.

The graph below shows trends in greenhouse gases (GHGs), with the most recent data covering the period from 2014 to 2024, as documented by leading global monitoring networks, including the NOAA Global Monitoring Laboratory and the Scripps Institution of Oceanography. (Lan, 2026).

Figure 3: Global trends in greenhouse gases (2014–2024).



The graph above shows a sustained increase in CO₂: globally, it crossed the 400-ppm threshold in 2015. Since then, the rate has remained above 2 ppm per year, reaching approximately 423 ppm in 2024 (Lan, 2026). Methane (CH₄), which has also risen sharply following a period of relative stability, has shown a marked increase since 2020, reaching approximately 1,930 ppb in 2024.

A cross-analysis of Gervais (2020) and Gérondeau (2022), supported by peer-reviewed FACE experiments, indicates that rising atmospheric CO₂ can contribute to biospheric growth and increase yields for some crops under favorable conditions. However, heat and water stress may reduce or offset these benefits (IPCC, 2023); (Jiang., Medlyn., Drake., & ..., 2020). Table 1 summarises the observed trends in atmospheric CO₂ and their reported agronomic and economic implications based on these sources.

Table 1: Trends in atmospheric CO₂ and their agronomic and economic impact.

Period / CO ₂ concentration	Impact on vegetation and yields	Economic and global impact
1880–2020 (280 to 415 ppm)	Increase in global plant biomass. (Gervais, p. 39)	Despite population growth, supports food security.

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1961–2011 (gradual increase)	Record yields of cereals (wheat, maize, rice) have continued to rise.	Estimated gain of \$3.2 trillion for global agriculture (Idso, 2013) ^{††} .
1982–2015 (+~70 ppm)	14 per cent increase in the productivity of the terrestrial biosphere. (Gervais, p. 39)	Reduced pressure on agricultural land, thanks to photosynthetic efficiency.
Current level (~415 ppm)	Plants lose less water through transpiration while absorbing carbon.	Optimisation of crops in semi-arid areas.
Projection (CO2 doubled)	Increased yields: wheat (+35%); rice (+30%); maize (+10%). (Gervais, p. 40)	Potential to feed 9 to 10 billion people without major expansion of cultivated land. (Gérondeau, p. 84)
Risk management	Stability: The available data do not indicate a clear increase in losses associated with extreme events.	Modern agriculture absorbs 2 to 8 times more carbon than it emits. (Gérondeau, p. 73)
Pre-industrial to present (280 to ~410 ppm)	FACE experiments confirm that CO2 fertilisation alone can raise yields by up to 18% in cereals, legumes and root crops under non-stress conditions (IPCC, 2023).	In field conditions, the gain is increasingly offset by heat stress, water scarcity and extreme weather in major food-producing regions, limiting the net benefit. (Jiang., Medlyn., Drake., & ..., 2020)
Mature forest ecosystem (~400 ppm) (Jiang., Medlyn., Drake., & ..., 2020)	Increased photosynthesis and carbon uptake, but no increase in net ecosystem carbon storage	Fertilisation does not necessarily increase net sequestration
Consensus	The CO2-fertilisation effect	IEA and IRENA do not publish

^{††}This estimate does not come from an article published in a peer-reviewed scientific journal. It is an institutional report published by the Centre for the Study of Carbon Dioxide and Global Change. The calculation is based on data from the FAO covering 45 crops, a reference concentration of 280 ppm CO₂, and crop response factors from the CO₂ Science database. It would therefore be prudent to present the figure as an estimate by Idso, rather than as a scientific finding established by consensus.

assessment (IEA, 2024), (IPCC, 2023), (IRENA, 2023)	is explicitly included in the crop and Earth-system models used by the IPCC; it is not an overlooked or suppressed variable (IPCC, 2023).	independent agronomic data; their assessments (energy and decarbonisation pathways) treat continued fossil-fuel-driven CO2 growth as a net risk to development, not a net agronomic benefit.
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Note: the estimates in the two rightmost rows of this table originate from a single, non-consensus source (the Idso study) and should be read as illustrative rather than as an agreed scientific estimate.

CO₂, long reduced to the mere role of a pollutant, is of great importance to vegetation, the economy and crop yields alike through its fertilising effect, a dimension that tends to be overlooked in favor of the prevailing approaches, notably that of the IPCC, which advocate massive decarbonisation, or even net-zero carbon, without explaining the consequences.

However, a distinction must be made between the biological role of CO₂ as an essential nutrient for the biosphere (supporting photosynthesis, essential to biomass, and feeding the entire food chain) and its climatic impact: CO₂ acts as a greenhouse gas because it absorbs the Earth's infrared radiation and contributes to the retention of atmospheric heat, thereby influencing the planet's overall temperature, effectively functioning as a thermal regulator of the atmosphere.

3.1. The effects of a significant reduction in CO₂ levels

A significant reduction in atmospheric CO₂ would have consequences for the climatic and biological balance. From a physical perspective, lower concentration could contribute to reducing the extent of greenhouse effect and promote global cooling, while limiting ocean acidification, benefiting calcifying marine organisms such as corals (IPCC, 2021).

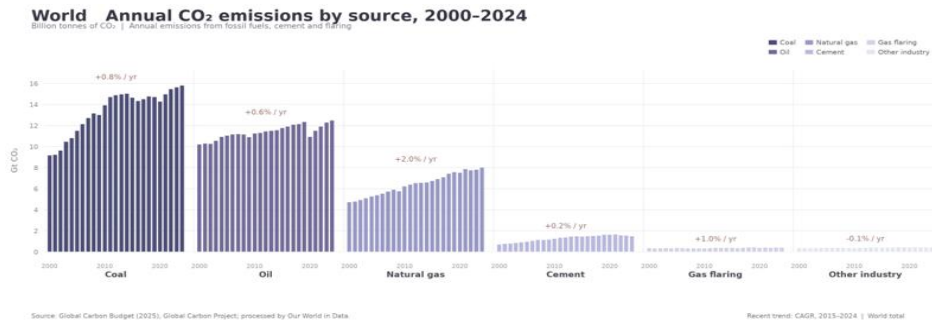
From a biological perspective, lower CO₂ levels would slow the process of photosynthesis, thereby limiting plant growth and biomass production (Taiz, 2015). This would reduce plant productivity through a weakened carbon-fertilisation effect, consequently diminishing the natural capacity of terrestrial ecosystems to absorb atmospheric carbon (Raven, 2013).

3.2. Selected carbon policies and measures

According to the Global Carbon Project, fossil-fuel and industrial activities accounted for approximately 89% of global anthropogenic CO₂ emissions in 2024. Within this category, coal contributed approximately 41%, oil 32%, and natural gas 21%, while cement production, flaring, and other sources accounted for the remainder (Friedlingstein P. , O'Sullivan, Matthew , & ..., 2025).

Six years earlier, in 2020, global CO₂ emissions from fossil fuels and industrial activities were distributed among coal combustion (40%), oil (32%), natural gas (21%), cement production (5%), and gas flaring and other sources (approximately 2%), according to the Global Carbon Project (Friedlingstein, O'Sullivan, & ..., 2021).

Figure 4: Annual CO₂ emissions by energy source, 2000–2024.



Source: Global Carbon Project, Global Carbon Budget 2025, via Our World in Data.

According to the graph above, the largest share of CO₂ emissions continues to come from coal combustion, despite a slight 0.6 per cent decrease in recent years, due mainly to the health crisis caused by COVID-19, which slowed global economic activity. Oil combustion follows closely, with natural gas in third place.

A further issue relates to the reliance on American shale gas, which is transported over greater distances and is therefore more expensive and more polluting. Maritime transport of LNG adds to the environmental cost, as large cargo vessels generate significant emissions.

This return to coal-fired generation runs counter to the commitments ostensibly made to reduce CO₂ and greenhouse-gas emissions, whether

within international climate conferences (COP 21 to COP 26) or at the domestic level within individual countries. This creates a paradox: promoting electric vehicles in a context where electricity is generated primarily from coal combustion calls into question the consistency and real effectiveness of transport decarbonisation policy, highlighting the need for better-calibrated and less restrictive policy measures.

4. Global warming

4.1. What is global warming?

As with the energy transition, there is no universally accepted definition of global warming; it refers to the rise in the average temperature of the Earth's oceans and atmosphere observed over several decades.

Global warming is widely attributed to human-induced climate change, primarily driven by the accumulation of greenhouse gases in the atmosphere. Among these gases, carbon dioxide (CO₂) is the principal contributor to the observed rise in global temperatures. The following section therefore examines the relationship between atmospheric CO₂ concentrations and global warming.

4.2. Uncertainty in climate models

The IPCC's climate models have been subject to criticism, particularly on methodological grounds, highlighting their limited ability to simulate the Earth's highly complex biophysical systems. According to Allègre (2010), the reliability of these simulations is limited by their incomplete representation of non-linear physical variables such as cloud dynamics, deep ocean currents and their heat exchanges, and solar activity cycles. This lack of precision creates a discrepancy between computer projections and satellite observations and measurements, which is why the precision of some model-based projections has been questioned. The uncertainty surrounding both the scale of the regional and sectoral impact of climate change, and the extent of the contribution of anthropogenic CO₂, as highlighted in consensus reports, remains a recurrent argument of climate sceptics.

4.3. Approaches to climate change: A comparative analysis of divergences and paradoxes

Different interpretations of global warming are reflected in scientific literature. While the IPCC provides a synthesis based on the prevailing body of climate research, alternative perspectives, including those of Allègre (Allègre, 2010), (Wrightstone, 2017)^{††}, the authors of the Idso study (Idso, 2013), question aspects of the prevailing interpretation and draw on historical observations and alternative analyses.

These differences primarily concern methodological and empirical interpretations. Alternative perspectives question the extent to which climate models capture the complexity of climatic processes and argue that historical climate variability and natural cycles should receive greater consideration. They also examine the strength of the causal relationship between anthropogenic CO₂ emissions and observed warming, as well as the uncertainties associated with long-term climate projections. In addition, some scholars have raised questions about the economic and energy implications of policy measures such as carbon pricing and emissions restrictions, particularly regarding their potential effects on development and energy security. In (Millot, 2019) further discusses the socio-political dimensions of the energy transition and the extent to which these may influence interpretations of environmental policy.

The prevailing approach advocated by the IPCC, while acknowledging uncertainties surrounding both the regional and sectoral impact of climate change and the extent to which anthropogenic CO₂ is responsible for global warming, does not extend that uncertainty to the link between anthropogenic CO₂ emissions and global warming itself. Analysis of the isotopic composition of atmospheric CO₂ reveals a specific signature associated with fossil fuels (13C) that differs from that of natural sources, making it possible to distinguish CO₂ of natural origin from CO₂ of anthropogenic origin. This allows recent increases in atmospheric CO₂ to be attributed to human activity (Keeling, 1979), (IPCC, 2021).

^{††} Wrightstone, a former geologist in the energy sector and executive director of the CO₂ Coalition, is known, amongst other things, for his views in favor of the ‘positive impact of CO₂’ and for criticising climate alarmism; he is the author of **Inconvenient Facts**.

The IPCC's position rests on convergent lines of evidence beyond isotopic attribution: instrumental temperature records spanning more than a century, satellite-based measurements of outgoing radiation, and physically based forcing calculations that are tested against, and updated with, observational data (IPCC, 2021). This body of evidence underpins the consensus view that the anthropogenic contribution to recent warming is well established, even while acknowledging uncertainty about the precise regional and sectoral scale of future impacts.

The IPCC's data also derive from a combination of palaeoclimatological analysis and recent instrumental measurements.

Global warming is nonetheless a reality that must be considered in economic development planning, though not necessarily at the scale indicated by the IPCC; the scale of its effects still needs to be demonstrated objectively and scientifically, based on real, historical observations, and on serious forecasting studies carried out without bias or conflicts of interest.. Considerable uncertainty remains in modelling a phenomenon as complex and variable as the climate. In the absence of a forecasting methodology broadly accepted within the scientific community, such projections are increasingly questioned and should not serve as the sole basis for policy decisions on climate change.

To this should be added practices sometimes attributed to climate change that result from deliberate human intervention in weather patterns, such as Operation Popeye, carried out by the USA in Vietnam, which involved prolonging the rainy season for military purposes. This type of intervention is precisely what the ENMOD Convention, adopted by the UN in 1976, (UN, 1976), was designed to prohibit. The convention provides for peaceful uses to alleviate periods of drought, a practice that remains controversial.

5. Which energy transition path for Algeria?

Algeria views the energy transition as a key driver of energy security and an environmental necessity. The country is actively pursuing the diversification of its energy mix, in which hydrocarbons (natural gas and oil) account for 99 per cent of energy sources.

5.1. Algeria's share of GHG emissions

Algeria's share of global emissions remains marginal, accounting for no more than 0.3 to 0.4% of total emissions, according to data from the First Biennial Transparency Report (BTR1) (Ministry of the Environment and Quality of Life) (MEQV, 2024), despite a slight increase in domestic emissions driven mainly by industrial and demographic growth. According to the same source, using 2022 as the reference year, Algeria's total emissions are estimated at approximately 240.4 million tonnes of CO₂ equivalent (MtCO₂eq), excluding the forestry sector, broken down as follows: CO₂ accounts for 80.2%, followed by methane (CH₄) at 14.5%, and nitrous oxide (N₂O) at 5.3% (MEQV, 2024). The energy sector accounts for 87% of emissions and pollution, followed by the agriculture, waste and industrial-processing sectors, at 7%, 4% and 2% respectively.

Despite its low, and negligible overall contribution, Algeria has committed to reducing its emissions under the Paris Agreement, while also seeking to diversify its energy mix, Algeria's transition pathway should be adapted to its own development level, fiscal structure, resource endowment, institutional capacity and international commitments, and instead adapting its approach to its own economic and development needs.

As part of its commitment to clean energy (the Paris Agreement) and its strategy to diversify its energy mix, Algeria has pledged to reduce its GHG emissions by between 7% and 22% by 2030 (7% using state resources alone, 22% subject to securing international funding and technology).

5.2. Hydrocarbon valorisation and industrial strategy

The Algerian economy remains heavily dependent on hydrocarbons: in 2022, they accounted for 19% of GDP, 92% of exports and nearly 57% of budget revenue, highlighting a structural dependence and, consequently, the need for substantial reform to enable the transition to a diversified, low-carbon economy (MEQV, 2024).

A strategic restructuring of the hydrocarbon sector is under way, according to Algeria's First Biennial Transparency Report BTR1 (MEQV, 2024), focused on reconciling economic sovereignty with climate challenges. To this end, and to break away from dependence on crude-oil

exports, national policy aims to increase the local processing of natural resources to a rate exceeding 50%, achieve full self-sufficiency in refined products, and bring about a domestic energy transition supported by cleaner fuels; LPG fuel alone accounted for 13% of road-transport consumption in 2022. Added to this is the industrial-decarbonisation pathway taking shape through Sonatrach's commitment to eliminate routine gas flaring by 2030, an initiative that has already enabled the recovery of 2.39 billion cubic meters of associated gas between 2019 and 2021, thus improving economic efficiency while freeing up gas volumes for export, given that oil generates higher revenue per unit for foreign exchange.

5.3. Drivers of the energy transition

The drivers of the energy transition in Algeria are based on several key areas:

1. Solar photovoltaics is the main driver; Algeria aims for 27% of renewable electricity to come from solar photovoltaics by 2030;
2. Energy efficiency;
3. Reducing the carbon footprint of transport through the promotion of LPG fuel, with the aim of gradually replacing diesel and petrol;
4. Optimising the use of hydrocarbons through the optimal allocation of resources;
5. Green and blue hydrogen^{§§}: as an energy carrier rather than an energy source (it is manufactured and does not occur naturally in this form), hydrogen makes it possible to store and transport energy generated from renewable sources, namely solar and wind power. It also helps address the intermittency of solar power by storing surplus electricity generated during the day in the form of gas (MEQV, 2024). Green hydrogen also enables the decarbonisation of heavy industry (steel, cement and petrochemicals) by replacing fossil fuels, offering Algeria, given its natural resource endowments, a significant opportunity to maintain its role as an energy supplier to Europe; Clean hydrogen offers a realistic decarbonisation

^{§§} **Green** hydrogen (which is lower in carbon) is produced using renewable electricity, particularly solar power; **Blue** hydrogen is produced from natural gas with CO₂ capture; this differs from grey hydrogen, part of whose production process involves natural gas that emits large amounts of CO₂.

pathway for heavy industry, but its deployment remains constrained by cost and scaling challenges that no single policy can overcome (Zhu , Keolelian, & Cooper, 2025).

6. Carbon sinks: the forestry sector is a key driver of the energy transition, and Algeria is proceeding with the rehabilitation and extension of the Green Dam.

5.4. The optimal energy mix for Algeria

Rather than proposing a single optimal mix, this article considers three illustrative 2035 scenarios: business as usual, gas-solar diversification and accelerated renewable deployment. These scenarios are assessed in terms of energy security, emissions, affordability, fiscal exposure, and system flexibility, with the proposed shares serving as indicative rather than optimal estimates. Drawing on Sonelgaz's projections for the electricity mix and data from Algeria's First Biennial Transparency Report (MEQV, 2024), a potential energy mix for Algeria by 2035 may be outlined as follows:

Natural gas at approximately 61.5%: used mainly for electricity generation, domestic heating and as an industrial feedstock;

- Petroleum and derivatives at approximately 24%: gradually decline, but remaining essential for heavy road, maritime and air transport, as well as for the plastics industry;
- Solar photovoltaics (approximately 11.5%): corresponding to the ambitious target of 15,000 MW of installed capacity, and representing the cornerstone of the energy transition;
- Other renewables and energy efficiency, approximately 3%: including wind power, hydroelectricity and biomass.

Discussion

The analysis provides qualified support for H1 and clear support for H2, suggesting that Algeria's energy transition should be understood not as an abrupt rupture with existing energy structures, but as a gradual and context-sensitive process of optimisation. For countries of the Global South with relatively limited historical emissions, accelerated decarbonisation must be pursued in conjunction with considerations of equity, access to finance, and development. In Algeria's case, a phased strategy combining

natural gas, solar photovoltaics, and economic diversification could enhance energy security while preserving export capacity.

Limitations of the study

This study has two important limitations. First, it is a qualitative study of a set of documents. Therefore, results obtained cannot be used for generalizing. Second, this study focuses on a set of authors who do not accept the climate change consensus as well as on the margins of this group of authors. As a result, the study's scope is subject to a few selection biases.

6. CONCLUSION

This study shows that the energy transition and climate policy must be viewed within their actual biophysical, geopolitical and economic contexts. Carbon dioxide plays an essential biological role, but its accumulation also contributes to radiative forcing; both functions must be considered together.

The methodological limitations and uncertainties associated with certain climate models may raise questions regarding the robustness of policy decisions based on their projections. Furthermore, debates surrounding energy transition and global warming underline the need to balance environmental objectives with broader economic and energy considerations. For countries such as Algeria, energy security, economic development, and long-term sustainability should therefore remain key priorities in the formulation of energy policy.

For Algeria, a phased strategy combining the domestic use of natural gas, the decarbonization of industrial processes, energy efficiency and the gradual development of renewable energies can reconcile, under appropriate institutional and financing conditions, economic growth, energy security and international environmental commitments.

Prospects for future research

1. A technical and economic assessment of the cost of integrating battery storage into the national electricity grid by 2030.
2. Econometric modelling of the impact of green hydrogen export policies on Algeria's balance of payments.

3. A comparative study of the European Union's carbon border adjustment mechanisms (CBAMs) and their implications for Algerian industrial exports.

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