

GREEN ENERGY TRANSITION AND REGIONAL ECONOMIC RESILIENCE

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Summary. As regions increasingly face environmental challenges, energy security concerns, and economic transformation pressures, understanding how green energy transition contributes to sustainable and resilient regional development has become an important research priority. This study aims to examine the influence of green energy transition on regional economic resilience by analyzing the mediating role of green investment and its effect on green innovation capability. Using survey data collected from 364 professionals representing energy sectors, industrial organizations, public institutions, universities and sustainability-related organizations in Azerbaijan, Structural Equation Modeling was applied to evaluate the proposed relationships. The results reveal that green energy transition has a significant positive impact on both regional economic resilience and green innovation capability. The findings further confirm that green investment partially mediates the relationship between green energy transition and regional economic resilience, indicating that financial mechanisms are essential for converting renewable energy initiatives into sustainable regional development outcomes. The study contributes to sustainability transition literature by demonstrating that successful green transformation depends not only on renewable energy adoption but also on investment capacity and innovation development. These findings suggest that policymakers and regional stakeholders should integrate green energy strategies with investment mechanisms to enhance long-term regional adaptability and sustainable economic development.

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1. Introduction

The global transition toward green energy systems has become a key response to climate change and the pursuit of sustainable economic development. Efforts to reduce carbon emissions, decrease fossil fuel dependence, and enhance energy security have accelerated the adoption of renewable energy, making the green energy transition (GET) both an environmental necessity and a strategic driver of economic transformation and regional development (Markard, 2018).

Regional economic resilience (RER) refers to a region's ability to adapt to structural change, withstand disruptions, and sustain long-term growth. GET can strengthen resilience by promoting economic diversification, structural transformation, and reduced reliance on conventional energy systems, particularly in resource-dependent economies such as Azerbaijan.

Although previous studies have examined the effects of renewable energy on economic growth and environmental outcomes (Saidi & Omri, 2020; Mukhtarov et al., 2023), limited attention has been given to the relationship between GET and RER and the mechanisms underlying this relationship.

Therefore, this study examines the direct effect of GET on RER and the mediating role of green investment (GI), providing an integrated framework for understanding how green investment translates energy transition into stronger regional economic resilience.

2. Literature review and hypotheses development

2.1. Green energy transition, regional economic resilience, and green innovation capability

GET is reshaping regional development through renewable energy adoption, energy efficiency, technological modernization, and low-carbon transformation. As a strategic response to environmental and economic challenges, GET strengthens regional adaptability, competitiveness, and sustainable development (Sovacool, 2016; Hasanov & Safarli, 2023). From a socio-technical perspective, energy transitions involve interactions among technologies, institutions, industries, and society, driving structural transformation and innovation across multiple sectors (Geels et al., 2017).

RER refers to the ability of regional economies to withstand disruptions, adapt to change, and sustain long-term development. GET enhances RER by reducing fossil fuel dependence, improving energy security, promoting economic diversification, and supporting green industries (Dincer, 2000). At the same time, GET creates technological opportunities that stimulate green innovation capability (GIC) by encouraging knowledge creation, technological learning, and capability development (Rennings, 2000; Chen, 2008; Huang & Li, 2017).

GIC reflects the capacity of regions and organizations to develop and apply environmentally oriented innovations. Its development depends on internal capabilities, external pressures, technological readiness, and continuous innovation (Cai & Li, 2018; Song et al., 2019). Although previous studies have examined renewable energy, innovation, and economic growth, limited attention has been given to the role of GET in simultaneously strengthening RER and GIC.

Drawing on the preceding discussion, the following hypotheses are proposed:

H1. Green energy transition positively influences regional economic resilience.

H2. Green energy transition positively affects green innovation capability.

2.2. The mediating role of green investment

GI is a key financial mechanism through which the GET contributes to RER. By financing renewable energy, clean technologies, sustainable infrastructure, and environmentally responsible projects, GI supports long-term economic transformation (Chen et al., 2023; Ristanović et al., 2024).

Beyond financing, GI promotes technological upgrading, industrial restructuring, and sustainable development. Previous studies show that green finance accelerates technological progress, low-carbon development, and sustainability-oriented strategies (Zhang et al., 2021; Wang et al., 2022). However, GET alone is unlikely to strengthen regional resilience without investment mechanisms that transform renewable energy initiatives into innovation and sustainable industrial development (Tan & Zhou, 2025; Guliyeva et al., 2021).

GI also enhances RER by encouraging economic diversification, reducing vulnerability to energy-related shocks, and supporting green development. Institutional frameworks, financial systems, environmental regulations, and investment incentives are essential for mobilizing resources for sustainable transformation (Tao, 2026; Zeynalova, 2019). Despite its importance, the mediating role of GI between GET and RER remains underexplored, as previous studies have focused mainly on its direct effects on sustainability and green growth (Feng & Li, 2025).

Therefore, this study proposes that GI serves as a transmission mechanism linking GET to stronger regional economic resilience.

H3. Green investment mediates the relationship between green energy transition and regional economic resilience.

3. Materials and methods

3.1. Research design, measurement and data collection

Data were collected through a structured questionnaire based on validated scales for green energy transition, green innovation, green investment, and sustainable regional development. The survey was conducted in Azerbaijan between January and March 2026 using purposive sampling to select respondents with relevant expertise in energy transition, investment, innovation, and regional development.

All items were measured on a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). After data screening, 364 valid questionnaires were retained for analysis. Respondents' demographic characteristics are presented in Table 1.

Table 1

Demographic profile of respondents

Variable	Category	Sample size	%
Gender	Male	188	51.6
	Female	176	48.4
Age	18–35	95	26.1
	36–65	232	63.7
	65 and above	37	10.2
Experience with Sustainability	Less than 1 year	72	19.8
	1–5 years	205	56.3
	More than 5 years	87	23.9
Field Knowledge	Renewable energy transition	111	30.5
	Green innovation activities	103	28.3
	Regional economic development	95	26.1
	Environmental/sustainability projects	55	15.1

3.2. Data Analysis Procedures

Data analysis was performed using SPSS 26 and SEM. A multi-stage analytical procedure was applied to evaluate the reliability and validity of the measurement model and to test the proposed hypotheses.

First, descriptive statistics were calculated to summarize respondents' demographic characteristics. The reliability of the constructs was assessed using Cronbach's alpha (α) and CR). Values exceeding the recommended threshold of 0.70 indicated acceptable internal consistency reliability.

CFA was conducted to assess the measurement model. Convergent validity was evaluated using standardized factor loadings and AVE. Factor loadings above 0.60 and AVE values greater than 0.50 were considered acceptable indicators of convergent validity. Discriminant validity was assessed using the Fornell–Larcker criterion and the HTMT ratio.

The overall model fit was evaluated using multiple goodness-of-fit indices, including χ^2/df , CFI, TLI, RMSEA, and SRMR.

After confirming the adequacy of the measurement model, SEM was applied to examine the hypothesized structural relationships. The direct effect of GET on RER was analyzed to test H1, while the effect of GET on GIC was examined to test H2.

Finally, the mediating role of GI in the relationship between GET and RER (H3) was tested using a bootstrapping procedure with 5000 resamples and bias-corrected 95% confidence intervals. The indirect effect was considered statistically significant when the confidence interval did not include zero.

4. Results

The results of the structural model examining the relationships among GET, GIC, GI, and RER are presented in Figure 1. The structural model illustrates the estimated path coefficients for the proposed hypotheses, including the direct relationships and the mediating mechanism of GI.

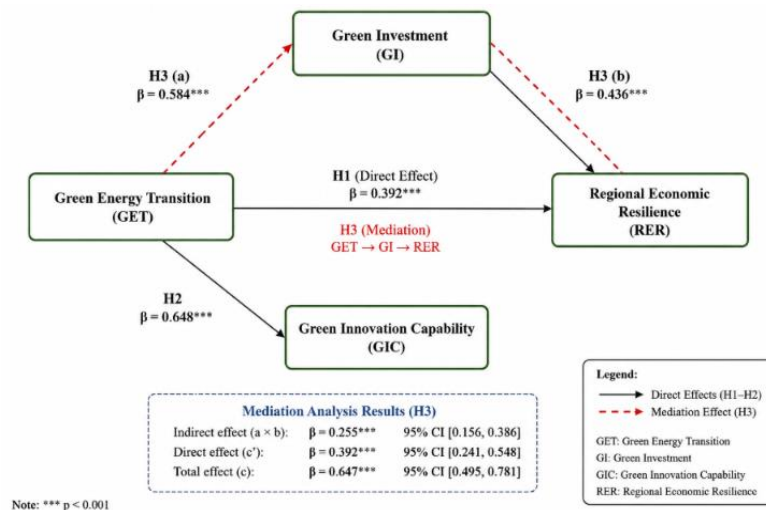


Fig. 1. Structural model results

The detailed results of the structural relationships are presented in Table 2. The findings show that all estimated structural paths are positive and statistically significant.

Table 2

Results of the structural relationships

Path Relationship	Path Coefficient (β)	S.E.	C.R.	Hypothesis Result
GET $\rightarrow$ RER	0.392	0.079	5.762	H1 Supported
GET $\rightarrow$ GIC	0.648	0.073	8.657	H2 Supported
GET $\rightarrow$ GI	0.584	0.068	7.914	H3 mediation path (a) Supported
GI $\rightarrow$ RER	0.436	0.071	6.325	H3 mediation path (b) Supported

The results indicate that GET has a significant positive influence on RER ($\beta = 0.392$, $p < 0.001$), supporting H1. This result suggests that the development of renewable energy systems, improvements in energy efficiency, and low-carbon transformation processes contribute to strengthening regional adaptability and sustainable economic development.

The results also demonstrate that GET has a strong positive effect on GIC ($\beta = 0.648$, $p < 0.001$), confirming H2. This finding indicates that the transition toward cleaner energy systems encourages technological development, environmental innovation practices, and the creation of new green capabilities.

Furthermore, GET significantly enhances GI ($\beta = 0.584$, $p < 0.001$), and GI contributes positively to RER ($\beta = 0.436$, $p < 0.001$).

The explanatory power of the structural model was evaluated using R^2 values. GET explains 45% of the variance in GIC ($R^2 = 0.45$), indicating its important role in promoting environmentally oriented innovation capacity. Additionally, GET and GI together explain 59% of the variance in RER ($R^2 = 0.59$), demonstrating strong explanatory capability of the proposed model.

After examining the direct structural relationships, mediation analysis was conducted to evaluate the indirect effect of GET on RER through GI. The results are presented in Table 3.

Table 3

Mediation analysis results

Effect Type	Path	Standardized Effect (β)	S.E.	95% Bootstrap CI
Direct effect (c')	GET $\rightarrow$ RER	0.392	0.079	[0.241, 0.548]
Indirect effect ($a \times b$)	GET $\rightarrow$ GI $\rightarrow$ RER	0.255	0.061	[0.156, 0.386]
Total effect (c)	GET $\rightarrow$ RER	0.647	0.072	[0.495, 0.781]

The mediation results presented in Table 3 confirm the mediating role of GI in the relationship between GET and RER. The indirect effect of GET on RER through GI is positive and statistically significant ($\beta = 0.255$, $p < 0.001$), and the 95% bootstrap confidence interval does not include zero.

Since both the direct effect of GET on RER and the indirect effect through GI are significant, the findings indicate a partial mediation effect. Therefore, H3 is supported.

5. Discussion

5.1. Green energy transition, regional economic resilience, and green innovation capability

The findings confirm that GET has significant positive effects on both RER (H1) and GIC (H2). These results indicate that GET is not merely a shift from fossil fuels to renewable energy but a broader socio-economic transformation that reshapes industrial structures, investment patterns, and regional development.

GET strengthens regional resilience by reducing dependence on conventional energy sources, improving energy security, promoting economic diversification, and enhancing regions' capacity to respond to environmental and economic shocks. At the same time, the transition stimulates technological learning, knowledge creation, and the development of sustainable production processes, thereby strengthening regional green innovation capability.

These findings support environmental innovation theory by demonstrating that sustainability-oriented energy transitions create favorable conditions for technological advancement and capability development. Unlike previous studies that primarily emphasized the effects of renewable energy on economic growth, emissions, or existing innovation capacity, this study shows that GET simultaneously enhances both the adaptive capacity

of regional economies and the development of green innovation capability, highlighting its broader contribution to sustainable regional transformation.

5.2. The Mediating Role of Green Investment

The mediation analysis confirms that GI partially mediates the relationship between GET and RER (H3). This finding indicates that GET strengthens regional resilience both directly and indirectly through investment-driven mechanisms.

From a theoretical perspective, GI serves as a strategic mechanism that transforms renewable energy initiatives into technological progress, sustainable infrastructure, and regional competitiveness. Renewable energy transition alone is insufficient to enhance resilience without adequate investment to support clean technologies, energy efficiency, and sustainable industrial transformation.

These findings extend the sustainability literature by showing that GI is not only a financial resource but also a key mechanism linking energy transition to regional adaptation, structural transformation, and long-term economic resilience.

6. Conclusion

The transition toward sustainable energy systems is a key driver of regional transformation. This study developed and tested a structural framework explaining how the GET enhances RER through the mediating role of GI. Using structural equation modeling, the study provides empirical evidence on the mechanisms linking energy transition to long-term regional development.

The findings indicate that GET is not only an environmental initiative but also a catalyst for economic transformation. Renewable energy and low-carbon systems improve regional adaptability, reduce vulnerabilities, and promote sustainable development, while these benefits depend on the effective mobilization of GI.

The results offer practical implications for policymakers, regional authorities, financial institutions, businesses, and universities. Renewable energy policies should be integrated with green financing and supportive regulations, while regional stakeholders should foster sustainable industries, clean technologies, innovation, and university–industry–government collaboration.

Appendix 1. Measurement items.

Green Energy Transition
GET1 – Adoption of renewable energy technologies
GET2 – Improvement of energy efficiency practices
GET3 – Reduction of dependence on fossil energy sources
GET4 – Implementation of low-carbon energy strategies
Green Innovation Capability
GIC1 – Development of environmentally friendly technologies
GIC2 – Ability to implement green process innovations
GIC3 – Capacity to create sustainable products and services
GIC4 – Integration of environmental knowledge into innovation processes
Green Investment
GI1 – Allocation of financial resources to green projects
GI2 – Investment in renewable energy infrastructure
GI3 – Availability of green financing mechanisms
GI4 – Long-term commitment to sustainable investment activities
Regional Economic Resilience
RER1 – Ability of the region to adapt to economic changes
RER2 – Capacity to recover from economic and environmental shocks
RER3 – Diversification of regional economic activities
RER4 – Creation of sustainable employment opportunities

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ПЕРЕХОД К ЗЕЛЁНОЙ ЭНЕРГЕТИКЕ И УСТОЙЧИВОСТЬ РЕГИОНАЛЬНОЙ ЭКОНОМИКИ

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Резюме. В условиях, когда регионы всё чаще сталкиваются с экологическими проблемами, угрозами энергетической безопасности и давлением, связанным с экономической трансформацией, изучение вклада перехода к зелёной энергетике в устойчивое и стабильное региональное развитие становится важным направлением научных исследований. Цель исследования заключается в изучении влияния перехода к зелёной энергетике на региональную экономическую устойчивость посредством анализа посреднической роли зелёных инвестиций и их воздействия на потенциал зелёных инноваций. Для оценки

предполагаемых взаимосвязей применён метод моделирования структурными уравнениями (Structural Equation Modeling – SEM) на основе данных опроса 364 специалистов, представляющих энергетические отрасли, промышленные организации, государственные учреждения, университеты и организации, связанные с устойчивым развитием в Азербайджане. Результаты показывают, что переход к зелёной энергетике оказывает статистически значимое положительное влияние как на региональную экономическую устойчивость, так и на потенциал зелёных инноваций. Полученные результаты также подтверждают, что зелёные инвестиции частично опосредуют взаимосвязь между переходом к зелёной энергетике и региональной экономической устойчивостью, указывая на важную роль финансовых механизмов в преобразовании инициатив в области возобновляемой энергетики в результаты устойчивого регионального развития. Исследование вносит вклад в научную литературу по вопросам перехода к устойчивому развитию, демонстрируя, что успешная зелёная трансформация зависит не только от внедрения возобновляемых источников энергии, но и от инвестиционного потенциала и развития инноваций. Полученные результаты свидетельствуют о том, что разработчикам государственной политики и региональным заинтересованным сторонам следует интегрировать стратегии развития зелёной энергетике с инвестиционными механизмами для повышения долгосрочной адаптивности регионов и обеспечения устойчивого экономического развития.

Ключевые слова: внедрение возобновляемых источников энергии, устойчивое развитие, низкоуглеродная трансформация, зелёные инвестиции, экологические инновации

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Xülasə. Regionların ekoloji problemlər, enerji təhlükəsizliyi ilə bağlı narahatlıqlar və iqtisadi transformasiya təzyiqləri ilə getdikcə daha çox üzləşdiyi şəraitdə yaşıl enerjiyə keçidin dayanıqlı və davamlı regional inkişafa necə töhfə verdiyinin öyrənilməsi mühüm tədqiqat istiqamətinə çevrilmişdir. Tədqiqatın məqsədi yaşıl investisiyaların vasitəçi rolunu və yaşıl innovasiya potensialına təsirini təhlil etməklə yaşıl enerjiyə keçidin regional iqtisadi dayanıqlığa təsirini araşdırmaqdır. Azərbaycanda enerji sektorlarını, sənaye təşkilatlarını, dövlət müəssisələrini, universitetləri və dayanıqlı inkişaf əlaqəli təşkilatları təmsil edən 364 mütəxəssisdən toplanmış sorğu məlumatları əsasında irəli sürülən əlaqələrin qiymətləndirilməsi üçün struktur tənliklərin modelləşdirilməsi (Structural Equation Modeling – SEM) metodundan istifadə edilmişdir. Nəticələr göstərir ki, yaşıl enerjiyə keçid həm regional iqtisadi dayanıqlığa, həm də yaşıl innovasiya potensialına statistik baxımdan əhəmiyyətli müsbət təsir göstərir. Əldə edilən nəticələr, həmçinin yaşıl investisiyaların yaşıl enerjiyə keçidlə regional iqtisadi dayanıqlıq arasındakı əlaqədə qismən vasitəçi rol oynadığını təsdiqləyir. Bu işə bərpa olunan enerji təşəbbüslərinin dayanıqlı regional inkişaf nəticələrinə çevrilməsində maliyyə mexanizmlərinin mühüm əhəmiyyət daşıdığını göstərir. Tədqiqat uğurlu yaşıl transformasiyanın yalnız bərpa olunan enerji mənbələrinin tətbiqindən deyil, həm də investisiya imkanlarından və innovasiyaların inkişafından asılı olduğunu nümayiş etdirməklə dayanıqlılığa keçid üzrə elmi ədəbiyyata töhfə verir. Əldə edilən nəticələr göstərir ki, siyasətçilər və regional maraqlı tərəflər uzunmüddətli regional uyğunlaşma qabiliyyətini və dayanıqlı iqtisadi inkişafı gücləndirmək üçün yaşıl enerji strategiyalarını investisiya mexanizmləri ilə inteqrasiya etməlidirlər.

Açar sözlər: bərpa olunan enerji mənbələrinin tətbiqi, davamlı inkişaf, aşağı karbonlu transformasiya, yaşıl investisiyalar, ekoloji innovasiyalar