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RENEWABLE ENERGY LANDSCAPES: A COMPARATIVE ANALYSIS OF LITHUANIA'S, EUROPE'S AND AFRICA'S GREEN STRATEGIES*

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Abstract. This study explores the renewable energy trajectories of Lithuania, Europe, and Africa, focusing on their strategies, achievements, and prospects. It highlights Lithuania's significant investment in wind and biomass energy, evaluating its progress within the broader European context and its role in the Baltic region's energy transition. The analysis underscores Europe's leadership in renewable energy, noting its advanced policies and technological innovations that set global benchmarks. In contrast, Africa's renewable energy potential is examined alongside its infrastructural and financial challenges, revealing opportunities and barriers. Key findings include Lithuania's substantial reliance on wind and biomass, Europe's prominent role in renewable energy adoption, and Africa's promising yet uneven progress. This comparative study provides insights into diverse approaches to renewable energy and their implications for the global transition towards sustainable energy.

Keywords: Renewable Energy; Lithuania; Europe; Africa; Green Strategy

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1. Introduction

The transition to renewable energy has emerged as a critical global priority, spurred by the urgent need to combat climate change and bolster energy security. For nations like Lithuania, this shift is not only an environmental imperative but also a strategic move to lessen dependence on imported fossil fuels and diversify energy sources (A. Adesina and G. Demas 2022; European Commission 2021a; Lietuvos Respublikos energetikos ministerija 2024). Lithuania's commitment to renewable energy positions it as a key player in the Baltic region's energy transformation, aligning with broader European objectives to cut greenhouse gas emissions and achieve climate neutrality (A. Adesina 2022; International Energy Agency 2023b; IRENA 2023).

Lithuania's renewable energy trajectory is marked by ambitious targets and significant progress. The country has made considerable investments in wind, solar, and biomass energy (CAN Europe 2024; European Environment Agency. 2022), reflecting its determination to reduce its carbon footprint and enhance its energy independence. By adopting a forward-thinking energy strategy, Lithuania aims to balance its renewable energy portfolio while navigating the challenges of a smaller national energy market (REN21 2022; World Bank Group 2004).

As Lithuania pursues its renewable energy goals, it is crucial to evaluate how its achievements and challenges measure up against the broader European landscape. This article delves into Lithuania's renewable energy journey, comparing its progress with that of other European nations (bp 2023; European Commission 2023a). We will explore the drivers behind Lithuania's energy policies, assess the implications of its successes and setbacks, and consider how its experience fits into the larger European context (Artelys 2018; United Nations Environment Programme 2022).

Furthermore, to provide a comprehensive view of the global renewable energy movement, this article will also offer a comparative perspective on Africa's renewable energy landscape. Africa, with its vast potential for solar and wind energy, presents both opportunities and obstacles that parallel those faced by Lithuania (Alex 2022; SolarPower Europe 2023). By examining these diverse contexts, we aim to contextualize Lithuania's renewable energy efforts within a global framework and highlight the interconnected nature of the renewable energy transition (Ramírez, Fraile, and Brindley 2019; Kou 2023; European climate foundation 2024; Murphy 2022).

2. Lithuania's Renewable Energy Landscape

Lithuania, a small Baltic nation, has made commendable progress in renewable energy development, particularly given its historical reliance on imported energy sources. The closure of the Ignalina Nuclear Power Plant in 2009 marked a significant turning point, leading Lithuania to prioritize energy security and sustainability. This shift has been marked by a focused effort to increase the share of renewables in its energy mix. As of 2023, Lithuania generates about 50% of its electricity from renewables, a significant achievement for a country with a relatively small energy market (Gecevičius and Kavaliauskas 2021; Jorgenson et al. 2024; Klevas, Streimikiene, and Grikstaite 2007). This section details Lithuania's renewable energy achievements and future targets as shown in Figure 1.

Wind Energy

Wind energy has emerged as the most successful renewable source, with wind farms generating 11.5% of the nation's electricity in 2021(Lietuvos vejo elektriniu asociacija 2022). Lithuania's investment in onshore wind farms, particularly along the Baltic Sea coast, has leveraged favorable wind conditions that bolster their efficiency (Wind 2024). Wind power is the largest contributor, producing approximately 25% of the nation's electricity (Janeliūnas 2021; Jankevičienė and Kanapickas 2023).

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Biomass Energy
Biomass has also become a cornerstone of Lithuania's renewable energy strategy, especially in the heating sector. Biomass, sourced from local wood waste and agricultural residues, now accounts for 70% of district heating, significantly reducing dependence on imported natural gas and supporting local job creation (Jonynas et al. 2020). Biomass, leveraging Lithuania's agricultural and forestry byproducts, provides about 20% of the country's energy, demonstrating its crucial role in the national energy mix (Varnagiryte-Kabasinskiene et al. 2019).

Solar Energy
Solar energy, while less prominent due to lower solar irradiance compared to southern Europe, has been growing steadily (Guigaitė and Jakubavičius 2022). As of 2023, solar power contributes approximately 7% to Lithuania's electricity generation, supported by increasing residential and commercial installations (Gecevičius and Kavaliauskas 2021; Kozlovas et al. 2023).

Future Targets
The Lithuanian government has been proactive in fostering renewable energy through policies like the National Energy Independence Strategy, which aims for 100% renewable electricity consumption by 2050, and advancements in energy storage technologies like the Kruonis Pumped Storage Plant with a capacity of 165 MW (European Investment Bank 2024; Lietuvos Respublikos energetikos ministerija 2018; Media 2020). Additionally, decentralized energy production is on the rise, with increasing installations of solar panels supported by government incentives (Katinas and Markevicius 2006; Vezzoli et al. 2018).

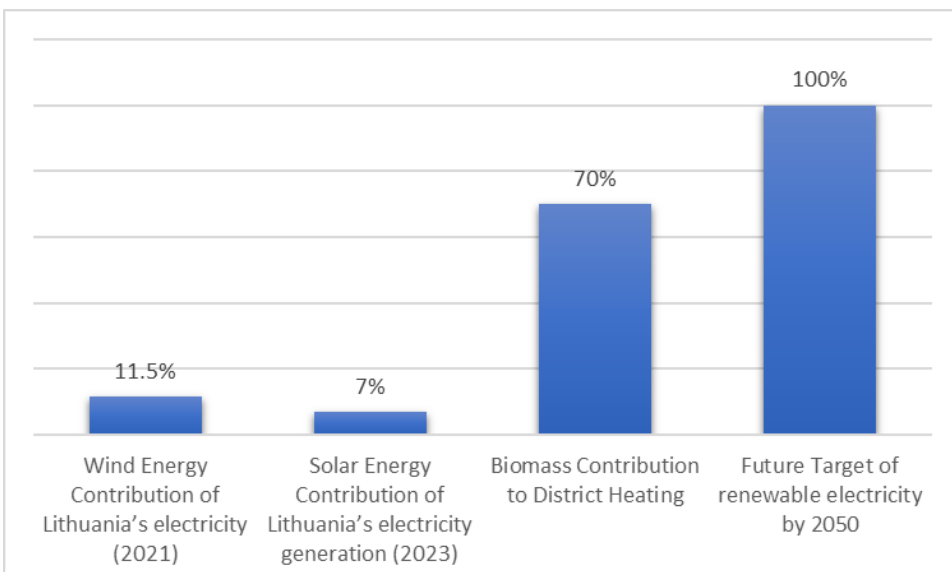

Figure 1. Lithuania's Renewable Energy Statistics and Target
Source: Lietuvos vejo elektriniu asociacija (LVEA) and International Renewable Energy Agency (IREA)

3. Renewable Energy in Europe

Europe has been a global leader in the adoption of renewable energy, driven by the urgency of addressing climate change, reducing greenhouse gas emissions, and enhancing energy security. The European Union (EU) has implemented several pivotal policies to spearhead this transition, with the European Green Deal being a cornerstone (Sandri et al. 2023). This ambitious initiative aims to make Europe the first climate-neutral continent by 2050, with a target of increasing the share of renewable energy in gross final energy consumption to at least

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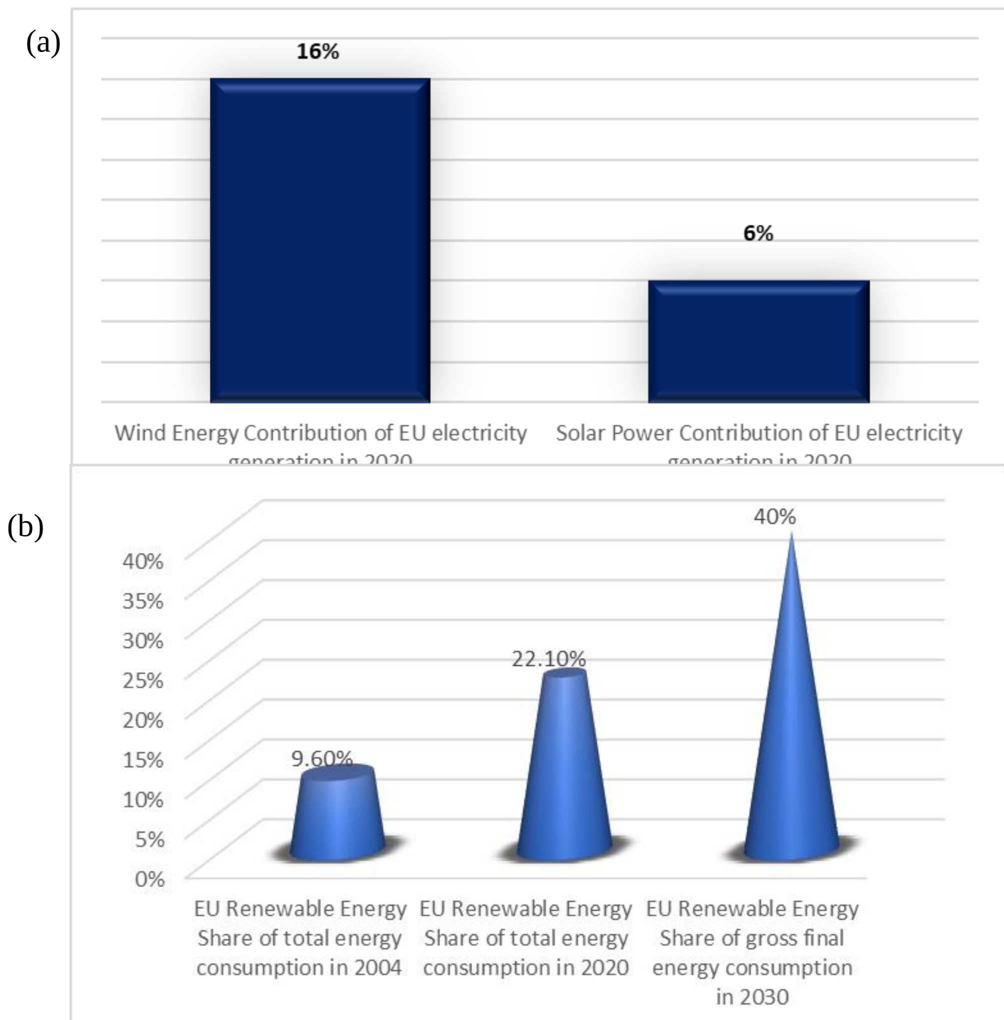
40% by 2030 (European Commission 2022; European Parliament 2022). This section reviews Europe's overall renewable energy progress, key contributors, and challenges.

Renewable Energy Share

By 2022, the EU had made significant strides, with renewable energy sources accounting for approximately 22.1% of its total energy consumption, a considerable increase from just 9.6% in 2004 (Fig.2.b) (Eurostat Statistic Explainer 2024). The rapid growth of wind and solar power has been a notable success story (Fig.2.a). Wind energy alone contributed 16% to the EU's electricity generation in 2020 (European Commission 2023b), while solar power accounted for nearly 6% (International Renewable Energy Agency 2024). This growth has been underpinned by robust national policies, generous subsidies, and the establishment of an integrated European energy market that facilitates cross-border electricity trade. The EU's €1.8 trillion investment under the European Green Deal Investment Plan underscores its commitment to this green transition, positioning Europe as a global leader in environmental sustainability (European Commission 2021b).

Figure 1. Wind and solar energy contribution in EU electricity generation (a), the evolution of renewable energy share during years (b)



Source: European Commission, Eurostat, and European parliament.

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Country-Specific Insights

Denmark is a frontrunner in wind energy, with wind turbines supplying nearly 50% of the country's electricity in 2022, thanks to extensive investments in both onshore and offshore wind farms (Agnolucci 2007). Spain and Italy are key players in solar energy (Fig.3.a), with Spain boasting over 20 GW of installed solar capacity and Italy surpassing 25 GW as of 2023, driven by supportive policies and favorable weather conditions (Ferrara et al. 2024; International Energy Agency 2023a; Red Eléctrica 2024). Hydropower remains a cornerstone of renewable energy in countries like Sweden and Austria, where it supplies approximately 40% and 60% of their electricity needs, respectively, owing to their abundant water resources and advanced hydropower infrastructure (Wagner et al. 2015; Wang 2006; Zhong, Bollen, and Rönnberg 2021) (Fig.3.b). This rich tapestry of renewable energy sources across Europe not only highlights the region's commitment to reducing greenhouse gas emissions and improving energy security but also underscores its leadership in technological innovation and sustainability practices.

Nonetheless, Europe faces substantial challenges in achieving its renewable energy goals. The recent energy crisis, exacerbated by geopolitical tensions such as the war in Ukraine, has highlighted vulnerabilities in Europe's energy supply chains and the urgent need to accelerate the shift towards domestically produced renewable energy (Kuzemko et al. 2022; Skalamera 2023). While countries like Germany and Spain are making notable progress, the pace of transition varies significantly across the EU, with some nations still heavily reliant on coal and other fossil fuels (Eyl-Mazzega and Mathieu 2020).

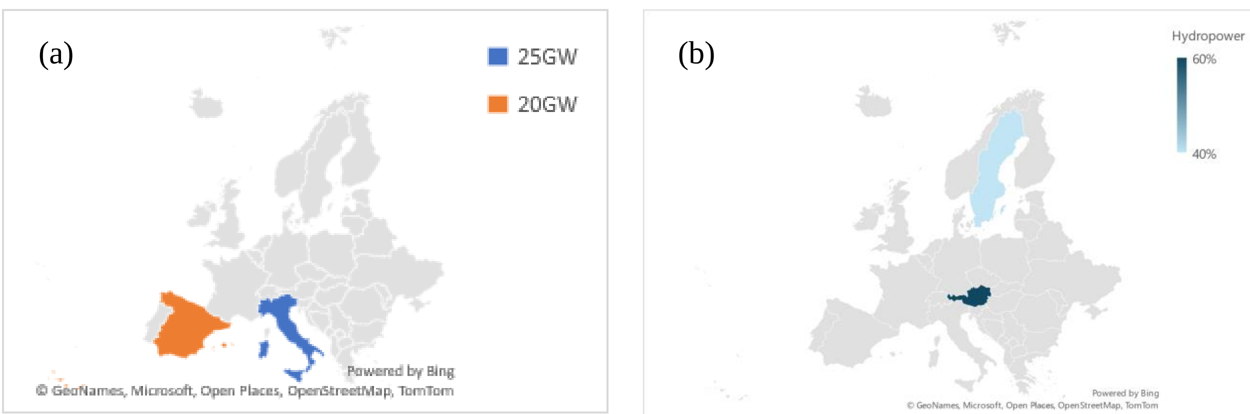

Figure 2. Solar energy potential in Spain and Italy (a), Hydropower production in Sweden and Austria (b)
Source: International Energy Agency, and IEA

4. Africa's Diverse Renewable Energy Resources

Africa's renewable energy potential is vast, encompassing solar, wind, hydropower, biomass, and geothermal energy (Fig.4). This section explores Africa's progress, key projects, and challenges.

Solar Energy

Solar energy is a major focus, with Africa's high solar irradiance enabling significant solar power projects. For instance, Morocco's Noor Ouarzazate Solar Complex, with a capacity of 580 megawatts (MW), is one of the world's largest solar installations and demonstrates the continent's solar potential (Cantoni and Rignall 2019; World Bank Group, African Development Bank, and European Investment Bank 2017).

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Wind Energy
Wind energy is also expanding, particularly in regions with favorable wind conditions. Kenya's Lake Turkana Wind Farm, the largest in Africa, boasts a capacity of 310 MW and plays a crucial role in the country's energy mix (Mukhtar et al. 2023; Simberg-Koulumies 2024).

Hydropower
Hydropower remains a significant component, with the Grand Ethiopian Renaissance Dam expected to provide approximately 6,450 MW, substantially increasing regional energy capacity (Ahmed et al. 2024; Liersch, Koch, and Hattermann 2017), (Jiregna Tadese 2020).

Biomass and Geothermal Energy
Biomass energy, derived from agricultural residues and wood, supports rural energy needs and small-scale industries. Geothermal energy, while less developed, shows considerable promise in the East African Rift region, with Ethiopia and Kenya leading exploration efforts. Ethiopia's Aluto Langano Geothermal Plant contributes 70 MW to the national grid, showcasing the potential for geothermal development (Benti et al. 2023; Samrock et al. 2020). Together, these renewable sources address critical energy access issues and position Africa as a key player in the global clean energy transition.

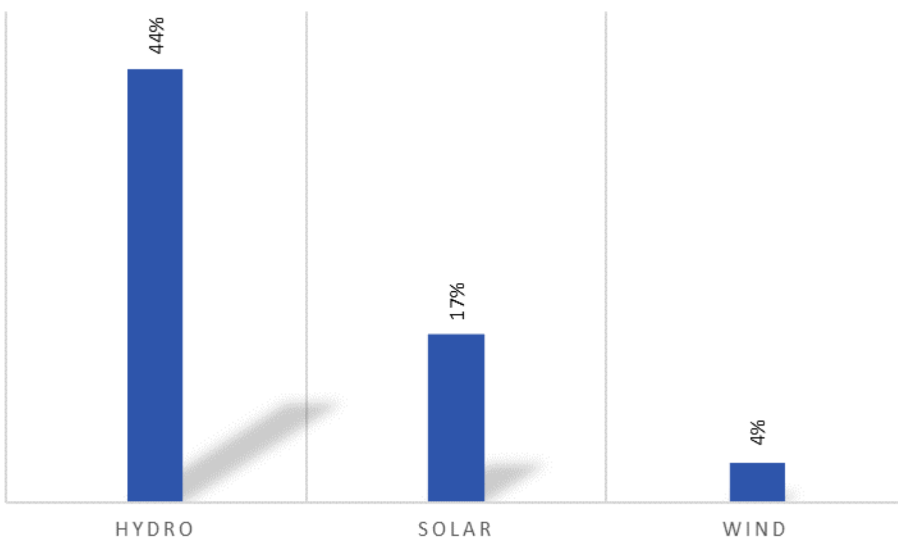

Figure 3. Top Renewable Energy Sources in Africa (2022)
Source: International Renewable Energy Agency (IRENA)

5. Comparative Analysis

Comparing Lithuania's renewable energy achievements with those of other European countries and Africa reveals differing levels of progress and potential. Lithuania and Europe are both advancing in the realm of renewable energy, though their approaches and achievements reflect their unique contexts. In Lithuania, approximately 50% of electricity is derived from renewable sources, with wind power and biomass. Solar energy, while expanding, remains limited due to the country's lower solar irradiance compared to sunnier regions. This mix is largely shaped by Lithuania's geographic advantages for wind and biomass resources and the ongoing efforts to enhance its solar infrastructure (Eurostat n.d.; Janeliūnas 2021). In contrast, Europe's renewable energy landscape is more varied and advanced (Fig.5). Denmark stands out with wind power generating approximately 50% of its electricity, thanks to extensive investments in both onshore and offshore wind farms (Danish Energy Agency 2023). Additionally, hydropower plays a significant role in northern and central Europe (International Energy

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Agency 2022). Europe's broader renewable energy portfolio is supported by comprehensive policies and substantial investments from the EU and member states, enabling a more diversified approach to renewable energy (European Commission 2021b). Germany, despite its challenges with phasing out nuclear power and reducing coal dependence, has made substantial progress. By 2022, Germany generated 40% of its electricity from renewables, with wind and solar power being pivotal (Agora Energiewende n.d.). The Energiewende policy has been crucial in this achievement, establishing Germany as a major player in the global renewable energy market (Hake et al. 2015). In contrast, Lithuania's progress is more modest, though impressive given its size and economic capacity. Among the Baltic states, Lithuania is leading in renewable energy development, with Latvia heavily reliant on hydropower (about 40% of its energy mix) (Streimikiene and Klevas 2007) and Estonia still depending on oil shale, although efforts to diversify with wind and biomass are underway (Miskinis et al. 2020). Lithuania's focus on wind and biomass provides a balanced approach, but challenges remain, particularly in expanding offshore wind and solar energy capacity (Lietuvos vėjo elektrinių asociacija 2022). In summary, while Lithuania focuses on harnessing wind, biomass, and gradually increasing its solar capacity, Europe leverages its diverse geography to support a wide array of renewable technologies, bolstered by robust policy frameworks and significant investments.

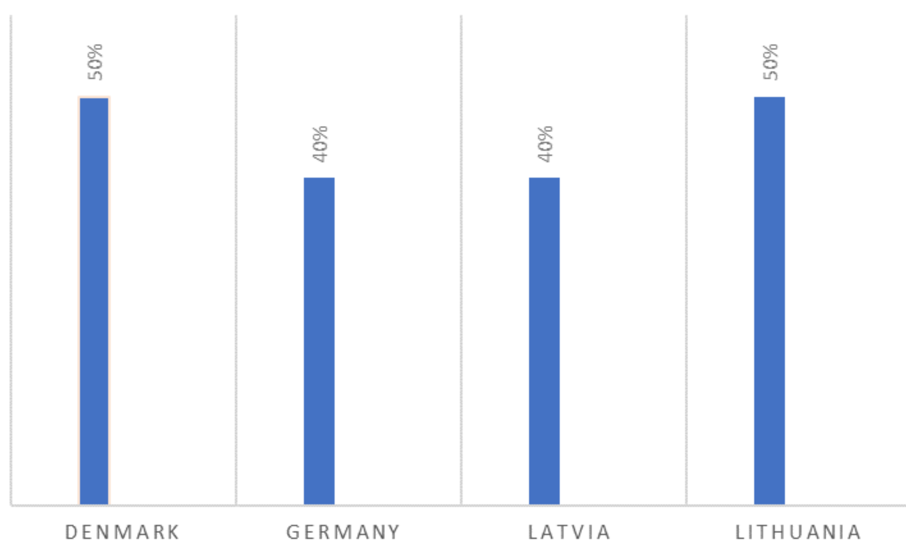

Figure 4. Electricity generation from renewable sources in 2022
Source: International Hydropower Association (IHA), Bundesnetzagentur (German Federal Network Agency), Danish Energy Agency, Eurostat

Comparing Europe's renewable energy landscape with Africa's reveals a stark contrast in progress and potential. Europe, with its advanced infrastructure and substantial financial investments, has made significant strides in renewable energy. In contrast, Africa, despite having abundant renewable resources like solar and wind, faces different challenges. In Africa, solar energy presents a significant opportunity, given the continent's high solar irradiance levels. Countries like Morocco and South Africa are leading the way, with Morocco's Noor Ouarzazate Solar Complex and South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) demonstrating substantial investments in solar power (Ministry of Youth, Culture and Communication 2016). However, the continent's overall renewable energy capacity remains underdeveloped compared to Europe's advanced infrastructure. As of 2022 (Fig.6), renewables accounted for about 21% of Africa's total energy generation, with a strong emphasis on hydroelectric power, which constitutes a large portion of the continent's

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renewable energy mix (OECD 2022). Comparing Lithuania with Africa shows that Africa has significant renewable potential, particularly in solar and wind, but faces challenges such as financial constraints and infrastructure gaps (Amoah et al. 2020; Global Renewables Outlook 2020).

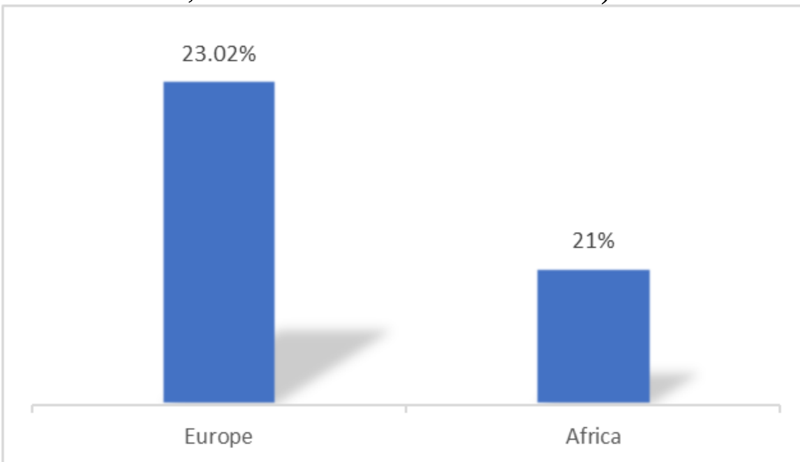

Figure 5. Europe and Africa's Renewable Energy Share of 2022
Source: Eurostat, International Renewable Energy Agency (IRENA)

Challenges in Africa include limited financial resources, inadequate infrastructure, and political instability, which can hinder the development and deployment of renewable energy projects. Additionally, many African countries face significant energy access issues, with a large portion of the population lacking reliable electricity (Gabrah, Amoako, and Ampong 2023). Despite these challenges, there is a growing recognition of the potential for renewables to drive economic development and improve energy access across the continent (Juju et al. 2020). Initiatives such as the African Renewable Energy Initiative (AREI) aim to mobilize investment and support large-scale renewable energy projects, reflecting a commitment to harnessing the continent's renewable potential (Maged 2023).

Conclusions

Lithuania's advancements in renewable energy are notable, yet they must be viewed within a broader European and global context that showcases the diverse strategies and outcomes in the transition to sustainable energy. Lithuania has made significant strides, particularly in wind and biomass energy, which are crucial to its national energy strategy and reflect its commitment to reducing carbon emissions and enhancing energy security. However, its progress is part of a larger European landscape where nations have adopted varied approaches to meet ambitious climate goals. Europe's advanced renewable energy portfolio, characterized by leading technologies and extensive infrastructure investments, contrasts with the emerging but challenging renewable energy landscape in Africa. While Africa holds vast potential for solar and wind energy, its development is hindered by infrastructural limitations and financial constraints. This comparative analysis highlights the complexity of global energy transitions, emphasizing that the path to sustainability is not uniform but shaped by regional contexts and capabilities. It underscores the need for continued investment in renewable technologies, supportive policy frameworks, and strengthened international collaboration to drive progress and overcome barriers. By addressing these challenges collectively, the global community can better support diverse approaches and enhance the overall advancement of renewable energy development worldwide.

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https://doi.org/10.70132/c7824282627

References

Adesina, A. (2022). Supporting climate resilience and a just energy transition in Africa. African Development Bank Group. www.afdb.org

Adesina, A., & G. Demas, W. (2022). Development in a Context of Global Challenges: Experiences and Lessons from the African Development Bank. https://www.afdb.org/sites/default/files/dr_akinwumi_adesina_-_william_d._delma_memorial_lecture_june_14_2022_final.pdf

Agnolucci, P. (2007). Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction. *Renewable and Sustainable Energy Reviews*, 11(5), 951–963. https://doi.org/10.1016/j.rser.2005.07.004

Agora Energiewende. (n.d.) Deutschland. Retrieved September 24, 2024, from https://www.agora-energiewende.de/international/laender-und-regionen/deutschland

Ahmed, M., Abdelrehim, R., Elshalkany, M., & Abdrabou, M. (2024). Impacts of the Grand Ethiopian Renaissance Dam on the Nile River's downstream reservoirs. *Journal of Hydrology*, 633, 130952. https://doi.org/10.1016/j.jhydrol.2024.130952

Alex. (2022, April 4). Global Wind Report 2022. Global Wind Energy Council. https://gwec.net/global-wind-report-2022/

Amoah, A., Kwablah, E., Korle, K., & Offei, D. (2020). Renewable energy consumption in Africa: The role of economic well-being and economic freedom. *Energy, Sustainability and Society,* 10(1), 32. https://doi.org/10.1186/s13705-020-00264-3

Artelys. (2018). Investigation on the interlinkage between gas and electricity scenarios and infrastructure projects assessment (p. 76). https://eepublicdownloads.entsoe.eu/clean-documents/Publications/Position%20papers%20and%20reports/ENTSOs%20-%20Interlinkages%20Focus%20Study%20-%20Final%20report.pdf

Benti, N. E., Woldegiyorgis, T. A., Geffe, C. A., Gurmesa, G. S., Chaka, M. D., & Mekonnen, Y. S. (2023). Overview of geothermal resources utilization in Ethiopia: Potentials, opportunities, and challenges. *Scientific African*, 19, e01562. https://doi.org/10.1016/j.sciaf.2023.e01562

bp. (2023). Statistical Review of World Energy to pass to new home at the Energy Institute | News and insights | Home. Bp Global. https://www.bp.com/en/global/corporate/news-and-insights/press-releases/statistical-review-of-world-energy-to-pass-to-new-home-at-the-energy-institute.html

CAN Europe. (2024). Energy Compass for the new policy cycle 2024-2029: Recommendations for the new European Comission. www.caneurope.org

Cantoni, R., & Rignall, K. (2019). Kingdom of the Sun: A critical, multiscalar analysis of Morocco's solar energy strategy. *Energy Research & Social Science*, 51, 20–31. https://doi.org/10.1016/j.erss.2018.12.012

Danish Energy Agency. (2023, February 9). New virtual platform to share Danish offshore wind experiences. The Danish Energy Agency. https://ens.dk/en/press/new-virtual-platform-share-danish-offshore-wind-experiences

European climate foundation. (2024, June 27). A growing European movement for a community-driven energy transition—European Climate Foundation. Https://Europeanclimate.Org/. https://europeanclimate.org/stories/a-growing-european-movement-for-a-community-driven-energy-transition/

European Commission. (2021a). Delivering the European Green Deal—European Commission. https://commission.europa.eu/publications/delivering-european-green-deal_en

European Commission. (2021b, July 14). The European Green Deal—European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2022, April 8). Energy and the Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en

European Commission. (2023a). Eighth report on the state of the energy union—European Commission. https://energy.ec.europa.eu/topics/energy-strategy/eighth-report-state-energy-union_en

European Commission. (2023b). EU wind energy. https://energy.ec.europa.eu/topics/renewable-energy/eu-wind-energy_en

European Environment Agency. (2022). Trends and projections in Europe 2022. Publications Office. https://data.europa.eu/doi/10.2800/16646

European Investment Bank. (2024, March 14). Lithuania gets energy-independence boost with EIB loan to Ignitis. European Investment Bank. https://www.eib.org/en/press/all/2024-108-lithuania-gets-energy-independence-boost-with-eib-loan-to-ignitis

European Parliament. (2022, June 22). Green Deal: Key to a climate-neutral and sustainable EU. Topics | European Parliament. https://www.europarl.europa.eu/topics/en/article/20200618STO81513/green-deal-key-to-a-climate-neutral-and-sustainable-eu

Eurostat. (n.d.). Renewables steadily increasing in heating and cooling. Retrieved September 24, 2024, from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20220211-1

Eurostat Statistic Explainer. (2024, January 3). Share of renewable energy more than doubled between 2004 and 2022. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics

Eyl-Mazzega, M.-A., & Mathieu, C. (2020). The European Union and the Energy Transition. In M. Hafner & S. Tagliapietra (Eds.), The Geopolitics of the Global Energy Transition (pp. 27–46). Springer International Publishing. https://doi.org/10.1007/978-3-030-39066-2_2

Ferrara, C., Marmiroli, B., Carvalho, M. L., & Girardi, P. (2024). Life Cycle Assessment of Photovoltaic electricity production in Italy: Current scenario and future developments. *Science of The Total Environment*, 948, 174846. https://doi.org/10.1016/j.scitotenv.2024.174846

Gabrah, A. Y. B., Amoako, G. K., & Ampong, G. O. A. (2023). Africa's Response to SDGs: Barriers and Challenges. In S. Adomako, A. Danso, & A. Boateng (Eds.), Corporate Sustainability in Africa: Responsible Leadership, Opportunities, and Challenges (pp. 47–63). Springer International Publishing. https://doi.org/10.1007/978-3-031-29273-6_3

Gecevičius, G., & Kavaliauskas, Ž. (2021). Development of Renewable Energy in Lithuania: Experience, State and Trends. *Environmental Research*, 77, 64–72. http://dx.doi.org/10.5755/j01.erem.77.4.29902

Global Renewables Outlook. (2020). ENERGY TRANSFORMATION SUB-SAHARAN AFRICA. https://www.irena.org//media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_R10_Sub-Saharan_Africa.pdf?la=en&hash=DB067EF85E0FDB6B8762833E77CC80F3975E46DC

Guigaitė, A., & Jakubavičius, A. (2022). Trends in solar energy development projects in Lithuania. Mokslas - Lietuvos Ateitis, 14, 1–7. https://doi.org/10.3846/mla.2022.15857

Hake, J.-F., Fischer, W., Venghaus, S., & Weckenbrock, C. (2015). The German Energiewende – History and status quo. *Energy*, 92, 532–546. https://doi.org/10.1016/j.energy.2015.04.027

International Energy Agency. (2022, October 5). IEA – International Energy Agency. IEA. https://www.iea.org

International Energy Agency. (2023a). Italy 2023 Energy Policy Review. OECD. https://doi.org/10.1787/278dd18f-en

International Energy Agency. (2023b). Medium-Term Gas Report 2023: Including the Gas Market Report, Q4-2023. OECD. https://doi.org/10.1787/5da099e5-en

International Renewable Energy Agency. (2024). Solar energy. https://www.irena.org/Energy-Transition/Technology/Solar-energy

IRENA. (2023). Renewable energy benefits: Leveraging local capacity for small-scale hydropower. https://www.irena.org/

Janeliūnas, T. (2021). Energy Transformation in Lithuania: Aiming for the Grand Changes. In M. Mišík & V. Oravcová (Eds.), From Economic to Energy Transition: Three Decades of Transitions in Central and Eastern Europe (pp. 283–313). Springer International Publishing. https://doi.org/10.1007/978-3-030-55085-1_10

Jankevičienė, J., & Kanapickas, A. (2023). Projected Wind Energy Maximum Potential in Lithuania. *Applied Sciences*, 13(1), Article 1. https://doi.org/10.3390/app13010364

Jiregna Tadese. (2020). The Grand Ethiopian Renaissance Dam (GERD): Diplomatic War Between Ethiopia and Egypt. https://doi.org/10.13140/RG.2.2.16518.09286

Jonynas, R., Puida, E., Poškas, R., Paukštaitis, L., Jouhara, H., Gudzinskas, J., Miliauskas, G., & Lukoševičius, V. (2020). Renewables for district heating: The case of Lithuania. *Energy,* 211, 119064. https://doi.org/10.1016/j.energy.2020.119064

Jorgenson, J., Doubleday, K., Chernyakhovskiy, I., Obika, K., Williams, T., Rosenlieb, E., & Igwe, V. (2024). The Lithuania 100% Renewable Energy Study—Interim Results: Electricity System Scenarios for 2030. https://doi.org/10.2172/2350649

Juju, D., Baffoe, G., Dam Lam, R., Karanja, A., Naidoo, M., Ahmed, A., Jarzebski, M. P., Saito, O., Fukushi, K., Takeuchi, K., & Gasparatos, A. (2020). Sustainability Challenges in Sub-Saharan Africa in the Context of the Sustainable Development Goals (SDGs). In A. Gasparatos, A. Ahmed, M. Naidoo, A. Karanja, K. Fukushi, O. Saito, & K. Takeuchi (Eds.), Sustainability Challenges in Sub-Saharan Africa I: Continental Perspectives and Insights from Western and Central Africa (pp. 3–50). Springer. https://doi.org/10.1007/978-981-15-4458-3_1

Katinas, V., & Markevicius, A. (2006). Promotional policy and perspectives of usage renewable energy in Lithuania. Energy Policy, 34(7), 771–780. https://doi.org/10.1016/j.enpol.2004.07.011

Klevas, V., Streimikiene, D., & Grikstaite, R. (2007). Sustainable energy in Baltic States. *Energy Policy*, 35(1), 76–90. https://doi.org/10.1016/j.enpol.2005.10.009

Kou, H. (2023, October 9). 2H 2023 Energy Storage Market Outlook. BloombergNEF. https://about.bnef.com/blog/2h-2023-energy-storage-market-outlook/

Kozlovas, P., Gudzius, S., Ciurlionis, J., Jonaitis, A., Konstantinaviciute, I., & Bobinaite, V. (2023). Assessment of Technical and Economic Potential of Urban Rooftop Solar Photovoltaic Systems in Lithuania. *Energies*, 16(14), Article 14. https://doi.org/10.3390/en16145410

Kuzemko, C., Blondeel, M., Dupont, C., & Brisbois, M. C. (2022). Russia's war on Ukraine, European energy policy responses & implications for sustainable transformations. *Energy Research & Social Science*, 93, 102842. https://doi.org/10.1016/j.erss.2022.102842

Liersch, S., Koch, H., & Hattermann, F. F. (2017). Management Scenarios of the Grand Ethiopian Renaissance Dam and Their Impacts under Recent and Future Climates. *Water*, 9(10), Article 10. https://doi.org/10.3390/w9100728

Lietuvos Respublikos energetikos ministerija. (2018). NATIONAL ENERGY INDEPENDENCE STRATEGY: ENERGY FOR LITHUANIA' FUTURE. https://enmin.lrv.lt/uploads/enmin/documents/files/National_energy_independence_strategy_2018(1).pdf

Lietuvos Respublikos energetikos ministerija. (2024, April 28). Planned Changes to Increase Energy Efficiency in Energy Transformation. https://enmin.lrv.lt/en/news/planned-changes-to-increase-energy-efficiency-in-energy-transformation/

Lietuvos vejo elektriniu asociacija. (2022). Wind energy in Lithuania 2022. Lvea.Lt. https://lvea.lt/en/lithuanian-statistics/

Lietuvos vėjo elektrinių asociacija. (2022, March 25). Offshore wind energy development in Lithuania is in the focus of attention of business and government, but approaches differ. Lvea.Lt. https://lvea.lt/en/offshore-wind-energy-development-in-lithuania-is-in-the-focus-of-attention-of-business-and-government-but-approaches-differ/

Maged, M. (2023). THE IMPORTANT ROLE OF REGULATION TO SCALE-UP RE DEVELOPMENT IN AFRICA TO ACHIEVE SDGS: LESSONS FROM NORTH AFRICA AND MIDDLE EAST. https://www.arei.info/docs/rub18ssr6/THE_IMPORTANT_ROLE_OF_REGULATION_TO_SCALE_UP___RE_DEVELOPMENT_IN_AFRICA_TO_ACHIEVE_SDGS___LESSONS_FROM_NORTH_AFRICA_AND_MIDDLE_EASTcalb469163.pdf

Media, F. (2020). Kruonis Pumped Storage Hydroelectric Power Plant (KPSHP) | Ignitis gamyba. Kruonis Pumped Storage Hydroelectric Power Plant (KPSHP) | Ignitis Gamyba. https://www.ignitisgamyba.lt/en/our-activities/electricity-generation/kruonis-pumped-storage-hydroelectric-power-plant-kpshp/4188

Ministry of Youth, Culture and Communication. (2016, February 5). Noor Ouarzazate, World's Largest Solar Power Complex. Maroc.Ma. https://www.maroc.ma/en/news/noor-ouarzazate-worlds-largest-solar-power-complex

Miskinis, V., Galinis, A., Konstantinaviciute, I., Lekavicius, V., & Neniskis, E. (2020). Comparative analysis of energy efficiency trends and driving factors in the Baltic States. *Energy Strategy Reviews*, 30, 100514. https://doi.org/10.1016/j.esr.2020.100514

Mukhtar, M., Adun, H., Cai, D., Obiora, S., Taiwo, M., Ni, T., Ozsahin, D. U., & Bamisile, O. (2023). Juxtaposing Sub-Sahara Africa's energy poverty and renewable energy potential. *Scientific* Reports, 13(1), 11643. https://doi.org/10.1038/s41598-023-38642-4

Murphy, C. (2022). Renewable-Storage Hybrids in a Decarbonized Electricity Supply. https://research-hub.nrel.gov/en/publications/renewable-storage-hybrids-in-a-decarbonized-electricity-supply

OECD. (2022). Africa Energy Outlook 2022. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/energy/africa-energy-outlook-2022_2abd9ce2-en

Ramírez, L., Fraile, D., & Brindley, G. (2019). World Energy Scenarios | 2019: European Regional Perspectives. World Energy Council. https://www.worldenergy.org/publications/entry/world-energy-scenarios-2019-european-regional-perspectives

Red Eléctrica. (2024, May 21). Press release- In 2023, Spain implemented the largest installed solar photovoltaic power system in its history. https://www.ree.es/es

REN21. (2022). RENEWABLES 2022: GLOBAL STATUS REPORT. https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf

Samrock, F., Grayver, A., Cherkose, B., Kuvshinov, A., & Saar, M. (2020). Aluto-Langano Geothermal Field, Ethiopia: Complete Image Of Underlying Magmatic- Hydrothermal System Revealed By Revised Interpretation Of Magnetotelluric Data. https://doi.org/10.3929/ethz-b-000409980

Sandri, S., Hussein, H., Alshyab, N., & Sagatowski, J. (2023). The European Green Deal: Challenges and opportunities for the Southern Mediterranean. *Mediterranean Politics*, 0(0), 1–12. https://doi.org/10.1080/13629395.2023.2237295

Simberg-Koulumies, N. (2024). Just sustainabilities: Lessons from the Lake Turkana Wind Power project in Kenya. *Local Environment*, 29(1), 40–56. https://doi.org/10.1080/13549839.2023.2249497

Skalamera, M. (2023). The Geopolitics of Energy after the Invasion of Ukraine. *The Washington Quarterly*, 46(1), 7–24. https://doi.org/10.1080/0163660X.2023.2190632

SolarPower Europe. (2023). EU Market Outlook for Solar Power 2023-2027. https://www.solarpowereurope.org/insights/outlooks/eu-market-outlook-for-solar-power-2023-2027/detail

Streimikiene, D., & Klevas, V. (2007). Promotion of renewable energy in Baltic States. *Renewable and Sustainable Energy Reviews*, 11(4), 672–687. https://doi.org/10.1016/j.rser.2005.03.004

United Nations Environment Programme. (2022). Emissions Gap Report 2022: The Closing Window—Climate crisis calls for rapid transformation of societies (DEW/2477/NA). https://www.unep.org/emissions-gap-report-2022

Varnagiryte-Kabasinskiene, I., Lukmine, D., Mizaras, S., Beniušienė, L., & Armolaitis, K. (2019). Lithuanian forest biomass resources: Legal, economic and ecological aspects of their use and potential. *Energy, Sustainability and Society*, 9. https://doi.org/10.1186/s13705-019-0229-9

Vezzoli, C., Ceschin, F., Osanjo, L., M'Rithaa, M. K., Moalosi, R., Nakazibwe, V., & Diehl, J. C. (2018). Distributed/Decentralised Renewable Energy Systems. In C. Vezzoli, F. Ceschin, L. Osanjo, M. K. M'Rithaa, R. Moalosi, V. Nakazibwe, & J. C. Diehl (Eds.), Designing Sustainable Energy for All: Sustainable Product-Service System Design Applied to Distributed Renewable Energy (pp. 23–39). Springer International Publishing. https://doi.org/10.1007/978-3-319-70223-0_2

Wagner, B., Hauer, C., Schoder, A., & Habersack, H. (2015). A review of hydropower in Austria: Past, present and future development. *Renewable and Sustainable Energy Reviews*, 50, 304–314. https://doi.org/10.1016/j.rser.2015.04.169

ISSN 2669-0195 (online) https://jssidoi.org/ird/
2025 Volume 7 Number 1 (March)
https://doi.org/10.70132/c7824282627

Wang, Y. (2006). Renewable electricity in Sweden: An analysis of policy and regulations. *Energy Policy*, 34(10), 1209–1220. https://doi.org/10.1016/j.enpol.2004.10.018

Wind, B. (2024, January 5). LVEA: Lithuanian Wind Energy Sector Achieves Milestones in 2023. Baltic Wind. https://balticwind.eu/lvea-lithuanian-wind-energy-sector-achieves-milestones-in-2023/

World Bank Group. (2004, April 5). Lithuania Country Assistance-Evaluation. https://documents1.worldbank.org/curated/pt/434161468773124836/pdf/Lithuania-Country-Assistance-Evaluation.pdf

World Bank Group, African Development Bank, & European Investment Bank. (2017). Morocco: Noor Ouarzazate Concentrated Solar Power Complex. https://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/2022-02/MoroccoNoorQuarzazateSolar_WBG_AfDB_EIB.pdf

Zhong, J., Bollen, M., & Rönnberg, S. (2021). Towards a 100% renewable energy electricity generation system in Sweden. *Renewable Energy*, 171, 812–824. https://doi.org/10.1016/j.renene.2021.02.153

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