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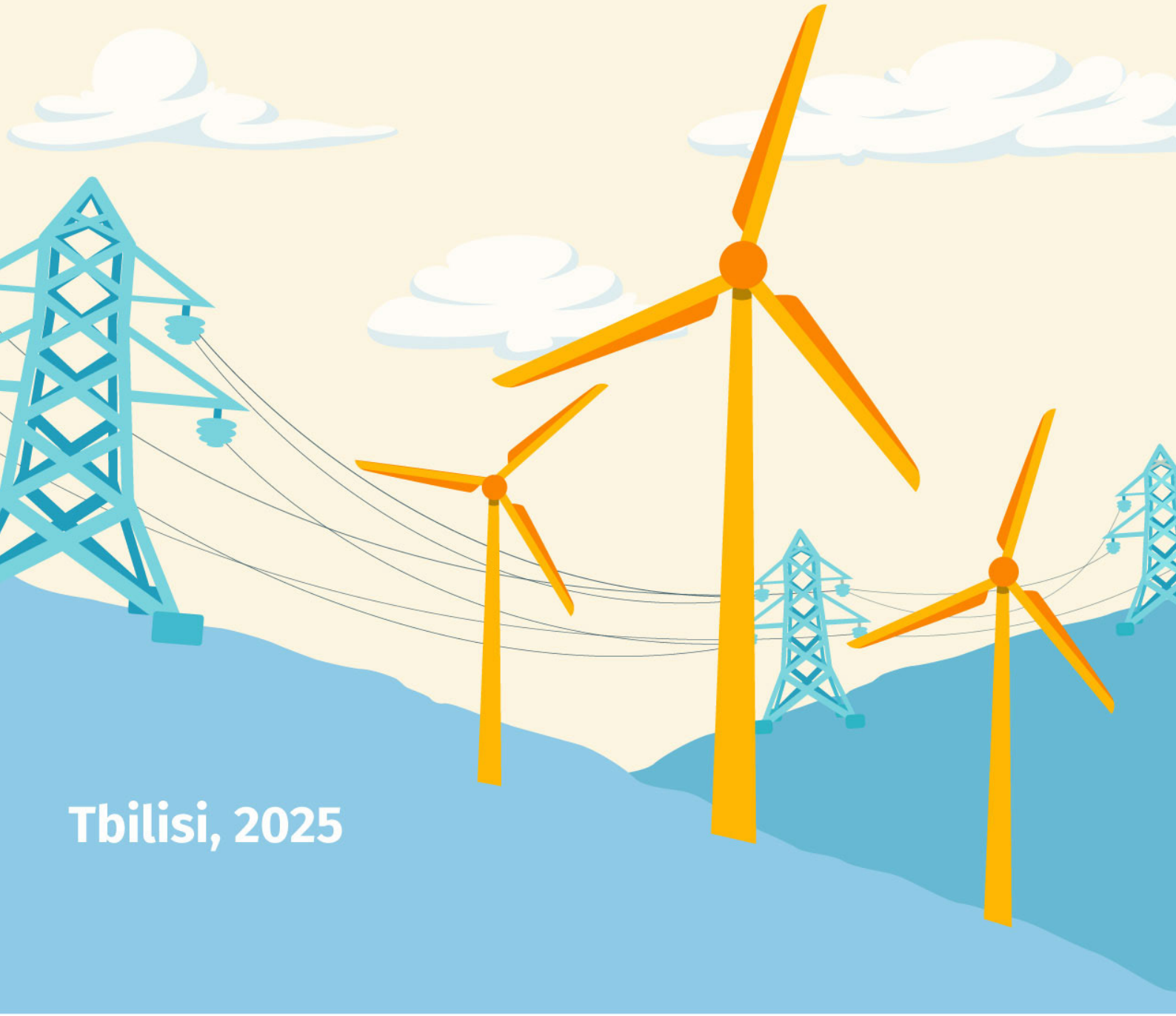
ENERGY SECURITY AND REGIONAL COOPERATION

Georgia, Armenia, Azerbaijan



Tbilisi, 2025

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About the Publication

This publication features original research conducted by young researchers from Georgia, Armenia, and Azerbaijan under the mentorship of esteemed experts in the field. The young researchers were selected through a competitive regional selection process. This initiative aimed to promote cross-border exchange, collaboration, and professional dialogue among the next generation of energy policy specialists in the South Caucasus region.

Each article examines a distinct dimension of energy security. They address critical gaps by analyzing the unique challenges and opportunities specific to Armenia, Azerbaijan, and Georgia. At the same time, they identify regional commonalities and potential areas for cooperation.

The articles were presented by their authors at an international conference in Tbilisi, Georgia. Beyond the policy research, this publication also captures highlights from the professional dialogue that emerged during the conference. It provides additional context and perspective on the policy research findings by presenting expert opinions on the selected research topics.

This publication was produced with the financial support of the European Union and UNDP. Its contents are the sole responsibility of the authors and do not necessarily reflect the views of the European Union and UNDP.

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Introduction

The South Caucasus has gained strategic significance in global geopolitics amid rapidly evolving regional dynamics. The forthcoming peace agreement between Armenia and Azerbaijan could transform decades of conflict into new opportunities for regional cooperation and development. This diplomatic achievement, coupled with the ongoing war in Ukraine, is fundamentally reshaping the region's security architecture and international relations. As Western countries seek to reduce their dependence on Russian energy resources, the South Caucasus has emerged as a crucial alternative energy transit corridor, with Azerbaijan's energy resources and Georgia's strategic location creating new patterns of economic interdependence. The Middle Corridor, a trans-Caspian international transport route connecting Europe and Asia through the South Caucasus, has gained significant momentum as an alternative to existing routes through Russia. This increases the region's importance in global trade and logistics networks. This evolution of the geopolitical landscape has attracted renewed attention from major powers including the European Union, the United States, Turkiye, and China. The region's energy infrastructure represents critical national assets that require protection from both conventional and cyber threats. Diversifying energy sources and routes has become fundamental to each country's energy security and influences their national and foreign policies.

Nikoloz Khatiashvili, Senior Research Fellow, Geocase

The Middle Corridor is emerging as a vital pillar of European security architecture. Amid growing instability and the fallout of Russia's war in Ukraine, this multimodal trade route offers a strategic alternative for Europe—diversifying energy and goods supply chains, enhancing energy resilience, and bypassing Russian-controlled territory. It strengthens ties between the EU, Central Asia, and South Caucasus countries, reinforcing regional cooperation and economic interdependence.

Georgia plays a central role, and its EU integration will further anchor the region in the West. The corridor's success requires continued investment, regulatory harmonization, and strong engagement from the EU and US. With strategic coordination, the Middle Corridor can serve as a bridge for peace, prosperity, and geopolitical stability not only for the South Caucasus, but across Eurasia.

Murman Margvelashvili, Director, World Experience For Georgia

The Central Asia and the Caucasus hold a pivotal role in the EU's strategy to enhance energy security and accelerate its green transition. While the EU pursues its 2050 net-zero goal, natural gas remains essential for stabilizing supply amid disruptions, such as those caused by Russia's invasion of Ukraine. The EU is deepening engagement with Azerbaijan and Turkmenistan, Kazakhstan, and Uzbekistan, though there is no investment decision on any strategic clean energy, while the new gas infrastructure, like the Trans-Caspian Pipeline, faces risks due to future decarbonization trends. At the same time, Central Asia's vast solar and wind resources position it as a potential global green energy hub.

Developing dual-use infrastructure—pipelines initially built for gas but adaptable to hydrogen or ammonia—offers a flexible solution to bridge current needs and future demands. Initiatives such as White Stream and Black Sea power interconnectors could form a " Green Energy Corridor with diversified mix of gas, hydrogen and electricity. However, challenges around financing, technology, security and multinational coordination must be overcome through stronger political will and strategic cooperation.

The Green Energy Corridor initiative, which aims to transport renewable energy from the energy resources-rich Caspian region to European markets, alongside the ambitious Black Sea Submarine Cable project connecting Azerbaijan, Georgia, and Romania, has positioned the South Caucasus as an important part of Europe's energy transition strategy. These projects promise to enhance regional energy security and represent strategic partnerships that extend beyond energy policy. As climate change accelerates the global energy transition, the South Caucasus countries face the additional challenge of balancing immediate energy security needs with long-term sustainability goals, highlighting the complex interrelations between energy security and national security in the region.

In this context of geopolitical transformation, transboundary cooperation on renewable energy presents a unique opportunity to address energy security concerns while simultaneously fostering regional integration.

Renewable energy collaboration offers energy security advantages that address each country's specific interests. For Azerbaijan, whose economy remains heavily dependent on fossil fuels exports, renewable energy development creates an opportunity for economic diversification while maintaining its strategic role as an energy exporter. Georgia, which imports approximately 70% of its energy, could enhance its energy independence by developing local renewable resources further and securing its position as an important transit hub in the European energy security architecture. Armenia can benefit significantly from developing domestic renewable energy sources, reducing its dependence on aging nuclear facilities, and participating in the economic benefits of regional electricity trade. Perhaps most importantly, this model of cooperation creates mutual economic interests that can support peace-building efforts.

Nino Maghradze, Head Of Regulatory And Commerce, Caucasus Clean Energy Holding

Georgia is emerging as a key player in the South Caucasus' transition to renewable energy, supported by its abundant hydropower resources and growing interest in diversifying through solar and wind. As the country continues to liberalize its electricity market, it is increasingly positioned to serve as a bridge between the region and Europe. A major step in this direction is the Black Sea Submarine Cable project, which will connect Georgia to Romania and facilitate the flow of green electricity to European markets.

This project enhances Georgia's role as a strategic energy link, contributing to regional energy security, deeper economic integration, and the development of sustainable partnerships.

Integrating digital technologies is another crucial step in enhancing energy security and regional cooperation. As Armenia, Azerbaijan, and Georgia modernize their energy infrastructure, digital transformation provides an opportunity to optimize energy systems, improve operational efficiency, and strengthen transboundary energy cooperation.

Technologies such as IoT sensors, blockchain, and advanced metering infrastructure optimize energy efficiency, promote transparent and secure transactions, and support integration of renewable sources. Additionally, digital tools facilitate proactive maintenance, effective energy storage management, rapid emergency response, data-driven policy-making, and international energy cooperation. Collectively, these digital measures build a resilient, efficient, and adaptable energy system, reducing vulnerabilities and strengthening overall energy security.

Artificial intelligence applications are particularly promising for strengthening energy security. AI-powered predictive analytics can significantly improve the forecasting of renewable energy production. This helps system operators anticipate fluctuations and maintain grid stability as the region introduces more intermittent renewable energy sources. Additionally, AI can also enhance the resilience of energy systems by identifying potential vulnerabilities and automatically implementing protective measures before disruptions occur. These capabilities are especially valuable amid cybersecurity threats and geopolitical tensions in this region.

The digitalization of critical energy infrastructure also introduces new vulnerabilities that must be proactively addressed. Recent worldwide incidents have demonstrated that energy infrastructure remains a prime target for cyberattacks motivated by geopolitical tensions, criminal activity, or other factors. The dual focus on leveraging digital innovation while strengthening cybersecurity will be fundamental to realizing the full potential of renewable energy cooperation and enhancing regional energy security.

Technological innovations and infrastructure development are the backbone of regional energy integration. However, the success of these initiatives ultimately depends on an informed civil society and policymakers.

Regional initiatives to enhance energy literacy offer unique opportunities for practical cooperation. Joint educational programs, including shared curricula, student exchanges, and collaborative research, can create space for transboundary dialogue and build regional expertise in the clean energy transition. Training programs for energy professionals in all three countries can establish common technical languages, which will facilitate future collaboration. By investing in human capacity alongside physical infrastructure and digital systems, the South Caucasus countries can establish the social foundation necessary for sustainable energy cooperation that withstands political fluctuations. In this way, energy literacy becomes not only a technical necessity but a strategic investment in the region's capacity to transform historical tensions into productive partnerships.

Alen Gasparian Amirkhanian, Director, AUA Acopian Center For The Environment

Energy literacy is needed to enable policymakers to make informed decisions and garner the political support of the public. Energy literacy is a critical enabler of the energy transition. It provides the understanding needed to make informed decisions about energy use, including where energy comes from, its political and economic costs, how it is consumed (including behavioral factors), and the environmental and social impacts of different energy sources.

An energy-literate population is more likely to adopt energy-efficient behaviors, invest in renewable technologies, and support policies that advance sustainability goals in a measured and effective manner, avoiding extremes. It fosters the ability to critically assess energy-related information, helping counter misinformation and build public trust in necessary reforms.

Why do we believe such initiatives, focusing on regional cooperation, matter?

- Energy security is a shared regional challenge, with countries facing similar risks.
- By bringing together energy policy experts, we can facilitate cross-border dialogue and knowledge exchange.
- Regional policy research and collaboration can provide valuable insights to EU stakeholders on national and regional energy security challenges, opportunities, and needs.
- Joint research and dialogue platforms support the next generation of energy security specialists with transboundary perspectives, creating a new professional generation.
- Energy cooperation initiatives provide concrete, practical entry points for broader regional integration, demonstrating immediate shared benefits that can build momentum for more complex political processes.

The Role of Digital Transformation in Enhancing Energy Security and Regional Cooperation in the South Caucasus

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This article was developed under the mentorship of Giorgi Mukhigulishvili, Lead Researcher in Energy and Sustainability Studies.

Introduction

The South Caucasus is at a crucial moment, where global pressures are increasingly affecting local tensions, especially in the area of energy security. The research suggests that digital transformation—through measures such as smart technologies (grids, meters), data-sharing platforms, and AI-driven infrastructure—has the potential to ease these challenges. As energy issues become more pressing, these technologies offer practical ways to shift from competition to cooperation, turning them into key drivers for regional stability. The focus here is not just on improving efficiency, but also on fostering shared stability and cooperation in the region through innovation.

The central research question guiding this analysis is: **"How can digital transformation enhance energy security and promote regional cooperation in the South Caucasus?"** By looking into this, it aims to show how technology can help open up dialogue and enhance energy security, ultimately supporting stability in a region that needs more cooperation.

This study focuses on Azerbaijan, Armenia, and Georgia, with an emphasis on the current situation in the region. While the historical context offers important background, the primary attention is on how recent developments, especially in digitalization and technology, are influencing energy security and regional cooperation today.

As Georgia and Armenia aspire to closer ties with the European Union, adapting their legal frameworks to align with EU standards is not just a requirement but a strategic necessity. A key aspect of this alignment lies in the development of a sustainable digital energy infrastructure—one that ensures efficiency, resilience, and long-term security. For Azerbaijan, the importance of a strategic

partnership with the EU underscores a similar need for modernization and cooperation. Investing in digital energy systems is not merely about technical upgrades; it is about creating an interconnected framework that enhances both national energy security and collective resilience. By prioritizing these advancements, the South Caucasus countries can not only strengthen their individual positions but also shape a future in which the region as a whole becomes more aligned, more adaptable, and better integrated into the evolving European energy landscape

This study starts by giving an overview of energy security in the South Caucasus, highlighting key challenges and the growing role of digital transformation in addressing them. Next, it explores various policy options based on the findings, showing how digital tools can improve energy security, modernize infrastructure, and boost cooperation between the South Caucasus countries. From there, the study recommends a practical policy, outlining clear steps to implement it and addressing any potential obstacles. In conclusion, it emphasizes the urgency of using digital transformation to tackle energy security in the South Caucasus, urging action to secure a more stable and sustainable energy future.

Methodology

The research adopts qualitative methods to explore digital transformation, energy security, and regional cooperation in the South Caucasus. Interviews with subject matter experts—Armen Danielyan, Dr. Zviad Gachechiladze, Girshel Chokhonelidze, and Dr. Fariz Ismailzade—were conducted to analyze trends, challenges, and opportunities related to these topics.

Primary data comes from interviews with experts and policymakers in Armenia, Georgia, and Azerbaijan on digital transformation, energy security, and regional cooperation. Informed consent was obtained from all participants. While expert interviews may introduce subjectivity, this is mitigated through cross-checking with secondary data. Additionally, the study's focus on the South Caucasus limits the generalizability of the findings to other regions. Secondary data includes relevant policy documents, reports, and academic articles. The study employs document analysis to identify patterns and gaps in digital transformation and energy security. Comparative analysis examines international models to assess their applicability to the South Caucasus. Thematic analysis is used to extract key themes from interview data, ensuring a clear understanding of the qualitative

findings. These methods collectively provide practical insights into the topic. The research is guided by three key concepts:

1. **Digital Transformation** - Defined as the integration and application of digital technologies to enhance energy infrastructure, optimize energy resources, and promote regional collaboration. Indicators include investment in digital infrastructure such as smart grids and data centers, adoption of digital energy management tools such as AI and IoT, development of regional digital strategies or policies, and levels of digital literacy and technology adoption within energy sectors.

2. **Energy Security** - Energy security pertains to the reliable and uninterrupted supply of various types of quality energy to all consumers within a country at affordable prices, while also safeguarding national security interests and ensuring sustainable development in the short, medium, and long term.

3. **Regional Cooperation** - Defined as the collaborative efforts between Armenia, Georgia, and Azerbaijan aimed at achieving shared energy security goals through digital transformation. Indicators include the existence of joint digital infrastructure or energy projects, regional policy frameworks addressing energy and technology integration, and interconnected energy grids or shared digital systems. These concepts provide context for interpreting the data.

Key Findings

Digital transformation can significantly enhance energy security by improving the resilience and efficiency of energy infrastructure. The adoption of advanced digital tools, such as smart grids, advanced metering infrastructure and predictive analytics, can enable real-time monitoring and management of energy resources, thereby reducing vulnerabilities associated with supply disruptions. Furthermore, the integration of digital technologies can facilitate the transition to sustainable energy practices, allowing for better resource management and the incorporation of renewable energy sources, which are essential for long-term energy security in the region.

From a regional cooperation perspective, digital transformation can act as a bridge for collaborative initiatives among South Caucasus states. Joint projects, such as energy management systems and shared data platforms, can facilitate better communication and coordination in energy planning and crisis response. (Alieva et al., 2007) **However, the success of such initiatives hinges on the**

political will and trust among the nations involved, which can be complicated by historical tensions and competing interests. Therefore, while digital collaboration offers promising avenues for cooperation, it must be approached with caution, acknowledging the underlying geopolitical dynamics that may hinder progress.

Looking at the regional context, each country in the South Caucasus faces distinct energy security challenges, shaped by their resources and geopolitical positioning. Azerbaijan, rich in oil and gas, has significant exports but is exposed to economic risks as global markets increasingly shift toward sustainability. (Econjournals.com, 2024) Armenia, on the other hand, lacks fossil fuels and depends heavily on Russian energy imports. Its reliance on Russian energy is partially offset by its trade in electricity with Iran, which plays a key role in Armenia's energy security. (Aslanidze, 2016) Armenia is seeking to diversify by strengthening ties with the EU, but outdated infrastructure remains a significant obstacle. Meanwhile, Georgia serves as an essential energy transit hub with pipelines that connect the region to Europe. (Margvelashvili and Mukhigulishvili, 2011) However, like its neighbors, Georgia faces the challenge of outdated energy infrastructure and depends on imports to meet its own energy needs. (Carnegie Endowment for International Peace, 2024) Commonly, all three countries face challenges stemming from obsolete infrastructure, inefficient energy consumption, and low energy diversification. They all suffer from outdated legal and institutional frameworks to foster energy efficiency and renewable energy development. Additionally, except Azerbaijan, Georgia and Armenia experience low per capita energy consumption due to low GDPs, and there is low economic cooperation between them. The varying degrees of dependence on external energy influences create significant challenges in stabilizing energy transit and fostering regional cooperation. The lack of coordinated regional energy policies and differing levels of energy security among these nations complicate efforts to ensure a sustainable and reliable energy supply across the South Caucasus. (Avedissian, 2020)

Therefore, the regional energy landscape underscores the interconnectedness of energy security and the need for cooperation and modernization across all three countries. At the same time, it highlights the importance of strategic investments in infrastructure, not only for energy security but also to support broader economic development. Just as digital transformation relies on equal access to infrastructure for growth and innovation, these countries need to focus on building strong, reliable energy systems to secure a sustainable future in today's interconnected world.

As mentioned above, digitalization refers to the integration of digital technologies into various sectors, fundamentally altering operations, processes, and interactions. In the energy sector, this transformation leads to more connected, intelligent, efficient, reliable, and sustainable energy

systems, driven by advancements in data analytics, connectivity, and digital applications. As the process evolves, the following trends can be observed:

Enhanced Efficiency and Productivity

Digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics enable energy systems to operate more efficiently. For instance, smart grids utilize real-time data to optimize electricity distribution, reducing losses and improving reliability. The IEA notes that smart grid technologies can lead to a 10% reduction in energy demand by 2040 through better management of heating, cooling, and lighting systems. Additionally, predictive maintenance powered by AI can reduce downtime in energy production facilities by up to 30%, significantly enhancing overall productivity.

Improved Energy Management

Digitalization allows for real-time monitoring and management of energy consumption. Smart meters and connected devices provide consumers with detailed insights into their energy usage, enabling informed decisions about energy conservation. This capability is crucial as the transport sector alone accounts for 28% of global energy demand, and optimizing energy use in this area can significantly reduce emissions. Furthermore, demand response programs, facilitated by digital technologies, can shift energy consumption during peak periods, alleviating stress on the grid and reducing the need for additional generation capacity. (OECD, n.d.)

Integration of Renewable Energy Sources

Digital technologies facilitate the integration of variable renewable energy sources, such as wind and solar, into the energy grid. Advanced forecasting tools and demand response systems help balance supply and demand, ensuring grid stability. The IEA emphasizes that digitalization can enhance energy security by improving the matching of energy demand to supply fluctuations. For example, real-time data analytics can predict solar energy generation based on weather patterns, allowing grid operators to adjust other energy sources accordingly, thus minimizing reliance on fossil fuels.

New Business Models and Market Dynamics

Digitalization is also giving rise to new business models, such as peer-to-peer energy trading and energy-as-a-service. These models disrupt traditional energy markets, allowing consumers to become active participants in energy generation and consumption. For instance, blockchain technology enables decentralized energy trading platforms

where consumers can buy and sell excess energy generated from their solar panels. However, this shift poses challenges for existing market structures and regulatory frameworks, necessitating updates to policies to accommodate these innovations.

Data-Driven Decision Making

Access to vast amounts of data enables policymakers and energy companies to make informed decisions. Digital tools can improve energy statistics, providing insights into consumption patterns and infrastructure needs. This data-driven approach is essential for developing effective energy policies and strategies. The IEA emphasizes that enhanced data collection and analysis can lead to better forecasting of energy demand and supply, ultimately supporting more sustainable energy planning. (IEA, 2017).

Digitalizing energy systems unlocks greater efficiency and reliability by streamlining operations, minimizing waste, and optimizing resource use. AI-driven analytics identify inefficiencies, while predictive monitoring enhances system stability, reducing the risk of outages. Smart grids take this a step further, automatically rerouting power to ensure uninterrupted supply. Beyond efficiency, digitalization drives significant cost savings and empowers consumers. Automation and data-driven decision-making lower operational expenses for energy providers, with estimates suggesting global savings of up to $1 trillion by 2030. At the consumer level, smart technologies offer greater control over energy consumption, enabling users to adjust usage in real-time and reduce costs. The environmental benefits are equally compelling. By improving efficiency and integrating renewables more effectively, digitalization contributes to emissions reduction, potentially cutting global CO2 output by 2.5 gigatons annually by 2040. This shift also fuels innovation, leading to new technologies, services, and economic opportunities within the energy sector. Security remains a crucial aspect of this transformation. Advanced monitoring and real-time data analysis help detect vulnerabilities early, while cybersecurity measures to safeguard critical infrastructure against potential threats, ensuring a more resilient and secure energy system. (IEA, 2017).

As the potential benefits of digitizing energy systems become increasingly clear, it is equally important to recognize the opportunities this transformation presents for enhancing energy security. In the South Caucasus, a region with a significant amount of energy resources such as oil, gas, and hydropower, digital technologies can be pivotal in optimizing resource management.

Through advanced analytics and IoT applications, the region can boost efficiency across extraction, distribution, and consumption, reducing reliance on external energy sources and fostering greater energy independence. Also, the region's significant renewable energy potential, particularly in

hydropower, wind and solar, can greatly benefit from digitalization, as integrating these sources into the existing energy grid would enhance both grid stability and resilience. In this context, smart grid technologies will play a key role in managing the intermittency of renewable energy generation, ensuring a consistent and reliable power supply.

Beyond national benefits, digitalization opens up opportunities for stronger regional connectivity. By improving energy trade and collaboration between South Caucasus countries, digital platforms can help optimize resources, boost energy security, and reduce costs through shared infrastructure and services.

Digitalization brings exciting opportunities but also presents some serious challenges, particularly when it comes to cybersecurity. As energy systems become more connected, they're increasingly vulnerable to cyber threats. These can range from malware attacks targeting critical infrastructure to breaches in supply chains or the manipulation of control systems. The risks are real, with the potential to cause serious disruptions to both the economy and society. This issue is compounded by the region's outdated infrastructure, which isn't equipped to handle modern digital threats. Without investment in both cybersecurity and infrastructure upgrades, energy systems in the region could become more susceptible to attacks that threaten energy security.

Furthermore, as digital systems become more integrated into the energy sector, they become prime targets for cybercriminals and state-backed attackers. As a cybersecurity consultant and expert, Girshel Chokhonelidze noted, the risks here are significant—everything from power grid failures to data breaches or disruptions in the energy supply chain. These are not just technical issues; they pose direct threats to national security and economic stability. To address this, Georgia needs a proactive approach. First, it's essential to strengthen cybersecurity regulations for critical energy infrastructure. Collaborating with energy companies, cybersecurity experts, and government agencies is key to sharing knowledge and improving practices. Regular cybersecurity audits, vulnerability assessments, and testing will also help identify weak spots. It's equally important to build up a skilled workforce that can recognize and handle cyber threats. That means investing in training and awareness programs. On top of that, Georgia should develop a solid incident response plan, bolster the national Computer Emergency Response Team (CERT), and improve communication between public and private sectors. Strengthening the cybersecurity of the power grid will make it easier to spot, contain, and recover from attacks.

Alongside cybersecurity concerns, the digitalization of energy systems also presents significant challenges in terms of market adaptation and the scalability of new technologies. Traditional en-

ergy markets may struggle to accommodate decentralized energy models, leading to regulatory gaps that hinder the smooth integration of innovative solutions. The high initial costs of implementing digital technologies further exacerbate this issue, particularly for smaller energy providers who may lack the financial capacity to compete with larger firms. The need for an agile regulatory framework, which can adapt to these changes while ensuring consistent standards for security and market operations, becomes paramount in this context.

The digital transformation of the energy sector also underscores the importance of human capital. As the workforce must acquire new skills in data analytics, cybersecurity, and digital technologies, there is a growing demand for professionals capable of supporting the transition. However, the rapid pace of technological change can outstrip the availability of skilled workers, leading to gaps that may undermine the effectiveness of digital systems. Moreover, increased reliance on these technologies introduces new risks: failure in the digital infrastructure could result in cascading operational failures, making it essential for energy providers to develop contingency plans that account for potential technological breakdowns.

Another critical issue is unequal access to digital technologies, which could aggravate existing energy inequalities. In the South Caucasus, as in other regions, not all consumers or communities have the same level of access to the digital infrastructure required for the benefits of energy digitalization to be fully realized. Addressing these disparities is essential, as ensuring equitable access to digital technologies can help foster a more inclusive and resilient energy system.

Although the energy sector in the South Caucasus faces complex and evolving challenges, there is a clear way forward. This path lies in the power of regional cooperation and the willingness to improve over time. Challenges like cybersecurity, infrastructure issues, and limited resources are not unique to the South Caucasus; other regions, including EU countries, face similar problems. However, these challenges have not been impossible to overcome in Europe, and we can draw valuable lessons from their experience. In fact, these challenges present a great opportunity for collaboration and growth.

However, it's essential to acknowledge that the EU's successes are the result of decades of research, development, and significant investments. For South Caucasus countries, while these innovations provide valuable learning examples, the reality is that implementing similar transformations will be a gradual process, requiring substantial groundwork in terms of research, innovation, and capacity building.

The EU has set ambitious targets, such as reducing greenhouse gas emissions by 55% by 2030 and achieving a 45% share of renewable energy in its overall energy mix. These goals are the result of years of careful planning and policy alignment across member states. For South Caucasus countries, setting similar long-term targets is important, but it's essential to understand that these changes won't happen immediately. Reaching such goals requires a steady, phased approach, beginning with foundational research and pilot projects. Once these initial steps prove successful, they can be scaled up. It's crucial for these countries to establish realistic objectives and targets that will allow for sustainable progress over time.

The EU has also made significant strides in digitalizing its energy systems. Technologies like smart grids, digital twins, and decentralized intelligence are now being used to optimize energy consumption and improve system efficiency. These advancements, however, are the result of decades of technological evolution and consistent investment. For the South Caucasus, digitalization presents a long-term aspiration. Developing digital technologies and integrating AI-driven solutions will all require considerable investment in infrastructure and capacity. Rather than expecting quick results, the focus should be on laying the groundwork by establishing foundational technologies and creating a regulatory environment that fosters innovation. In doing so, local startups and the wider digital ecosystem can gradually be supported and allowed to grow over time.

The EU's achievements in renewable energy and digital technologies owe much to its strong commitment to research and development (R&D). Initiatives like Horizon Europe and the Digital Europe Programme have been crucial in funding and supporting key innovation projects. This focus on R&D highlights the importance of building a strong base of innovation in the South Caucasus. Expecting immediate results without first investing in research, fostering an innovative culture, and collaborating with global and regional partners would be unrealistic. Without such investments, the region risks falling behind in the race to develop green energy solutions.

As energy systems become more digitalized, cybersecurity becomes an increasingly vital concern. The EU has made substantial investments to secure its energy infrastructure against growing cyber threats. The energy sector, particularly in Europe, has witnessed an alarming rise in cyberattacks, which doubled between 2020 and 2022, with 48 successful attacks targeting energy infrastructure in 2022 alone. These threats range from ransomware, which locks critical systems, to more complex multi-layered attacks, including denial-of-service (DoS) & DDoS attacks and supply chain vulnerabilities. (Eurelectric, 2025)

In the EU, these measures, however, have been developed over the years of responding to emerging threats and challenges. For South Caucasus countries, cybersecurity must be integrated into their digitalization strategies from the start. This requires significant investment in cybersecurity infrastructure, alongside ongoing capacity-building and training. Protecting energy systems from cyberattacks will take time and effort, and it will require international collaboration to address shared vulnerabilities.

One of the EU's major achievements has been its focus on designing energy systems that empower consumers, giving them the tools to manage their energy consumption. This consumer-centric approach has been essential to making the transition to more sustainable energy more equitable and accessible. However, this process is still ongoing, as the EU faces challenges related to consumer engagement and digital literacy. For South Caucasus countries, there is a need to invest in educating consumers, building digital literacy, and developing accessible tools that allow people to manage their energy use. This will take time, and it's important to set realistic expectations about the pace of widespread adoption.

For the South Caucasus, learning from the EU's experience offers valuable lessons. However, this must be coupled with a practical approach and realistic expectations. A gradual, well-researched strategy with incremental goals will be essential in navigating energy transformation. Progress will take time, but with careful planning and the right foundation, the region can move toward a more sustainable, digitally integrated energy future. (EU Commission, 2022)

What we've gathered from this is that while digitalization holds tremendous potential for strengthening energy security—offering benefits like enhanced efficiency, cost savings, and greater consumer control, also brings along a series of challenges that need to be addressed. In the South Caucasus, issues such as cybersecurity vulnerabilities, aging infrastructure, and the need for updated regulatory frameworks are particularly urgent. Equally important is ensuring that these digital advancements are accessible to all. Therefore, to fully use the power of digital transformation, it's essential to strike a careful balance: managing the risks effectively while advancing the opportunities that come with digitalization.

Moreover, a deal between Baku and Yerevan could open the door for investment in transport, trade, energy, and communications, while also easing border restrictions and paving the way for Armenia-Turkey relations to improve. The terms of such an agreement would also reshape the balance of power in the South Caucasus, which would foster more cooperation. (Melvin, 2024)

For regional collaboration to be effective, it must be inclusive and representative of all stakeholders, including civil society, private sector actors, and local communities. Engaging diverse perspectives can lead to more comprehensive solutions to energy security that address the unique needs and aspirations of each country. Furthermore, inclusive frameworks can enhance the legitimacy of collaborative efforts, ensuring that they are perceived as equitable and beneficial by all parties involved. **Building trust** is paramount for effective regional collaboration. Open channels of communication and dialogue can help dismantle the barriers of suspicion and foster a culture of cooperation. Initiatives aimed at promoting people-to-people connections and cultural exchanges can serve as foundational elements in establishing a cooperative spirit, which is essential for addressing shared energy challenges, such as resource management and infrastructure development. Such grassroots efforts can complement high-level diplomatic negotiations, creating a more conducive environment for collaboration.

As we look to the future, the significance of regional collaboration and cooperation has never been more pronounced. In a rapidly evolving global landscape, where neighboring regions are advancing swiftly, it is imperative for South Caucasus nations to actively pursue partnerships focused on resilience-building initiatives. Such initiatives are crucial, especially in the face of emerging threats like cybersecurity risks; when challenges arise, collective action becomes essential. By pooling resources and expertise, stakeholders can effectively address regional vulnerabilities and foster a more secure energy environment.

Ultimately, it takes joint efforts to tackle these pressing issues, and in a region that is interconnected in myriad ways, recognizing and leveraging these connections will be vital. Embracing a forward-thinking approach that prioritizes collaboration will not only enhance energy security but also contribute to a more stable and prosperous future for the South Caucasus.

Henceforth, it is imperative to adopt a nuanced and critical perspective that acknowledges the multifaceted nature of these advancements. Diverse stakeholders—from government officials to private sector leaders—must grapple with the inherent risks of digitalization, including cybersecurity vulnerabilities and the potential for exacerbating existing inequalities. By fostering an inclusive dialogue that embraces varied viewpoints, stakeholders can collaboratively navigate the challenging landscape of digital energy transformation, ultimately striving for a future that is not only secure and cooperative but also equitable and resilient against the backdrop of shifting geopolitical dynamics. Embracing collaboration is not just a strategic choice; it is imperative for the region's resilience and long-term sustainability.

Policy Recommendations

The following chapter will outline a set of policy recommendations designed for the South Caucasus region. It will assess their feasibility, efficiency, and effectiveness within the regional context, providing a balanced evaluation of their potential for implementation and impact.

1. Building Resilience Through Regional Cooperation

The digital transformation of energy systems in the South Caucasus will benefit from increased collaboration across the region. This approach stands as the recommended option due to its practicality, cost-effectiveness, and significant impact on enhancing digital energy security while fostering long-term regional cooperation. The following initiatives could help build the necessary technical and policy expertise and serve as a good starting point:

Knowledge and Expertise Sharing: Exchanges of knowledge and best practices could serve as a strong foundation for progress, with joint workshops and seminars offering a practical way to build expertise in digital energy systems. Given the relatively low cost and the region's increasing focus on digitalization, such initiatives are both feasible and beneficial. From Armen Danielyan's perspective, an expert in energy economics and electricity market regulation and an Adjunct Lecturer at the American University of Armenia, while knowledge exchange is essential, countries must protect sensitive data and avoid sharing vulnerabilities, ensuring that cooperation moves forward in a way that respects national security. One effective way to enhance cybersecurity readiness is through table-top exercises, where professionals come together to simulate cyber-incident scenarios. For instance, a joint exercise that simulates an attack on energy systems would allow participants from the South Caucasus to practice response strategies, identify weaknesses, and learn from each other's expertise.

Girshel Chokhonelidze emphasized that in this area, the countries can draw inspiration from global leaders in digital energy. Estonia, for example, has set a benchmark with its use of blockchain for energy transactions and robust cybersecurity practices. Germany's advancements in smart grids, Singapore's AI-driven energy management systems, and the Nordic countries' integration of renewable energy with smart grid technology all offer valuable insights. Additionally, Dr. Zviad Gachechiladze, an expert in energy management

and Director of Development for Organized Markets, Interconnection, and Electricity Metering Issues at Georgian State Electrosystem, pointed out that Austria's experience with Siemens Energy's digital tools could offer valuable insights for the South Caucasus. With proven solutions like grid automation (Siemens-energy.com, 2025) and energy management systems already in use across several EU countries, including Austria, these technologies could help the region modernize its energy networks.

Regional Energy Diplomacy Workshops: In the view of Dr. Fariz Ismailzade, Director of the Institute for Development and Diplomacy and Vice Rector at ADA University, workshops focused on boosting diplomatic engagement in energy security could play a key role in strengthening regional cooperation. These sessions would tackle common challenges, build trust, and help craft unified strategies for digitalizing energy systems. With the current momentum in regional dialogue, this initiative has the potential to be both practical and impactful. (Poghosyan, n.d.)

Regional Training Programs in Digital Energy Systems: By building on the region's existing institutions and the growing need for digital energy expertise, these programs can make a real impact. Traineeships and internships with regional partners can also help close the experience gap. They offer hands-on learning and valuable insights while boosting collaboration and creating stronger connections across the region.

As noted by Dr. Zviad Gachechiladze, energy companies should offer hands-on training and internship programs to help students and professionals gain real-world experience. Public-private partnerships can provide additional funding and expertise, ensuring that training programs are aligned with actual industry needs.

Regional Workforce Digitalization Capacity-Building: Each country could establish its own workforce reskilling program focused on digital energy technologies. Upon completion, professionals could convene in regional meetings to share knowledge and expertise, fostering collaboration and enhancing the collective capacity for digital energy management across the region.

Therefore, a well-educated workforce with digital skills is crucial for leveraging the benefits of digital technologies in energy management. Also, the role of supportive institutional frameworks in promoting innovation and the diffusion of green technologies is essential for achieving sustainable energy transitions. (Thanh et al., 2022)

2. Building Resilience Through Community Involvement

Developing technological and institutional resilience in digital energy systems requires sustained collaboration between academia, industry, and local communities through shared knowledge production, skill-building, and applied research. Building on that perspective, Dr. Zviad Gachechiladze observed that establishing joint training programs and university exchange initiatives at the Bachelor's, Master's, and Doctoral levels can play a crucial role in strengthening expertise in digital development and energy security. At the bachelor's level, these programs enhance grassroots awareness and foundational skills, while at the Master's and Doctoral levels, they foster advanced research collaboration, equipping experts with the knowledge necessary to address emerging challenges.

To put this into action, the first step is for each country to develop its own training programs in digital energy. Universities and technical institutes should work with industry experts to create courses that align with the sector's needs. Reflecting on this matter, Dr, Zviad Gachechiladze observed that in Georgia, for example, there is a growing demand for educational programs in energy security across Bachelor's, Master's, and PhD levels. However, many universities have yet to introduce relevant courses into their curricula. Expanding academic programs in this field would not only address the skills gap but also ensure that the next generation of professionals is equipped to manage the country's evolving energy landscape. Governments can support this effort by offering scholarships and incentives for students pursuing careers in digital energy technologies. Once national programs are in place, regional knowledge exchanges can bring professionals together to share best practices. Workshops, study visits, and university partnerships with European institutions can provide access to global expertise, ensuring that the region remains up to date with the latest developments in digital energy. These exchanges would also create opportunities for collaboration in a way that respects security considerations.

Hence, by integrating these initiatives into existing educational frameworks, institutions can foster lasting partnerships that drive innovation, inform policy development, and yield practical solutions through applied research, policy innovation, and direct industry engagement.

3. Leveraging International Partnerships

Collaborating with international partners will be essential in overcoming the challenges associated with energy digitalization in the South Caucasus. Partnerships with energy organizations, financial institutions, and private sector actors can provide access to advanced technologies, financial resources, and expertise in energy system management. This effort is closely tied to the first point—partnering with European universities, for instance, can expand academic exchanges and facilitate professional knowledge-sharing, equipping local experts with the latest insights in digital energy solutions. These connections not only enhance technical capabilities but also create pathways for innovation and policy development, ensuring that the region stays aligned with global advancements.

4. Investing in Renewable Energy Projects with Digital Management

Investing in renewable energy projects supported by digital management tools could significantly enhance energy security, sustainability, and integration within the region. These projects might include digital platforms to monitor and optimize energy flows between countries. The feasibility of such projects is strengthened by the growing interest in renewable energy and the increasing availability of digital management tools for energy systems.

5. Encouraging Private Sector Investment in Digital Energy Systems

Incentivizing private sector investment in digital energy infrastructure could play a pivotal role in scaling up technologies like smart grids and renewable energy integration. Tax incentives, subsidies, or public-private partnerships (PPPs) could be used to attract investors. This approach can be feasible due to the growing attractiveness of the energy sector to private investors and the regional government's potential interest in fostering green technologies.

Conclusion

In conclusion, the intersection of digitalization and energy security presents a profound duality, embodying both unprecedented opportunities for innovation and significant challenges that demand our immediate attention. As technological advancements unfold at an accelerated pace, the necessity for comprehensive security risk assessments becomes paramount; these assessments must not only address existing vulnerabilities but also anticipate emerging threats that could compromise regional stability. The complexity of fostering effective regional cooperation in this critical domain underscores the need for a nuanced approach, where every aspect of energy security is subjected to rigorous scrutiny and validation.

While the vast data provides valuable insights, making sense of it requires a deeper, more strategic approach. Tackling complex challenges isn't just about access to information—it's about how effectively stakeholders collaborate. Governments, technology industries, ministries, and the private sector must work in synergy, ensuring that resources are mobilized with a clear purpose and aligned with broader objectives.

Finally, it is vital to systematically assess the objectives of our initiatives, clarify the specific goals we aim to achieve, and outline the actionable steps required to create a resilient and secure energy framework for the region.

While the advantages of digitalization are considerable, they come with inherent risks that demand a thorough and pragmatic evaluation of our resources and limitations. **Enhancing regional dialogue, building trust, and establishing collaborative partnerships can significantly expedite the resolution of existing challenges;** however, this process requires a sincere commitment to mobilizing resources and a collective readiness to confront historical obstacles. By coming together, these nations can accelerate the development of resilient, efficient, and sustainable energy systems, far beyond what they could achieve individually. Through collaboration, they can not only catch up with the fast-evolving digital landscape but also position themselves as leaders in this transformation, with the power to share their expertise and set a benchmark for others to follow. Ultimately, by prioritizing these efforts today, the region can fully unlock the potential of digital technologies for energy security. Absent such trust and dedication, our initiatives risk being ineffective, leaving us exposed to the vulnerabilities we strive to address.

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Domestic and regional energy literacy and cooperation attitudes in the South Caucasus in the context of energy security and green transition: A student perspective

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Acknowledgments

I would like to express my sincere gratitude to the World Experience for Georgia (WEG) and the American University of Armenia (AUA) Acopian Center for the Environment for their support in facilitating this research. I would also like to extend my gratitude to the European Union for their generous support of this initiative through the United Nations Development Programme (UNDP). Additionally, I am deeply grateful to my mentors, Mr. Armen Danielian, Mr. Alen Gasparian Amirkhanian, and Dr. Uros Prokic, for their guidance and encouragement throughout this journey.

Introduction

Sustainable policies centered on energy transitions necessitate not only appropriate infrastructure, regulatory landscape, and political will but also an energy-literate public that is informed on and in line with such policies (IEA, 2023; Santillan & Cedano, 2023). Environmental education, including energy literacy, is fundamental not only for public support of adopting sustainable policies but also for the more extensive and efficient use of the technologies that result in successful policy implementation – installation of solar panels and electrification of end-services, to name just a few (Mehmood et al., 2022; Ramachandran et al., 2023). In addition to technological advancements within the energy sector, energy literacy and attitudes toward green transition are critical for obtaining general public approval of various environmental fees and taxes or higher costs of clean energy (Sovacool & Blythb, 2015; Solarz et al., 2023). Along with instilling responsible energy consumption behavior, environmental education assists students in making informed decisions and participating in social and political activities, underscoring the interconnectedness of human activity and climate change (Bekele et al., 2024; Bialynicki-Birula et al., 2022; DeWaters & Power, 2012; Dwyer, 2011; Gladwin & Ellis, 2022; Khuc et al., 2023; Martins et al., 2020). A stark example is South Korea actively placing importance on education in preparing young individuals for political

engagement and career aspirations in the field of renewable energy (Jorgenson et al., 2019). Likewise, research conducted among the youth in Austria, Croatia, Greece, Slovenia, and Poland has demonstrated that environmental education is a determining factor in shaping increased energy literacy (Kovacic et al., 2024). Therefore, environmental education entails the provision of better access to information, assisting students in comprehending complex energy concepts (Kovacic et al., 2024).

It can further be noted that an energy-literate public can be pivotal in supporting policies centered on regional energy cooperation. When it comes to the role of energy literacy in promoting regional cooperation, studies have shown that Denmark has a profound history of policy support for renewable energy sources, such as wind energy, which is reflective of the broader cultural attitudes and higher energy literacy levels in Denmark (Sovacool & Blyth, 2015; Simcock et al., 2016). Likewise, in Germany, the population has maintained robust and stable support for renewable energy sources. As a result, both countries have substantially benefited from regional cooperation in the context of green transition, with the implementation of projects such as Bornholm Energy Island, connecting wind farms through a single hub, and transporting green electricity to consumers in both countries (Bornholm Energy Island, 2021).

Building on the above discussion, the focal point of this paper involves gaining a preliminary understanding of the energy literacy levels among undergraduate students alongside studying their attitudes toward green transition, energy security, and regional energy cooperation in the South Caucasus (Armenia, Azerbaijan, and Georgia) to propose an initial course of action centered on energy literacy initiatives extending across formal and informal educational settings. Given that there is a lack of research focusing on energy literacy levels and attitudes toward regional cooperation in the energy sector among students in the region, the research aims to fill in an academic gap and propose courses of action derived from the research findings.

The research conceptualizes energy literacy (including a regional awareness component) among university students in the South Caucasus as being sufficiently knowledgeable about 1) the primary sources of electricity and heating, 2) the share of renewable energy in the energy mix, 3) the proportions of imported energy, and 4) percentages of energy supply deriving from fossil fuels in all three countries, respectively. As a result, within the scope of this policy paper, students' energy literacy levels have been assessed alongside their attitudes toward domestic energy transition, energy security, and the potential for regional cooperation in this regard.

Contextual overview of energy literacy in the South Caucasus

Historically, it should be noted that at the beginning of the 1990s, the countries of the South Caucasus were facing significant challenges in sustaining reliable provision of energy services following the collapse of the Soviet Union. The political instability and the disruption of the critical infrastructure in the region generated concerns over energy security, which were addressed differently based on each country's needs and natural endowment. These factors can result in different approaches and implications when addressing environmental concerns. Nonetheless, energy-literate citizenship and its acceptance of energy policies are common prerequisites for all three countries, including when questions of regional cooperation are raised in dealing with the problems of security and emissions reduction.

In the context of weak institutional capacity in the South Caucasus, efforts have been made by non-governmental bodies and private entities to initiate energy literacy programs in Georgia and Armenia. Particularly, measures have been implemented aimed at increasing awareness centered on sustainable energy and the development of sustainable energy policies in Georgia (Heinrich-Boll-Stiftung, 2014). In Armenia, the "Financial and Environmental Literacy to Promote Energy Efficiency of Communities in Armenia" (FELCA) initiative was implemented, encompassing 237 two-day courses in 167 rural communities, with 3,650 participants. As part of the Ecoserva environmental program, the initiative was run in partnership with ministries and was supported by the German Society for International Cooperation (GIZ). The initiative was implemented by the Armenian branch of the German Sparkassenstiftung for International Cooperation (DSIK) (RA Ministry of Environment, 2022). In addition, research in the field has likewise been conducted, e.g., a study in Azerbaijan which highlighted that literacy levels and renewable energy consumption mutually affect each other (Huseynli, 2024).

Energy security concerns coupled with the need for green transition persist in the South Caucasus, necessitating the establishment of regional cooperation measures. The reports (2023) of the International Energy Agency (IEA) underscore the need for energy diversification in the South Caucasus to achieve energy security and green transition. In particular, Armenia's challenges stem from reliance on imported natural gas, outdated infrastructure, and untapped renewable energy poten-

tial (IEA, 2023). In Georgia, only 22.5% of hydropower capacity is utilized, while solar and wind resources remain largely untapped (IEA, 2023b). Overreliance on hydropower further emphasizes the country's need for energy diversification (IEA, 2023a). Furthermore, the need for energy diversification is likewise pronounced in Azerbaijan, given its reliance on oil and gas. Thus, "the current situation of energy security in South Caucasus countries can still be considered risky. To reduce the risk, there is a need to increase the use of renewable energy sources and increase the efficiency of energy use" (Aliyev et al., 2024, p. 662).

As mentioned in the previous section, an evaluation of the public's energy literacy and attitudes can provide insights into the implementability of regional energy policies. Within the scope of this study, university students were selected to be surveyed on energy literacy and attitudes as an easy-to-access group as well as representative of the voting population with higher education levels. The resulting data can provide insights into the potential challenges of implementing regional energy policies given the students' energy literacy and attitudes, followed by proposed approaches to address these challenges.

Survey methodology

An online self-administered survey methodology aiming to assess the domestic and regional energy literacy levels and attitudes towards regional cooperation in the context of energy transition and security has been implemented among undergraduate students in Armenia and Georgia. The online survey questionnaire comprises 28 questions with four subsections. The collected data has been analyzed using descriptive statistics. In order to maintain anonymity, the demographic data of the surveyed individuals have been aggregated into broader categories for analysis to ensure no identifiable information is disclosed. The online survey was circulated in Armenian and English. The surveys have been disseminated across universities in Armenia and Georgia through social media groups, internal communications channels, and e-mail addresses. As a result, 43 responses have been collected from the Armenian version of the survey and 30 responses have been collected from the English version of the survey, the latter including 13 respondents from Georgia and 17 respondents from Armenia. Consequently, overall 60 responses have been gathered from Armenia and 13 from Georgia.

Survey data findings

Based on the collected online survey data with 60 (82.2%) respondents from Armenia and 13 (17.8%) respondents from Georgia, the average domestic and regional energy literacy score on a 15-point-scale for the surveyed students is 8.1 for Georgia and 7.8 for Armenia, respectively. Nonetheless, due to the unequal response rates between the two countries, conclusions involving direct comparisons cannot be made. Overall, for both countries, the surveyed students have demonstrated moderate levels of literacy, with scores relatively above the halfway point, that is, 7.5 on a 15-point scale. As for the surveyed students' attitudes toward the green transition and energy security, as well as their views on regional cooperation in this context, the table below presents the average ratings of their responses to the provided attitude statements.

Figure 1. The average rating for attitude statements on the energy transition and security

Scale: 1 - strongly disagree; 2 - disagree; 3 - neutral; 4 - agree; 5 - strongly agree

Attitude statements	Average rating
My country should invest in shared renewable energy projects in the South Caucasus even if other countries benefit more than mine.	2.7
My country should prioritize transitioning to renewable energy, even if it may pose risks to energy security.	3.1
Political and historical tensions in the South Caucasus region make it unrealistic to achieve effective energy cooperation.	3.4
In order to increase the share of renewables in its energy mix, my country should collaborate with other states in the South Caucasus.	3.5
My country should move away from fossil fuels, such as oil, gas, and coal, and adopt renewable energy, such as hydro, wind, and solar, even if it leads to higher electricity costs.	3.6
Regional cooperation with all the countries in the South Caucasus should be a priority for my country in the context of energy development.	3.6
My country should focus on developing its own energy resources rather than relying on regional cooperation in the South Caucasus.	3.6
My country should prioritize renewable energy over fossil fuels in its trade policies.	3.9
My country should prioritize transitioning to a higher share of renewable energy sources to reduce its emissions.	4.4
My country should prioritize transitioning to renewable energy to improve its energy security.	4.4

When it comes to the attitudes towards domestic energy transition and security coupled with attitudes toward regional cooperation, it should be noted that the surveyed students of both countries maintain favorable attitudes towards their countries transitioning to a higher share of renewable energy sources to reduce emissions with an average weighted 4.4 on a scale of 1-5 (see Figure 1). The same is true about attitudes toward transitioning to renewable energy to improve energy security in their countries, respectively. On another note, the respondents lean toward moderate support (an average of 3.6) for renewable energy adoption if it results in higher energy costs; similarly, they are more hesitant to energy transitions if it involves an energy security trade-off (an average of 3.1). Additionally, there is clear support (an average of 3.9) for their countries prioritizing renewable energy over fossil fuels in their trade policies.

With regard to the attitudes toward regional energy cooperation, the survey respondents in both countries showcase moderate support for regional energy cooperation in the context of energy development (an average of 3.6) and an increasing share of renewables in the energy mix through regional cooperation (an average of 3.5). The data further reveals a mixed or ambivalent perspective since the respondents likewise moderately support self-reliance in terms of the development of energy resources (an average of 3.6). Furthermore, the surveyed students were significantly less likely (an average of 2.7) to maintain favorable attitudes toward the development of shared renewable energy projects in the South Caucasus in cases when other countries would benefit more. Lastly, respondents have demonstrated a moderate level of agreement (an average of 3.4) with the statement that political and historical tensions in the region make it unrealistic to achieve effective energy cooperation.

Grounded in the above-elaborated findings, it can be deduced that the surveyed students in Armenia and Georgia have moderate domestic and regional energy literacy levels, showcasing room for improvement. The target population maintains relatively favorable attitudes towards transitioning to renewable energy sources to reduce emissions and enhance energy security on a domestic level. Nonetheless, moderate or low levels of agreement are observed regarding regional energy cooperation within the context of achieving green transition and energy security at the regional level. The findings highlight the need for policy analysis aimed at crafting measures to address the gaps in energy literacy among the students, along with facilitating dialogue and engagement on the benefits and feasibility of cross-border collaboration within the context of energy security and green transition in the South Caucasus.

Policy alternatives

Description of the policy alternatives

To establish the best course of action, it is necessary to delve into the policy alternatives in an attempt to foster energy literacy levels and awareness-raising efforts of regional cooperation opportunities and challenges among the students. Within the scope of this research, three main policy alternatives have been established, as presented in Figure 2 below:

Figure 2. Key elements of proposed policy alternatives

Policy alternatives	Policy description	Illustrative cases
1. Maintaining the status quo, that is, preserving the current state of affairs	• Suggests that "keeping present policies or programs, or defending them, maybe a viable option" (Kraft & Furlong, 2018, p. 268). • Implies that currently implemented efforts (if any) aimed at promoting domestic and regional energy literacy in the context of green transition and energy security seem viable.	Not applicable
2. Introducing an institutionalized formal educational approach	• Entails the integration of domestic and regional energy literacy within the undergraduate curriculum in higher education (HE) institutions in the South Caucasus.	• Sweden has integrated education for sustainable development (ESD) within its national curricula, from preschool to adult education (Manni, 2023). Adult education is a rather extended reach, including non-degree and practical learning for adults.
3. Introducing a non-institutionalized informal educational approach and communication strategies implemented jointly by government agencies, civil society, media organizations, and HE institutions	• Encompasses implementing initiatives including but not limited to educational/research programs, volunteering, community-led activities, and/or other forms of activism with the engagement of the state, civil society actors, media organizations, and higher education institutions. • Involves awareness-raising efforts and increased public dialogue through media campaigns, expert discussions, public forums, and digital outreach, encouraging active and informed discourse on domestic and regional energy challenges and opportunities.	• In Spain, the integration of theoretical and practical aspects of energy literacy—through extracurricular activities like volunteering, internships, clubs, and sustainability events—has showcased its impact on shaping energy-related knowledge, attitudes, and behaviors (Martinez-Borreguero et al., 2024; Miller et al., 2024). • The "Energiewende" campaign in Germany has raised awareness about the country's shift to renewable energy and energy efficiency. It encompassed extensive public outreach and collaborations between government agencies and NGOs (Clean Energy Wire, 2018).

3.2. Evaluation of the policy alternatives

"Education Strategy 2030," established by the Ministry of Education, Science, Culture and Sports (MoESCS) in Armenia, has made a limited effort for curriculum integration of environmental education, suggesting that energy literacy has not yet been a central focus in educational reforms (European Training Foundation [ETF], 2023). In addition, governance and capacity constraints, along with the required financial and human resources to administer educational reforms effectively, pose coordination and scaling challenges. On another note, the number of civil society organizations that implement educational programs and participate in the discussion of educational policies within the formal education sector has significantly increased (UNICEF, 2022). Nonetheless, the higher education and research landscape in Armenia is also fragmented, and there is a general lack of energy specialists (IEA, 2022). Additionally, the MoESCS lacks a comprehensive analysis of education policy implementation and does not apply a region-specific approach. Furthermore, the monitoring efforts in education remain unclear, with no defined mechanisms for oversight (UNICEF, 2022). Funding for education, research, and innovation pertaining to the energy sector lacks a specific strategy, and most funding is sourced from project-based contracts with international organizations (IEA, 2022; UNICEF, 2022).

As for Georgia, to address the existing educational loopholes in the country, the state has increased financial allocations within the education sector as an attempt to ensure "[...] the professional development of teachers, increase accessibility and quality of vocational education are the focus areas of planned reforms, with the main goal being to increase human capital and respond to labor-market demand" (Bochorishvili & Peranidze, 2020, p. 2). As for the cooperation and coordination efforts, "[...] civil society organizations (CSO) provide training and capacity-building services for the government, the media, and other CSOs" (Asian Development Bank [ADB], 2020, p. 4). The country has a well-established civil society landscape that is actively engaged in the organization of educational, sports-related, and cultural activities. The cooperation efforts between the industry, academic, and research institutions have primarily been limited, and the integration process of environmental education, including energy literacy within the curricula of the HE, has been proposed by the IEA (2020). The IEA report (2020) further emphasizes the potential of fostering energy expertise in the country. In addition, Georgia's established system for educational monitoring is largely inconsistent (Li et al., 2019). As for operational funding, Georgia spends more per capita on primary or secondary education, placing limited public funding for higher education institutions (Li et al., 2019).

The context descriptions centered on Armenia and Georgia above showcase that under policy 1 – status quo, the current challenges would persist; a shift toward policy 2 – institutional approach would entail government-led structural reforms, requiring state funding and capacity-building efforts; alternatively, policy 3 – non-institutional approach would imply joint cooperation and coordination efforts between the state officials, civil society, media actors, and HE institutions ensuring flexibility but inconsistent implementation.

In an attempt to evaluate policies based on the above-elaborated context, the table below encompasses an analysis of the feasibility of the proposed policy alternatives, basing the analysis framework on the PASTEL technique with regard to the political and administrative factors (Herman, 2013). The analysis further expands on contextually relevant factors, namely political (feasibility), administrative (institutional capacity), technical (human resources and expertise), evaluative (effectiveness and impact), and operational (financial and logistical viability) components.

Figure 3. Evaluation of the feasibility of the proposed policy alternatives in the South Caucasus

Analysis component	Indicators for appropriateness	Institutional approach	Non-institutional approach
1. Political feasibility	• Political will and support • Political context	Moderate	High
2. Institutional capacity	• Coordination and co-operation (state, civil society and HE) • Scaling capacity	Moderate	High
3. Human resources and expertise	• Availability of qualified energy experts and educators	Low	Moderate
4. Evaluative	• Effectiveness and impact	High	Moderate
5. Operational	• Availability of funding and resources	Low	High

The discussion above showcases that in terms of the factors presented in the table (see Figure 3), implementable policy alternatives revolve around policy recommendations focusing on introducing a non-institutionalized informal educational approach coupled with communication strategies advanced by government agencies, civil society, media organizations, and HE institutions in an attempt to advance domestic and regional energy discourse centered around energy security and green transition in the South Caucasus. Nonetheless, for effectiveness and impact, there is high feasibility for a formal institutionalized educational approach to energy literacy since it ensures long-term and consistent impact.

Recommended policy

Steps for enactment of proposed policy

Driven from the above-discussed policy alternatives, it should be noted that integrating informal education with a strategic communication plan driven by joint efforts from the government, civil society, media, and HE institutions is contextually implementable within the current realities. Taking into account the structural educational reforms requiring long-term policy measures, a non-institutionalized informal approach can be feasible for both countries, considering factors such as political feasibility, institutional capacity, along with the availability of resources and expertise. The table below outlines the steps centered on the implementation of the policy:

Figure 4. Steps for enacting the best course of action

Steps toward **a non-institutional, informal education approach and communication strategies** led by government agencies, NGOs, and media organizations.	Description
Step 1. Develop a comprehensive energy literacy program with theoretical and practical components ongoing throughout the year for students in HE. **1.1.** Design online courses on energy-related topics. **1.2.** Integrate workshops, seminars, and or panel discussions on energy-related topics. **1.3.** Organize student-led initiatives.	• Develop online platforms for open-access learning on energy-related issues. • Ensure the availability of updated, accurate educational resources on energy topics on the platform. • Organize face-to-face meetings facilitating energy discourse. • Encourage students to create and manage energy literacy campaigns or projects on campus or within their communities.
Step 2. Leverage media and digital platforms. **2.1.** Utilize social media, online forums, and educational websites to disseminate accessible energy-related content. **2.2.** Develop interactive materials such as videos, infographics, and podcasts to engage diverse audiences.	• Collaborate with media outlets, journalists, and influencers on diverse social media platforms to disseminate energy-related information. • Establish an online resource hub where students and the general public can access up-to-date energy-related information.
Step 3. Evaluate and monitor the policy progress. **3.1.** Establish Key Performance Indicators (KPIs) to track progress effectively. **3.2.** Conduct regular assessments and feedback loops to sustain quality and consistency.	• Define indicators such as student participation rates, engagement metrics on digital platforms, and knowledge retention assessments. • Conduct regular surveys, stakeholder consultations, and impact evaluations to identify gaps and ensure improvement of the implemented initiatives.

Challenges and mitigation mechanisms

Potential loopholes associated with the proposed policy of introducing an informal, non-institutionalized approach, along with increased communication strategies revolving around energy discourse, include the potential lack of effectiveness, capacity-building challenges, evaluation, and oversight complexities. Firstly, the lack of the proposed policy effectiveness primarily lies in the policy's non-institutionalized and inconsistent nature, which can produce positive effects in the short-run; nonetheless, observing long-run and impactful policy outcomes through formally institutionalized curriculum integration of domestic and regional energy literacy could be viewed as a long-term solution. That is to say that the proposed informal educational and awareness-raising efforts can prepare solid groundwork for the introduction of rather formal, consistent, and structural measures. Secondly, capacity-building challenges, namely limited expertise, funding, and institutional support, can potentially hinder the smooth implementation of the proposed policy. To resolve the issue, it is of critical importance for the countries to provide training for educators and foster cooperation between civil society, government bodies, media organizations, and educational institutions. Lastly, complexities associated with the proper evaluation and oversight of the implemented measures can arise, which could be mitigated through clear performance indicators, regular feedback mechanisms, and collaboration with independent evaluators to ensure transparency and accountability.

Conclusions

This policy paper has attempted to advance evidence-based policy recommendations by conducting research aimed at establishing a preliminary understanding of the energy literacy levels and attitudes towards regional energy cooperation in the context of energy security and green transition among undergraduate students in the region, with a focus on Armenia and Georgia. The research has applied a survey methodology among the students in both countries, which has indicated a moderate level of energy literacy among the surveyed population and relatively low attitudes towards regional energy cooperation in comparison to the favorable attitudes towards domestic energy transition and security. The policy analysis has showcased that introducing an informal educational approach (i.e., educational/research programs, community-led initiatives, volunteering, and other forms of activism within the context of regional energy cooperation) and robust communication strategies (i.e., podcasts involving government officials, dissemination of awareness-raising leaflets and briefs) with joint efforts of the government, civil society, media, and HE institutions would be a solid policy approach.

On another note, it should be noted that this policy paper has limitations. These include the use of convenience non-probability sampling, a low response rate, and the underrepresentation of Georgian students, which limit the generalizability of the findings. Furthermore, the analysis has been relatively descriptive and does not encompass in-depth comparisons within the surveyed population. Additionally, the survey design may not fully capture the complexity of energy literacy, and the exclusion of qualitative insights limits the depth of understanding. The inclusion of a few graduate students, rather than focusing on undergraduates, further skews the results. Potential respondent bias and the specific timing and geographic scope also restrict the paper's applicability. Therefore, since the sample of the survey respondents is not fully representative of the general student body in its scope and quantity, considering the application of the non-probability sampling technique, the findings should be treated as tentative.

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Renewable energy cooperation in the South Caucasus as a step towards sustainable peace and economic integration

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Azerbaijan

Introduction

The South Caucasus region, long marked by geopolitical tensions and economic fragmentation, stands at a critical crossroads in its energy transition. The International Energy Agency (IEA) defines energy security as the uninterrupted availability of energy sources at an affordable price (University of Plymouth, n.d.). Moreover, according to OSCE energy security means having stable access to energy sources on a timely, sustainable, and affordable basis. Access to energy is not only crucial in supporting the provision of basic needs - such as food, lighting, water, and essential health care, but it is first and foremost a precondition to economic growth, political stability, and prosperity (The Organization for Security and Co-operation in Europe, n.d.).

The growing global focus on decarbonization, energy diversification, and sustainability offers Azerbaijan, Armenia, and their neighbors an unprecedented opportunity to modernize their energy production patterns and diversify sources. While Azerbaijan has traditionally been regarded as a hydrocarbon-rich state, its recent policy shifts towards renewable energy signal a commitment to long-term economic resilience and environmental responsibility. Similar to this, Armenia has been increasing its renewable capacity in spite of its energy limitations, recognizing the necessity of a more diversified and self-sufficient energy sector.

However, unresolved conflicts, political mistrust, and infrastructure gaps are the main reasons why regional cooperation in the renewable energy sector is still largely underdeveloped. Azerbaijan has made significant strides in forging international partnerships with key players such as BP, Masdar, and ACWA Power, while also launching the ambitious Green Energy Corridor project, aimed at exporting clean electricity to European markets. In contrast, Armenia is still working to develop its own renewable energy sources but is not included into larger regional energy projects.

This paper argues that renewable energy cooperation in the South Caucasus is not only feasible but imperative for sustainable economic growth, regional security, and geopolitical stability. A

gradual energy integration strategy based on institutional cooperation, cross-border infrastructure development, and diplomatic engagement could provide a pragmatic pathway towards reconciliation and mutual economic benefit. The paper offers a thorough plan for promoting a sustainable and interconnected energy future in the South Caucasus by examining the renewable energy landscapes of Azerbaijan and Armenia, current policy frameworks, and the possibility of cooperative mechanisms.

Background & Context

Collaboration on renewable energy in the South Caucasus is urgent due to geopolitical, economic, and environmental reasons. As Europe is trying to diversify away from Russian gas against the background of the wake of the war in Ukraine, the region found itself in the epicenter of changes in the global energy market. The European Union's decarbonization policies are in line with Azerbaijan's Green Energy Corridor, which aims to export clean electricity to Europe through Georgia and the Black Sea. Expanding renewable energy is crucial for long-term economic stability because Azerbaijan's economic dependence on fossil fuels remains its vulnerability.

Despite its reputation as a petrostate, Azerbaijan has been making systematic efforts to reduce its dependence on hydrocarbons for energy supply and export revenues and is actively pursuing the development of renewable energy production. The establishment of the State Renewable Energy Agency in September 2020 was an important milestone that spearheaded a number of decisive steps towards green development. In February 2021, a respective strategy titled "Azerbaijan 2030: National Priorities for Socio-economic Development" was officially adopted (Republic of Azerbaijan, 2023). Paragraph 5 of this strategy elaborates on the country's approach to the issues of climate change and the fight against it and heralds the application of renewable energy in all sectors of the Azerbaijani economy based on the principles of green growth. In one of the crucial decisions taken back then, Baku announced the establishment of a net zero-emission zone across the whole de-occupied territories (the regions of Karabakh and Eastern Zangezur).

While Baku had previously adopted a commitment to reduce greenhouse gas emissions by 2030 by 35% compared to the 1990 level, to around 37 million tons, at the COP26 in Glasgow it fully volun-

tarily expanded this commitment to 40%, to be achieved by 2050 (EU4Climate, n.d.). According to Azerbaijan's green transition plans, the share of renewable energy in the total installed capacity is set to reach 30% by 2030 (Ministry of Energy of the Republic of Azerbaijan, 2024). Currently, this figure constitutes 20.3%, as the capacity of the power plants on renewable energy sources, including large HPPs equals 1687.8 MW out of the total of 8320.8 MW (Ministry of Energy of the Republic of Azerbaijan, 2024). Of this, 1301.8 MW falls into the share of hydropower capacity (35 stations, 24 of which is SHPP), 281.9 MW into solar energy production (13 stations, 3 of which is hybrid), wind power capacity is 66.4 MW (8 stations, 3 of which is hybrid) and bioenergy production 37.7 MW (2 stations, 1 of which is hybrid), solar energy capacity (Ministry of Energy of the Republic of Azerbaijan, 2024). It is notable that only in 2023, electricity volumes generated from renewable energy sources made up 7% of total production (Ministry of Energy of the Republic of Azerbaijan, 2024). In April 2024, The Ministry of Energy of Azerbaijan, with the support of the European Bank for Reconstruction and Development (EBRD), announced the country's first renewable energy auction for a 100-megawatt solar power plant project in Garadagh (European Bank for Reconstruction and Development, 2024).

These targets, seemingly ambitious, are quite in line with Azerbaijan's potential renewable capacity and greatly exceed current figures. The technical potential of onshore renewable energy sources in Azerbaijan is estimated at 135 GW onshore and 157 GW offshore, while the economic potential of renewable energy sources is estimated at 27 GW, including 23 GW of solar energy, 3 GW of wind, 380 MW of bioenergy potential and 520 MW of mountain rivers (Ministry of Energy of the Republic of Azerbaijan, 2024). Recently, solar has been the fastest-growing sector in renewable energy production, though there is very strong untapped potential for wind energy, due to strong winds occurring in many parts of the country. Its available economic potential could only generate around 2.4 TWh and conserve approximately 1 Mt of conventional fuel, but many times more may be produced offshore if relevant technologies develop to an extent that would make such production economically viable (International Renewable Energy Agency, 2023).

The nationwide approach to green energy development emphasizes the diversification of sources, the establishment of regional clusters based on the natural advantages and economic significance of certain areas, and long-term partnerships. Thus, green energy zones have been launched in Karabakh, Eastern Zangezur, and Nakhchevan regions which are strongly endowed with sunlight (which reaches 3,200 hours annually in some areas (Mammadov, F., 2013)), while the task of rebuilding the economy of the de-occupied areas from scratch makes it easier to implement new technologies on a larger scale than elsewhere (Azernews, 2024). Under the coordination of the Renewable Energy Agency, technical research and feasibility studies have been initiated for offshore

wind capacity, bioenergy production, grid transmission facilities, battery storage capacity, etc. In 2021, the Azerbaijani government signed a milestone memorandum with the country's major energy investor, BP, which in 2020 had announced its own net zero emissions targets (BP, 2021). This memorandum covers clean energy projects, low-carbon transport, green buildings, waste management, clean industry, natural climate solutions, integrated partnerships, as well as the development of integrated and de-carbonized energy and transport systems; it envisaged preparing a Master Plan on decarbonization for the relevant regions and cities of Azerbaijan. As the first step on this road, on 3 June 2021 an implementation agreement was signed with BP on cooperation in the field of evaluation and implementation of the project for the construction of a 240 MW solar power plant in the Jabrayil region, one of those which had been devastated the most after 1994 (Azerbaijan Renewable Energy Agency, 2021).

Correspondingly, incorporating renewable energy infrastructure can stimulate post-conflict economic recovery and draw in foreign investment in conflict-affected regions like Karabakh and Eastern Zangezur. Moreover, regional collaboration in renewable energy could promote economic interdependence, ease political tensions, and support South Caucasus stability. Now seems to be a crucial moment for Azerbaijan and the larger South Caucasus region to embrace renewable energy cooperation as a pillar of economic modernization, geopolitical leverage, and environmental responsibility, given the global acceleration of green transitions, technological advancements, and growing international financing for sustainable energy.

The role of international partnerships in Azerbaijan's renewable sector

The 2021 agreement highlighted a landmark moment for the role of international partnerships in Azerbaijan's green strategy, which is envisaged to pursue multiple targets. On one hand, such partnerships secure precious investment, and on the other, tie the interests of influential international economic actors to Azerbaijan, at the same time also raising the latter's status in the global green economy network as an important hub. There is yet another strategic reason for Baku's growing interest in renewable energy: growing reliance on it for domestic consumption will free up more natural gas for export to Turkiye and Europe through already existing infrastructure, helping the country to increase its budget revenues, still strongly dependent on hydrocarbons, and bolster its geopolitical weight as an important energy supplier for Southern and Eastern European countries.

The aforementioned collaboration with BP was the first harbinger of this trend, soon followed by a bigger deal with the Emirati wealth fund Masdar in 2022. Within the framework of this cooperation, in October 2023 the largest solar power plant in the Caspian region and the CIS, was put into operation in Qaradagh (Azerbaijan Renewable Energy Agency, 2021), with the capacity of 230 MW. The plant was built with foreign investment worth $262 million and is the first utility-scale solar power plant realized by attracting foreign investment in Azerbaijan (Azerbaijan Renewable Energy Agency, 2021); It will produce 500 million kilowatt-hours of electricity annually, saving 110 million cubic meters of natural gas (Masdar, 2021). Two other plants to be built jointly by SOCAR and Masdar will be even bigger - a 445 Megawatt (MW) Bilasuvar solar facility, expected to be operational by the end of 2026, and the 315 MW Neftchala solar plant (Ministry of Energy of the Republic of Azerbaijan, 2024). In total, Masdar envisages creating a capacity of up to 10 GW by 2030, which is equivalent to about 20% of the country's total gas export (Turan News Agency, 2024).

At the same time, Azerbaijan has established a collaboration with another giant of the Gulf region, Saudi Arabia's ACWA Power, which is planning to build the Khizi-Absheron Wind Power Plant with a capacity of 240 MW (Azerbaijan Renewable Energy Agency, n.d.). At the Baku Energy Week in 2024, the parties discussed two further mega-projects with ACWA Power, presupposing the building of onshore facilities with a total capacity of 1 GW, and a 1.5 GW offshore wind farm and battery storage facility (Bowden, J. ; Roberts, J. , 2024).

An even more ambitious project was launched in June 2023 with China, with an MoU signed between Azerbaijan's Energy Ministry and China Gezhouba Group Overseas Investment on the im-

plementation of renewable energy projects with a capacity of 2 GW (Azerbaijan Renewable Energy Agency, 2024). It includes cooperation on utility scale solar energy, onshore and offshore wind power, energy storage and integrated smart energy systems, as well as capacity assessment for investment in green hydrogen production projects in Azerbaijan. Moreover, despite the currently very difficult political relations with France, French energy major Total, which has been operating the Shakhdeniz gas field in the Azerbaijani sector of the Caspian Sea for many years, is also involved in discussions around the development of renewable projects in the Nakhchivan exclave capable of generating 500 MW of power (Azernews.az, 2025).

Corridor ventures

Another dimension of Azerbaijan's international renewable development strategy is building regional cooperation formats spanning several countries in order to establish interdependencies and obtain new foreign policy leverages. The most tangible example of this policy has been the planning of the Green Energy Corridor which started as a duo with Baku's vital energy partner - Georgia, which itself is very rich in potential hydropower resources and has been seeking for investment of at least $3 billion in the renewable sector with the purposes of boosting the country's energy security and potentially, exporting some of it (Eurasianet, 2023). Further on, Azerbaijan started to expand this strategy horizontally: first, to the West, with the signing of "Strategic Partnership Agreement in Green Energy Development and Transmission" with Georgia, Romania and Hungary in December 2022 (Azerbaijan Renewable Energy Agency, 2022). The purpose of this project is to establish the export of renewable-produced electricity from Azerbaijan towards the West, through the cable which is to be laid under the Black Sea, to the EU countries. This cable, expected to span approximately 1,200 km, will be by far the longest of its kind in the world, with a total capacity of 1000 MW, enough to supply approximately one million European homes (Natia Gamkrelidze, 2024). Long-distance lines would carry up to 1.5 GW of clean electricity to Anaklia, Georgia, at the east end of the Black Sea (IEEE Spectrum, 2024). An undersea cable would move the electricity across the Black Sea and deliver it to Constanta, Romania, where it could be distributed further into Europe (IEEE Spectrum, 2024).

Although this project initially seemed "too bold to be realistic" for many experts, the initial feasibility study presented on November 12, 2024, at COP 29 in Baku, confirmed its potential econom-

ic plausibility and announced the interest from the part of EBRD and ADB to finance it (Report News Agency, 2024). Shortly before, in September, the participant countries established a joint venture tasked with implementing the project. The scheme's proponents say this Caspian-Black Sea energy corridor will help decrease global carbon emissions, provide dependable power to Europe in the context of the Ukraine war, and modernize developing economies at Europe's periphery, while also contributing to the long-term stabilization of the South Caucasus. Organizers hope to build the undersea cable within the next six years at an estimated cost of €3.5 billion (IEEE Spectrum, 2024). Nevertheless, there are reservations that production capacities should be strongly increased for the Corridor to become plausible. This is why discussions have been going about finding additional energy sources; among proposals, installing new hydropower capacities in Georgia loomed large. However, hydropower development in Georgia has often faced resistance from environmentalists and other civil society groups, so this option is not considered fully reliable (CEE Bankwatch Network, 2024).

Another necessary element for the implementation of the Green Corridor initiative is European political and financial contribution, the lack of which up to this day has failed a number of ambitious interregional projects, including Nabucco- a would-be pipeline from Kazakhstan through Azerbaijan to Europe which was strongly championed for during the 2000s but never materialized (Celia Davies, 2011). A positive signal was sent by Ursula von der Leien at a joint EU–US–Armenia high-level meeting in Brussels on April 5, 2014 where she claimed that the EU is ready to support the construction of the cable which would "bring clean, renewable energy into Europe", along with investing into Armenia's renewable energy production and better interconnections with Georgia (Report News Agency, 2025). The commissioner responsible for EU enlargement policy projected that the union would pay an estimated €2.3 billion toward building the cable.

In order to gain access to different supply sources and expand its energy-geopolitics nexus, Baku embarked on building renewable energy partnerships with Central Asian countries, relations with whom have been generally flourishing recently. The process was kickstarted with the signing of Joint Communiqué of heads of energy ministries of Azerbaijan, Kazakhstan and Uzbekistan in November 2023, which centered around cooperation on renewables. The following August, the three countries reached a breakthrough agreement on developing electrical energy export from Kazakhstan and Uzbekistan via another undersea high-voltage cable to be built in the Caspian Sea to Azerbaijan, where it would be connected with a planned route running to Turkiye and Europe (AIR Center, 2024). In his tweet as of November 13, 2024, Hikmet Hajiyev emphasized that this project would be linked with the Black Sea cable as well. According to Kazakhstani Energy Minister Satkaliyev, technical specifications for the transmission line have been already developed (Eurasianet,

2024).This agreement was underpinned by the earlier MoU on the merging of energy systems of the three countries, aimed at enabling the smooth transition of electricity. The energy running through the “Caspian Corridor”, is supposed to come from both solar and wind sources, which are plentiful in Central Asia.

The expansion of renewable energy in Kazakhstan and Uzbekistan is closely linked to regional cooperation in the Caucasus through emerging energy corridors and joint infrastructure projects. Kazakhstan’s renewable production had skyrocketed, rising over 16 times between 2014 and 2023; currently, it generates about 2.9 GW of power from renewable sources and aims to add at least another 5 GW by 2030 (Omirgazy, 2024). Uzbekistan’s plans are even more ambitious. Tashkent plans to produce up to 25 GW of wind and solar energy by 2030; in 2023, their share in the daytime generation had already reached 18% (CaspianPost, 2024). Moreover, the Transcaspian partnership goes further as the countries (for now, only Baku and Astana) are exploring opportunities for joint hydrogen production, which is considered a next-generation renewable fuel (Ministry of Energy of the Republic of Azerbaijan, 2024). In 2022, Kazakhstan signed a green hydrogen deal with the German renewable giant SVEVIND that envisages investment worth $40-50 billion (World Economic Forum, 2021), with the final decision to be made next year (H2 Energy Group, 2022). A smaller project launched in the Mangystau region, is set to produce 2 million tons of hydrogen annually since 2030 (Research Institute for Sustainability, 2024). The Caucasus region, particularly Azerbaijan, serves as a strategic transit zone for Central Asian renewables, facilitated by projects like the Azerbaijan-Türkiye Interconnection. Additionally, collaborations in hydrogen production, such as Kazakhstan’s deal with Germany, could utilize this infrastructure to reach European markets.

Finally, Azerbaijan has been working with Turkiye to establish energy transmission and export infrastructure. The role of Turkiye will be particularly significant, given the establishment of a green energy zone in Karabakh and Nakhchivan. The potential Azerbaijan-Turkiye-Europe route will pass through these regions, so renewable energy produced at their facilities, the BP-managed Jabrayil Energy Junction Project being the first among them, will be enabled to export. The possible route for connecting Central Asian countries to Azerbaijan and then Turkiye involves a multi-step pathway. Central Asian countries like Kazakhstan and Uzbekistan would first connect with Azerbaijan, likely through existing or planned energy infrastructure across the Caspian Sea. From Azerbaijan, the energy would be transmitted to Turkiye via the Azerbaijan-Türkiye Interconnection project, which is currently under development. This interconnection would allow for the efficient transfer of renewable energy from Central Asia to Turkiye. Once in Turkiye, the energy could be further transmitted to Europe through established or future energy corridors. The route would essential-

ly follow a Caspian Sea-Black Sea-Europe trajectory, facilitating the export of green energy from Central Asia to European markets.

The export capacity of Nakhchivan only is expected to reach 1 GW, and on September 29, 2024, Baku's and Ankara's Energy Ministries signed an MoU on the transmission of electricity produced there. Another memorandum on the technical details of this export was signed with "Nobel Energy", Baltech, and Total Energies. The Azerbaijan-Türkiye Interconnection project is already being carried out jointly by "TEIAŞ" and "Azerenerji" JSC to be finished this year (Mammadov & Koksharova, 2024). Saudi Arabia has also taken interest in Azerbaijani-Central Asian energy ouverture, eventually signing a memorandum of understanding on "ensuring the participation of Saudi Arabia in the Project for the Development and Transfer of Green Energy, between Azerbaijan, Kazakhstan, and Uzbekistan and expanding cooperation in the area of green energy with Azerbaijan" in May 2024 (Ministry of Energy of the Republic of Azerbaijan, 2024). Ultimately, these connections, which for now are projected to link Kazakhstani and Azerbaijani networks via an undersea cable, will position Baku and Ankara as key transit points for renewable energy from Central Asia to Europe, enhancing regional energy security and cooperation.

The establishment of the Azerbaijan-Türkiye renewable hub is made much easier by the fact that cooperation between the countries in the field of electrical energy dates back to the early 2000s. Azerbaijan began importing electrical energy from Türkiye in 2003, but these imports gradually decreased, reaching a minimum by 2006 and ceasing entirely in 2013 (AIR Center, 2024). From 2006 onward, Azerbaijan shifted to exporting electrical energy to Türkiye, since 2013- as part of the "Azerbaijan-Georgia-Türkiye Energy Bridge Project" (AIR Center, 2024). Additionally, three aerial power lines connect Nakhchivan to Iğdır, further strengthening the energy link between Azerbaijan and Türkiye and ensuring a more robust and reliable electricity supply to the region (AIR Center, 2024).

Armenia: state of renewable sector

Remarkably, missing from all the aforementioned projects and initiatives is Armenia, the third independent country in the South Caucasus. The reason for this is quite obvious: the country's longstanding conflict with Azerbaijan, which left the two neighbors without any diplomatic or economic relations. For the last 30 years, Baku has been building its international economic infrastructure, including major oil and gas pipelines, roads, railway, and electricity grids, in a way that they bypass Armenia. There have been a number of proposals throughout these years that economic cooperation between Baku and Yerevan may soften up their hostility and pave the way for eventual normalization, but they have never materialized.

For this reason, Armenia's and Azerbaijan's economic development pathways have strongly diverged, and this relates to the clean energy sector as well. Nevertheless, there is a striking similarity. Until recently, Armenia's efforts in this field have been largely focused on hydropower (Yu, W. ; Cestti, R. E. ; Lee, J. Y., 2015). The oldest hydropower plant, the privately owned Sevan-Hrazdan Cascade complex of hydroelectric plants, has an operating capacity of 552 MW (The International Energy Agency, 2022). Vorotan Cascade power generation complex had been completed by 1989 and is operated by the private company ContourGlobal Hydro Cascade CJSC; it has an operating capacity of 404 MW and has been providing up to 15% of the country's annual energy consumption. At the same time, the country has a large number of small private hydropower plants (189 in total), generating 943 GWh of energy annually (International Energy Agency, n.d.). They are mostly concentrated in Armenia's southern provinces, Syunik and Vayots Dzor, in the direct vicinity of the projected corridor running from Azerbaijan to Turkiye (Ismailzade, F. ; Krnjević Mišković, D, 2021).

Recently, the Armenian government has started to pay attention to the development of other types of renewable energy, primarily solar and wind. Solar farms are concentrated in the regions of Aragatsotn, Gegharkunik, and Vayots Dzor, which together contribute nearly 95% of Armenia's total installed solar capacity (Nazaretyan, 2023). While total numbers don't seem very impressive now, the momentum in the industry is huge: more than half of all solar farms (34 of 60) were built in 2022 alone (Nazaretyan, 2023).

Renewable sector development results in the growing electricity production in Armenia: in 2022, the output amounted to 8,907.9 GWh, up 16% from 2021 (Nazaretyan, 2023). Overall, renewable sources combined generated 24.5% of the total (Nazaretyan, 2023). While the sector is mostly concentrated on satisfying domestic consumption, Armenia managed to export 17.3% of its total

electricity output to Iran and Georgia, and this figure is rising as well (The World Bank, 2024). This export follows a seasonal pattern, as it mostly falls into the periods of peak production. By 2030, the government intends to increase electricity generation to 12,000 GWh and electricity exports to 5,000 GWh compared to 7,600 GWh and 1,250 GWh in 2019, respectively (Nazaretyan, 2023).

To reach these targets, the Armenian government approved a number of documents, starting from the National Programme on Energy Savings and Renewable Energy in 2007 and the National Energy Efficiency Action Plan in 2010. The Renewable Energy Investment Plan for Armenia was approved within the framework of the Climate Investment Funds' Scaling-Up Renewable Energy Programme (SREP), which has allocated resources to develop up to 110 MW of utility-scale solar PV generation (International Energy Agency, 2014). In 2021, the Government of the Republic of Armenia adopted the energy sector development strategy program until 2040; one of the targets is establishing a "regionally significant" energy sector (Government of the Republic of Armenia, 2020).

The government is working to align its policies and market protocols with those of the European Union and of the Eurasian Economic Union, of which Armenia is a treaty member; development agencies and lenders are allocated a special role in shaping Armenia's energy efficiency policy agenda. Yerevan's 2017 CEPA agreement with the EU had already committed it to promote the use of renewable energy sources (Sweden Abroad, 2017). In its March 2024 resolution on EU-Armenia relations, the European Parliament adopted a resolution calling on the Armenian authorities to "to accelerate the development of renewable energy in order to diversify energy sources", bringing specifically political arguments: the country's dependence on Russian gas imports (which constitutes 80% of its total gas consumption) and on cooperation with Iran (European Parliament, 2024).

For the near future, Armenia prioritizes the expansion of solar plants (with the capacity of about 1000 MW until 2030) over other renewables, targeting also better storage capacity, whose lack has this far been the major factor stalling the development of this industry (Nazaretyan, 2023). Yerevan also envisages the construction of wind power stations with a total capacity of 500 MW for the period 2030-2040 (EcoLur, 2022). Another important goal is the deepening and integration of regional cooperation, embodied in the projects on construction of Armenia-Georgia 400 kV and Armenia-Iran 400 kV transmission lines, currently under implementation (Mgdesyan, 2024). Their completion will not only endow Armenia with new modern electricity infrastructure from the south to the north, but also significantly increase its opportunities for electricity exchange and transit, while sheer export capacity will be boosted up to 3 billion kWh annually (Mgdesyan, 2024).

Armenia's: integration into regional renewable projects

When it comes to the prospects for Armenia's integration into renewable energy projects, first of all it can be helpful to compare its geographical peculiarities with the adjacent Azerbaijani regions. Both of them bordering Armenia's southern provinces Syunik and Vayotsdzor, Azerbaijani regions Nakhchivan and Karabakh, are on the forefront of green transition. When it comes to its photovoltaic power potential, Nakhchivan is leading in the whole region with 1600-1650 pWh/kWh annually, while the southern lowland parts of Karabakh register a respective figure of 1500 PWh/kWh. Comparable figures for the valleys of Syunik and Vayotsdzor also fluctuate between 1500-1600 pWh/kWh. When it comes to the wind power potential, while it is no so high in these regions on average, in the Araz valley of Nakhchivan and some areas in the southern provinces of Armenia there are pockets where wind density at a 100-m altitude reaches 700-800 W/m2 (Mustafayev, Kulawczuk, & Orobello, 2022).

Currently, Armenia can meet only around 35% of the current demand for energy with its domestic resources (Karapetyan & Orbelyan, 2019). Therefore, the country's energy security requires a significant increase in production capacity, which is reflected in the government's energy policy priorities. Integrating into the projects driven by Azerbaijan can be an important step on this way.

In fact, there are multiple reasons why Baku and Yerevan should be interested in considering this strategy. First of all, regionalization in general, and that of energy grids in particular, has been among the hottest trends of recent years. Global disruptions caused first by the COVID-19 pandemic, and later, by the war in Ukraine and subsequent diplomatic crisis, have greatly increased skepticism towards globalization and accentuated feelings of insecurity, sparking isolationist tendencies in many parts of the world. On the other hand, those very security considerations push many countries to build stronger cooperation networks with neighboring and/or like-minded partners. When it comes to renewable energy, its very nature favours regional-scale projects. While very long-range networks of renewable facilities are hardly economically plausible due to the persisting problems of production instability and storage capacity deficiencies, regionalisation, on the one hand, can provide better supply guarantees by linking dispersed supply and demand centers (when due to natural reasons production is insufficient at a certain plant, excess output from another may compensate it), and on the other, larger-scale networks shall make it more attractive for investors to finance the industry.

This is why experts believe transboundary power trade patterns will become increasingly important. A number of investigations have been conducted as to the potential economic effects of such patterns. Just to bring a couple of examples: in Europe, the potential benefits of market integration range from $14 billion to $45 billion per year, or roughly 1% to 10% of system costs (UN ESCAP, 2024), while ADB's study of the Greater Mekong Sub-region in Southeast Asia suggests that regional cooperation in energy could reduce energy costs by nearly 20%, for a saving of $200 billion from 2005 to 2025 (UN ESCAP, 2024).

If we imagine the gradual creation of such networks between Azerbaijan and Armenia, the latter can play both the role of supplier and exporter (at least of local importance), and that of a customer, depending on the rate of its energy production and consumption growth. When a stable supply corridor from Central Asia and Azerbaijan towards Türkiye, it may deem both economically and politically viable selling some of the green energy it produces, through this network (Report News Agency, 2024). If the domination of the southern provinces in the development of the renewable sector in Armenia, continues, it may be economically more viable to sell the excesses of the energy through the existing corridor rather than trying to bring it to other provinces of Armenia.

Energy integration and peace

Of course, there is a larger issue complicating potential interconnection of Azerbaijani and Armenian energy networks- the countries' longstanding conflict which this far has prevented them from establishing any economic partnership at all. However, I argue that the policy logic should be exactly opposite: economic cooperation, especially if it has a permanent, rather than sporadic, character, can be a strong boost for peaceful agenda in a number of ways.

Interestingly enough, the only episode of meaningful interstate economic contact happened in the energy dimension. In 2021, while maintenance works were being done on the Transcaucasian pipeline which brings gas from Russia to Armenia, the sides quickly reached an ad hoc agreement that Azerbaijan would temporarily supply a respective volume of gas to Armenia, via Georgia (Krikorian, 2024). Although this moment was brief, it inspired many experts and policymakers to suggest a way towards reconciliation, up to the highest level: President of Azerbaijan Ilham Aliyev

and Armenian National Assembly Speaker Alen Simonyan at some moments suggested that in a near future Baku may start to export gas to Yerevan on a regular basis (Krikorian, 2024).

Indeed, for the first time since their independence, the foreign policy strategies of the two countries now have a tendency to converge. Azerbaijan, constantly pressured by two ambitious neighbours with historic claims in the South Caucasus, Russia and Iran for a long time, has been pursuing a policy of equidistance from major power centers, refusing to join any major military-political blocks, while using its energy resources in a way that maximizes Azerbaijani independence (von Essen, 2023). Pashinyan's government in many aspects has been trying to replicate this model, replacing traditional alliance with Russia with a system of partnerships with different actors while minimising dependencies on Moscow and Tehran Yerevan has had until now (Enveroglu, 2025). Given the critical role of energy in ensuring national security, reducing Armenia's dependence on external energy sources is essential for achieving this goal. This objective aligns with the broader vision of a "Real Armenia" promoted by Pashinyan since 2022 as an antidote to the dominant nationalistic, anti-Turkish, and anti-Azerbaijani narrative rooted in the historical grievances that prioritised Armenian irredentism over its normal relations with the neighbours. The concept of "Real Armenia" envisages that Armenians find peace with their official, rather than extended, borders and abjure territorial and other claims on them (Nasibova, 2024). By integrating Armenia into regional energy infrastructure networks and participating in large-scale energy projects, the country can enhance its energy security and diversify its energy mix. This integration would not only reduce reliance on imported fuels but also contribute to a more sustainable and stable energy future, aligning with Armenia's commitment to increase renewable energy sources in its energy mix.

History provides a lot of examples when economic cooperation served as a crucial component of establishing trust and building long-term peace. While the creation and growth of the EU after the WWII is the most famous example, in some instances such arrangements worked even without a multilateral framework strongly supported by an outside power. This is true for Japan and South Korea: Tokyo, whose post-war economic growth had taken off much earlier, was interested that its poorer neighbour caught up and fuelled its development (Kōsai & Goble, 1989). There is also a very interesting case of a much poorer region in South-East Asia formerly called "Indochina" (Vietnam, Laos, Cambodia, and Myanmar): the efforts of ASEAN to boost economic integration since the 1990s greatly stabilised the region which had experienced significant violence in the previous decades, usually due to the great-power rivalry (Chia, 2013). Their experience should be relevant for Azerbaijan and Armenia, whose conflict has also been strongly sustained by the power politics in the South Caucasus.

A number of empirical studies confirm the beneficial effects of economic interaction for peace-building. A study by Cali and Oliver of the World Bank shows when trade leads to higher incomes, states are less likely to forgo them to engage in conflict (Calì, n.d.). Another study by Lee and Ju, based on a large panel data set of 243,225 country-pair observations from 1950 to 2000, confirms that increased bilateral trade interdependence is significant in promoting peace (Lee & Pyun, 2009). Increased bilateral interdependence and global trade openness are thus key elements in promoting peace. There are also more specific pieces of research on the energy and electricity interaction between the conflict sides; for example, this has been the case in Cyprus where the grids of Greek and Turkish sides were interconnected in 2011 under the guidance of the respective Chambers of Commerce (Camp, 1980). In general, practice of interconnecting electricity grids to establish transboundary networks has been on the rise, both in order to better manage risks and navigate growing complexity and to create links binding participant countries. Central Asian countries are now contemplating the integration of their national energy systems, one of the goals being to enable a more robust use of solar and wind energy, while also ensure stronger peak capacity (Asian Development Bank, 2022). Their experience may serve as an important source of expertise for Baku and Yerevan, if they decide to follow suit.

Technically, integrating energy networks takes a few steps. Some crucial advice can be:

- Use the international standards set by organizations like IEC and the ISO when developing national standards for the integration of solar and wind energy into power systems (International Renewable Energy Agency, 2013);
- Harmonize new and existing national standards, taking into account the peculiarities of national energy systems, with international standards developed in IEC technical committees (TC) and subcommittees (SC);
- Participate in the work of CIGRE committees and expert groups to share good practice and contribute to regional standard setting;
- Develop working methods to regulate frequency of electric current to enable cross-border distribution of power for an energy connected region.

How specifically can energy cooperation promote the peace between Azerbaijan and Armenia? Beyond the rather straightforward political logic, it can also act through various mechanisms. Armenia's participation in Azerbaijani energy corridors will require a lot of technical coordination, thus establishing communication channels other than those that exist on the highest level,

between sectoral professionals and technical specialists. The nature of renewable energy (particularly solar and wind) with its periodic production rises and falls means that operating shared networks requires constant information exchange. Professionals involved in this exchange will see each other as partners rather than representatives of a hostile country, maybe for the first time in decades. Moreover, if a protracted de jure or at least de facto peace holds, work trips of energy sector professionals to the facilities in each other's countries can be imagined, which would be a historic step towards more structural normalisation.

Recommended Policy

The most effective policy pathway for the South Caucasus is a multifaceted, phased approach to regional cooperation in renewable energy. The first step should focus on diplomatic engagement, fostering trust and political willingness between Azerbaijan and Armenia through confidence-building measures, technical working groups, and energy diplomacy forums. High-level bilateral discussions will show both parties' commitment to economic interdependence and aid in coordinating policy priorities. The success of the bilateral negotiation track, barely believable as late as in 2023, should be a good guarantee that such a format can develop, too. Concurrently, joint renewable energy projects could be tested in low-tension regions like Nakhchivan and Syunik through pilot projects, which would enable both countries to establish technical coordination and investment synergies. This would create a foundation for a more comprehensive regional energy network.

The South Caucasus Renewable Energy Council is one example of an institutional mechanism that should be put in place to supervise technological standardization, investment coordination, and regulatory alignment. The council would mediate possible conflicts, promote information sharing, and offer a broad strategic framework for sustained collaboration. The suggested investment in cross-border infrastructure is yet another essential component. Ensuring smooth energy trade between Azerbaijan, Armenia, Georgia, and Turkiye will require modernizing and expanding energy transmission lines and storage capacity to handle the increased flow of renewable energy. The region's grid stability and energy security will be improved by the development of smart grids, interconnectors, and flexible storage options.

International partnerships and financing mechanisms must also be leveraged to support the development of renewable energy corridors. Financial and technical support should be obtained from organizations such as the World Bank, the Asian Development Bank (ADB), and the European Bank for Reconstruction and Development (EBRD). Capital inflows, technology transfer, and infrastructure development will all be further accelerated by strategic alliances with international energy companies and private sector investors. Finally, policy harmonization is key to ensuring regulatory coherence and market integration. A stable and predictable investment climate will result from national energy policies that are in line with international standards, such as those established by the European Union's energy framework and the International Renewable Energy Agency (IRENA).

Additionally, establishing mechanisms for energy pricing agreements, market liberalization, and tariff standardization will enable smoother cross-border electricity exchange. Even though there are still political obstacles to overcome, renewable energy can be positioned as a game-changing factor for long-term peace and economic integration in the South Caucasus with a methodical and incremental approach based on infrastructure investment, pilot projects, regulatory alignment, and diplomatic engagement.

Conclusion

Collaboration on renewable energy in the South Caucasus is not only a strategic imperative but also an economic opportunity. There are significant geopolitical, economic, and environmental ramifications to the region's shift to a sustainable energy framework. Despite their past conflicts, regional energy integration has a lot to offer Azerbaijan and Armenia and could serve as a spark for long-term stability and economic growth.

By embracing a cooperative approach, Azerbaijan shall further solidify its role as a regional energy leader while diversifying its economic dependencies. Conversely, Armenia can improve its sustainability credentials, fortify its economic resilience, and lessen its energy vulnerability. A structured energy integration strategy, such as underpinned by diplomatic engagement, infrastructure investment, and international partnerships, would pave the way for a more interconnected and secure South Caucasus.

Cross-border renewable energy projects will also boost regional competitiveness, draw in foreign investment, and establish the South Caucasus as a key player in the global clean energy transition. To maintain both economic sustainability and geopolitical relevance, the region must take advantage of its renewable energy potential as global energy markets continue to change.

Through strategic investments, policy harmonization, and confidence-building initiatives, the obstacles to regional energy cooperation—such as political disagreements, infrastructure deficiencies, and regulatory misalignment—must be methodically addressed. In order to coordinate efforts and guarantee that energy projects are in line with more general regional development objectives, the establishment of a South Caucasus Renewable Energy Council would be crucial.

In the end, the South Caucasus's interconnected and sustainable energy system is the way to a more resilient, prosperous, and stable future rather than merely a policy goal. The success of this endeavor will depend on the political will of regional actors, the support of international stakeholders, and the ability to leverage renewable energy as a force for peace and economic transformation.

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