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## A critical review on climate policy shifts and the increasing role of LNG as a transition fuel

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### Abstract

The global energy transition presents a fundamental policy dilemma: how to reconcile rapid decarbonization with persistent energy poverty and economic development needs. This dual challenge of climate mitigation and energy poverty alleviation requires pragmatic policy solutions. The acceleration of global climate governance following the Paris Agreement has reshaped energy markets, regulatory institutions, and investment flows. This paper therefore advances a critical perspective that Liquefied Natural Gas (LNG) can serve as a necessary and development-oriented transition fuel, particularly in low- and middle-income countries, when embedded within a structured decarbonization pathway by integrating climate science, energy systems, development economics and political economy perspectives. To tackle this dilemma, LNG has emerged as a contested “transition fuel,” as both a transitional solution and a structural risk within this transformation positioned between coal dependence and renewable energy expansion. Proponents argue that LNG reduces carbon intensity, improves air quality, enhances grid stability, and accelerates electrification in developing economies while critics contend methane leakage, lifecycle emissions, and long-lived infrastructure risk undermining climate targets consistent with limiting warming to 1.5 °C. The paper assesses whether LNG can serve as a transition fuel without undermining long-term decarbonization goals. This was conducted through reviewing of past works by different investigators, reports by Intergovernmental Panel on Climate Change (IPCC), International Energy Agency, United Nations Environmental Programme, World Bank, and European Commission on liquefied Natural Gas. The review indicates that LNG’s legitimacy as a transition fuel depends on stringent methane regulation, time-bound infrastructure deployment, carbon capture integration, and differentiated pathways between advanced and developing economies. The review also highlights a justice dilemma: strict fossil fuel restrictions versus growth in low-income economies. The paper concludes that LNG can function as a transition fuel rather than a definitive climate solution, with its legitimacy contingent upon strict regulatory oversight and temporal constraints.

**Keywords:** LNG; Climate transition; Methane leakage; Energy security and poverty; Development policy; Net-zero; Carbon capture; Transition fuel

### 1. Introduction

LNG is basically methane (CH<sub>4</sub>) cooled to -162 °C and transported in large, specialised vessel. Energy access remains central to economic development. Approximately 675 million people globally still lack access to electricity, with the majority located in Sub-Saharan Africa and parts of South Asia (International Energy Agency, 2023). Energy poverty constrains industrialization, healthcare delivery, education, and overall economic productivity. Therefore, developing economies face urgent imperatives of energy access, industrialization, and economic growth. At the same time, climate policy is rapidly shifting toward decarbonization in line with the goals of the United Nations Framework Convention on

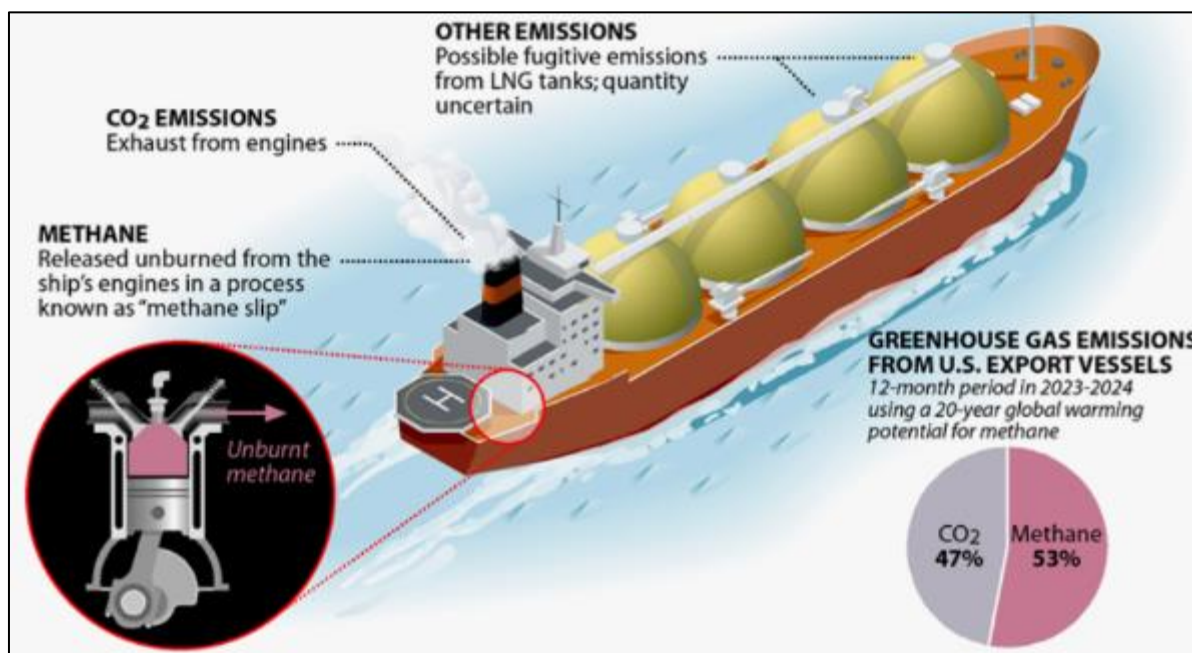
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Climate Change and the Intergovernmental Panel on Climate Change (IPCC). This creates tension between development priorities and emissions reduction commitments.

The global energy system is undergoing an unprecedented structural transformation driven by climate change mitigation commitments, technological innovation, geopolitical instability, and financial market realignment. Since the adoption of the Paris Agreement in 2015, countries representing over 90 % of global emissions have announced net-zero targets (IEA, 2023a). These commitments have reshaped fossil fuel investment trajectories and introduced regulatory uncertainty across hydrocarbon markets. Carbon pricing regimes, methane regulations, fossil fuel subsidy reforms, and coal phase-out mandates are reshaping fuel hierarchies.

Within this context, LNG has emerged as a prominent transition fuel, bridging high-carbon fossil fuels and renewable energy systems. LNG offers several advantages including lower carbon intensity than coal and oil, flexibility to support intermittent renewable generation, and the ability to enhance energy security (IEA, 2021; Maxwell & Das, 2023). LNG can facilitate industrialization, urbanization, and expansion of energy access, aligning with immediate development imperatives while providing a pathway to integrate low-carbon energy sources over time. Within this evolving policy architecture, LNG occupies a paradoxical position. On one hand, LNG enables coal displacement, reduces local air pollutants, and enhances energy security through flexible global trade. On the other hand, long asset lifetimes, and financial investment inertia may undermine deep decarbonization goals.

LNG infrastructure typically requires 20–30 years supply contracts, high upfront capital expenditure and stable policy frameworks. LNG-specific emissions include liquefaction energy use and maritime transport, increasing lifecycle intensity relative to pipeline gas. Climate-related financial disclosure requirements are increasing scrutiny of LNG investments. Long-lived LNG assets risk underutilization if decarbonization accelerates. However, the role of LNG in climate-aligned energy pathways is not without controversy. Methane leakage along the LNG supply chain can offset emissions benefits (Figure 1), and uncoordinated infrastructure expansion risks creating long-lived fossil lock-in, undermining net-zero targets (IPCC, 2022; Maxwell & Das, 2023). Policymakers must therefore navigate a delicate balance including enabling LNG to support near-term development and energy security while ensuring that its deployment is consistent with climate goals. Governance frameworks, stringent methane controls, and integration of emissions-reduction technologies such as carbon capture and storage are critical to maximizing the climate benefits of LNG (IEA, 2021; UNEP, 2021).



**Figure 1** LNG Tanker Emissions (Inside Climate News, 2025)

This review critically examines LNG's role within evolving climate sensitivity, energy poverty and development imperatives, political economic imperatives, LNG in future energy pathways, governance challenges, trade-offs inherent in reconciling development imperatives with global decarbonization objectives, and consideration for emerging economies. By synthesizing perspectives from international energy agencies, climate science assessments, and

economic analyses, the review assesses how LNG can serve as a credible transitional fuel without compromising long-term climate commitments (Adekoya et al., 2024).

## 2. Climate Sensitivity

The climate implications of LNG are closely linked to the concept of climate sensitivity, which describes how strongly the Earth's climate system responds to increased greenhouse gas concentrations. While LNG combustion produces lower carbon dioxide emissions than coal or oil, its overall climate impact depends on lifecycle emissions especially methane leakage and how these emissions interact with climate sensitivity and feedback mechanisms. One perspective in the literature views LNG as a relatively lower-carbon alternative capable of reducing near-term emissions. Studies by the International Energy Agency suggest that replacing coal with natural gas in electricity generation can significantly reduce carbon dioxide emissions and local air pollutants. In its *Net Zero by 2050* roadmap, the agency notes that natural gas can support the transition by replacing higher-emitting fuels and enabling greater integration of renewable energy. This perspective emphasizes that LNG can contribute to emissions reductions when used strategically as a transitional fuel in the power sector. LNG combustion emits significantly less carbon dioxide than coal, methane leakage, infrastructure lock-in, and long-lived capital assets complicate its compatibility with net-zero emissions trajectories. The narrative that LNG is a cleaner transition fuel rests on a narrow comparison of combustion CO<sub>2</sub> alone and must therefore include methane emissions (Daudu, et al., 2024).

However, a second body of literature emphasizes the importance of methane emissions across the LNG supply chain. Methane is a potent greenhouse gas with strong short-term warming effects, making it particularly relevant to discussions of climate sensitivity. Methane (CH<sub>4</sub>) is the dominant climate-forcing component in the LNG lifecycle. The Intergovernmental Panel on Climate Change notes that methane has a significantly greater warming potential than carbon dioxide over shorter time horizons. This finding highlights how leakage from natural gas production, liquefaction, transport, and regasification can offset the climate benefits of switching from coal to gas if not effectively managed. Methane regulations have intensified, particularly in the European Union. Methane has a 100-year global warming potential (GWP100) of 28–34 and a 20-year GWP (GWP20) exceeding 80 (IPCC, 2022). Methane's global warming potential (GWP100) is 28–34 times that of CO<sub>2</sub> (IPCC, 2022), significantly affecting lifecycle gas emissions. Short-term warming effects are particularly significant under rapid decarbonization timelines. Recent satellite-based measurements indicate methane leakage rates in some basins may exceed previously reported inventory estimates, raising questions about gas's net climate advantage (IEA, 2023b). Methane emissions from LNG transport (so-called "methane slip") have been documented from LNG carrier vessels, with methane released during use of dual-fuel engines. (Axsen & Wolinetz (2023)

The global transition toward a low-carbon economy is increasingly defined by the "Water-Energy-Food Nexus," a framework championed by Loáiciga (2024, 2025) to analyze the sustainability of a growing human population under natural constraints. A critical component of this transition is the shift in climate policy that repositioned Liquefied Natural Gas (LNG) not merely as a fossil fuel, but as a "transition fuel" capable of bridging the gap between coal-intensive power generation and a fully renewable future.

As demonstrated in Table 1, the "Reference Case" for carbon dioxide emissions from natural gas use highlights a significant regional variance in atmospheric impact. According to Loáiciga (2025), the world has become increasingly carbon-intensive since 1950, with CO<sub>2</sub> intensity rising by nearly 92.4%. The data provided by Raimi et al. (2024) and DeCarolis & LaRose (2023) supports the observation that while advanced economies are beginning to decouple growth from emissions, emerging regions—particularly in Asia and Africa—continue to see rising CO<sub>2</sub> outputs from natural gas as they prioritize energy security and infrastructure development.

**Table 1** World CO<sub>2</sub> Emissions from Natural Gas Use by Region (Reference Case) Million metric tons of carbon dioxide (CO<sub>2</sub>)

Region	Primary Drivers & Policy Context
Americas / USA	Shift toward LNG as a coal replacement in the power sector; focus on methane leak mitigation.
Europe & Eurasia	Accelerated pivot to LNG imports to ensure energy sovereignty while maintaining strict carbon pricing.
Asia Pacific	Rapid infrastructure growth; natural gas viewed as essential for displacing higher-emission coal.

Africa & Middle East	Focus on domestic gas utilization and export-led LNG growth to fund renewable transitions.
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Data adapted from: Raimi et al. (2024); DeCarolis & LaRose (2023). Ref: Loáiciga (2024, 2025).

The increasing role of LNG is a pragmatic response to what Loáiciga (2024) describes as the "nature constraints" of the energy-water provision. While renewables like wind and solar are expanding rapidly, the intermittent nature of these sources requires the flexible, high-density energy provided by natural gas. However, as noted in the 2025 Global Energy Review, natural gas emissions rose by roughly 2.5% in recent years, making it a double-edged sword: it offers a lower-carbon alternative to coal but remains a fossil fuel that adds to the record-high atmospheric CO<sub>2</sub> concentrations (reaching 422.5 ppm in 2024).

As a summary, the data in Table 2 underscores the necessity of a nuanced climate policy. For LNG to truly serve as a bridge to sustainability, its deployment must be coupled with breakthroughs in clean energy and carbon management, as traditional carbon capture and storage (CCS) alone may be insufficient to offset the projected rise to 43.2 gigatons of CO<sub>2</sub> by 2050 (Loáiciga, 2025).

**Table 2** World carbon dioxide emissions from natural gas use by region, Reference case million metric tons of carbon dioxide (Loaiciga, (2024, 2025))

Region	2022	2025	2030	2035	2040	2045	2050	Average percentage change 2022-2050 (%)
Americas	2,405	2,293	2,267	2,264	2,352	2,435	2,517	0.20
United States	1,724	1,580	1,515	1,482	1,529	1,571	1,607	-0.30
Canada	231	242	231	240	259	279	301	0.90
Mexico	147	155	173	183	201	210	218	1.40
Brazil	72	81	95	89	82	79	79	0.30
Other Americas	230	236	254	269	281	295	311	1.10
Europe and Eurasia	2,318	2,362	2,439	2,503	2,607	2,719	2,849	0.70
Western Europe	1,086	1,128	1,195	1,188	1,194	1,201	1,221	0.40
Russia	931	918	935	994	1,051	1,108	1,166	0.80
Eastern Europe and Eurasia	300	315	309	321	363	409	462	1.60
Asia Pacific	1,847	1,986	2,131	2,266	2,433	2,658	2,879	1.60
Japan	225	229	216	197	185	187	185	-0.70
South Korea	137	135	130	125	122	121	123	-0.40
Australia and New Zealand	91	91	94	92	92	97	101	-0.40
China	738	806	870	962	1,075	1,195	1,314	2.10
India	137	159	213	273	334	397	458	4.40
Other Asia Pacific	519	567	607	617	624	660	699	1.10
Africa and Middle East	1,517	1,582	1,664	1,783	1,901	2,021	2,137	1.20
Africa	331	339	362	393	432	471	514	1.60
Middle East	1,186	1,243	1,302	1,390	1,469	1,550	1,623	1.10
World	8087	8223	8,501	8,815	9,294	9,833	10,382	0.90

Data source: Raimi et al. (2024); DeCarolis & LaRose (2023) Note: Totals may not equal sum of components due to independent rounding.

A third perspective focuses on lifecycle assessment and the cumulative emissions associated with LNG infrastructure. Researchers examining the full LNG value chain argue that the climate benefits of LNG depend on maintaining low methane leakage rates and ensuring that gas replaces more carbon-intensive fuels rather than delaying renewable energy deployment. The United Nations Environment Programme emphasizes that reducing methane emissions is one of the most effective short-term strategies for slowing global warming. Its methane assessment reports that rapid methane reductions could significantly limit near-term temperature increases (Brandi, 2013).

Long-term climate strategies emphasize rapid scaling of renewables, storage technologies, and grid modernization. High near-term methane emissions increase radiative forcing, which can accelerate short-term warming. The climate advantage of LNG depends heavily on methane leakage across the supply chain, including extraction, liquefaction, transport, and regasification.

Research by Robert (2024) suggests that when full lifecycle emissions are considered, LNG may have a greenhouse gas footprint comparable to or even exceeding coal under certain leakage assumptions and short-term time horizons. Thus, LNG's climate performance is highly sensitive to leakage rates, measurement accuracy and time horizon assumptions (20 vs. 100 years). This sensitivity highlights the importance of methane mitigation strategies if LNG is to be justified as part of climate policy. The review reinforces that methane leakage throughout the LNG supply chain is a significant contributor to total GHG emissions. Regulatory frameworks inclusion of full lifecycle emissions (including methane) in environmental assessments and permitting decisions is increasingly argued to be necessary for accurate climate evaluation of LNG exports. According to Victor et al. (2023), the future fossil fuel (LNG) demand under different climate scenarios and current ship building investments are consistent with pathways that limit global warming to 1.5 °C under the Paris Agreement. However, rapid expansion in LNG shipping capacity may become incompatible with global decarbonization goals.

Overall, the literature presents a range of perspectives on LNG's climate implications. Proponents emphasize its role in replacing coal, improving air quality, and stabilizing electricity systems during the transition to renewable energy. Critics, however, highlight methane leakage, lifecycle emissions, and infrastructure lock-in as significant risks that could undermine global climate goals.

LNG's climate impact is closely linked to broader climate sensitivity considerations, particularly the role of methane in amplifying near-term warming. While LNG can reduce emissions when displacing coal and supporting renewable integration, its climate benefits depend heavily on strict methane controls, limited infrastructure expansion, and alignment with long-term decarbonization strategies. Without strong governance and technological mitigation measures, LNG risks undermining rather than supporting climate stabilization efforts (Koch et al., 2025).

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### 3. Energy Poverty and Development Imperatives

Energy poverty refers not only to lack of access to modern, reliable, and affordable energy but also to reliance on traditional biomass for cooking, which contributes to indoor air pollution and health risks. This remains a critical development challenge, particularly in emerging economies. Maxwell and Das (2023) note in their Climate Analytics report, *"LNG can provide reliable energy access in regions transitioning from traditional biomass or coal, supporting economic growth while offering lower-carbon options"*. According to the International Energy Agency, nearly 770 million people worldwide lacked electricity access in 2021, with most concentrated in Sub-Saharan Africa and parts of South Asia. Meeting the energy needs of these populations is essential for achieving development imperatives such as improved health, education, industrialization, and poverty alleviation. However, the choice of energy pathways involves trade-offs between rapid development and long-term climate objectives. Historically, industrialized economies relied heavily on fossil fuels to achieve development milestones. Requiring developing nations to bypass all fossil fuels without scalable, affordable alternatives risks perpetuating structural inequality. Developing economies often argue that strict decarbonization pathways may limit their ability to industrialize at the pace historically followed by advanced economies, particularly in sectors like manufacturing and transportation that are energy-intensive (UNFCCC, 1992; Stern, 2007).

Economic development fundamentally depends on access to reliable and affordable energy. The International Energy Agency emphasizes that energy access and affordability are critical enablers of sustainable development, enabling industrialization, urbanization, and social services expansion (IEA, 2021). In developing regions, however, the deployment of renewable energy faces significant barriers, including high financing costs, limited grid infrastructure, and intermittency challenges, which can slow the pace of decarbonization while meeting growing energy demand (IPCC, 2022; UNEP, 2021).

Reliable energy systems and overall energy consumption are strongly correlated with socio-economic outcomes. Historical analyses show that energy availability drives GDP growth, industrial capacity expansion, healthcare improvements, and infrastructure development (Stern, 2007; World Bank, 2021). This linkage underscores the importance of transitional fuels such as LNG, which can provide stable electricity and support industrial energy demand while lower-carbon alternatives scale up.

The global response to geopolitical shocks (e.g., energy security concerns after 2022) has also reshaped energy markets, increasing short-term investment in liquefied natural gas (LNG) infrastructure. LNG terminals, liquefaction facilities, and gas-fired power plants represent multi-decade investments that shape future energy choices that amplifies sunk costs and political and economic pressures for the installed LNG capacity Unruh (2000).

For low- and middle-income countries, LNG may offer faster electrification, reduced reliance on coal and diesel and lower local air pollution. Balancing energy poverty alleviation with decarbonization would require strong methane controls, time-bound transition planning and increased renewable investment and climate finance mechanisms to avoid infrastructure lock-in. The IEA (2023) reports that electricity access is strongly correlated with improvements in income, education, healthcare delivery, and industrial productivity.

The development economics literature emphasizes that energy consumption and GDP growth are tightly linked, particularly during early stages of industrialization. Historically, high-income countries industrialized through fossil fuel-intensive pathways. Developing countries now face pressure to pursue alternative, lower-carbon growth trajectories, raising concerns regarding equity and “common but differentiated responsibilities” under the UNFCCC framework.

Restricting LNG development in lower-income countries while high-income countries maintain high per-capita energy consumption raises equity concerns. A development-centered climate policy therefore must recognize that poverty eradication remains a primary Sustainable Development Goal, and immediate full electrification through renewables alone may not be technically or financially feasible in all contexts. Under these conditions, LNG can accelerate electrification, reduce coal dependency, support industrial diversification and attract foreign direct investment.

LNG presents an opportunity to address energy poverty and support development imperatives while reducing emissions relative to more carbon-intensive fuels. Carefully managed, LNG can bridge the gap between urgent development needs and global decarbonization commitments.

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#### 4. Political Economy Analysis

The political economy of LNG as a transitional fuel is shaped by competing imperatives: the urgent need for economic development in emerging economies and the global demand for climate mitigation. Energy access is strongly correlated with economic growth, industrialization, urbanization, and improved social outcomes, yet rapid decarbonization can constrain development opportunities in low-income countries (IEA, 2021; Stern, 2007; World Bank, 2021). Renewable deployment in developing regions often faces financing limitations, grid infrastructure constraints, and intermittency challenges, further complicating the energy–development–climate nexus (IPCC, 2022; UNEP, 2021).

The political economy of LNG is therefore not merely a technical question of emissions, but a strategic negotiation between development imperatives and climate responsibilities. Investment, policy, and trade decisions are shaped as much by socio-economic priorities and energy security concerns as by emissions targets, reflecting the principle of common but differentiated responsibilities articulated in international climate governance (Maxwell & Das, 2023; UNFCCC, 1992).

When well-managed, LNG can facilitate a credible transition toward low-carbon energy systems while allowing emerging economies to meet immediate development needs. By displacing more carbon-intensive fuels and stabilizing power grids, LNG provides a bridge for industrialization and energy access, provided that methane emissions are minimized and infrastructure buildout is aligned with net-zero pathways (IEA, 2022).

A “just energy transition” seeks to reconcile climate mitigation with social equity, economic stability, and intergenerational fairness. The political economy of energy transitions examines how power structures, institutional capacity, and economic incentives shape the feasibility and distributional outcomes of policy choices. LNG, as a transition fuel, intersects with these dynamics, particularly in emerging economies where energy poverty, industrialization pressures, and fiscal constraints converge. OECD countries have accelerated coal retirement schedules, structurally increasing gas demand for grid reliability.

The assessment of investment inertia, institutional incentives, and geopolitical factors are shaping LNG expansion. A balanced policy framework would recognize that LNG may provide short-to medium-term development and energy security benefits, and its climate compatibility depends on strict methane regulation and clear transition timelines as well as climate financing to help developing countries avoid long-term infrastructure lock-in. Such a framework aligns development priorities with decarbonization pathways rather than treating them as mutually exclusive.

The political and economic debate over LNG as a transition fuel reflects broader tensions between economic development and climate mitigation. Proponents view LNG as a pragmatic bridge away from coal and energy poverty. Critics warn that methane emissions and infrastructure lock-in could undermine climate targets. Balancing development and climate stabilization requires nuanced, context-specific approaches rather than categorical acceptance or rejection of LNG.

Energy transitions are deeply political because they redistribute resources, rents, and economic opportunities. Key stakeholders influencing the transition include:

- **Government actors:** Ministries of energy, finance, and environment may have conflicting mandates - economic growth vs. climate compliance.
- **State-owned energy companies:** often reliant on LNG revenues and politically connected, they may resist rapid decarbonization.
- **Private sector investors:** LNG infrastructure attracts foreign investment, but contract structures (e.g., take-or-pay agreements) can influence national bargaining power.
- **Labor unions:** LNG industries provide employment; worker's interests may oppose rapid coal or oil phase-out.
- **Civil society and communities:** Local populations demand clean air, affordable electricity, and participation in infrastructure siting decisions.

A politically viable transition must therefore balance these competing interests to avoid social backlash, policy paralysis, or regulatory capture. The global political economy must shape domestic just transition strategies such that climate finance and technology transfer from high-income countries can offset developmental constraints, international carbon pricing or border adjustment mechanisms can influence domestic energy decisions and Fossil fuel trade relations (e.g., LNG imports) can affect national bargaining power and fiscal exposure.

Finally, emerging economies require policy coherence across domestic and international layers to leverage LNG for development while avoiding long-term climate vulnerability. These measures must align developmental, environmental, and social objectives, enhancing the legitimacy of transitional energy policies. A politically and socially legitimate LNG transition requires integrated planning that embeds governance safeguards, labour protections, and equity-focused finance into decision-making. Therefore, developing countries must prioritize affordable and reliable energy access to drive industrialization, urbanization, and social development.

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## 5. LNG in Future Energy Pathways

LNG can play a legitimate role in future energy pathways if deployed strategically as a transition fuel by reducing reliance on coal and diesel in the near term. It supports energy access, industrial growth, and economic development in emerging economies. LNG has gained prominence as a transitional fuel in global energy pathways, positioned between high-carbon fossil fuels and renewable energy systems. Its potential arises from its relatively lower carbon intensity compared to coal and oil, flexible power generation capabilities, and capacity to enhance energy security. Its climate compatibility depends on methane governance, time-bound use, renewable integration, and supportive finance mechanisms.

The International Energy Agency (2021) emphasizes that LNG can support short- to medium-term decarbonization by displacing coal in power generation and providing grid flexibility for intermittent renewables. Similarly, UNEP (2021) notes that LNG infrastructure can improve energy access in regions where electricity demand is rapidly growing, particularly in developing economies. Ultimately, LNG should be treated not as an end-point but as a transitional tool in carefully designed decarbonization future energy pathways that balance short-term development imperatives with long-term climate objectives.

Despite these benefits, the literature highlights significant challenges that complicate LNG's role in future energy pathways. Methane leakage across the production, liquefaction, shipping, and regasification chain presents a major

climate risk, as methane is a potent greenhouse gas with strong near-term warming potential. The Intergovernmental Panel on Climate Change (2022) stresses that if methane emissions exceed approximately 2% of total gas production, LNG may lose its climate advantage over coal. Moreover, rapid expansion of LNG infrastructure risks creating long-lived assets that could lock economies into fossil dependence, potentially conflicting with net-zero emissions targets (IEA, 2021; Maxwell & Das, 2023).

Economic and geopolitical considerations also influence LNG's future trajectory. Global LNG trade has surged following geopolitical shocks, such as the European energy crisis triggered by Russia's invasion of Ukraine, yet Climate Analytics research warns that projected global LNG demand under a 1.5 °C-compatible pathway may not justify current shipbuilding and infrastructure investments (Maxwell & Das, 2023). This indicates a potential mismatch between short-term market drivers and long-term climate-aligned energy pathways.

Several studies advocate a cautious and strategic approach to LNG deployment. Governance measures to reduce methane leakage, alignment of infrastructure expansion with net-zero-consistent demand, and integration of carbon capture and storage technologies where feasible are critical to ensuring that LNG contributes to climate-compatible energy transitions (UNEP, 2021; IEA, 2021). Additionally, policy frameworks must prevent LNG from becoming a permanent fossil-fuel lock-in, instead positioning it as a bridge fuel that enables growth in renewable capacity and energy access (Stern, 2007).

LNG occupies a nuanced position in future energy pathways as it offers tangible benefits for near-term emissions reductions, grid reliability, and energy access, particularly in emerging economies. However, its long-term role is contingent on robust governance, technological mitigation of emissions, and alignment with decarbonization strategies. Without these measures, LNG risks undermining climate objectives and delaying the transition to truly low-carbon energy systems.

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## 6. Development – Climate Trade-Offs

The relationship between economic development and climate mitigation represents one of the central dilemmas in contemporary political economy and environmental policy. Developing economies seek rapid growth to reduce poverty and improve living standards, yet the historical experience of industrialization shows that economic expansion is closely associated with increased greenhouse gas emissions. This creates a fundamental trade-off between development goals and climate stability.

Economic growth has historically been carbon intensive. Industrialization increases energy consumption, infrastructure expansion, and manufacturing output, all of which tend to raise emissions. Research on development and emissions often refers to the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental degradation increases during early stages of development before eventually declining at higher income levels due to technological change and stronger environmental institutions (Ma, X., & Jiang, Q. (2019).

This dynamic presents particular challenges for developing countries. Many low-income states require substantial energy use to achieve improvements in human development indicators such as health, infrastructure, and industrial productivity. Empirical analysis shows a strong relationship between human development and carbon emissions, suggesting that significant emissions may be required before countries reach high development thresholds (Costa, L., et al. 2010).

Therefore, understanding LNG's role as a transition fuel requires contextual differentiation. Climate policy capacity, energy system maturity, capital access, and development priorities vary significantly across regions. For example, geopolitical disruptions of Russian pipeline gas flows triggered an immediate energy security crisis which reshaped European gas flows with increase of LNG imports to stabilize markets while their energy security considerations temporarily outweighed decarbonization priorities to compensate for supply shortages. (IEA, 2023). This response illustrates a key paradox: climate leadership coexisting with expanded LNG infrastructure. The EU justified LNG expansion under the REPowerEU strategy, which simultaneously aims to accelerate renewable deployment and reduce fossil fuel dependency (European Commission, 2022).

Yet climate trade-offs advocates argue that near-term methane-driven warming disproportionately harms vulnerable regions as per capita emissions in many African nations remain a fraction of OECD levels. Immediate fossil fuel and LNG prohibition in energy-poor regions risks entrenching poverty, slowing industrialization and limiting economic sovereignty. The development-climate justice framework also requires climate finance transfers to enable low-income countries to leapfrog fossil and LNG dependency.

The relationship between development and climate mitigation is best understood as a dynamic policy trade-off shaped by technology, institutions, and global cooperation. While traditional development pathways have relied on fossil-fuel-intensive growth, emerging technological and policy innovations create opportunities to reconcile development objectives with climate goals. Achieving this balance remains one of the defining challenges of twenty-first-century sustainable development.

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## 7. Emerging Economy Considerations

Emerging economies face a complex policy dilemma in balancing economic development with climate mitigation. Rapid industrialization, urbanization, and population growth significantly increase energy demand, yet global climate commitments require reductions in greenhouse gas emissions. Within this context, LNG has increasingly been considered a transitional energy source that may support development while reducing reliance on higher-carbon fuels such as coal and oil (Stern, 2007).

Energy demand in emerging economies is expected to grow substantially over the coming decades. According to the International Energy Agency, developing countries account for the majority of projected global energy demand growth due to industrial expansion and rising living standards. In many cases, energy poverty remains a major challenge; hundreds of millions of people still lack reliable electricity access. Expanding energy systems is therefore essential for economic development, infrastructure growth, and improved social welfare. (Stern, N. (2007).

Emerging economies therefore face distinct structural constraints in the global energy transition such as capital access, grid reliability and industrial development. While advanced economies prioritize rapid decarbonization, developing and emerging markets must simultaneously address energy poverty, industrialization, macroeconomic stability, and infrastructure deficits. Any assessment of LNG as a transitional fuel must therefore account for the differentiated economic, institutional, and technological conditions in these contexts. Energy poverty remains a dominant development challenge (IEA, 2023c).

Renewable costs have declined significantly, challenging LNG's economic case in some regions. Price volatility in global LNG markets particularly during 2022 Russian-Ukraine war exposed developing economies to affordability risks. South Asia (notably India, Pakistan, and Bangladesh) faces rapid electricity demand growth, coal dependency, air pollution challenges and energy import vulnerability. India has pledged net-zero emissions by 2070, while maintaining near-term development priorities (Government of India, 2021). Several South Asian utilities curtailed LNG imports when prices spiked. This reveals a structural vulnerability: LNG supports decarbonization relative to coal, but only if price stability is maintained.

Sub-Saharan Africa (SSA) contains most of the global population without electricity access, Low per capita emissions and Significant untapped natural gas reserves. Per capita emissions in SSA are far below global averages. Climate justice arguments suggest that African countries should retain development space within global carbon budgets (Steckel et al., 2022). The Energy transition for SSA must avoid overdependence on exports, neglect of decentralized renewables and Infrastructure that exceeds long-term global demand. A development-aligned approach would prioritize domestic gas-to-power where it replaces diesel, revenue reinvestment into renewable infrastructure and international climate finance support

Energy transitions in these contexts must prioritize affordability and reliability. Unlike advanced economies with mature grids, many emerging markets cannot absorb high shares of intermittent renewable energy without substantial infrastructure upgrades. LNG may therefore be considered as a near-term option for replacing diesel-based generation, reducing coal reliance and supporting grid stabilization.

Industrial development requires reliable baseload or dispatchable power. Emerging economies seeking to expand manufacturing, mining, or heavy industry prioritize energy reliability over rapid decarbonization. The principle of differentiated responsibility under the United Nations Framework Convention on Climate Change (UNFCCC) implies that advanced economies should support developing countries through Concessional climate finance, Technology transfer and Capacity-building initiatives.

LNG presents both opportunities and risks for emerging economies navigating the development-climate trade-off. While LNG can provide a lower-carbon alternative to more polluting fuels and help expand energy access, long-term reliance on LNG may conflict with global decarbonization objectives. A balanced strategy combining LNG as a transitional resource with accelerated investment in renewable energy and climate-aligned infrastructure offers the most viable pathway for aligning development priorities with global climate commitments.

## 8. Governance Conditions for a Legitimate Transitional Role

The role of liquefied natural gas (LNG) in the global energy transition has become a central policy debate, particularly for emerging economies seeking to balance development needs with climate mitigation commitments. While LNG is often framed as a lower-carbon alternative to coal and oil, its legitimacy as a transitional energy source depends largely on the governance frameworks that regulate its deployment. Effective governance is therefore essential to ensure that LNG contributes to decarbonization pathways rather than prolonging fossil-fuel dependence (International Energy Agency, 2021).

One key governance condition involves aligning LNG investments with long-term climate targets. The International Energy Agency emphasizes that natural gas can support the transition only if it replaces more carbon-intensive fuels and operates within broader decarbonization strategies. Without clear policy guidance, large investments in LNG infrastructure such as liquefaction plants, import terminals, and pipelines risk creating long-term carbon lock-in. As the Intergovernmental Panel on Climate Change warns, “existing fossil fuel infrastructure could commit the world to emissions that exceed the carbon budget for limiting warming to 1.5°C.” This highlights the need for regulatory frameworks that ensure LNG development remains compatible with climate objectives.

A third governance requirement relates to transparency and international cooperation. Global energy markets are increasingly interconnected, and LNG trade involves multiple jurisdictions, regulatory regimes, and private actors. The World Bank highlights that effective governance in the energy transition requires clear regulatory institutions, predictable investment frameworks, and strong public accountability mechanisms. Transparent governance structures can help ensure that LNG projects contribute to national development objectives while also complying with international climate commitments.

LNG may play a transitional role through coal displacement, grid stabilization, and energy security diversification, but only under strict governance conditions including low methane leakage, infrastructure alignment with net-zero demand pathways, integration of carbon capture technologies, and policies preventing fossil-fuel lock-in (IEA, 2021; IPCC, 2022; UNEP, 2021).

Governance conditions should ensure LNG combustion emissions are subject to carbon pricing, Methane emissions should carry explicit economic penalties, while Renewable energy maintains cost competitiveness. For liquefied natural gas (LNG) to function as a credible and legitimate transition fuel within global decarbonization pathways, its deployment must be embedded within strict governance frameworks. Without these enforceable conditions, LNG risks undermining climate targets and creating long-term fossil dependency.

A legitimate transitional framework therefore would require mandatory methane measurement across the full supply chain, independent third-party verification, satellite-based emissions monitoring and transparent public reporting. Binding methane standards must be incorporated into national regulatory regimes and international trade frameworks. Carbon pricing mechanisms (carbon taxes or emissions trading systems) are essential to prevent LNG from crowding out renewable investment.

Without internalizing climate externalities, LNG may appear artificially inexpensive relative to clean alternatives. Therefore, international coordination among nations would enhance such credibility. LNG governance could therefore be strengthened through multilateral methane agreements, Trade standards incorporating methane intensity thresholds and harmonized lifecycle accounting methodologies. This would prevent regulatory arbitrage and “carbon leakage” across jurisdictions.

A legitimate transitional role for LNG in the global energy system must be supported by strong governance structures that align investments with climate targets, methane emissions control, transparency, and that prioritize renewable energy development embedded within the broader energy transition strategies. According to the International Energy Agency, achieving global climate goals requires a rapid scaling of renewable electricity, energy efficiency, and electrification. Within this framework, LNG can serve as a bridging fuel that supports energy security and grid stability during the transition period. Without such governance conditions, LNG risks perpetuating fossil-fuel dependence rather than facilitating the transition to a sustainable and low-carbon energy system.

## 9. Conclusion

For an efficient energy poverty alleviation and economic development, the development–climate balance would require differentiated responsibilities, region-specific policies rather than any universal prescriptions. Thus, while advanced economies should accelerate renewable transitions, emerging economies may utilize LNG strategically under controlled frameworks as emerging economies confront a structurally different energy transition challenge than advanced economies. Their pathways must reconcile developmental urgency with climate responsibility under constrained fiscal and institutional conditions. Without adequate climate financing for poorer economies, LNG may become the default option rather than a transition fuel. The availability, predictability, and affordability of international climate finance significantly influence transition pathways in these emerging economies.

Climate policy shifts have enhanced LNG's short-term competitiveness while simultaneously constraining its long-term role. This conclusion synthesises that LNG can reduce emissions relative to coal and support renewable integration, but methane leakage and infrastructure lock-in present systemic risks. LNG's transitional legitimacy in coal-dependent economies depend on strict regulatory constraints and temporal limits. Therefore, the legitimacy of LNG as a transition fuel in emerging markets depends not only on emissions metrics but also on governance quality, time horizons, financing structures, and alignment with long-term decarbonization strategies and development contexts.

LNG represents a bounded transitional energy whose compatibility with 1.5°C pathway create the right balance between economic development and decarbonization. Policymakers must define LNG's transitional role explicitly within the net-zero-aligned time horizons. This requires accountability, investment discipline, and alignment with carbon budgets. The paper reveals that LNG may function as a transition fuel in specific contexts, but only under strict governance and as part of a clearly defined pathway toward low-carbon energy systems.

In navigating the prospects and the broader challenges, collaboration among nations and policymakers must design a climate policy that is balanced and integrates environmental urgency, economic realism, global equity and economic development. Therefore, it has been demonstrated that striking the right balance between development and climate goals for use of LNG as a transition fuel depends on a development-sensitive transition requiring differentiated timelines, robust international support, and policy coherence across energy, climate, and economic planning frameworks.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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