

NAVIGATING ENERGY POLICY AND SUSTAINABILITY TRANSITIONS: GLOBAL LESSONS AND RESEARCH INSIGHTS FOR INDONESIA'S NATURAL GAS FUTURE

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ABSTRACT:

The global transition towards cleaner energy positions natural gas as a critical bridge between conventional fossil fuels and renewable energy sources. In Indonesia, where household energy remains reliant on imported liquefied petroleum gas (LPG), transitioning to natural gas offers a promising alternative. However, challenges related to infrastructure, socio-economic disparities, and policy frameworks hinder this shift. This paper addresses the gap between global sustainability trends and Indonesia's household energy challenges by conducting a systematic literature review. It analyzes global best practices in natural gas policy to explore how Indonesia can transition from LPG to natural gas, considering renewable energy integration, socio-economic factors, and energy policy. A rigorous methodology was employed, beginning with 2,783 documents, which were refined to 48 relevant articles that align with "Energy Policy" and sustainability. The results highlight strategies and reveal research gaps in areas such as infrastructure, public engagement, and sustainability practices. The study concludes with research recommendations for developing policies that ensure natural gas plays a central role in Indonesia's broader energy transition, emphasizing its potential as a transitional fuel for sustainable development.

Keywords: Energy transition, Indonesia, Natural gas, Policy, Renewable energy, Sustainability

1) INTRODUCTION:

Natural gas has emerged as a pivotal transitional fuel in the global shift towards sustainable and renewable energy systems. It is widely recognized for its ability to serve as a bridge between more carbon-intensive fossil fuels, such as coal and oil, and cleaner energy alternatives like solar and wind power [1]. This transition is driving the natural gas industry to innovate and adopt more sustainable practices, setting new standards, integrating advanced technologies, and establishing strategic partnerships to provide safer, cleaner, and more cost-effective energy solutions [2]. As countries seek to balance immediate energy security needs with long-term environmental responsibility, natural gas continues to play a critical role in this evolving energy landscape [3].

However, despite its role as a relatively cleaner fossil fuel, natural gas production is not without significant environmental impacts. The extraction process, particularly hydraulic fracturing (fracking), raises concerns due to methane emissions, water contamination risks, and other environmental hazards [4]. [5]. Methane, the primary component of natural gas, is a potent greenhouse gas with a global warming potential more than 25 times greater than carbon dioxide over a 100-year period [6]. Critics argue that the continued expansion of natural gas production, especially through liquefied natural gas (LNG) exports, could undermine global climate goals by locking in fossil fuel infrastructure [1]. To address these concerns, sustainability initiatives such as the Natural Gas Sustainability Initiative (NGSI) have emerged, aiming to improve transparency in sustainability reporting and align industry practices with environmental objectives [7].

Indonesia provides a unique context within the global natural gas landscape. Despite being the third-largest holder of natural gas reserves in the Asia-Pacific region, the country's household energy sector remains heavily dependent on imported liquefied petroleum gas (LPG), which poses challenges in terms of both energy security and economic sustainability [8]. The uneven distribution of gas infrastructure across the archipelago further complicates efforts to transition to a cleaner, more reliable energy source for households [9]. In light of these challenges, natural gas

offers a promising solution to reduce Indonesia's reliance on LPG, providing a cleaner energy option for households while also improving energy equity by ensuring more widespread access to affordable and sustainable energy [8].

This paper aims to address the gap between global sustainability trends and Indonesia's household energy challenges by conducting a systematic literature review. By analyzing global best practices in natural gas policy, this review identifies key strategies that could inform Indonesia's transition from LPG to natural gas in the household sector. The review highlights gaps in understanding how renewable energy integration, socio-economic factors, and energy policy interplay in the context of developing regions like Southeast Asia. Drawing from these insights, the paper provides future research recommendations for developing policies to ensure that natural gas plays a central role in the country's broader energy transition strategy.

The findings from this review are expected to offer insights to a clearer path for developing targeted, region-specific household gas policies in Indonesia. These policies must balance the country's energy security needs with its environmental goals, ensuring that natural gas serves not only as a transitional fuel but also as a catalyst for sustainable development. As Indonesia continues its energy transition, particularly in the household sector, lessons from the global natural gas industry will be critical in shaping policies that support sustainable energy consumption, reduce environmental impacts, and contribute to long-term development goals [10].

2) The Role of Natural Gas in Modern Energy Systems:

2.1 Defining "Natural Gas"

Natural gas, a critical fossil fuel in global energy systems, is primarily composed of methane, along with smaller amounts of natural gas liquids (NGLs) and nonhydrocarbon gases such as carbon dioxide and water vapor. It forms from the decomposition of organic matter deep within the Earth over millions of years, making it a versatile energy source used for heating, cooking, electricity generation, and as a feedstock in manufacturing plastics and other materials [11]. Despite being cleaner-burning than coal and oil, natural gas remains a significant contributor to climate change due to the release of greenhouse gases during extraction and consumption. In many countries, including the U.S., natural gas is predominantly extracted from shale formations through hydraulic fracturing (fracking), a process that raises environmental concerns like groundwater contamination and methane leaks [12]. Alternatively, Renewable Natural Gas (RNG), or biomethane, offers a more sustainable option. Produced through the anaerobic digestion of organic materials, RNG can be upgraded to pipeline-quality standards, contributing to a greener energy landscape while retaining the versatility of conventional natural gas [13].

The extraction and processing of natural gas involve several steps, from geological surveys and drilling to production and refinement. Drilling methods, including vertical and horizontal drilling and fracking, release the gas from underground formations. After extraction, natural gas is processed to remove impurities, with NGLs separated from wet gas. It is then distributed via pipelines, and in some cases, unmarketable gas is re-injected into oil wells to enhance production [14]. RNG production follows a similar process, where biogas is purified into a clean, pipeline-quality vehicle fuel, positioning it as a sustainable alternative to conventional natural gas. The entire journey from exploration to consumption underscores the complex and essential role of natural gas in modern society [15].

2.2 Global and Indonesian Policy Context for Natural Gas

Western countries exhibit a varied landscape in their natural gas policies, each characterized by distinct Natural gas policies around the world vary significantly, with Western countries exhibiting distinct regulatory frameworks, market structures, and strategies. In Europe, some countries have increased oil and gas production to combat energy shortages, classifying natural gas as a sustainable investment [16]. In Canada, the focus is on securing natural gas supplies, with new LNG facilities and pipelines facilitating the transport of natural gas to international markets [17]. The European Union has also introduced measures to alleviate high gas prices, including capping retail prices and supporting energy-intensive industries [18]. These policies reflect the diverse and complex approaches to natural gas in Western countries, shaped by each region's energy priorities and economic challenges.

In Asia, natural gas policies are similarly varied. China, for example, aims to increase natural gas's share of its energy mix from 8.5% in 2021 to 15% by 2030, primarily to reduce its dependence on coal and improve air quality [19]. Other countries in the region are implementing strategic reserve policies and constructing new infrastructure to ensure energy security and reduce emissions from fossil fuels [20]. Indonesia, governed by the 2001 Oil and Gas Law, mandates that 25% of oil and gas production must be allocated for domestic use [21]. Although Indonesia has committed to reducing its greenhouse gas emissions under the Paris Agreement, the country's energy mix remains heavily reliant on fossil fuels. To address these challenges, Indonesia plans to increase the share of natural gas in its primary energy mix from 17.8% in 2013 to 24% by 2050, gradually reducing its dependence on coal [22], [23].

3) METHODOLOGY:

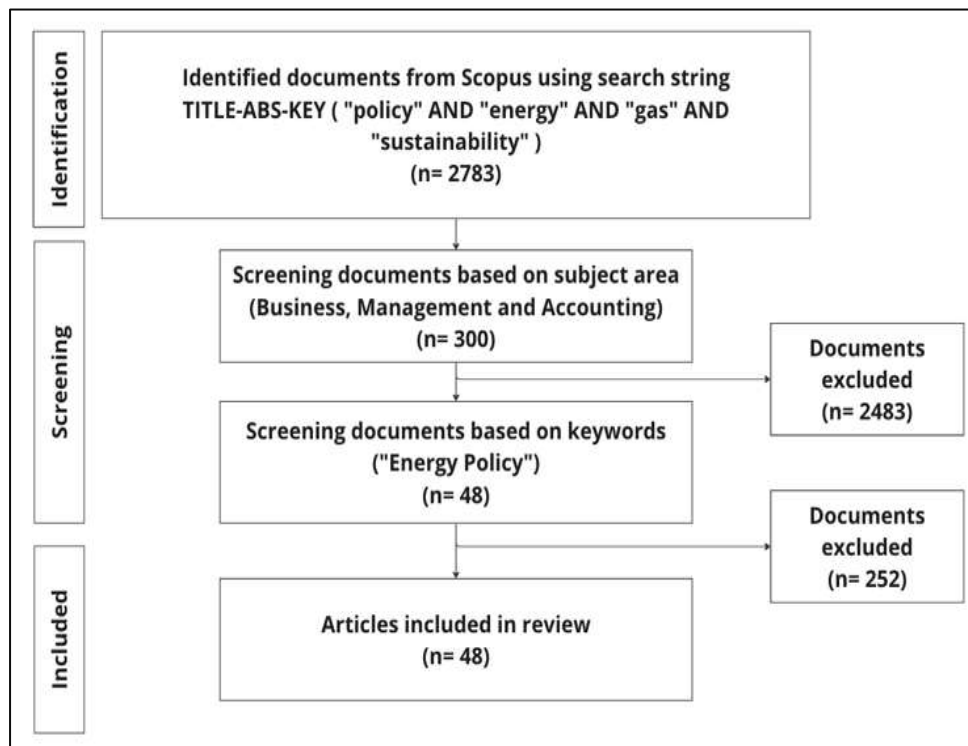


Figure 1 Flow Diagram

The systematic literature review method depicted in the process flow diagram (Figure 1) reveals a detailed and methodical approach for selecting pertinent articles for the review. The process commenced with a comprehensive search in the Scopus database, utilizing a well-defined search string. This string encompassed specific terms within the titles, abstracts, and keywords of the documents, focusing on policy, energy, gas, and sustainability. This initial foray into the database yielded a substantial number of documents, totaling 2,783.

To refine this extensive collection, the documents underwent a meticulous screening process, with an initial focus on narrowing down articles relevant to Business, Management, and Accounting. This specificity in subject area was crucial to align the review with the intended research context, reducing the pool to 300 documents. The refinement process was further tightened by examining these documents for the explicit presence of the keywords "Energy Policy." This step was instrumental in aligning the remaining articles closely with the core theme of the review. As a result, the number of documents under consideration was further reduced to 48.

These 48 articles successfully met the stringent inclusion criteria set for the review. It's noteworthy that during this rigorous selection process, a significant number of documents were excluded to maintain the review's relevance and focus. Specifically, 2,483 documents were excluded after the initial subject area screening, indicating a vast array of initially retrieved but unrelated articles. Following this, an additional 252 articles were excluded after the keyword-based screening, demonstrating the precise and targeted approach of the review methodology. This comprehensive and systematic process ensured that the final selection of articles was highly relevant and specific to the research objectives, exemplifying the thoroughness and precision required in conducting effective systematic literature reviews.

4) RESULTS

4.1 Global Lessons: Navigating Natural Gas and Renewable Energy Policy

4.1.1 Geographic Focus and Policy Development

Global energy policies offer valuable insights into how regions can align their energy production with sustainability goals (Table 1). For example, Australia has taken significant steps toward a sustainable energy future by focusing on protecting natural resources and promoting intergenerational equity. The country has abundant renewable energy resources, including solar, wind, and hydropower, but faces challenges related to its economic structure and market reforms [24]. Similarly, the UK has explored the use of electric vehicles (EVs) as a way to reduce dependency on non-renewable energy sources. The study by Raugei et al. [25] highlights how renewable energy impacts EV-related energy demand.

In contrast, SAARC countries have made notable progress in promoting green logistics to reduce CO₂ and greenhouse gas emissions. However, challenges such as regulatory weaknesses and insufficient governmental support hinder the full integration of renewable energy into logistics operations [26], [27]. These regional

experiences highlight the importance of tailored approaches to energy policy, depending on geographical and socio-economic contexts.

Table 1. Geographic focus on sustainability policies, renewable energy strategies, and barriers across regions

Authors	Year	Country/Region	Sustainability Policy	Renewable Energies	Barriers
Ravichandran et al. [24]	2007	Australia	Sustainable energy focused on protecting natural capital and equity	Solar, wind, biomass, hydropower, ocean power	Economic structure, market reforms, lack of visionary sustainability focus
Raugei et al. [25]	2018	UK	Electric vehicles to reduce non-renewable energy dependency	Renewable electricity for transport	N/A
Khan et al. [26]	2019	SAARC countries	Green logistics and renewable energy integration for CO2 and GHG reduction	Green energy (biofuels, renewable power for logistics)	Regulatory weaknesses, insufficient support, high costs
Rehman Khan et al. [27]	2018	Global (43 countries)	Green supply chain management to promote sustainable economic growth	Green practices and renewable energy for logistics	High costs, reliance on non-renewable sources
Silbergliitt & Kimmel [28]	2015	ASEAN	ASEAN energy scenarios and policy implications.	Not specified	Variations in flexibility and resilience of policy paths

4.1.2 Sustainability Policies and Energy Transition Frameworks

Table 2 outlines various global examples of sustainability policies and energy transition frameworks, highlighting a diverse range of efforts and approaches across different regions. These examples show how countries are integrating renewable energy technologies within their policy frameworks, addressing contextual challenges, and employing broader sustainability strategies. Each country's approach reflects its unique energy landscape, policy focus, and renewable energy resources, showcasing both successes and ongoing barriers to achieving sustainable energy transitions.

For instance, Australia's sustainable energy policy emphasizes the protection of natural capital and intergenerational equity while leveraging its vast renewable resources, including solar, wind, and biomass [24]. Similarly, the UK focuses on reducing dependence on non-renewable energy through the promotion of electric vehicles, aligning transportation with broader sustainability goals [25]. In SAARC countries, green logistics efforts are supported by renewable energy integration, although regulatory challenges and cost barriers remain significant obstacles [26]. Pakistan's biogas policy, which promotes renewable energy from waste materials like manure and rice husk through government subsidies, demonstrates how financial incentives can drive energy transitions [29]. The Gulf Cooperation Council (GCC) countries have also begun shifting strategies toward solar and wind energy but still face significant hurdles related to fossil fuel dependency and the commercialization of renewable technologies [30]. Meanwhile, China and Germany's frameworks, which focus on biomass gasification and wind power, illustrate a strong commitment to renewable energy integration despite the technical and societal challenges involved [31], [32]. Moreover, Spain's regulation promoting photovoltaic energy and green hydrogen production offers valuable lessons on integrating renewable energy sources with natural gas, which could inform Indonesia's approach [33]. In Italy, economic sustainability strategies for power-to-gas technologies provide a model for enhancing the financial viability of natural gas projects through policy support, further demonstrating how renewable integration can be facilitated [34].

Table 2. Global Sustainability Policies and Energy Transition Frameworks

Authors	Year	Country/Region	Sustainability Policy	Renewable Energies	Description of the Framework
Ravichandran et al. [24]	2021	Australia	Sustainable energy policy focused on natural capital and intergenerational equity	Solar, wind, biomass, hydropower, ocean power	Broad emphasis on protecting natural capital, ensuring intergenerational equity, and transitioning to renewable energy resources.

Authors	Year	Country/ Region	Sustainability Policy	Renewable Energies	Description of the Framework
Raugei et al. [25]	2018	UK	Electric vehicle policy to reduce dependence on non-renewable energy	Renewable electricity for transport	Focus on evaluating renewable electricity supply scenarios for electric vehicles to minimize cumulative non-renewable energy demand.
Khan et al. [26]	2019	SAARC countries	Green logistics policies promoting renewable energy integration	Biofuels, renewable energy in logistics	Policies emphasize CO ₂ and GHG emission reduction through adoption of green logistics practices, supported by subsidies for renewable energy and green industry development.
Yaqoob et al. [29]	2021	Pakistan	Government-backed biogas promotion policies	Biogas from waste materials	Subsidies, loans, and policy support to promote biogas technology adoption from biomass sources such as animal manure and kitchen waste.
Bhutto et al. [30]	2014	GCC countries	Reorientation of strategies towards renewable energy, focusing on solar and wind	Solar, wind	Efforts to integrate renewable energy face barriers such as heavy reliance on fossil fuels and challenges in commercializing renewable technologies.
Yang et al. [31]	2018	China	Biomass gasification policies to reduce emissions from wastewater treatment	Biomass gasification	Policy framework addressing large-scale carbon emissions, focusing on energy efficiency improvements in biomass gasification and cost reduction.
Dehler-Holland et al. [32]	2022	Germany	Wind power legitimacy policies	Wind power	Framework centered on maintaining the legitimacy of wind power amid public perception, environmental, political, and legal conflicts.
Singh [35]	2017	India	State and central assistance for biomass projects	Biomass	Policies provide financial assistance to encourage biomass energy projects, with challenges related to logistics, technology, and regulatory implementation.
Balaman [36]	2016	Turkey	Policies supporting bioenergy production with an eco-friendly focus	Biomass	Framework facilitates the identification of viable bioenergy production targets while considering regional energy demands and environmental footprint limitations.
Kelly et al. [37]	2019	USA	Policy efforts promoting renewable energy market share, including reducing fossil fuel investments	Solar photovoltaic (PV), wind energy	Focus on increasing renewable energy market shares through technological improvements and financial incentives, with an emphasis on water and carbon footprint reduction.
Olaya & Dyner [38]	2005	Colombia	Natural gas substitution for gasoline in transportation to reduce emissions	Natural gas	Promotes natural gas as an efficient energy source for reducing transportation emissions, addressing energy efficiency and air quality improvements.

Authors	Year	Country/ Region	Sustainability Policy	Renewable Energies	Description of the Framework
Lin & Ahmad [39]	2016	Pakistan	Energy diversification policies, including natural gas and renewable energy sources	Natural gas, hydro	Policy framework focused on rationalizing energy prices and subsidies to promote a diversified energy mix, addressing both economic and sustainability goals.
Abdul-Manan et al. [40]	2015	Malaysia	Biofuel policy emphasizing market liberalization and competitiveness	Palm biodiesel	Encourages biofuel adoption through policy liberalization and regulatory support, fostering competitiveness and industry growth.
Aliev [41]	2023	Caspian region	Integrated sustainability approach supporting decarbonization measures	Carbon-free energy sources	To support decarbonization, countries in the Caspian region focus on carbon-free energy and operational decarbonization measures.
Als Salman et al. [42]	2021	UAE	Renewable energy policy mechanisms addressing gaps in solar energy deployment	Solar energy	The gap between policy formulation and implementation in the UAE's solar energy initiatives highlights the need for policy reforms.
Businge et al. [34]	2020	Italy	Economic sustainability strategies for power-to-gas technologies within Italy's National Climate and Energy Plan (NECP)	Power-to-gas	Enhancing the financial viability of power-to-gas projects through policy support to sustain economic viability and reduce operating costs.
Fernández-González et al. [33]	2022	Spain	Regulation promoting photovoltaic energy and green hydrogen production	Photovoltaic energy, green hydrogen	Spain's regulation to promote photovoltaic energy and green hydrogen production offers insights into how Indonesia can integrate renewable energy with natural gas.
Mehmood et al. [43]	2022	Not specified	Sustainability assessments using multi-level hierarchical structures to rank energy alternatives	Gas, coal, nuclear, solar, hydro, wind, biomass	Multi-level hierarchical assessments to prioritize energy infrastructure, ensuring sustainability of hybrid energy infrastructures such as natural gas.

4.1.3 Policy Innovations in Renewable Energy

In the global context of energy transitions, natural gas has emerged as a pivotal element in numerous national policies, offering a bridge between conventional fossil fuels and renewable energy sources (Table 3). As highlighted by policies from countries such as Colombia and Pakistan, natural gas plays a crucial role in reducing emissions in both the transportation and household sectors. In Colombia, policies promoting the substitution of gasoline with natural gas have shown potential to increase energy efficiency while simultaneously controlling air emissions in urban areas [38]. Similarly, Pakistan's diversification strategy, which incorporates abundant natural gas alongside hydro and other renewables, demonstrates how a balanced energy mix can support sustainability goals [39]. These examples provide valuable insights for Indonesia, where natural gas could be strategically integrated into the household energy sector to enhance sustainability efforts and reduce reliance on more polluting fuels. The emphasis on leveraging natural gas within national energy policies, as seen globally, underscores its importance in transitioning towards a cleaner, more resilient energy future, particularly in contexts where immediate large-scale renewable adoption faces infrastructural and economic challenges.

Table 3. National strategies to reduce reliance on fossil fuels and promote natural energy resources

Innovation Type	Country /Region	Policy Innovation Description	Renewable Energies
Biomass Gasification	China	National policy aimed at reducing carbon emissions from wastewater treatment through biomass gasification [31].	Biomass gasification
	Pakistan	Government subsidies and loans promoting biogas technology using animal and agricultural waste [29]	Biogas
	India	State and central financial aid supporting biomass gasifier projects and grid-connected systems (Singh, 2017).	Biomass
	Turkey	Policies to support eco-friendly bioenergy production, including guidance for government units on bioenergy targets [36].	Biomass
Wind Power Development	Germany	Energiewende policy promoting renewable energy through wind power, with CO2 regulation and subsidies [32].	Wind power
	Germany	Transition strategy to achieve long-term renewable energy targets post-2022 through wind energy development [44].	Wind energy
Electric Vehicles and Transportation	UK	National strategy promoting electric vehicles (EVs) to reduce dependency on non-renewable energy in transportation [25].	Renewable electricity for EVs
Green Logistics and Supply Chains	SAARC Countries	Green logistics policies to reduce CO2 emissions, supported by renewable energy adoption in logistics [26].	Biofuels, renewable energy in logistics
	Global (43 countries)	National and international policies focusing on green supply chain management to drive sustainable growth [27].	Renewable energy, green logistics
Natural Gas Substitution	Colombia	Policy supporting substitution of gasoline with natural gas in transportation to improve urban air quality [38]	Natural gas
	Pakistan	Energy diversification policy integrating natural gas with hydropower to enhance energy sustainability [39].	Natural gas, hydro
Biofuel Development	Malaysia	National biofuel policy fostering the growth of the palm biodiesel industry through government incentives [40].	Palm biodiesel
Waste-to-Energy	Brazil	National waste-to-energy policy using biogas from agricultural and animal waste to improve rural energy access [45].	Biogas from animal waste
	Indonesia	National policy promoting the use of biomass residues for renewable energy generation, focusing on reducing GHG emissions [46].	Biomass residue
Carbon Transport Scenarios	Nigeria	Policy promoting low-carbon transport, highlighting natural gas as an alternative cleaner fuel [47].	Natural gas
Energy Policy Development	Australia	Absence of a comprehensive federal energy policy, providing lessons for Australia's natural gas strategy [48]	Renewable energy (solar, wind, etc.)

4.2 Sustainable Energy Transitions: Potential Role of Natural Gas in Indonesia

4.2.1 Natural Gas as a Cleaner Alternative for Household Use

In understanding the role of natural gas within sustainable energy transitions, global examples offer valuable insights that Indonesia can leverage for its household gas policy. Countries like Colombia and Pakistan have integrated natural gas into their energy strategies as a cleaner alternative to more polluting fossil fuels. Colombia's policy of substituting gasoline with natural gas in urban transportation highlights efforts to reduce emissions, although it still faces infrastructure and market development challenges [38]. Similarly, Pakistan's diversified energy supply, incorporating natural gas alongside hydroelectric power, has enhanced energy security while promoting sustainability [39]. These examples, summarized in Table 4, indicate that expanding access to natural

gas for households in Indonesia could simultaneously address environmental goals and energy equity challenges, offering a cleaner, more reliable energy source.

Table 4. Examples of natural gas as a cleaner energy implementation

Author	Year	Country/Region	Implementation of Natural Gas Policy
Olaya & Dynner [38]	2005	Colombia	Substitution of gasoline with natural gas in transportation to reduce emissions, addressing air pollution in urban areas.
Lin & Ahmad [39]	2016	Pakistan	Diversified energy supply mix incorporating natural gas alongside hydropower for energy security and efficiency.
Abdul-Manan et al. [40]	2015	Malaysia	Promotion of biofuel with policies encouraging competitive markets and liberalization, offering insights for natural gas use.
Ravichandran et al. [24]	2021	Australia	Focus on protecting natural capital and ensuring intergenerational equity with natural gas as part of the energy strategy.
Ajayi[49]	2023	GECF Countries	Gas Exporting Countries Forum (GECF) policies to regulate and manage natural gas rents and address energy price volatility.
Khayat Basiri et al. [45]	2020	Iran	Implementation of NGSS (Natural Gas Supply Security) policies aimed at minimizing disruptions and enhancing supply efficiency.
Choudhary & Jain [50]	2022	India	Incorporation of resilience strategies to manage supply-demand imbalances and price fluctuations in the oil and gas sector.
Ikram et al. [51]	2023	Pakistan	Improving resource utilization and addressing inefficiencies in electricity distribution, which will be essential for ensuring the success of Indonesia's natural gas transition.
Kumdokrub et al. [52]	2023	USA (Ithaca)	Sustainable urban metabolism strategies, focusing on geothermal energy and emissions reduction, provide a roadmap for Indonesia's future urban energy planning.
Luo et al. [53]	2020	Tanzania	Managing urban growth's impact on energy consumption and emissions, underscoring the need for energy demand management during Indonesia's transition to natural gas.

Beyond Colombia and Pakistan, countries like Malaysia, India, and others provide additional models for expanding energy access through innovative policy frameworks. Malaysia's liberalization of biofuel markets, for instance, highlights how competitive policies can facilitate energy adoption in underserved regions—an approach that could inform Indonesia's natural gas strategy [40]. India's government-backed financial assistance for biomass projects further underscores the importance of fiscal support to overcome logistical barriers and extend energy access to diverse regions [35]. Additionally, incorporating resilience strategies to manage supply-demand imbalances and price fluctuations in the oil and gas sector, as demonstrated in India [50] is another lesson that could benefit Indonesia. Improving resource utilization in electricity distribution, as seen in Pakistan [51]. Other international examples, such as Ithaca's urban metabolism strategies that focus on geothermal energy and emissions reduction [52], or Dar es Salaam's experience with managing energy demand in the context of rapid urban growth [53], offer further guidance for Indonesia's urban energy planning. Along with insights from Australia's natural gas strategy, which emphasizes protecting natural capital and ensuring sustainability for future generations [24], these lessons point to how Indonesia can navigate its household gas policy to foster energy equity and sustainability transitions across urban and rural areas.

4.2.2 Addressing Energy Equity and Access Challenges

Addressing energy equity and access challenges for natural gas adoption in rural and underserved regions requires targeted interventions. The logistical and technological challenges, as seen in countries like India with its biomass energy projects, highlight the need for both state-level and central government assistance to overcome infrastructure deficits [35]. Similarly, in Pakistan, underdeveloped infrastructure and high costs have hindered rural energy access, emphasizing the importance of financial incentives like subsidies and government-backed loans to improve the adoption of sustainable energy sources such as biogas and natural gas [29]. Furthermore, the gap between policy formulation and implementation, as observed in the UAE's solar energy deployment, underscores the critical need for robust regulatory frameworks to ensure successful natural gas access in underserved regions [42]. Moreover, optimizing Indonesia's energy mix by integrating natural gas with other renewable sources, as highlighted by the energy indicators framework for sustainable development will be essential for creating a balanced and sustainable energy policy. These examples demonstrate the necessity of comprehensive governmental support to address physical, regulatory, and financial barriers to energy access, as summarized in Table 5.

Table 5. Overview of natural gas equity and access challenges and the strategies to address them,

Challenges	Description	Address the Challenge	Author
Logistical and infrastructure challenges	Countries like Colombia face logistical challenges in expanding natural gas infrastructure, especially in rural areas where the transportation of gas is limited.	Developing national policies that invest in infrastructure development, such as building pipelines and storage facilities, can help overcome logistical barriers.	Olaya & Dyer [38]
Regulatory and market development issues	In regions like Pakistan, natural gas markets are hindered by imperfect demand knowledge and regulatory limitations that affect pricing and market efficiency.	Policy reforms that rationalize tariffs and improve market regulations, alongside incentives for private-sector participation, can improve market efficiency and accessibility.	Lin & Ahmad, [39]
Rural energy accessibility	In many developing countries, rural regions struggle to access natural gas due to underdeveloped infrastructure and financial constraints.	Government-backed financial initiatives, such as subsidies and loans for natural gas infrastructure, can bridge the gap in rural energy access.	Yaqoob et al., [29]
High initial costs and insufficient support	High upfront costs for establishing natural gas infrastructure and limited government financial support create barriers to adoption.	Implementing subsidies, low-interest loans, and long-term government investment plans can reduce initial costs and facilitate adoption.	Khan et al., [26]; Rehman Khan et al., [27]; Yaqoob et al., [29]
Optimizing energy mix for sustainability	Inadequate integration of natural gas with other renewable energy sources could limit the sustainability of Indonesia's energy policy.	Leveraging energy indicators frameworks to optimize the energy mix and ensure that natural gas policies support long-term sustainable development goals.	Lima et al., [54]

In addition to logistical challenges, regulatory weaknesses and limited public awareness, particularly in regions like SAARC, have delayed the adoption of renewable energy and natural gas technologies [26]. The gap between policy formulation and implementation, as seen in the UAE's solar energy deployment [42] highlights the importance of effective regulatory frameworks to enhance natural gas access in underserved regions. Additionally, leveraging energy indicators frameworks, as proposed by Lima et al. [54], could help optimize the energy mix for Indonesia's natural gas policies, ensuring they align with long-term sustainability goals.

To address these gaps, countries like Malaysia have promoted biofuel market liberalization, which has facilitated the growth of renewable energy markets by fostering competition and could serve as a model for natural gas policy reforms aimed at increasing household access in Indonesia [40]. Regulatory reforms, combined with educational initiatives, have been shown to improve adoption rates by enhancing public understanding and engagement, as seen in biogas programs in Pakistan, where training on waste management has supported rural energy development [29]. The integration of natural gas in underserved areas could similarly benefit from these policy approaches, providing both cleaner energy options and contributing to sustainable development in rural communities.

4.3 Barriers to Sustainability and Policy Implementation

The categorization of barriers into 10 broader categories provides a comprehensive view of the common challenges across various regions and technologies, especially for natural gas implementation (Table 6). Regulatory and Policy Barriers emerge as the most significant obstacle, with studies frequently citing insufficient regulatory frameworks and ineffective policy implementation as major hindrances to progress [24], [26], [41], [42]. These barriers often result from gaps in long-term sustainability planning, which complicate efforts to transition toward cleaner energy. Technological Limitations, particularly in sectors like biogas and biomass, present another substantial challenge, as existing technologies have not yet reached the efficiency or scalability required for widespread commercial adoption [29], [30].

Economic and Financial Barriers further complicate the transition to renewable energy, as the high initial costs of adopting green technologies deter both consumers and industries [26], [49], [50], [55]. Regions heavily dependent on Fossil Fuels, such as the Gulf Cooperation Council (GCC) countries, face additional hurdles since their energy systems are deeply entrenched in traditional energy sources, delaying the shift to more sustainable options [30],

[37], [41], [56]. Moreover, Public Perception and Political Conflicts, such as societal resistance or political opposition, further obstruct the adoption of renewable technologies [24], [30], [32].

Table 6. Key Barriers to Sustainability and Renewable Energy Adoption with Relevant References

Barrier	Definition	Relevant Reference Count	References
Regulatory and Policy Barriers	Challenges related to insufficient or ineffective regulatory frameworks, gaps in policy implementation, and lack of long-term sustainability vision.	8	[24], [26], [27], [29], [30], [37], [41], [42]
Technological Limitations	Limitations in current technology, including inefficiencies in renewable energy solutions such as biogas, biomass, and energy efficiency technologies.	4	[29], [30], [31], [57]
Economic and Financial Barriers	High costs associated with adopting green practices and transitioning to renewable energy sources, including energy price volatility and funding gaps.	7	[26], [27], [29], [37], [49], [50], [55]
Fossil Fuel Dependency	Dependence on fossil fuels as a primary energy source, which delays the transition to renewable energy and complicates the adoption of new technologies.	5	[24], [30], [37], [41], [56]
Public Perception and Political Conflicts	Resistance from the public or political opposition to the adoption of renewable energy technologies, influenced by social and political factors.	3	[24], [30], [32]
Logistical and Supply Chain Barriers	Challenges related to transportation, logistics, and supply chain inefficiencies, particularly for biomass, natural gas, and renewable technologies.	5	[35], [36], [38], [58], [59]
Market Penetration and Commercialization	Slow commercialization and market resistance to renewable energy technologies due to entrenched economic interests or commercial constraints.	2	[30], [37]
Energy Efficiency and Lifecycle Complexities	Difficulties in improving energy efficiency and conducting comprehensive lifecycle assessments for renewable energy solutions.	4	[30], [31], [57], [60]
Customer Awareness and Acceptance	Low awareness or understanding of renewable energy and green practices among consumers, affecting adoption and market demand.	2	[26], [30]
Environmental and Social Impacts	Concerns related to the environmental and social impacts of renewable energy technologies, including resource use, habitat disruption, and social equity.	2	[30], [32]

The most significant barrier to implementing more sustainable policies, based on six references, is Regulatory and Policy Barriers [24], [26], [27], [29], [30], [37]. Addressing these barriers requires a more structured policy framework and long-term sustainability planning. Technological Limitations and Economic and Financial Barriers are also critical, with four and five references respectively [26], [29], [30], [31], [49], [50], [57] highlighting the need for more efficient natural gas technologies and financial incentives to lower the costs of adoption. Additionally, Fossil Fuel Dependency (three references: Bhutto et al. [30]; Kelly et al. [37]; Ravichandran et al. [24]; Aliev, [41]; Mulongo & Kholopane, [61]) and Public Perception and Political Conflicts (three references: Dehler-Holland et al., 2022; Bhutto et al. [30]; Ravichandran et al. [24]) must be addressed to shift the focus away from traditional energy sources and build support for natural gas. These barriers must be tackled comprehensively to ensure a successful natural gas transition in Indonesia's household energy sector. Sustainability assessments [60] and electricity policy reforms [58] can further guide Indonesia's approach to transitioning to natural gas.

5. Research Gap and Future Research Trajectory:

The future research themes outlined in the table address key areas critical for the successful implementation of Indonesia's natural gas household policy, based on the insight given by systematic literature review. Integrated Energy Systems research will explore the interdependence between natural gas and renewable energy sources, providing insights into how natural gas can serve as a transitional energy solution [24], [53], [62]. Research on Policy Framework and Energy Security is essential to creating balanced policies that promote both economic growth and sustainability, drawing on international examples for context [1], [16], [41], [63]. Optimizing Resource Management and Efficiency in the natural gas supply chain, from extraction to distribution, will improve the resilience and efficiency of the sector [38], [39], [51].

Public Engagement and Social Acceptance is another critical area, as understanding public attitudes and developing effective communication strategies will be vital for societal acceptance of natural gas as a cleaner energy option [27], [29]. Finally, Environmental Sustainability and Lifecycle Assessment research will provide essential data on the carbon footprint and environmental risks associated with natural gas, ensuring its use aligns with Indonesia's sustainability goals [30], [31], [43]. Together, these research areas will guide the development of a comprehensive and sustainable natural gas policy for households in Indonesia. Table 7 outlines the key research themes necessary for advancing Indonesia's natural gas household policy, addressing gaps in integrated energy systems, policy frameworks, resource management, public engagement, and environmental sustainability.

Table 7. Future Research Themes for Indonesia's Natural Gas Household Policy

Category	Future Research Themes	Description of Gaps and Needs	Relevant References
Integrated Energy Systems	Interdependence Between Natural Gas and Renewables	Investigating how natural gas can serve as a transitional energy source alongside renewables.	[24], [53], [54]
Policy Framework and Energy Security	Developing Balanced Energy Policies for Natural Gas Transition	Examining how policy frameworks can balance energy security, economic growth, and sustainability.	[1], [16], [41], [63]
Resource Management and Efficiency	Optimizing Natural Gas Supply Chains and Distribution	Improving the efficiency of natural gas supply chains from extraction to distribution.	[38], [39], [51]
Public Engagement and Social Acceptance	Enhancing Public Awareness and Acceptance of Natural Gas	Understanding how public perception and education can influence societal attitudes towards natural gas.	[27], [29]
Environmental Sustainability and Lifecycle Assessment	Evaluating the Environmental Impact of Natural Gas Usage	Conducting detailed lifecycle assessments to identify potential environmental risks and benefits.	[30], [31], [43]

The application of Systems Theory, Energy Policy Theory, and Resource Orchestration Theory (ROT) can significantly contribute to future research in the context of Indonesia's natural gas policy. Systems Theory, with its focus on the interdependence and feedback loops within complex systems, provides a robust framework for understanding the interconnected nature of energy systems and the interactions between natural gas and renewable energy sources [64], [65]. Energy Policy Theory emphasizes the importance of integrating economic, environmental, and social factors in the formulation of energy strategies, ensuring long-term sustainability and energy security [66], [67]. This theory guides the development of balanced policies that can adapt to evolving market conditions and environmental challenges, crucial for Indonesia's energy transition. Meanwhile, ROT extends the Resource-Based View by focusing on the structuring, bundling, and leveraging of resources to create firm capabilities [68], [69]. In the context of natural gas, ROT can inform the optimization of resource management and coordination within supply chains, ensuring efficiency and resilience. These theories collectively offer a multi-dimensional approach to research, integrating system-wide perspectives, policy frameworks, and resource management strategies to support Indonesia's natural gas industry in its transition towards a more sustainable future [69], [70].

6. CONCLUSION:

This paper successfully addresses its aim by bridging the gap between global sustainability trends and Indonesia's household energy challenges. Through a systematic literature review of global best practices in natural gas policy, the paper identifies key strategies that can guide Indonesia's transition from LPG to natural gas in the household sector. The review provides insights into how policies from different countries balance energy security,

environmental sustainability, and economic factors, offering a framework that can be adapted to Indonesia's unique socio-economic and infrastructure context.

The systematic literature review conducted in this study demonstrates a rigorous process, starting with a comprehensive search that yielded 2,783 documents. Through methodical screening, this pool was refined to 48 key articles that directly addressed the central theme of "Energy Policy" with relevance to sustainability and renewable energy transitions. The selected documents span various geographical contexts and offer insights into global approaches to emission reduction, energy security, and sustainable technology adoption. By analyzing the integration of renewable energy, policy frameworks, and socio-economic factors in global contexts, the review highlights gaps in Indonesia's current approach, particularly in aligning energy policy with broader sustainability goals. The findings suggest that while Indonesia has strong natural gas resources, there is a critical need for region-specific policies that take into account infrastructure challenges, public engagement, and environmental concerns. The future research recommendations derived from this review are focused on these gaps, ensuring that natural gas is not only a transitional fuel but also a central component of Indonesia's long-term energy strategy. This will help Indonesia balance its energy security needs with its environmental commitments, fostering a sustainable and equitable household energy transition.

REFERENCES

- [1] I. E. A, "Oil and gas industry faces moment of truth – and opportunity to adapt – as clean energy transitions advance - News - IEA," 2023, [Online]. Available: <https://www.iea.org/news/oil-and-gas-industry-faces-moment-of-truth-and-opportunity-to-adapt-as-clean-energy-transitions-advance>
- [2] M. J. Economides and D. A. Wood, "The state of natural gas," *J Nat Gas Sci Eng*, vol. 1, no. 1–2, 2009, doi: 10.1016/j.jngse.2009.03.005.
- [3] J. Sathaye et al., "Chapter 9 - Renewable Energy in the Context of Sustainable Development," in IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011.
- [4] R. D. Vidic, S. L. Brantley, J. M. Vandenbossche, D. Yoxtheimer, and J. D. Abad, "Impact of shale gas development on regional water quality," 2013. doi: 10.1126/science.1235009.
- [5] P. Balcombe, K. Anderson, J. Speirs, N. Brandon, and A. Hawkes, "The Natural Gas Supply Chain: The Importance of Methane and Carbon Dioxide Emissions," 2017. doi: 10.1021/acssuschemeng.6b00144.
- [6] M. R. Allen et al., "Indicate separate contributions of long-lived and short-lived greenhouse gases in emission targets," 2022. doi: 10.1038/s41612-021-00226-2.
- [7] S. Garg, D. E. Boz, B. Gilbert, and J. Crompton, "A critical review of natural gas emissions certification in the United States," 2023. doi: 10.1088/1748-9326/acb4af.
- [8] Kementerian ESDM, Handbook Energy & Economic Statistics Indonesia 2021. 2021.
- [9] E. H. Purwanto, "Assessment of exploration strategies, results and costs of geothermal fields in Indonesia," *Unu-Gtp*, no. September, 2019.
- [10] L. Rosmayati, M. Eviani, D. Kurniawan, L. Lusyana, and M. D. Atmanto, "Analysis of Land Potential for Infrastructure Development of Natural Gas Distribution Pipeline for Households in Bekasi Regency, Indonesia," in IOP Conference Series: Earth and Environmental Science, 2021. doi: 10.1088/1755-1315/887/1/012033.
- [11] Z. R. Chong, S. H. B. Yang, P. Babu, P. Linga, and X. Sen Li, "Review of natural gas hydrates as an energy resource: Prospects and challenges," *Appl Energy*, vol. 162, 2016, doi: 10.1016/j.apenergy.2014.12.061.
- [12] M. L. Finkel and A. Law, "The rush to drill for natural gas: A public health cautionary tale," 2011. doi: 10.2105/AJPH.2010.300089.
- [13] R. W. Howarth, "A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas," *Energy Sci Eng*, vol. 2, no. 2, 2014, doi: 10.1002/ese3.35.
- [14] G. Sriram et al., "Gas migration signatures over the volcanic cratered seamount, off the Nicobar Islands in the Andaman Sea," *Geo-Marine Letters*, vol. 43, no. 3, 2023, doi: 10.1007/s00367-023-00757-y.
- [15] Y. Li et al., "Chemical and toxicological properties of emissions from a light-duty compressed natural gas vehicle fueled with renewable natural gas," *Environ Sci Technol*, vol. 55, no. 5, 2021, doi: 10.1021/acs.est.0c04962.
- [16] W. G. Moore and T. Moss, "Europe to Africa: Gas for me but not for thee," Nov. 2022, [Online]. Available: <https://foreignpolicy.com/2022/07/14/europe-africa-energy-crisis-gas-oil-fossil-fuels-development-finance-hypocrisy-climate-summit-world-bank/>
- [17] IEA, An Energy Sector Roadmap to Net Zero Emissions in Indonesia. OECD, 2022. doi: 10.1787/4a9e9439-en.
- [18] Jeromin Zettelmeyer, "The architecture of the euro: Prospects for the next decade," in *The Making of the European Monetary Union 30 Years Since the ERM Crisis (2023)*, 2023.
- [19] GECF, "Expert Commentary - The future of natural gas in Asia Pacific," Gas Exporting Countries Forum, Doha, Mar. 2023.
- [20] Chow and Obayashi, "Wary of 2022 crisis, Asian buyers to build strategic gas reserves," Reuters, 2022.
- [21] ICLG, "Oil and Gas Regulation – Indonesia," Global Legal Group, Mar. 06, 2023.

- [22] ANGEA, "Natural Gas & Energy in Indonesia | ANGEA." [Online]. Available: <https://angeassociation.com/location/indonesia/>
- [23] Spectra, "Indonesia's net zero future: sustainable energy transition," Nov. 2022. [Online]. Available: <https://spectra.mhi.com/indonesias-net-zero-future-sustainable-energy-transition>
- [24] A. Ravichandran, N. Diaz-Elsayed, S. Thomas, and Q. Zhang, "An assessment of the influence of local conditions on the economic and environmental sustainability of drain water heat recovery systems," *J Clean Prod*, vol. 279, 2021, doi: 10.1016/j.jclepro.2020.123589.
- [25] M. Raugei, A. Hutchinson, and D. Morrey, "Can electric vehicles significantly reduce our dependence on non-renewable energy? Scenarios of compact vehicles in the UK as a case in point," *J Clean Prod*, vol. 201, 2018, doi: 10.1016/j.jclepro.2018.08.107.
- [26] S. A. R. Khan, C. Jian, Y. Zhang, H. Golpîra, A. Kumar, and A. Sharif, "Environmental, social and economic growth indicators spur logistics performance: From the perspective of South Asian Association for Regional Cooperation countries," *J Clean Prod*, vol. 214, 2019, doi: 10.1016/j.jclepro.2018.12.322.
- [27] S. A. Rehman Khan, Y. Zhang, M. Anees, H. Golpîra, A. Lahmar, and D. Qianli, "Green supply chain management, economic growth and environment: A GMM based evidence," *J Clean Prod*, vol. 185, 2018, doi: 10.1016/j.jclepro.2018.02.226.
- [28] R. Silbergliitt and S. Kimmel, "Energy scenarios for Southeast Asia," *Technol Forecast Soc Change*, vol. 101, pp. 251–262, Dec. 2015, doi: 10.1016/j.techfore.2015.04.010.
- [29] H. Yaqoob et al., "The potential of sustainable biogas production from biomass waste for power generation in Pakistan," 2021. doi: 10.1016/j.jclepro.2021.127250.
- [30] A. W. Bhutto, A. A. Bazmi, G. Zahedi, and J. J. Klemeš, "A review of progress in renewable energy implementation in the Gulf Cooperation Council countries," in *Journal of Cleaner Production*, 2014. doi: 10.1016/j.jclepro.2013.12.073.
- [31] Q. Yang et al., "Hybrid life-cycle assessment for energy consumption and greenhouse gas emissions of a typical biomass gasification power plant in China," *J Clean Prod*, vol. 205, 2018, doi: 10.1016/j.jclepro.2018.09.041.
- [32] J. Dehler-Holland, M. Okoh, and D. Keles, "Assessing technology legitimacy with topic models and sentiment analysis – The case of wind power in Germany," *Technol Forecast Soc Change*, vol. 175, 2022, doi: 10.1016/j.techfore.2021.121354.
- [33] R. Fernández-González, F. Puime-Guillén, and M. Panait, "Multilevel governance, PV solar energy, and entrepreneurship: the generation of green hydrogen as a fuel of renewable origin," *Util Policy*, vol. 79, 2022, doi: 10.1016/j.jup.2022.101438.
- [34] C. N. Businge, P. Grisi, and A. Gelmini, "Economic analysis of a Power-to-Gas pilot plant within the Italian energy transition framework," in *12th AEIT International Annual Conference, AEIT 2020*, 2020. doi: 10.23919/AEIT50178.2020.9241156.
- [35] J. Singh, "Management of the agricultural biomass on decentralized basis for producing sustainable power in India," 2017. doi: 10.1016/j.jclepro.2016.10.056.
- [36] Ş. Y. Balaman, "Investment planning and strategic management of sustainable systems for clean power generation: An ϵ -constraint based multi objective modelling approach," *J Clean Prod*, vol. 137, 2016, doi: 10.1016/j.jclepro.2016.07.202.
- [37] C. Kelly, N. C. Onat, and O. Tatari, "Water and carbon footprint reduction potential of renewable energy in the United States: A policy analysis using system dynamics," *J Clean Prod*, vol. 228, 2019, doi: 10.1016/j.jclepro.2019.04.268.
- [38] Y. Olaya and I. Dynner, "Modelling for policy assessment in the natural gas industry," *Journal of the Operational Research Society*, vol. 56, no. 10, 2005, doi: 10.1057/palgrave.jors.2601895.
- [39] B. Lin and I. Ahmad, "Technical change, inter-factor and inter-fuel substitution possibilities in Pakistan: A trans-log production function approach," *J Clean Prod*, vol. 126, 2016, doi: 10.1016/j.jclepro.2016.03.065.
- [40] A. F. N. Abdul-Manan, A. Baharuddin, and L. W. Chang, "Application of theory-based evaluation for the critical analysis of national biofuel policy: A case study in Malaysia," *Eval Program Plann*, vol. 52, 2015, doi: 10.1016/j.evalprogplan.2015.03.007.
- [41] R. A. Aliev, "The Role of the Sustainable Development Concept in Shaping Energy Policy Transformations in the Caspian Region Countries," *Vestnik MGIMO-Universiteta*, vol. 16, no. 3, 2023, doi: 10.24833/2071-8160-2023-3-90-7-55.
- [42] M. Alsaman, V. Ahmed, and S. Saboor, "Analyzing feasible renewable energy policies: Uae electricity authorities," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2021. doi: 10.46254/an11.20210150.
- [43] A. Mehmood, L. Zhang, J. Ren, T. Zayed, and C. K. M. Lee, "Multi-facet assessment and ranking of alternatives for conceptualizing sustainable hybrid energy infrastructure in Pakistan based on evidential reasoning driven probabilistic tool," *J Clean Prod*, vol. 378, 2022, doi: 10.1016/j.jclepro.2022.134566.
- [44] A. Abuzayed and N. Hartmann, "Triggering Germany's ambitious dream of a completely renewable electricity sector by 2035," in *2022 International Conference on Renewable Energies and Smart Technologies, REST 2022*, 2022. doi: 10.1109/REST54687.2022.10022950.

- [45] A. C. L. de Oliveira, N. dos S. Renato, M. A. Martins, I. M. de Mendonça, C. A. Moraes, and M. de O. Resende, "Modeling for estimating and optimizing the energy potential of animal manure and sewage in small and medium-sized farms," *J Clean Prod*, vol. 319, 2021, doi: 10.1016/j.jclepro.2021.128562.
- [46] E. I. Rhofita, R. Rachmat, M. Meyer, and L. Montastruc, "Mapping analysis of biomass residue valorization as the future green energy generation in Indonesia," *J Clean Prod*, vol. 354, 2022, doi: 10.1016/j.jclepro.2022.131667.
- [47] M. O. Dioha, A. Kumar, D. R. E. Ewim, and N. V. Emodi, "Alternative Scenarios for Low-Carbon Transport in Nigeria: A Long-Range Energy Alternatives Planning System Model Application," in *Economic Effects of Natural Disasters: Theoretical Foundations, Methods, and Tools*, 2020. doi: 10.1016/B978-0-12-817465-4.00030-3.
- [48] P. Pearce, "Australian energy policy: shortfalls and roadblocks for sustainable change," *Transnational Corporations Review*, vol. 9, no. 4, 2017, doi: 10.1080/19186444.2017.1401254.
- [49] T. A. Ajayi, "Natural gas rents and institutions as co-growth drivers: evidence from Gas Exporting Countries Forum with a panel 2SLS approach," *International Journal of Energy Sector Management*, vol. 18, no. 3, 2024, doi: 10.1108/IJESM-01-2023-0015.
- [50] P. Choudhary and N. K. Jain, "System Dynamics Based Analysis of Oil and Gas Supply Chain Disruptions During COVID-19," *IEEE Engineering Management Review*, vol. 50, no. 3, 2022, doi: 10.1109/EMR.2022.3180003.
- [51] M. Ikram, M. Z. Rafique, K. S. Mohammed, R. Waheed, and D. Ferraz, "Efficient resource utilization of the electricity distribution sector using nonparametric data envelopment analysis and influential factors," *Util Policy*, vol. 82, 2023, doi: 10.1016/j.jup.2023.101571.
- [52] T. Kumdokrub, S. Carson, and F. You, "Cornell university campus metabolism and circular economy using a living laboratory approach to study major resource and material flows," *J Clean Prod*, vol. 421, 2023, doi: 10.1016/j.jclepro.2023.138469.
- [53] C. Luo, I. D. Posen, D. Hoornweg, and H. L. MacLean, "Modelling future patterns of urbanization, residential energy use and greenhouse gas emissions in Dar es Salaam with the Shared Socio-Economic Pathways," *J Clean Prod*, vol. 254, 2020, doi: 10.1016/j.jclepro.2020.119998.
- [54] F. Lima, M. L. Nunes, and J. Cunha, "Energy indicators framework and climate change policy implications," in *International Conference on the European Energy Market, EEM*, 2017. doi: 10.1109/EEM.2017.7981926.
- [55] V. Soni, S. P. Singh, and D. K. Banwet, "Enlightening grey portions of energy security towards sustainability," *International Journal of Energy Sector Management*, vol. 11, no. 1, 2017, doi: 10.1108/IJESM-07-2015-0005.
- [56] N. Y. Mulongo and P. Kholopane, "Exploring challenges impeding sustainable supply chain practices in mining sector," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2017, pp. 737–748. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85067046394&partnerID=40&md5=2e0649db365adb8d1d2a6a615a2b2f8e>
- [57] T. Tantisattayakul, J. Soontharothai, N. Limphitakphong, C. Pharino, O. Chavalparit, and P. Kanchanapiya, "Assessment of energy efficiency measures in the petrochemical industry in Thailand," *J Clean Prod*, vol. 137, pp. 931–941, Nov. 2016, doi: 10.1016/j.jclepro.2016.07.078.
- [58] H. Qudrat-Ullah and M. Karakul, "Modelling for policy assessment in the electricity supply sector of Pakistan," *International Journal of Energy Sector Management*, vol. 1, no. 3, 2007, doi: 10.1108/17506220710821125.
- [59] S. Lundie, T. Wiedmann, M. Welzel, and T. Busch, "Global supply chains hotspots of a wind energy company," *J Clean Prod*, vol. 210, 2019, doi: 10.1016/j.jclepro.2018.10.216.
- [60] M. Kucukvar, N. C. Onat, M. A. Haider, and M. A. Shaikh, "A global multiregional life cycle sustainability assessment of national energy production scenarios until 2050," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2017.
- [61] N. Y. Mulongo and P. Kholopane, "A sustainability assessment of electricity supply systems," in *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)*, IEEE, Apr. 2018, pp. 565–572. doi: 10.1109/IEA.2018.8387164.
- [62] M. A. R. Lopes, C. H. Antunes, and N. Martins, "Towards more effective behavioural energy policy: An integrative modelling approach to residential energy consumption in Europe," *Energy Res Soc Sci*, vol. 7, pp. 84–98, 2015, doi: 10.1016/j.erss.2015.03.004.
- [63] M. A. Cindy and Yusgiantoro, "Why Indonesia Should Abandon its Natural Gas Pricing Regulation," *The Diplomat*, 2021.
- [64] D. J. Teece, "Dynamic capabilities as (workable) management systems theory," *Journal of Management and Organization*, vol. 24, no. 3, 2018, doi: 10.1017/jmo.2017.75.
- [65] V. Valentinov, S. Roth, and I. Pies, "Social Goals in the Theory of the Firm: A Systems Theory View," *Adm Soc*, vol. 53, no. 2, 2021, doi: 10.1177/0095399720933826.
- [66] L. R. Geri and D. E. McNabb, *Energy Policy in the U.S.: Politics, Challenges, and Prospects for Change*. 2017. doi: 10.4324/9781315094502.

- [67] D. Scheer, H. Class, and B. Flemisch, "Geologic Carbon Sequestration," 2021, pp. 109–152. doi: 10.1007/978-3-030-51178-4_6.
- [68] C. CHADWICK, J. F. SUPER, and K. KWON, "RESOURCE ORCHESTRATION IN PRACTICE: CEO EMPHASIS ON SHRM, COMMITMENT-BASED HR SYSTEMS, AND FIRM PERFORMANCE," *Strategic Management Journal*, vol. 36, no. 3, pp. 360–376, 2015, [Online]. Available: <http://www.jstor.org/stable/43897774>
- [69] D. G. Sirmon, M. A. Hitt, R. D. Ireland, and B. A. Gilbert, "Resource Orchestration to Create Competitive Advantage," *J Manage*, vol. 37, no. 5, 2011, doi: 10.1177/0149206310385695.
- [70] S. Liu, J. Forrest, and Y. Yang, "A brief introduction to grey systems theory," *Grey Systems*, vol. 2, no. 2, 2012, doi: 10.1108/20439371211260081.