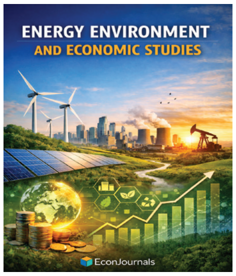

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Green Digitalization Capability and Sustainable Energy Investment Efficiency: The Mediating Role of Energy Transition Readiness in Jordan's Energy Sector

Ilhan Ozturk[1,2]*

[1]College of Business Administration, University of Sharjah, United Arab Emirates, [2]Faculty of Economics, Administrative and Social Sciences, Nisantasi University, Istanbul, Turkey. *Email: iozturk@sharjah.ac.ae

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ABSTRACT

This research analyses the impact of energy transition readiness (ETR) as a mediator between green digitalization capability (GDC) and sustainable energy investment efficiency (SEIE) in the energy sector in Jordan. This study in contrast to previous research that concentrated on corporate responsibility and reputational mechanisms proposes a new capability-based framework that is based on the emerging digital-energy nexus. The data were gathered in an online cross-sectional survey of 528 energy related companies such as renewable energy service providers, utilities, and energy technology services providing companies based in Jordan. The analysis uses partial least squares structural equation modeling (PLS-SEM) to provide a test of the suggested relationships. The results indicate that GDC does not have a direct significant impact on SEIE. Rather, a complete and substantial mediation of the relationship by ETR suggests a complete mediation effect. This implies that companies can only transform the GDC into the high efficiency of investment when sufficiently equipped to face energy transition processes, such as regulatory adaptation, technological integration, and sustainability alignment. It is theoretically based on the dynamic capabilities theory (DCT), institutional theory, and the resource-based view (RBV), which expands the existing theories to the under-researched area of digital transformation and energy transition in new economies. The findings have a contribution to the energy economics literature in the form of new constructs (GDC and ETR) that provide a new analytical perspective on sustainable energy performance in the developing context. In practice, the results emphasize the importance of institutional support structures in Jordan, such as regulatory incentives and policies of integrating digital and energy, to improve the transition preparedness of firms. Managers are urged to invest in organizational abilities that can match the digital innovation to energy sustainability targets, such that long-term investment efficiency and competitiveness in the emerging energy market are maintained.

Keywords: Green Digitalization, Sustainable Energy, Energy Transition, Jordan
JEL Classifications: Q4, Q56

1. INTRODUCTION

The world energy system is undergoing a structural transformation never witnessed before due to the reduction of climate change, digitalization, and redistribution of investments in low-carbon systems. This shift is more complicated in the emerging economies because of institutional restrictions, capital constraints and technological fragmentation. The situation in Jordan is especially topical as the country imports almost 90-95% of its primary energy resources, which exposes its economy to external shocks, fluctuation of prices, and insecurity of supply (Almarshad et al., 2024; Nica et al., 2026). Nevertheless, Jordan has become a regional leader in the adoption of renewable energy, aiming to achieve almost 50% of renewable electricity generation by 2030, which is powered mainly by solar investments and wind investment (Yang et al., 2025; Martínez-Peláez et al., 2023). Nevertheless, energy investments have not been efficient yet because of underdeveloped digital integration and lack of organizational preparedness, which is why it is urgent to analyze how companies can improve the results of sustainable energy investments with the help of high-level capabilities.

This paper presents three interconnected concepts, namely, GDC, ETR and SEIE. GDC refers to the strategic capability of a company to combine digital technologies to achieve environmental sustainability goals, maximize energy systems, minimize waste, and enhance performance of investments (Sarabdeen et al., 2024; Bergougui et al., 2025). It is said to be a multidimensional construct comprising (1) digital energy integration, (2) the capability of energy optimization that is driven by artificial intelligence, (3) the adaptability of smart infrastructure, and (4) the capability of data-driven sustainability decision-making (Al-Oun et al., 2025; Lyeonov et al., 2025). These dimensions indicate the way in which firms are changing conventional energy systems to intelligent, adaptive and environmental compatible infrastructures. ETR describes how much companies are ready to be flexible in terms of technological, regulatory, and structural adjustments related to the transition to the renewable and low-carbon energy systems (Al-Hyassat and Ghasemi, 2025; Sadaa et al., 2024). It embodies the institutional ability to comply, the malleability of the workforce, the technological readiness, and the alignment of strategies with the sustainability requirements. SEIE, in turn, quantifies the efficiency of the firms to allocate and use financial resources in renewable energy and sustainability projects in order to obtain the best economic results and environmental outcomes (Ganie et al., 2026; Tabash et al., 2025; Zighan et al., 2026). These variables are selected as they reflect an entire transformation pathway of the capability (GDC), readiness (ETR), and outcome efficiency (SEIE) providing a comprehensive energy economics framework.

The choice of the Jordan energy sector is highly reasonable, because of the changing market dynamics. Industrialization and urbanization increase electricity demand in the country more than 3.5% per year, and the investments in renewable energy have exceeded USD 10 billion in the last decade (Bergougui et al., 2025; Oubrahim et al., 2023; Wurarah et al., 2025). In Jordan, solar energy is among the largest adopters of solar energy in the Middle East, with an estimated contribution of 15-20% of the electricity production being produced by solar energy alone (Sadaa et al., 2024). Nonetheless, despite such investments, inefficiencies are present in the project implementation, grid integration, and financial returns, which implies the structural gaps between the inflows of investments and efficiency of operations. Such circumstances ensure that Jordan could be a perfect empirical site to explore the ideas of how digital capabilities may enhance investment performance in the energy industry. Previous research has made significant contributions to the knowledge base in digital transformation and sustainability, but there are still critical gaps in research, with Jaradat et al. (2025) and Wurarah et al. (2025) being the first ones to view digital transformation as a direct predictor of organizational performance without considering the intermediary roles of organizational readiness and capability maturity. Elhaj et al. (2025) and Ramadan (2026) mostly concentrate on manufacturing and service sectors, which does not apply to energy economics, where the investment cycle, regulatory intensity, and the intensity of infrastructure vary significantly. Chen et al. (2025) and Nica et al. (2026) consider digitalization and sustainability as two distinct concepts establishing conceptual fragmentation and restricting combined theoretical accounts.

Al-Hyassat and Ghasemi (2025) emphasizes the role of institutional pressure, but fails to relate it with the digital capabilities of the firm at the micro level, and thus, there is a micro macro gap in the description of energy transition behavior. Tabash et al. (2025) is a focus on digital maturity that does not take into consideration mediating pathways, especially mechanisms based on readiness that determine the performance of investments (Bergougui et al., 2025; Oubrahim et al., 2023). The emerging economies like Jordan have not been taken into consideration despite their critical role in energy transition around the world (Chen et al., 2025). Lastly, GDC is not operationalized in any of the preceding studies as a multidimensional concept that connects AI and smart infrastructure to integration systems and decision-making based on data. Moreover, the current literature does not consider the multidimensionality of GDC and does not describe the way digital competencies can be translated into the actual investment efficiency in capital-intensive sectors such as energy. The other gap is the minimal attention to the emerging economies in the Middle East, where the institutional uncertainty and transitions based on policy play a substantial role in the behavior of firms (Almarshad et al., 2024; Sadaa et al., 2024). This paper fills these gaps by suggesting a mediation model in which ETR is an important process connecting GDC to SEIE. This study is theoretically based and combines DCT (Teece, 2018), Institutional Theory (DiMaggio and Powell, 1983), and the RBV. Dynamic capabilities describe the way in which companies re-organize digital and sustainability resources in reaction to environmental shifts. Institutional theory emphasizes regulatory and policy pressures as important in determining energy transition behavior. RBV underpins the argument that GDC is a useful, rare and inimitable strategic asset which adds to long-term competitiveness and efficiency in investing. The main research questions of the study are: (1) How does GDC influence SEIE, (2) how does ETR mediate the effects of GDC and (3) how does a multidimensional construct of green digitalization capability explain the situation in the energy industry in Jordan. The research also seeks to contribute to energy economics literature by incorporating the digital transformation and sustainability investment efficiency as a single theoretical and empirical model.

This study has a multidimensional significance. In theory, it makes a difference in the economics of energy by closing the gap between digital transformation and sustainability transition literature via a capability-readiness efficiency framework. In practice, it offers practical recommendations to policymakers and Jordanian energy companies to achieve better investment performance by increasing their digitalization and institutional preparedness. The originality of the study is its attention on a growing energy-import-based economy and the integration of a new multidimensional GDC construct, never before attempted in the literature of energy economics. In sum, this study is driven by the pressing need to learn the role of strategic exploitation of digital capabilities in enhancing efficiency of sustainable energy investment in emerging economies with structural energy limitations.

2. THEORETICAL BACKGROUND

Three theoretical lenses (DCT, Institutional Theory and the RBV) are the basis of this study to help explain how GDC can affect SEIE by using ETR in the Jordanian energy industry. These theories are chosen due to the inability of each of them to explain the intricate process of interaction between digital transformation, institutional pressure, and efficiency in investment in an emerging energy market; nevertheless, their combination creates a solid explanatory framework. DC reminds us of the way in which firms feel, grab and restructure resources as a way of reacting to the quickly changing environments (Lyeonov et al., 2025). GDC, in terms of this research, is a higher-order dynamic capability that helps companies to combine digital technologies and sustainability objectives. This perspective is supported by the previous researches that indicate that digital capabilities contribute to adaptive performance in the industrial and energy industries (Satar et al., 2025; Yang et al., 2025; Chen et al., 2025). Nevertheless, these studies tend to ignore the way these capabilities transform into investment efficiency which this study tries to answer using the mediating variable of ETR. ETR is an indicator of the reconfiguration stage of the DCT, in which companies match internal systems, technologies and strategies with the requirements of energy transition (Wurarah et al., 2025; Labaran and Masood, 2023). RBV adds to this reasoning by stating that the competitive advantage based on firm-specific resources is sustainable due to their value, scarcity, imitability, and non-substitutability (VRIN) (Almarshad et al., 2024; Sadaa et al., 2024).

Conceptualizing GDC in this research, it is a type of intangible strategic resource that consists of four dimensions: digital integration of energy, AI-motivated optimization, adaptability of smart infrastructure, and data-based sustainability decision-making. Previous research attests to the fact that digital and green resources can lead to competitive positioning and financial performance (Almarshad et al., 2024; Rawashdeh et al., 2024; Zighan et al., 2026). But RBV alone cannot be used to explain how external institutional pressures influence the use of capabilities and this is why the Institutional Theory has been incorporated. The Institutional Theory is used to understand how organizations become compliant to regulatory, normative, and cognitive pressures to achieve legitimacy (Al-Oun et al., 2025; Satar et al., 2025). In the energy industry, companies are subject to tough regulations regarding decarbonization, renewable use, and digital regulations (Al-Hyassat and Ghasemi, 2025; Wurarah et al., 2025). Policymaking that facilitates the development of renewable energy and the modernization of the digital infrastructure in Jordan have a coercive effect on companies to increase their preparedness (Al-Hyassat and Ghasemi, 2025; Rawashdeh et al., 2024). The existing literature indicates that the concept of institutional pressures is an important factor affecting sustainability adoption and digital transformation strategies (Elhaj et al., 2025; Tabash et al., 2025). Nevertheless, these studies usually overlook the way in which these pressures can be translated into the output of efficiency in investments via readiness mechanisms; this is the focus of this study. The combination of these theories forms a logical sequence: RBV describes why it is possible to have GDC as a strategic resource, DCT describes how this resource becomes adaptive capabilities, and Institutional Theory describes why firms have to create a readiness towards energy transition. They jointly explain the mediation of ETR between GDC and SEIE. This hybrid model is aligns with current empirical evidence that indicates that digital capability by itself does not directly lead to financial or investment results, unless coupled with organizational preparedness and institutional fit (Jaradat et al., 2025; Sarabdeen et al., 2024; Zighan et al., 2026). This integrated model is further supported by empirical literature.

The works of Oubrahim et al. (2023) and Wurarah et al. (2025) prove the existence of the positive impact of digital capabilities on the performance of firms, however, stressing that the organization has to adapt to changes through the means of adaptation mechanisms. The role of external pressures is supported by the evidence of Al-Hyassat and Ghasemi, (2025) and Nica et al. (2026) that institutional environments are important in influencing the sustainability outcomes. Wurarah et al. (2025) and Chen et al. (2025) emphasize that operational efficiency in energy systems depends on the readiness and technological alignment. Nonetheless, none of these studies integrate the ability, preparedness, and efficiency of investment in a single energy economics model, especially in developing economies such as Jordan. The energy sector in the case of Jordan can be described as highly import-dependent, with swift growth of renewable, and high policy-based change (Tabash et al., 2025; Ganie et al., 2026). These circumstances augment the pressure in institutions and make firms create advanced digital and green capabilities. Hence, internal change is explained by DCT, resource advantage by RBV, and external constraints and motivations by Institutional Theory, which is why they should be combined to interpret the results of SEIE. In general, this theory offers a solid basis to propose the hypothesis that GDC positively impacts SEIE via ETR particularly under high institutional pressure in the changing energy market in Jordan.

2.1. Green Digitalization Capability and Energy Transition Readiness

To achieve the goals of energy system efficiency, innovation, and the quality of decisions, GDC is conceptualized as a strategic organizational capability that combines digital technologies, with environmental sustainability goals (Al-Oun et al., 2025). This paper argue that GDC can be of great benefit in enhancing ETR in the energy sector of Jordan. The rationale behind this association is that companies that have high digital-green level are more equipped to respond to regulatory, technological, and structural shifts that come with transition of energy systems to renewable energy (Yang et al., 2025; Elhaj et al., 2025). In the DCT angle, companies which build sensing, seizing, and reconfiguring competencies using digital tools have an increased chance of reacting successfully to environmental changes (Satar et al., 2025; Zighan et al., 2026). This adaptive capacity is augmented by GDC because it allows real-time energy monitoring, predictive analytics, and AI-based optimization which, in its turn, directly increases organizational readiness to the energy transition challenges (Almarshad et al., 2024; Satar et al., 2025). Likewise, RBV implies that the said capabilities can be utilized as valuable and rare resources that enhance competitive positioning and readiness outcomes (Yue et al., 2025; Chen et al., 2025). Moreover, according to the Institutional Theory, companies that have to work in regulated energy markets like Jordan are also subject to high coercive and normative pressure to adhere to sustainability and digital transformation policies (Sarabdeen et al., 2024; Al-Oun et al., 2025). These forces push companies to shift towards green digital to enhance compliance and strategic preparedness (Martínez-Peláez et al., 2023; Al-Hyassat and Ghasemi, 2025). In Jordan, where the renewable energy growth is gaining momentum and regulations are becoming stricter, companies that have greater GDC could better meet the expectations of institutions and prepare to the changes in energy transition (Lyeonov et al., 2025; Bergougui et al., 2025). This relationship is also backed up by empirical studies. The digital capability has been observed to improve the organizational flexibility and sustainability preparedness across various industries (Sadaa et al., 2024; Wurarah et al., 2025). Similarly, the green innovation literature also indicates that digital integration enhances environmental sensitivity and strategic readiness (Oubrahim et al., 2023; Al-Oun et al., 2025). Nevertheless, previous studies have not adequately explored this relationship within the energy economics frameworks or in the emerging economies which is a critical gap. Therefore,

H_1: GDC significantly and positively influences ETR.

2.2. Green Digitalization Capability and Sustainable Energy Investment Efficiency

GDC is also becoming a key facilitator of effective allocation of investments in the energy sector, especially where renewable projects are capital-intensive, and require high levels of precision, coordination and risk management (Yang et al., 2025; Ganie et al., 2026). Here, it is stated that GDC leads to a positive impact on SEIE significantly because digitally empowered green systems enhance the way companies plan, allocate, and utilize financial resources in energy projects (Oubrahim et al., 2023; Tabash et al., 2025). In terms of the RBV, companies with high levels of digital-green capabilities have better investment performance due to the capabilities contributing to better decisions, less operational inefficiency, and better quality project selection (Bergougui et al., 2025; Yang et al., 2025). This translates into improved capital budgeting, wastage and optimization of renewable energy utilization in energy-intensive industries. Similarly, DCT indicates that companies that have good sensing and seizing ability can easily recognize good opportunities to invest in energy and reorganize their resources to increase returns (Al-Oun et al., 2025; Satar et al., 2025). GDC boosts these processes with its core dimensions such as AI-driven optimization and data-enabled sustainability decision-making, which enable firms to make a more precise evaluation of energy projects and reduce uncertainty in investment decisions (Li and Lu, 2026; Zighan et al., 2026). The adaptability of smart infrastructure also allows the alignment of investments with changing energy technologies, enhancing financial sustainability in the long term (Ganie et al., 2026). Moreover, the Institutional Theory offers an extra rationale implying that the companies with high regulatory pressure in favor of adopting renewable energy are motivated to enhance efficiency in investments by complying with the rules and adopting a digital transformation (Wurarah et al., 2025; Ciobotea et al., 2024). Policies in Jordan supporting the growth of renewable sources and the involvement of the private sector promote the use of digital technologies to improve transparency and accountability in investments (Sadaa et al., 2024; Li and Lu, 2026). This line of reasoning is backed by empirical data, with previous research revealing that digital transformation enhances financial performance, resource distribution, and sustainability performance in a wide range of industries (Rawashdeh et al., 2024; Al-Hyassat and Ghasemi, 2025). Nevertheless, the majority of studies do not directly consider energy investment efficiency, and there is a large empirical gap in the knowledge of how digital-green capabilities can be converted into financial efficiency in renewable energy settings (Bergougui et al., 2025). Therefore,

H_2: GDC positively influences SEIE.

2.3. Energy Transition Readiness and Sustainable Energy Investment Efficiency

ETR is an important factor that can be used to identify the effectiveness of firms in transforming strategic intentions into financially efficient and sustainable energy investments. In the research, the ETR is suggested to affect the SEIE in a positive direction, which is significant, and the more prepared firms are to deal with technological, regulatory, and operational complexities in connection with the investments in renewable energy, the better they can address the problem (Lyeonov et al., 2025; Elhaj et al., 2025). In the framework of DCT, the concept of readiness indicates the capacity of a firm to keep on adjusting, integrating, and reorganizing its internal operations to meet the changing needs of the environment (Almarshad et al., 2024; Ramadan, 2026). Companies that prove to be better transition ready are better placed to be able to match the investments strategies to the new energy technologies thus enhancing cost effectiveness and minimizing failure of investments. This flexible attribute guarantees the initiation and successful implementation of energy projects with the optimal use of resources (Ciobotea et al., 2024; Tabash et al., 2025). This correlation is further reinforced by the Institutional Theory which states that companies that work in the regulated energy markets should adhere to the sustainability requirements, carbon mitigation policies, and renewable energy goals (Zighan et al., 2026; Jaradat et al., 2025). In Jordan, the growing regulatory stress and the national objectives of energy diversification make it necessary to become more prepared by companies to successfully handle investments in renewable energy (Wurarah et al., 2025; Li and Lu, 2026). Companies that are better prepared are thus at a more advantageous position to convert compliance mandates to effective investment guidelines. Also, according to RBV, readiness can be viewed as an organizational capacity that can contribute to the effective utilization of both internal and external resources and, consequently, lead to better financial and operational performance (Sarabdeen et al., 2024; Al-Hyassat and Ghasemi, 2025). It translates into the improved coordination of capital, technology, and human resources in energy-intensive sectors, which in turn leads to the increased performance in terms of sustainability, operational efficiency, and the use of technologies (Oubrahim et al., 2023; Yang et al., 2025). Nonetheless, readiness to investment efficiency in the energy sector is not explicitly linked to most of these studies with a significant conceptual gap. Therefore,

H_3: ETR positively influences SEIE.

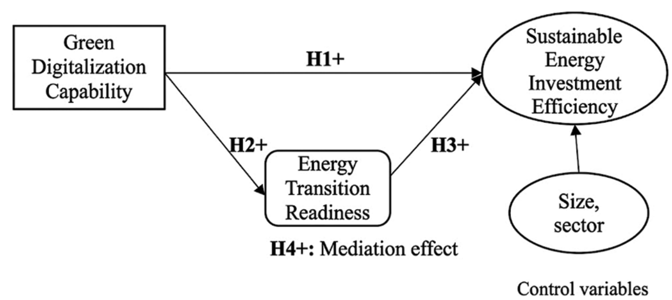
2.4. Mediating Role of Energy Transition Readiness

In this study, it is hypothesized that ETR is a mediating variable between GDC and SEIE. The essence is that, in order to guarantee the effective energy investment results, digital-green capabilities cannot be considered adequate without the firms being structurally, technologically, and institutionally ready to proceed with the energy transition processes (Chen et al., 2025; Satar et al., 2025). In terms of DCT, advanced capabilities are not only valuable since they exist but can be converted into organizational practical solutions under varying environmental conditions (Yue et al., 2025; Martínez-Peláez et al., 2023). This way, GDC ensures the sensing and technology base and ETR is the stage of reconfiguration when the capabilities are transformed into effective investment choices (Almarshad et al., 2024; Nica et al., 2026). Following the Institutional Theory, the companies in energy markets of transition have to address external forces, including decarbonization policies, renewable energy goals, and modernization of regulations (Zighan et al., 2026; Martínez-Peláez et al., 2023). Such pressures are not directly helpful to increase the efficiency of investments; rather, they demand internal preparedness to translate the compliance requirements into organized investment activities. In Jordan, energy reforms and renewable expansion policies establish the environment where readiness is the pivotal pathway to transforming digital and green strategies into tangible financial efficiency results (Nica et al., 2026; Al-Hyassat and Ghasemi, 2025). In the same manner, RBV indicates that although GDC is an important resource in organizations, its economic value hinges on complementary capabilities that facilitate its optimum use (Chen et al., 2025; Satar et al., 2025). ETR is a capability of this nature and guarantees that digital systems, human resources, and strategic investment planning are aligned, minimizing inefficiencies and maximizing the resource allocation in energy projects (Martínez-Peláez et al., 2023; Yang et al., 2025). The previous empirical data suggest that capability-related results tend to be indirect and modulated by the organizational adaptation process (Almarshad et al., 2024; Wurarah et al., 2025). Research findings also indicate that readiness variables play a significant role in the transformation of digital into operational and financial efficiency (Tabash et al., 2025; Elhaj et al., 2025). Nevertheless, the current literature seldom places readiness as a formal mediating variable in energy investment efficiency models, and especially in emerging economies. Therefore,

H_4: ETR mediates the relationship between GDC and SEIE.

The conceptual framework of the study is illustrated in Figure 1. As depicted, we would anticipate that GDC have a positive effect on ETR and SEIE. Moreover, ETR have a positive effect on SEIE, which suggests that the companies with a greater level of readiness have more abilities to transform digital-green capabilities into effective results in energy investments. Thus, it is expected that ETR positively mediate the GDC–SEIE relationship. Similarly, the control variables contain the size of firms and the nature of energy related industry (renewable energy, utilities and energy services) to consider structural and operational variations across firms.

Figure 1: Conceptual model



3. METHODOLOGY AND DATA

3.1. Study Context and Sample

In 2021, Jordan introduced its National Energy Digitalization Strategy 2030 to catalyze sustainable changes in energy and increase digitalization in the energy ecosystem as part of national economic modernisation plans (Satar et al., 2025). Among the main priorities the strategy focuses on are smart energy systems, renewable energy growth, AI-managed grid, cybersecurity of energy infrastructure and digital energy markets. According to a report by the Jordan Energy Research Center Al-Oun et al. (2025), the number of firms in the energy ecosystem is about 610 including production of renewable energy, power distribution services, energy technology solutions and industrial energy services in various sectors of utilities, manufacturing and energy consultancy. Purposive and simple random sampling methods were used in turn in this research. In the first instance, purposive sampling was employed to find firms that operated digital energy actively in line with the aim of the research. The survey contained a screening question on whether firms incorporate the digital technologies (e.g., AI-based energy systems, smart grids, big data analytics, or IoT energy monitoring systems) in their work. Those firms that answered no were not included in the final sampling frame. At this point, a total population of 610 firms was reduced by 82 firms. The final sampling frame was the remaining 528 digitally active firms. Subsequently, simple random sampling was used, making every firm an equal chance of being selected. Corporate websites and industry directories were searched to create a structured list of firms and their official email addresses. An online survey through Google Forms was conducted by emailing selected firms to take part in an anonymous survey. The purpose of the study was well described in detail to reduce the bias in the responses. The respondents targeted were the key managerial staff members like the energy managers, operations directors and chief executive officers in charge of strategic decision-making.

3.2. Data Collection

Electronic distribution of a structured questionnaire was used to collect primary data between February and April 2026. The survey tool was created and published on a safe web site, which is easy to access and reply. The questionnaire was accompanied by a detailed cover letter outlining the purpose of the study, confidentiality and academic nature of the study to ascertain informed participation. The pilot study was done on a small sample of energy professionals to verify validity and reliability before full-scale data collection. There were only slight changes made to the final instrument to include feedback. Cronbach alpha of the pilot test reliability analysis was 0.89, which is a strong internal consistency (Oubrahim et al., 2023). Invitations to the survey were sent by email to all sampled firms with the survey link. To improve the response rates, two automated reminders were planned after every 2 weeks. There were 58 responses in the first round. Following the second reminder, 33 more responses were obtained and the last wave provided 39 more responses, leading to total 130 responses obtained out of 528 questionnaires distributed. Through the completeness screening, 2 responses were eliminated because of missing data and the final analysis would be conducted using 128 valid responses, which is an effective response rate of 48.48. In order to limit the common method bias, the questionnaire items were randomized into several forms (ABC, BAC, CBA) through IT-assisted programming. Moreover, a non-response bias test was done by comparing early and late respondents in terms of construct means and demographic attributes. The findings showed that there were no significant differences in the two groups, which proves that the non-response bias was not a significant concern in this study (Bergougui et al., 2025).

3.3. Measures

We have used sound tested and well-tested items of past research. Since the scale items were original items/information borrowed in past studies, we conducted item validation during the pilot test and a confirmatory factor analysis (CFA) during the main data administration and collection which is addressed in the result section. We have measured GDC as a fifteen-item measure based on recent digital-energy integration research, which includes digital energy integration capability (4 items), AI-driven energy optimization capability (4 items), smart infrastructure adaptability (4 items), and data-enabled sustainability decision-making capability (3 items) (Tabash et al., 2025; Chen et al., 2025). This metric indicates how the company has embraced digital technologies in order to achieve sustainability goals in enhancing energy efficiency and returns on investment. As an illustration, one of the statements tells about our organization: we use real-time digital systems to track and streamline energy consumption in our operations. ETR is operationalized as the degree to which the company is ready to adjust to the requirements of renewable energy transition, technological upgrades, and regulatory transition to energy, and it was measured on a 4-point scale based on previous readiness and transition-to-sustainability studies (Al-Oun et al., 2025; Rawashdeh et al., 2024). A sample statement is: Our organization is completely ready to introduce the concept of renewable energy integration into its activities. SEIE is defined as how well the firm allocates and uses financial resources in sustainable and renewable energy projects relative to industry standards, and it was measured with 5-point items based on the energy efficiency and investment performance literature (Zighan et al., 2026; Jaradat et al., 2025). As an example, one of them says: Our organization receives greater returns on investments in sustainable energy than competitive organizations. The use of a 7-point Likert scale used anchors of 1 = strongly disagree and 7 = strongly agree. Since the efficiency of investing might be affected by the firm characteristics, we adjusted the variables of firms size and industry of operation (renewable energy, utilities, and energy services). This was through gathering of annual turnover data in order to categorize the firm size according to the EU 2003 framework. The size of firms was incorporated since bigger firms usually have more financial and technological resources to implement digital energy systems, whereas smaller firms may have resource limitations but tend to be more agile in adopting innovations (Almarshad et al., 2024; Tabash et al., 2025; Zighan et al., 2026). To adjust in favor of structural differences between energy intensity, regulatory exposure and technological complexity across the various energy sub-industries, sector of operation was added.

3.4. Common Method Bias

Common method bias is likely to affect survey research. Thus, measures have been taken during the design of the survey. To illustrate, we employed reliable and valid measurements (Fuller et al., 2016), explicitly disentangled the measures, provided anonymity to the participants (there is no wrong or right answer to the questions) (Podsakoff et al., 2003), balanced the sequence of the explanatory and outcome variables in the survey, and involved unambiguous and clearly defined and valid items. Because previous literature indicates that the common method variance can be reduced by using educated respondents (Rindfleisch et al., 2008), approximately 82% of the respondents in our research study had a college degree or higher. We then thought of using the single-factor test by Harman to test common method bias but this test did not find a significant common method bias problem. We also used the marker variable approach (Lindell and Whitney, 2001). As the marker variable, we made use of the general digital communication usage of the respondent since it was thought to be irrelevant to the constructs of the study.

3.5. Endogeneity Check

We also tested endogeneity in the model to determine whether it had any effect on the interpretation of the results. When the estimates of the variable under estimation are found to be correlated with the error term of the regression model, then this is known as endogeneity (Al-Oun et al., 2025; Tabash et al., 2025). The first way we tried to minimize this concern was to add a group of control variables (i.e. firm size and industry of operation). Furthermore, we performed the Gaussian Copula test in order to investigate the possibility of endogeneity issues due to the research being done using PLS-SEM. We tested the individual relationships and then the combined structural relationships with bootstrapping, but we found no significant endogeneity problems as the path estimates were not significantly different (βETR; B = 0.009; P = 0.812; βSEIE; B = 0.014; P = 0.694; βinteraction; B = 0.072; P = 0.841 These findings suggest that the outcomes of the structural estimates are not biased by endogeneity and that the model outcomes are robust (Hult et al., 2018).

3.6. Validation Higher-Order Construct (GDC)

The current paper viewed GDC as a higher-order construct that included four lower-order constructs, such as, digital energy integration capability (DEIC), AI-driven energy optimization capability (AIEOC), smart infrastructure adaptability (SIA), and data-enabled sustainability decision-making capability (DESSDC). Thus, we used a higher-order model where the four dimensions were considered lower-order formative measures of the higher-order measure of GDC. The reflective-formative type which we have employed is the two-stage approach embodied (Sarstedt et al., 2022). The standard evaluation procedures of reflective constructs were used to verify the measurement models of the LOCs (Almarshad et al., 2024). We also evaluated multicollinearity in terms of variance inflation factor (VIF) to justify the higher-order formative construct. The findings indicate that the VIF of every dimension was less than or as low as 4.8, which means that there is no issue of multicollinearity in the data (Sadaa et al., 2024). Moreover, the estimated coefficients of all four GDC dimensions were significant at the 95% level of confidence, which validates the fact that each GDC dimension is a significant contributor to the higher-order construct. In particular, the loadings of DEIC, AIEOC, SIA, and DESSDC on GDC were strong and significant. Thus, the second-order factor of Green Digitalization Capability was confirmed (Sarstedt et al., 2022).

4. ANALYSIS AND RESULTS

Our sample characteristics demonstrate that 51% of the respondents were males. 50.32% and 28.91% of the respondents were college and university graduates; 48.41% had been in business for 5-9 years; 53.17% were energy-sector-based (renewable, utilities, and energy services); and 30.16% were incorporated as limited liability firms. Finally, 25.40% of the firms had an annual income between $28,000 and $38,000. Moreover, the descriptive statistics of the constructs of the study in terms of means and standard deviation are shown in Table 1. The highest mean (M = 4.82) is the GDC (especially AI-driven energy optimization capability), then there are ETR (M = 4.63) and SEIE (M = 4.61), which demonstrate the relevance of GDC to the surveyed firms.

4.1. Measurement Model

To evaluate the validity of constructs of the study and the psychometric properties (discriminant and convergent), composite reliability, and average variance extracted (AVE) according to the procedures of (Martínez-Peláez et al., 2023), we performed a CFA. One of the indicators of the SEIE construct (SEIE_2) was dropped since its outer loading was <0.7. Upon re-examination, as indicated in Table 2, all constructs have passed the required thresholds as composite reliability and Cronbach alpha values were above 0.70. In addition, the values of AVE exceeded 0.50, which supports convergent validity (Oubrahim et al., 2023). The values of variance inflation factor (VIF) were between 2.39 and 4.61, which means that there were no problems with multicollinearity. Adequacy was also supported by the model fit indices, SRMR = 0.066, CFI = 0.92 and NFI = 0.75 which fall within reasonable values. The Table 3 validates the discriminant validity because the square root of the AVE values were greater than inter-construct correlations, which

Table 1: Descriptive statistics

Construct	n	Mean	Standard deviation	Skewness	Standard error	Kurtosis	Standard error
		Statistic	Statistic	Statistic	(Skewness)	Statistic	(Kurtosis)
DEIC_c	128	4.8126	1.35244	−0.338	0.214	−1.021	0.421
AIEOC_c	128	4.7649	1.51732	−0.241	0.214	−1.398	0.421
SIA_c	128	4.7896	1.48655	−0.176	0.214	−1.263	0.421
DESSDC_c	128	4.8031	1.53328	−0.315	0.214	−1.142	0.421
ETR_c	128	4.6218	1.41836	−0.283	0.214	−1.196	0.421
SEIE_c	128	4.5979	1.60341	−0.208	0.214	−1.311	0.421
Valid N (listwise)	128	—	—	—	—	—	—

Table 2: Measurement model

Constructs	Indicators	Outer loadings	Cronbach's alpha	Composite reliability	AVE
GDC					
Digital energy integration capability	DEIC_1	0.668	0.852	0.864	0.67
	DEIC_2	0.723			
	DEIC_3	0.799			
	DEIC_4	0.815			
AI-driven energy optimization capability	AIEOC_1	0.758	0.973	0.974	0.74
	AIEOC_2	0.805			
	AIEOC_3	0.819			
	AIEOC_4	0.811			
Smart infrastructure adaptability	SIA_1	0.786	0.932	0.933	0.73
	SIA_2	0.804			
	SIA_3	0.798			
	SIA_4	0.836			
Data-enabled sustainability decision-making capability	DESSDC_1	0.831	0.897	0.898	0.71
	DESSDC_2	0.764			
	DESSDC_3	0.845			
Energy transition readiness (ETR)	ETR_1	0.882	0.924	0.941	0.76
	ETR_2	0.858			
	ETR_3	0.891			
	ETR_4	0.844			
Sustainable energy investment efficiency (SEIE)	SEIE_1	0.887	0.925	0.944	0.77
	SEIE_3	0.859			
	SEIE_4	0.893			
	SEIE_5	0.842			

Model fit indices: SRMR=0.066; CFI=0.92; NFI=0.75; Chi-square=836.41, $P<0.05$. Source: Authors' compilation met the Fornell and Larcker (1981) criterion.

4.2. Results of Hypothesis Testing

The key findings of the hypotheses as a result of the analysis are provided in Table 4. We tested the structural model with the help of the beta, t-values, effect sizes and the coefficient of determination (R2) (Sadaa et al., 2024). First, we can see that GDC does not have any significant influence on SEIE (β = 0.009, P = 0.741). It implies that the increase in GDC by 1 standard deviation unit does not produce a significant change in SEIE, indicating that the green digitalization practices could be not directly associated with the sustainability of the energy investment efficiency by the firm. H_1 is, thus, not confirmable. Secondly, but, there was a positive and significant association between GDC and ETR (β = 0.581, P = 0.000), thus validating H_2. This demonstrates that an increase in the GDC practices by 1 standard deviation unit can increase the energy transition readiness by 0.581 standard deviation units, which means that when businesses engage in green digitalization efforts, they can raise their preparedness to the energy transition to a higher level. Lastly, there was a great and substantial positive correlation between ETR and SEIE (β = 0.948, P = 0.000) which means a 1 standard deviation unit rise in the energy transition preparedness leads to an increased sustainable energy investment efficiency by 0.948 standard deviation units. This implies that the energy transition readiness is closely correlated with the investment efficiency results, hence, H_3 should be supported.

4.3. Mediating Effect of Energy Transition Readiness

Preacher and Hayes (2008) bootstrapping method with 5000 resamples was used to test the mediating role of ETR between GDC and SEIE nexus because t-statistic and confidence interval were used to determine the significance. Table 5 demonstrates that ETR positively and significantly mediates the relationship between GDC and SEIE (β = 0.542, P = 0.000) since the confidence intervals do not include zero (Preacher and Hayes, 2008). This supports Hypothesis 4 and indicates that companies with green digitalization tendencies are better positioned to build stronger energy transition preparedness that subsequently greatly enhances efficiency in investing in sustainable energy. The findings also show that the impact of GDC on SEIE is only indirect and its direct impact would be statistically meaningless once ETR is added to the model. Thus, ETR has a complete mediation position in the connection between GDC and SEIE, which underscores its important role as a transformation tool to convert digital-green capabilities into effective investment results in the energy sector.

Table 3: Discriminant validity (HTMT)

Constructs	DEIC	AIEOC	SIA	DESSDC	ETR	SEIE
DEIC	0.828					
AIEOC	0.463	0.861				
SIA	0.255	0.576	0.835			
DESSDC	0.449	0.361	0.485	0.853		
ETR	0.521	0.438	0.372	0.467	0.871	
SEIE	0.331	0.374	0.356	0.549	0.612	0.879

5. DISCUSSION AND IMPLICATIONS

This paper looked at the correlation between GDC, ETR and SEIE in the Jordan energy industry. The results offer solid empirical evidence to a completely mediated model, in which ETR is at the center of the process of converting GDC into SEIE results. In general, the findings indicate that the digital-green capabilities do not suffice in the absence of firms coming up with sufficient transition preparedness to mobilize the capabilities effectively within the energy investment systems. The initial result indicates that SEIE is not impacted significantly by GDC. This finding stands in line with the idea that digital transformation does not necessarily result in financial or investment efficiency performance unless it is accompanied by organizational complementary mechanisms. Other studies have also found similar non-significant direct effects, including Bergougui et al. (2025), and Ramadan (2026) who state that digital capability can frequently demand a set of enabling conditions before it can lead to detectable efficiency improvements. Conversely, Li and Lu (2026) and Sarabdeen et al. (2024) reported that there was a positive direct correlation between digital transformation and performance but their research was in manufacturing and banks where digital adoption is more developed and structurally integrated. This divergence implies that in the energy-intensive industries such as those in Jordan the structural constraints and the large capital requirements undermine the short-term impact of GDC on investment efficiency.

The second conclusion supports the fact that there is a strong positive relationship between GDC and ETR. This finding

Table 4: Results of hypothesis testing

Hypotheses	Relationships	β	t-values	P-values	R^2	Decision
H_1	GDC→SEIE	−0.009	0.341	0.741	—	Not supported
H_2	GDC→ETR	0.581	7.286	0.000	0.346	Supported
H_3	ETR→SEIE	0.948	44.12	0.000	0.892	Supported
Controls						

Variables	Relationships	β	t-values	P-values
Size	Size→SEIE	0.121	3.087	0.031
Sector	Sector→SEIE	0.209	2.148	0.022

Source: Authors' compilation

Table 5: Mediation analysis

Hypotheses	Relationships	β	t-value	P-value	CI−	CI+	Decision
H_4	GDC→ETR→SEIE	0.542	7.621	0.000	0.386	0.675	Supported

Source: Authors' compilation

corresponds to the DCT (Teece, 2018), as according to which, companies with high capabilities can more easily detect changes in the environment and respond to them. Similar studies by Labaran and Masood (2023) and Yang et al. (2025) also state that digital capability increases the adaptability and sustainability transition readiness of organizations. The conclusion is also in line with the research by Chen et al. (2025) that discovered AI-based and data-driven systems enhance environmental preparedness to change within organizations. This study, however, builds upon previous studies that have operationalized readiness more specifically to the energy transition context, specifically, in an emerging economy where institutional pressures are more intense and infrastructure constraints are more severe (Tabash et al., 2025; Almarshad et al., 2024).

The third result shows that ETR has a significant positive impact on SEIE, which means that preparedness is a key investment efficiency driver. This is consistent with Institutional Theory (DiMaggio and Powell, 1983) in that firms that do not have regulatory and normative pressures are more likely to enhance performance outcomes by being adaptively compliant. The same results are indicated by Lyeonov et al. (2025); and Wurarah et al. (2025) that also demonstrate that organizational readiness enhances the sustainability performance and efficiency of resources. Elhaj et al. (2025) also validate the financial and operational efficiency of capital-intensive areas in preparedness of the energy context. Nevertheless, this work provides a new twist to this by putting the concept of readiness in a direct relationship with investment efficiency, and not overall performance, thus, reducing the scope of the study to energy economics outcomes. The greatest impact of the research is the complete mediation effect of the ETR among GDC and SEIE. This result suggests that GDC can only have an indirect effect on SEIE via mechanisms of readiness. This helps the perspective of Dynamic Capabilities, which asserts that capabilities need to be converted into operational processes prior to value creation (Yang et al., 2025; Lyeonov et al., 2025). It is also consistent with the RBV logic, which implies that resources like GDC can generate competitive advantage only when applied with the other capabilities in a complementary manner (Chen et al., 2025; Tabash et al., 2025). Likewise, Jaradat et al. (2025); and Zighan et al. (2026) note that digital capability effects can be indirect using organizational enablers.

Nevertheless, the studies never directly tested energy transition readiness as an intermediary per se, and thus the study is a new branching out in the literature of energy economics. Institutionally, the outcome of the mediation is especially significant in Jordanian context. Regulatory reforms, renewable energy goals, and digital modernization policies have a significant impact on the energy industry of the country (Ganie et al., 2026; Wurarah et al., 2025). Such institutional pressures compel companies to prepare in advance before they can achieve investment results using digital capabilities. This substantiates the claims of DiMaggio and Powell (1983) that coercive pressures influence the organization behavior and goes further to demonstrate that coercive pressures work via readiness channels, as opposed to direct efficiency incentives. Yue et al. (2025); and Jaradat et al. (2025) also support similar contextual arguments and point to the fact that institutional alignment is also significant in energy transition economies. The fact that the direct impact of GDC on SEIE is not significant, but the indirect impacts are high, due to the high effectiveness of ETR, also reveals a gap of structural inefficiency in the emerging energy markets. In contrast to developed economies where digital systems are thoroughly integrated into financial decision-making procedures Nica et al. (2026); Al-Hyassat and Ghasemi (2025), the Jordanian companies continue to experience technological fragmentation and institutional barriers to direct efficiency improvements brought about by digitalization. This is the reason why direct effects are stronger in studies in developed settings (Elhaj et al., 2025; Sarabdeen et al., 2024), but in this study, the direct effect is completely mediated. In general, the results prove a sequential logic: GDC lays the foundations of capabilities, ETR transfers these capabilities into the operational readiness, and SEIE becomes the ultimate economic result. It is a systematic route that reinforces the theoretical merging of RBV, Dynamic Capabilities Theory, and Institutional Theory, as well as covering key gaps in the existing literature in terms of sectoral focus, mediation processes and emerging economy environments (Almarshad et al., 2024; Rawashdeh et al., 2024; Yue et al., 2025).

5.1. Theoretical Contributions

The work has a high degree of theoretical contribution as it combines DCT, Institutional Theory and the RBV to a comprehensive explanatory model of sustainable investment in energy efficiency. First, it lifts DCT by showing that GDC is not a value generating process but it works via ETR. This narrows down the argument of Teece, demonstrating that sensing and seizing capabilities in digital-energy systems must have a readiness-based transformation layer before having an impact on financial outcomes. Second, it promotes the notion of RBV as it conceptualizes GDC as a multidimensional strategic resource, which solely generates economic value when integrated with complementary readiness capabilities, which reinforces the idea that resources are not sufficient by themselves without an efficient deployment mechanism (Barney, 1991). Third, the research builds on Institutional Theory by empirically demonstrating that the regulatory and normative pressures in the Jordanian energy industry do not only influence the adoption behavior but also internal structures of readiness that define the result of investment efficiency (DiMaggio and Powell, 1983). Combining these three theories, the study establishes a new capability-readiness-efficiency route, filling the gaps in explanations in the previous literature and broadening theoretical knowledge about the digital transformation in the context of energy economics. This framework helps in filling the gap between micro-level firm capabilities and macro-level institutional dynamics of emerging economies.

5.2. Practical Implications

This research has valuable practical implications to energy companies and policy-makers. First, the results indicate that companies cannot be limited to digital transformation investments but should, at the same time, create ETR to enjoy the maximum of GDC. In the energy sector of Jordan, managers need to focus on establishing organizational preparedness by training its workforce, planning on renewable integration, and aligning with digital infrastructure. Second, the findings indicate that AI-related energy optimization, data-driven decision-making tools, and smart infrastructure systems need to be integrated into operation frameworks; otherwise, they remain as a set of single technologies. Third, policymaking needs to create regulatory frameworks to enhance the capacity to prepare, such as incentives to integrate digital and energy, subsidies on renewable transition, and institutional backing of smart grid implementation. Fourth, the energy investment agencies must consider efficiency of a project not just in terms of financial returns, but also in terms of readiness indicators, which will ensure sustainability in the long-term. On the whole, the work offers an outline of the way forward to aligning digital transformation strategies with the aim of energy transition in emerging economies.

6. CONCLUSION, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This paper concludes that GDC will not be effective in improving SEIE unless companies build effective ETR. The empirical data proves the full mediation effect, which emphasizes that the readiness is the most important mechanism, in which digital-green capabilities are converted into investment efficiency results. The combination of DCT, RBV and Institutional Theory makes the study an in-depth explanation of the conversion of digital transformation to economic efficiency in the energy industry. The results reiterate the fact that in the developing economies such as Jordan, structural preparedness and alignment with the institution is critical in transforming the technological capabilities into long term investment performance.

Although it has made contributions, this study has a number of limitations. First, it is based on cross-sectional survey data, which precludes the possibility of tracking long-term dynamic changes in the results of digital capability and energy transition. Longitudinal studies need to be conducted in future to monitor the evolution of GDC and ETR with time. Secondly, the research is restricted to the energy sector of Jordan which may limit the generalization to other places with diverse institutional and technological settings. To be able to compare the model with other emerging and developed economies, future research ought to reproduce the model in those economies. Third, the research is performed at firm level which can be subject to subjectivity bias; objective financial and energy performance data can be included in future research. Fourth, the model can be further enhanced by the addition of other mediating or moderating variables, like digital maturity, innovation culture, or regulatory intensity. Lastly, future research can be done to investigate the industry-specific differences in the energy industry, e.g., renewable and conventional energy companies to offer more insights into the capability-performance relationships.

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