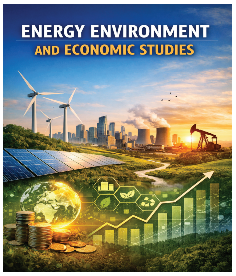

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Digital Energy Transformation and Decarbonization Performance for Sustainable Development: The Mediating Role of Energy Transition Capabilities

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ABSTRACT

In the era of global energy transition, achieving decarbonization performance (DP) has become a strategic imperative for energy-intensive industries. While digital energy transformation (DET) is widely recognized as a key enabler of low-carbon transitions, its specific influence on DP, particularly through the mediating roles of renewable integration capability (RIC), energy efficiency capability (EEC), and carbon reduction capability (CRC), remains underexplored. Drawing on the socio-technical systems theory (STST), this study examines how DET impacts DP by conceptualizing RIC, EEC, and CRC as mediating capabilities. A quantitative research approach was employed, utilizing survey data collected from 268 managers in Jordan's energy and industrial sectors. Data were analyzed using structural equation modeling (SEM-AMOS). The results indicate that DET positively affects RIC, EEC, and CRC, and also exerts a direct positive effect on DP. Furthermore, these three capabilities partially mediate the relationship between DET and DP, suggesting that digital technologies accelerate decarbonization outcomes by strengthening firms' transition-related capabilities. This study extends STST by validating the mediating roles of energy transition capabilities in the relationship between DET and DP. From a practical standpoint, the findings provide actionable insights for policymakers and firms aiming to enhance low-carbon performance through digital energy systems and transition-oriented strategies.

Keywords: Digital Energy Transformation, Decarbonization Performance, Energy Transition Capabilities, Socio-Technical Systems Theory, Jordan Energy Sector
JEL Classifications: Q43, O13, Q56

1. INTRODUCTION

Rapidly increasing rates of global environmental degradation and the increasing levels of carbon emissions have put industries in an unprecedented pressure to shift to low-carbon and sustainable models of operation. The necessity of curbing climate change has become particularly acute in recent years due to the international system like the Paris Agreement, which makes decarbonization one of the key components of sustainable development (Alvi et al., 2025). Special attention should be paid to energy-intensive industries, which cause an enormous portion of the global greenhouse gas emissions- nearly 70% of the industrial emissions in the world (Qamri et al., 2025). In this background, companies are rapidly resorting to the use of digital technologies to improve energy efficiency, resource efficiency and minimise carbon footprints (Ji and Chen, 2025; Shen et al., 2025). The DET, as it is commonly referred to, is the process of integrating advanced technologies into energy systems (artificial intelligence [AI], internet of things [IoT], and big data analytics) to allow them to be smarter and sustainable in their activities (Duong, 2026). Irrespective of the increased awareness of DET as an agent of sustainability, little is known on its direct and indirect impacts on DP especially among the emerging economies. DP is a capability of a firm to reduce carbon emissions in a systematically manner and at the same time. Keeping up operational efficiency and competitiveness (Wang et al., 2024). Although earlier research has identified a positive correlation of digitalization and environmental performance Baloch et al. (2024); Li and Allen (2025), the studies tend to be analysed independently of each other, and the organizational capabilities supporting the conversion of technological investments into a real sustainability result are not sufficiently addressed (Rizwan and Iqbal, 2025; Yu et al., 2024). This void demonstrates the necessity of a more sophisticated, capability-oriented approach that is capable of demonstrating how digital transformation is causing decarbonization by engaging in certain processes. This paper is based on the socio-technical systems theory (STS), and has conceptualised energy transition capabilities as an important mediator in the DETDP relationship. STS accentuates that technological systems and social or organisational structures inter-relate in terms of performance results development (Javed et al., 2026). In the frames of this framework, we distinguish such essential dimensions as RIC, EEC, and CRC so that firms can successfully exploit digital technologies to be sustainable. RIC is the capability of a firm to use renewable energy sources in its operations, which is necessary due to the growing global trend towards clean energy (Tufail et al., 2025). EEC reflects the ability of the company to streamline energy use and minimise waste by improving the processes and implementing digital monitoring systems (Ji and Chen, 2025).

The facility of organisation to make specific measures in reducing emissions, including carbon capture methods and low-carbon manufacturing processes (Duong, 2026). Such capabilities are not just theoretically based, but are also practically applicable since they are actionable avenues, by which the digital transformation may affect the results of decarbonization. It is also important to note that the selection of Jordan as the empirical setting reinforces the applicability of the study. High energy dependency is a feature of Jordan that imports more than 90% of its energy requirements, which puts the nation at risk of energy insecurity and economic weaknesses (Kemala et al., 2026). The Jordanian government, in its turn, has made renewable energy and digital transformation their national energy priorities so that by 2030, the proportion of renewables can be raised to 50% (Shen et al., 2025). The Jordanian industrial and energy sectors are going through the most important structural transformation due to the escalating energy prices, regulatory demands, and the need to adopt sustainable behaviours (Alvi et al., 2025). These industries are important contributors to the national economy and are also the biggest contributors to carbon emissions, and hence they serve as the best environment to analyse the relationship between digital transformation and decarbonization. Moreover, the increasing popularity of smart grids, digital monitoring, and energy management platforms in Jordan has become a promising sphere to research the topic of DET and its consequences (Yu et al., 2024). Despite the fact that existing literature has identified multiple features of digitalization and sustainability, multiple gaps still exist in the literature: Many studies concentrate on the overall level of environmental performance instead of directly studying the results of decarbonization (Qi et al., 2025; Li and Allen, 2025). The mediating role of company-specific capabilities is often overlooked in the literature, preventing the insight to understand how digital technologies can lead to performance improvements (Duong, 2026; Rizwan and Iqbal, 2025). An extensive lack of emp The literature tends to use the single-capability approach, which fails to consider the combined and complementary action of several energy transition capabilities (Baloch et al., 2024; Kemala et al., 2026). Small sample sizes and cross-sectional designs are other methodological limitations, which restrict the generalizability of the results (Yu et al., 2024). Altogether, these holes demonstrate the necessity of having a multi-capability model that incorporates both technological, organisational, and contextual elements. To address the above gaps, the primary. Purpose of this research is to analyse the effects of DET on DP, in particular, the mediating effects of RIC, EEC, and CRC. This study seek to offer an overall conceptualization of the interactions between digital technologies and the capabilities of the organisation to achieve sustainable outcomes by taking a STS approach. Moreover, the paper aim to make a contribution to the overall literature on energy economics, environmental sustainability, and digital transformation by providing empirical data within the framework of an emerging economy.

The aim and novelty of the study is that it is an integrated approach involving technological innovation and capability development as the means of the explanation of DP. In contrast to the previous studies, which investigate the aspect of digitalization as a single factor, this research brings out the significance of internal capabilities as major enablers of sustainability. The findings believed to give useful information to the policymakers, especially in formulating the policies to encourage digital energy solutions and capacity development. To practitioners, the study offers a blueprint of how to use digital technologies to make significant gains towards the attainment of low-carbon goals, which consequently improve environmental as well as economic performances. To sum up, the urgency of this study is caused by the necessity to solve the problem of climate change by means of innovative and sustainable business practises. It provides solutions to the gaps in the theoretical and empirical understanding of how digital energy transformation can offer decarburization in energy-intensive sectors. The suggested framework not only adds to the theory, but also, it provides a practical implication to the realisation of sustainable development goals in emerging markets.

2. THEORETICAL BACKGROUND

The paper is based on STS and supported by the ideas of resource-based view (RBV) and dynamic capabilities perspective (DCT) to describe the relationship between DET and DP in terms of energy transition capabilities. The combination of these theoretical lenses gives a holistic basis in understanding the dynamic between the technological development, organisational potentials and the sustainability performance results. STS is the main theoretical point of this paper. STS assumes that the results of an organizational performance are conditioned by the joint optimization of technologies systems and social structures (Trist, 1981). Digital technologies, in the environment of energy transition, cannot effectively decarburize the situation unless there is a proper implementation into the organisational processes and capabilities (Huang et al., 2024; Rizwan and Iqbal, 2025). This renders STS to be especially appropriate in this study because it elicits the interdependence of DET and energy transition capability like RIC, EEC and CRC. Previous studies have pointed out that the shifts to low-carbon systems need not only technological change, but institutional adjustments and capacity building (Tufail et al., 2025; Kemala et al., 2026). As an example, research revealed that digital energy systems improve sustainability outcomes when organizational preparedness and alignment of capability is involved (Alvi et al., 2025; Rizwan and Iqbal, 2025). Therefore, STS presents a strong model to support the reasons why DET should act via mediating capabilities to impact DP. As an addition to STS, the RBV can provide useful information on the importance of firm-specific resources to attain competitive and sustainable performance.

According to RBV, the organisations can obtain a competitive edge because of the creation of valuable resources that are inimitable, non-substitutable, and rare (Barney, 1991). In this research, it is possible to define DET as a strategic resource and RIC, EEC, and CRC as some of the specialised capabilities that allow firms to utilise this resource to the fullest. The reason why RBV should be adopted is that it can explain heterogeneity in the decarbonization results of the firms despite their possible operation in the same technological conditions (Li and Allen, 2025; Baloch et al., 2024). Empirical research has always shown that companies which are well equipped with their environmental capabilities can be placed better to transform technological. Investments into sustainability performance (Huang et al., 2024; Tufail et al., 2025). Moreover, RBV has been used broadly to explain the relationship between internal capabilities and green innovation and environmental performance through environmental and energy studies (Yu et al., 2024; Qi et al., 2025). Thus, RBV enhances the theoretical background of the given study as it emphasises the significance of capability development in exploiting DET in better DP. Developing the RBV, the DCT also adds to the explanatory value of the study by concentrating on the capacity of firms to integrate, build, and reconfigure resources based on the changing environment (Teece, 2018). Due to the fast-paced dynamics of the energy markets and the policies of sustainability, the existing capabilities cannot be static as the firms need dynamic capabilities in order to remain constantly changing and involving innovation (Javed et al., 2026; Shen et al., 2025). In this respect, RIC, EEC, and CRC may be regarded as dynamic capabilities that help firms to react to environmental challenges and technological opportunities. This selection of DCP is especially grounded in the explanation of how companies can become decarbonized in the long-term through constantly advancing their capabilities in accordance with the digital transformation efforts (Alvi et al., 2025; Rizwan and Iqbal, 2025).

As mentioned before, dynamic capabilities are essential to driving digital transformation and improving the performance of sustainability (Duong, 2026; Qi et al., 2025). In addition to that, the studies on energy and environmental management found that companies that have high adaptive capacities are more effective in realizing energy-efficient behaviours and minimising emissions (Ji and Chen, 2025 in Sarabdeen et al., 2024). A combination of the STS, RBV, and DCT forms a unified theoretical framework which useful in the proposed research model. STST describes the systemic relationship between digital technologies and organisational structures, RBV underlines the strategic significance of internal capabilities and DCT underlines dynamic character of the development of capabilities to the changing environment. Collectively, the theories can come up with a complete explanation of why DET can affect DP via the mediation of RIC, EEC, and CRC. The relationships suggested in this paper are empirically justified by an increasing amount of literature. In particular, it is reported that the digital transformation can be used to increase environmental and energy performance significantly by upgrading operational capabilities (Alvi et al., 2025; Rizwan and Iqbal, 2025). Likewise, studies have also shown that decarbonization of the industrial sectors largely depends on renewable integration and energy efficiency capabilities (Li and Allen, 2025; Yu et al., 2024).

The significance of the reduction of carbon reduction efforts and the mechanisms of governance to attain the objectives of sustainability has been emphasised in other works (Javed et al., 2026; Wang et al., 2024). Moreover, it is indicated that the mediating effect of organisational capabilities is critical in supporting the relationship between digital technologies and performance outcomes (Tufail et al., 2025; Javed et al., 2026). All these results help to support the effectiveness of the proposed model and support the topicality of the chosen theoretical frameworks. To sum up, the theoretical basis of the current research is solid and justified. It is a combination of STS, RBV, and DCT, so this study provides a profound and detailed insight into the processes by which digital energy transformation leads to a high level of decarbonization. This multi-theoretical model does not just fill the gaps that are currently present in the literature, but also provides a solid foundation of empirical study and application to the framework of energy transition and sustainable development.

2.1. Digital Energy Transformation and Renewable Integration Capability

The high rate of adoption of digital technology in energy systems has greatly transformed the way in which the companies incorporate renewable energy into their operational frameworks. DET, which is defined by the implementation of smart grids, tools of IoT-based monitoring, and predictive analytics, improves the capability of firms in dealing with intermittency and variability of renewable energy sources. Through this integration of technology, it becomes easy to balance the energy in real-time, optimise and distribute load efficiently, which is critical to effective RIC (Alvi et al., 2025; Javed et al., 2026). In comparison to traditional integration of energy systems, a renewable integration demands more sophisticated coordination tools that digital tools are well-positioned to offer (Duong, 2026; Qi et al., 2025). In addition, DET allows the companies to address the structural and operational obstacles related to the adoption of renewables by enhancing the data visibility and accuracy of the decision-making. An example is the use of digital platforms to enable organisations to predict the dynamics of renewable energy production and demand with greater accuracy and minimise uncertainty and improve the reliability of the system (Tufail et al., 2025). This feature is especially essential in emerging energy markets, whereby inefficiencies in infrastructure tend to hamper the deployment of renewable (Kemala et al., 2026). Moreover, digitalization aids in the development of decentralised energy providers, including solar and wind, as it facilitates the connexion between energy networks (Baloch et al., 2024). The empirical data also confirms this association, as it is evident that companies that invest in digital energy solutions show much more renewable adoption and integration efficiency (Shen et al., 2025). Therefore, DET is a base facilitator, which upholds RIC by aligning the technological infrastructure with the needs of renewable energy justifying the proposed hypothesis.

H_1: DET positively impacts RIC.

2.2. Digital Energy Transformation and Energy Efficiency Capability

Greater complexity of industrial energy usage has led to EEC becoming a decisive factor in sustainable performance, especially within energy intensive industries. DET is a central figure in improving EEC because it helps the firms to track, analyse, and optimise energy consumption throughout the operational processes. DET enables accurate detection of energy wastefulness and helps to make the process continuous with the assistance of sophisticated technologies: real-time data analytics, machine learning algorithms, and intelligent energy management systems (Baloch et al., 2024; Li and Allen, 2025). The technologies enable the firms to move towards proactive rather than reactive energy management which leads to optimal efficiency results. Moreover, DET increases transparency and control over energy flows that allow organisations to make automated changes that reduce waste and unnecessary consumption (Qi et al., 2025; Yu et al., 2024).

As an illustration, intelligent sensors and IoT-connected devices can enable companies to get detailed information about energy consumption patterns at machine and process-level, which will enable them to follow the production schedule and minimize idle energy waste (Sarabdeen et al., 2024; Javed et al., 2026). This degree of accuracy is critical towards creating powerful EEC, because it aligns working activities with energy-saving goals. Moreover, online platforms enable the incorporation of energy-efficient technologies and operations, as it helps to coordinate more departments and supply chains (Duong, 2026; Shen et al., 2025). This type of integration guarantees that innovation of efficiency gain is not singled out but are incorporated in the larger organisational system. Empirically, it has proved that companies that implement digital energy solutions have significant decreases in energy intensity and operating expenses (Li and Allen, 2025; Wang et al., 2024). Thus, DET plays an important role in enhancing EEC through its ability to optimise data, automate processes, and manage entire systems systematically and efficiently, which is why it is a good support to the given hypothesis.

H_2: DET positively impacts EEC.

2.3. Digital Energy Transformation and Carbon Reduction Capability

The increasing pressure of working towards carbon neutrality has added great pressure on companies to come up with effective CRC which is the organizational capacity to measure, control, and reduce carbon emissions in operations in a systematic manner. DET is an essential enabler in this process with the development of advanced digital infrastructures that can increase the accuracy of the programme in terms of emissions monitoring and decision-making on mitigation (Rizwan and Iqbal, 2025). DET enables firms to detect hot spots of emissions and apply specific reduction measures with a higher degree of precision through technologies like carbon accounting systems on blockchain, AI-powered analytics systems on emissions, and real-time monitoring tools (Tufail et al., 2025). Additionally, DET helps in merging the use of low-carbon technologies and cleaner production processes, enhancing the bonds in information flow and coordination of operations. One example is digital twins and simulation tools, which allow companies to simulate various production options and choose settings that produce the least carbon with efficiency (Alvi et al., 2025; Ji and Chen, 2025). Such predictive power is a major boost to CRC where the firms get to change their reactive compliance to proactive carbon management strategies. Also, digital solutions improve supply chain disclosure, enabling an organisation to track up and down the emissions and cooperate with stakeholders to minimise their total carbon footprint (Duong, 2026). Notably, the regulatory compliance and involvement in carbon markets are also supported by DET because it allows the precise measurement and authentication of emissions data that is a critical component of carbon trading and reporting protocols (Li and Allen, 2025). The findings of empirical research suggest that companies that harness the use of digital technologies are better in terms of emission-cutting programmes and carbon governance activities (Huang et al., 2024; Tufail et al., 2025). Thus, DET plays a great role in improving CRC by offering the technical basis and analytical tools to manage the carbon successfully, and in this way, it is highly favourable to the proposed hypothesis.

H_3: DET positively impacts CRC.

2.4. Digital Energy Transformation and Decarbonization Performance

The process of moving towards the low-carbon industrial system is becoming more and more reliant on the successful implementation of digital technologies allowing companies to gradually decrease emissions without compromising the efficiency of their work. DET has a direct positive relationship with DP as it incorporates the use of intelligent systems to maximize energy consumption, minimize the use of carbon and champion the production processes to be cleaner. By implementing sophisticated analytics, automation, and cyber-physical energy systems, companies able to attain an exact impact on energy use and emissions emissions that result in quantifiable enhancements in decarbonization results (Yu et al., 2024; Kemala et al., 2026). As opposed to the conventional methods, DET allows monitoring and adaptive optimization that are essential to long-term emission cuts. In addition, DET enables the replacement of low-carbon processes with digitally enabled ones that are less carbon emitting. As an example, electrification, the use of renewable energy, and process innovation are supported by smart energy management systems and digital platforms, which directly reduce the level of carbon emissions (Qamri et al., 2025). Digital tools integration also increases responsiveness of the organisation to environmental policies and market demands so that firms can align their operations with the emerging sustainability policies (Javed et al., 2026). This Alignment enhances the capacity of firms to meet the decarbonization goals in the long run. Furthermore, DET enhances communication between industrial units and value chains and minimises inefficiencies and emissions of disconnected systems (Wang et al., 2024). Empirical studies, Ensure that the decrease in carbon emissions and the enhancement of environmental performance indicators are significant in firms that have gone through digital transformation (Alvi et al., 2025; Rizwan and Iqbal, 2025). Thus, DET has a direct and positive impact on DP because it allows data-oriented, efficient, and low-carbon operational practice, which is one of the main reasons to prove the proposed hypothesis.

H_4: DET positively impacts DP.

2.5. RIC and EEC

RIC is of crucial importance to the organizations that aim to optimise the energy consumption at the same time integrating the clean energy sources within the organizations. With effective RIC, firms can effectively deal with variable renewable sources of energy like solar and wind, and optimise the generation with demand patterns to reduce energy waste and enhance the overall systems efficiency (Shen et al., 2025; Li and Allen, 2025). Incorporating renewables into the energy-intensive processes also allow organizations to decrease their reliance on fossil fuel, stabilise the energy use, and establish the environment where the energy efficiency can be enhanced (Ji and Chen, 2025). Digital instruments integrated into RIC, such as smart grids, predictive analytics, and automated energy management systems, also contribute to the accuracy of the distribution and use of energy so that organizations can make real-time changes to optimise energy flows (Wang et al., 2024). These changes lead to minimized waste and proper utilisation of energy inputs, which directly empower EEC in all production and functioning units (Qi et al., 2025). Also, according to empirical research, organisations able to integrate renewable resources are in a better position to track and manage the use of energy, which consequently increases their capacity to attain energy-saving goals (Li and Allen, 2025; Baloch et al., 2024). Process innovations and adaptive technologies can also be adopted with the help of RIC that reinforces energy efficiency through streamlining of operations and wasting or unnecessary energy consumption (Shen et al., 2025; Qamri et al., 2025). Therefore, by allowing the organisations to align the input of renewable energy with the operational needs, RIC establishes a structural and technological base of enhancing EEC. The connexion between RIC and EEC is very much justified as efficient integration of renewables not only help in achieving sustainability, but also in improving the efficiency of operations, which can prove the hypothesis proposed in the research.

H_5: RIC positively impacts EEC.

2.6. Renewable Integration Capability and Decarbonization Performance

RIC plays a central role in the fulfilment of DP since it defines the success with which the firms use renewable energy sources within their production to decrease carbon emissions. Having high RIC allows firms to cope with the fluctuation and intermittency of renewable energy, including solar and wind, as well as to ensure energy production evenness and as little dependence on fossil fuels as possible (Alvi et al., 2025). Through effective renewable integration, organisations will have a direct impact on carbon intensity reduction and greenhouse emissions in their operations, which contributing factors to quantifiable changes in DP (Shen et al., 2025). Digital technologies also contribute to the enhancement of RIC because they allow real-time monitoring, predictive forecasting, and optimization of the use of renewable energy. The systems of advanced energy management and IoT-enabling platforms enable companies to match the renewable generation to the energy demand to decrease energy loss and prevent the use of carbon-intensive backup consumption (Javed et al., 2026). It can be evidenced that empirically, companies that can implement renewable integration strategies successfully record substantial emission cuts and improved sustainability results (Qi et al., 2025). Besides, RIC promotes strategic investments in low-carbon. Infrastructure and supports the adherence to the environmental regulations and sustainability standards, which become more severe in energy-intensive industries (Yu et al., 2024). It also assists in the global emissions reduction initiative of the supply chain, by incorporating renewable energy into its upstream and downstream activities, which further increases its effect on DP (Ji and Chen, 2025). Summing it up, RIC is a direct facilitator of DP as it operationalizes the process of switching to low-carbon energy sources, decreases the reliance on fossil fuels, and streamlines the processes of energy systems towards the minimization of emissions. Such sound theoretical and empirical basis is a reason to support the proposed hypothesis and emphasise the importance of renewable integration in terms of sustainable decarbonization results.

H_6: RIC positively impacts DP.

2.7. Energy Efficiency Capability and Carbon Reduction Capability

EEC is an aptitude of a business to utilize energy judiciously to minimise waste and simplify operations to reduce unwarranted energy usage. EEC has a direct impact on CRC; as lower energy consumption results in lower carbon emissions, especially within energy-intensive industries where most of the operational carbon footprints are made up of electricity and fuel consumption (Duong, 2026). By having a robust EEC, companies have an opportunity to employ sophisticated surveillance channels, automation of processes, and energy saving strategies that not only minimize costs but also organise annual reductions of greenhouse gases (Rizwan and Iqbal, 2025). In addition, EEC improves CRC by allowing a specific identification of the processes that emit a lot, and make targeted interventions possible. With the use of digital technologies in the form of IoT-based sensors, predictive analytics, and smart metres, organisations can identify inefficiencies, predict energy spikes, and optimize operations beforehand, which ensures that emissions are limited to a maximum (Kemala et al., 2026). The empirical literature reveals that the substantial energy reduction in organisations that adopt energy efficiency programmes along with carbon emissions indicates the close relationship of the two concepts, namely EEC and CRC (Wang et al., 2024; Ji and Chen, 2025). Also, energy-saving measures encourage the culture of ongoing enhancement and sustainability in the organisation, which enhances the ability to implement low-carbon technologies and emissions mitigation practises (Rizwan and Iqbal, 2025). As an illustration, the combination of energy-saving equipment and a carbon tracking system guarantee that the changes in operations result in quantifiable decrease of CO_2 emissions, thus, improving CRC (Li and Allen, 2025). Altogether, EEC is an important facilitator of CRC as it systematically lowers energy usage, streamlines its processes, and offers practical information on mitigating emissions. This empirical and direct relationship is a strong representation of the proposed hypothesis and points to the significance of energy efficiency as a basic capacity of carbon minimization and sustainable DP.

H_7: EEC positively impacts CRC.

2.8. Energy Efficiency Capability and Decarbonization Performance

EEC is one of the main determinants of DP since it helps organisations to maximise the use of energy and at the same time minimise the emission of greenhouse gases. High EEC firms can detect efficiency inefficiencies in their manufacturing process and activities, use energy-efficient systems, and constantly observe consumption trends, all of which directly reduce carbon intensity and enhance sustainability results (Baloch et al., 2024). EEC reduces the operational costs by minimising the energy wasted and at the same time it also helps in the quantifiable decrease of carbon emissions, it renders it a critical pathway to the achievement of DP (Qamri et al., 2025). The digital technologies also enhance the effects of EEC on DP. Monitoring systems that are based on IoT, predictive analytics, and automated energy management systems enable firms to adjust the consumption of energy in relation to real-time business needs and therefore prevent unnecessary emission and overuse of energy (Duong, 2026). The empirical data show that the organisational performance regarding environmental performance, such as reduced CO_2 emissions and improved adherence to regulatory norms, can be improved significantly when the organisation implements energy efficiency interventions with the assistance of digital tools (Sarabdeen et al., 2024). Moreover, EEC also helps in integrating the low-carbon technologies and renewable sources of energy through a platform of creating an optimal energy management basis. Strong EEC allows organisations to introduce production schedules saving energy, use the advanced process controls, and align the energy flows on the whole value chain, which result in the effective decarbonization (Tufail et al., 2025; Kemala et al., 2026). Finally, EEC has a direct positive impact on DP through offering the operational and technological capacity to minimise energy use and carbon emissions. Such connexion is quite substantiated by theoretical arguments and practical data, which accentuate EEC as one of the essential intermediaries in the process of converting energy optimization endeavours to practical decarbonization results.

H_8: EEC positively impacts DP.

2.9. Carbon Reduction Capability and Decarbonization Performance

CRC is a paramount factor in DP in the sense that it is the interpretability of a firm to measure, manage, and minimize carbon emissions in the operations as well as the supply chain. Companies that have high CRC can pursue specific measures, including low-carbon production operations, carbon capture systems, and energy optimization, which have direct and direct impacts on reducing carbon footprint in organisations (Rizwan and Iqbal, 2025). Through incorporating CRC into organizational activities, companies can then transform the carbon management efforts into quantifiable decarbonization results that match the operational performance with the sustainability goals (Huang et al., 2024). Digital technologies also improve this relationship because they provide real time monitoring of emissions, predictive models and automated reporting of results that enhance accuracy and efficiency of carbon reduction initiatives (Yu et al., 2024). With high-technology CRC instruments, the companies have the chance to detect the emission hotspots in advance, streamline production process organisation, and take corrective actions that minimise CO_2 emissions without affecting the efficiency (Alvi et al., 2025). Empirical literature constantly proves that companies that have well-developed CRC models are more successful in decarbonization performance, and they have large decreases in both scope 1 and scope 2 emissions (Qi et al., 2025; Javed et al., 2026). Moreover, CRC promotes learning and perpetual enhancement within an organisation, which allows firms to be flexible to their changing regulatory obligations, be active players in carbon markets, and implement emerging low-carbon technologies (Shen et al., 2025). The commitment of CRC to strategic sustainability objectives guarantees the decarbonization of both operational and management decisions. To conclude, CRC is a direct facilitator of DP as it operationalizes the strategies of reducing carbon emissions and increases the capacity of firms to realise the attainment of quantifiable sustainability results. This robust theoretical and empirical base contributes to the suggested postulation, giving a critical role of CRC in the propulsion of effective DP.

H_9: CRC positively impacts DP.

2.10. Mediating role of Carbon Reduction Capability

DET and DP do not only relate in a direct manner, it also acts with a lot of CRC. DET offers companies with the high-technology tools real-time monitoring, predictive analytics, and AI-based energy optimization that allow companies to accurately measure and manage carbon emissions (Kemala et al., 2026). Nevertheless, the possibility of DET in enhancing the process of decarbonization would be limited until the internal capacity of the applicable digital insights is enhanced into actionable measures to reduce emissions (Tufail et al., 2025). CRC as this key mediating power translates digital data and system data into operational practises that translate to carbon footprints with systematic reductions (Javed et al., 2026). The mediating effect of CRC is given empirical evidence. Investigations have shown that the performance of decarbonization of those firms that have undertaken DET initiatives is high when the firms have strong carbon management capabilities such as the ability to monitor emission, streamline production and adopt low-carbon strategies (Alvi et al., 2025; Li and Allen, 2025). DET can increase the accuracy and effectiveness of these interventions by making a persistent visibility of energy use and emissions, and CRC guarantees that this knowledge is translated into effective operations (Qi et al., 2025). In addition, CRC makes it easier

to learn and adapt to evolving regulatory and market pressures and deploy digital initiatives into long-term DP (Yu et al., 2024). Being the engine by which DET catalyses the process of emission reduction, CRC enhances the overall sustainability effect of a digital transformation. Finally, CRC moderates the relationship between DET and DP through the realisation of the gap between potential of the technologies and their actual implementation. This mediation provides the importance of integrating digital energy solutions with robust carbon management, to obtain quantifiable and realisable decarbonization effects, which is a powerful theoretical and empirical support to the proposed hypothesis (Wang et al., 2024).
H_{10}: CRC mediates the relationship between DET and DP.

2.11. Mediating role of Energy Efficiency Capability

DET offers companies sophisticated devices and application suites, including IoT-based monitoring, smart metres, predictive analytics, and automated energy management platforms, that allow companies to gain a comprehensive understanding of the energy usage patterns and inefficiency (Sarabdeen et al., 2024). The immediate effects of DET on DP however, can be conditional on whether the firm is able to put such insights into effective operationalization. In such a process, the most important mediating factor is EEC that transforms digital energy insights into practical steps that decrease energy consumption and carbon emissions (Javed et al., 2026). Strong EEC firms can make specific interventions, including optimization of production schedules, idle energy minimization, and the introduction of technologies that will minimise the advantages of DET (Tufail et al., 2025). EEC allows organisations to convert digital information into work efficiencies, which leads to quantifiable reductions in energy consumption, which directly leads to better DP. This is empirically evidenced: researchers have revealed that digital transformation projects lead to substantial sustainability gains when the capacity of energy efficiency is capitalised on (Huang et al., 2024; Qamri et al., 2025). Moreover, continuous improvement and responsive management are enabled through EEC, which incorporates energy-saving practises at organisational processes and value chains, therefore, making sure that insights created by DET can be impactful on carbon reduction over the long term (Duong, 2026). This mediating factor is especially important in the new energy markets, where operational inefficiencies and the lack of resources optimization can destabilise the digital initiatives (Wang et al., 2024). Finally, EEC is the mediator between DET and DP to the extent that the potential of digital technologies is converted into practical energy management activities to make sure that the investment in digital energy transformation converted into the long-term DP. Both theoretical arguments and empirical research have a high level of support to this mediation and offer a solid rationale behind the hypothesis suggested (Li and Allen, 2025).
H_{11}: EEC mediates the relationship between DET and DP.

2.12. Mediating role of Renewable Integration Capability

DET also provides companies with cutting-edge technologies, including smart grids, IoT-powered monitoring systems, and forecasting analytics that allow creating the possibility of combining renewable energy sources with each other (Rizwan and Iqbal, 2025). But the immediate action of DET on DP. Is determined by how well these technological capabilities are operationalized by the organisation. RIC can play the role of a mediator by turning the technological potential of DET into a real-life plan of implementing and managing renewable energy, which would directly and positively influence the achievement of carbon reduction (Baloch et al., 2024). RIC enables companies to overcome intermittency and variability issues of renewable energy like the variation of solar or wind power by streamlining the process of matching the energy supply to the operational demand (Tufail et al., 2025). This process is supported by digital technologies that enable to have real-time data and predict the trends of generation and autonomously adjust its flows to use renewable resources efficiently (Huang et al., 2024). The mediating effect of RIC is supported by empirical data, so that the companies using DET can expect to experience substantial improvement in decarbonization solely when they have strong capabilities to organize and handle renewable energy successfully (Qi et al., 2025). Besides, RIC strengthens the alignment of the strategic focus between tech investments and sustainability targets. Strong RIC firms can more easily coordinate renewable energy through production systems, supply chains and ancillary processes, converting the DET initiatives to quantifiable carbon emission reductions (Duong, 2026). This ability also increases the resilience of organizations to energy market volatility to a long-term decarbonization objective (Sarabdeen et al., 2024). To conclude, RIC is the mediator of the relationship between DET and DP because it is the mechanism that makes digital technologies operationalized in the process of turning them into successful strategies of renewable adoption and management. This mediation makes sure that DET investments generate sustainable DP, which give solid theoretical and empirical ground to the hypothesis presented (Javed et al., 2026).
H_{12}: RIC mediates the relationship between DET and DP.

The study hypotheses could be visually demonstrated in Figure1.

3. METHODS AND DATA

3.1. Data Collection and Sampling

In this research, the quantitative research design was applied in order to test the hypotheses proposed and to test the research model. The data collection was done by use of an online questionnaire, which was created by reviewing the related literature and measurement scales under validation. The questionnaire was administered to energy and industrial companies in Jordan so that there would be wide coverage and receive sufficient responses. The target respondents were high-level managers who were chosen due to their pertinent knowledge and experience regarding digital energy change, the ability to undergo energy transition, and decarbonization practises. This questionnaire had three major sections. The initial part consisted of the letter of cover where the variables of the research were introduced and the participants were told that the information kept confidential and not be used in other purposes other than academic ones. The second part contained demographic data like job position, industry area and years of work experience. The core measures items were found in the third section. Research constructs. In order to increase the level of participation and to make the questionnaire understandable, it was translated into Arabic through the method of back translation. This method was used to maintain the original meaning of the English items once translated (Rizwan and Iqbal, 2025). The convenience sampling technique was used because there is no extensive and formal database that can be identified with the energy and industrial companies that are actively adopting the digital transformation of energy in Jordan. Although convenience sampling can be biassed in terms of representativeness and generalizability Ji and Chen (2025), it is deemed suitable when the researcher wants to focus on a group of participants who have certain expertise in a particular issue under study. Tufail et al. (2025) support this method in cases where the research involved is supposed to have respondents who possess specialized knowledge or experience, because this help to make the data collected more relevant and profound. A total of 268 respondents who were valid and complete in the energy and industrial sector in Jordan were obtained. A summary of respondent characteristics is given in Table 1. Most of the interviewees were the operations managers (59% of the sample). In terms of professional experience, over one-half of the respondents (54.5%) indicated that they had more than 10 years of experience.

The largest proportion of respondents worked in the chemicals and industrial materials sector, accounting for approximately 22% of the total sample.

3.2. Measurement Scales

The questionnaire was designed after a thorough literature review of related literature in order to achieve construct and reliability validity. The instrument has a total of 30 items that represent the five core constructs of the study as illustrated in Table 2. All the measurement items are listed in Appendix A. The measure of all the items was a five-point Likert scale between strongly disagree and strongly agree.

3.3. Common Method Bias (CMB)

Since the research was conducted online by using a questionnaire self-report, the possibility of CMB was taken into account. Two commonly used diagnostic tests were used to determine the existence of CMB. To start with, the single-factor test developed by Harman was carried out through the extraction of the first factor without rotation through principal axis factoring as suggested by Podsakoff et al. (2003). The findings show that the former causes 28.75% of the total variance, which is much less than the desired 50%, and CMB is not a major issue. Second, the outer variable inflation factor (VIF) was used to conduct a complete collinearity test. Kock and Lynn (2012) suggest that the values of VIF must be lower than 5 to show that there is no multicollinearity and possible CMB. The maximum value of the VIF was 4.213, which is not too big as it is in Table 3. According to the findings of the two tests, CMB could not pose a risk to the validity of the findings in this study.

Table 1: Demographic characteristics of the sample

Variable	n (%)
Job title	
Operations/energy manager	158 (58.96)
Plant manager	35 (13.06)
CEO	20 (7.46)
Others (in top managerial levels)	55 (20.52)
Years of experience	
>10	146 (54.48)
6–10	82 (30.60)
<6	40 (14.93)
Number of employees	
>100 (large)	112 (41.79)
50–100 (medium)	88 (32.84)
<50 (small)	68 (25.37)
Industry sector	
Renewable energy	52 (19.40)
Manufacturing	36 (13.43)
Oil and gas	41 (15.30)
Food and beverage	39 (14.55)
Chemicals and industrial materials	60 (22.39)
Construction materials	25 (9.33)
Others	15 (5.60)

4. DATA ANALYSIS

The research model was tested using a partial least squares structural equation modelling (PLS-SEM) to test the hypotheses proposed. A number of reasons made it preferable to PLS-SEM as opposed to covariance-based structural equation modelling (CB-SEM). To begin with, the aim of the study was to analyse

Table 2: Measurement items and constructs

Constructs	Measurement items	Sources
DET	5 items	(Shen et al., 2025; Kemala et al., 2026)
RIC	6 items	(Alvi et al., 2025; Li and Allen, 2025)
EEC	5 items	(Huang et al., 2024; Javed et al., 2026)
CRC	4 items	(Wang et al., 2024; Li and Allen, 2025)
DP	10 items	(Yu et al., 2024; Duong, 2026)

DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance

Table 3: Validity and reliability evidence

Construct	Items	Loading	CR	Alpha	AVE	VIF
DET	DET1	0.882	0.921	0.887	0.745	3.115
	DET2	0.894				3.248
	DET3	0.903				3.365
	DET4	0.772				1.712
RIC	RIC1	0.859	0.926	0.892	0.758	2.405
	RIC2	0.872				2.482
	RIC3	0.885				2.975
	RIC4	0.841				2.431
	RIC5	0.826				2.596
EEC	EEC1	0.834	0.901	0.869	0.615	2.615
	EEC2	0.860				3.312
	EEC3	0.818				2.467
	EEC4	0.849				3.091
	EEC5	0.635				2.521
CRC	CRC1	0.845	0.879	0.790	0.705	1.638
	CRC2	0.831				1.689
	CRC3	0.838				1.758
DP	DP1	0.817	0.945	0.934	0.620	4.102
	DP2	0.769				2.950
	DP3	0.633				1.611
	DP4	0.825				3.243
	DP5	0.878				4.372
	DP6	0.858				4.412
	DP7	0.791				2.879
	DP8	0.797				2.795
	DP9	0.809				2.832
	DP10	0.730				3.172

DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance, CR: Composite reliability, AVE: Average variance extracted, VIF: Variable inflation factor the causal links between the independent variable DET, the mediating variables RIC, EEC and CRC and the dependent variable DP. This emphasis on forecast and theory validation fits well the advantages of PLS-SEM that is especially appropriate in confirmatory research (Hair et al., 2017). Second, PLS-SEM is suggested to be used in studies that have rather small samples and complicated models Duong (2026), which is applicable to the current research. Third, PLS-SEM has gained popularity in the recent energy and sustainability research, which also justifies its applicability in this case (Shen et al., 2025; Li and Allen, 2025). The analysis of data was done in two steps. The first evaluation was on the measurement model to test its reliability and validity. Second, the structural model was tested to test the direct and indirect hypotheses of relationship in the conceptual framework.

4.1. Measurement Model

The first stage of the analysis involved assessing the measurement model to ensure the reliability and validity of the constructs. Reliability was evaluated at both the item and construct levels.

Item reliability was assessed by examining the outer loadings of each item. All item loadings exceeded the recommended threshold of 0.60, indicating acceptable reliability (Henseler et al., 2012). Construct reliability was evaluated using composite reliability (CR) and Cronbach's alpha. As shown in Table 3, the CR values for all constructs were above the threshold of 0.70, and Cronbach's α values also exceeded 0.70, confirming the internal consistency of the constructs (Hair et al., 2017). Convergent validity was assessed through the average variance extracted (AVE). All AVE values were greater than the recommended threshold of 0.50 (Hair et al., 2017), indicating that each construct explains more than half of the variance in its indicators.

Discriminant validity was evaluated using two approaches. First, the Fornell–Larcker criterion was applied. This criterion requires that the square root of the AVE for each construct is greater than its highest correlation with any other construct. As presented in Table 3, this condition was satisfied for all constructs. Second, the HTMT ratio of correlations was used as an additional test of discriminant validity. An HTMT value below 0.85 is considered acceptable (Hair et al., 2017). As shown in Table 4, all HTMT values were below this threshold, further confirming discriminant validity. Based on these results, the measurement model demonstrates adequate reliability, convergent validity, and discriminant validity.

Values were computed after deleting indicators with low loadings (Hair et al., 2019).

Table 4: Fornell–larcker criterion/heterotrait–monotrait ratio

Construct	DET	RIC	EEC	CRC	DP
1. DET	**0.864**	0.722	0.709	0.798	0.748
2. RIC	0.643	**0.869**	0.839	0.727	0.739
3. EEC	0.651	0.756	**0.775**	0.719	0.687
4. CRC	0.670	0.608	0.621	**0.832**	0.731
5. DP	0.705	0.689	0.658	0.638	**0.782**

The diagonal bold values represent the square root of AVE. Italicized numbers represent the HTMT values. DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance, AVE: Average variance extracted, HTMT: Heterotrait–monotrait ratio

Table 5: Assessment of model fit

Criteria	R^2	Q^2	Inner VIF
	RIC	EEC	CRC
DET	1.735	1.832	1.000
RIC	0.642	0.452	2.701
EEC	0.497	0.283	1.735
CRC	0.463	0.309	1.832
DP	0.635	0.352	

DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance, VIF: Variable inflation factor

4.2. Structural Model

4.2.1. Assessment of model fitness

Before testing the hypotheses, the overall fitness of the structural model was evaluated using four key criteria. First, the standardized root mean square residual (SRMR) was assessed. The SRMR value of the model was 0.069, which is below the recommended maximum threshold of 0.10, indicating acceptable model fit (Henseler et al., 2016). Second, multicollinearity was examined using the inner VIF. As shown in Table 5, all inner VIF values were below the threshold of 3.3, suggesting no evidence of multicollinearity among the latent variables (Hair et al., 2017). Third, the R^2 values for the dependent variables were evaluated to determine the model's explanatory power. As presented in Table 5, the model explains 63.5% of the variance in DP, indicating a substantial level of predictive relevance. Finally, to support the predictive accuracy of the model, Q^2 values were calculated using the blindfolding procedure. All Q^2 values were greater than zero, further confirming that the model has predictive relevance.

4.2.2. Goodness of fit of the research model (GoF)

To evaluate the overall adequacy of the model, the global GoF index was calculated following the approach proposed by (Kemala et al., 2026). This index assesses the model's explanatory power by integrating the performance of both the measurement and structural components.

According to their guidelines, a GoF value below 0.25 indicates a weak fit, values between 0.25 and 0.36 indicate a moderate fit, and values above 0.36 suggest a strong fit. The GoF value for the current model is 0.63, which exceeds the threshold for strong fit, thereby confirming the overall robustness and adequacy of the model.

4.2.2.1. Assessment of direct hypotheses

To test the proposed hypotheses, the bootstrapping technique with 5000 resamples was employed to estimate the path coefficients, t-values, and confidence intervals. As shown in Table 6, the results indicate that DET has a significant and positive impact on RIC, EEC, CRC and DP, thereby supporting hypotheses H_1, H_2, H_3, and H_4, respectively. The findings also reveal that CRC has a significant and positive influence on both EEC and DP, confirming support for H_5 and H_6. In terms of energy efficiency, the results show that EEC significantly and positively affects both RIC and DP, thereby supporting H_7 and H_8. Finally, the results confirm that RIC has a significant positive effect on DP, providing support for H_9.

4.2.3. Test for mediation

To evaluate the mediation effects proposed in H_{10}, H_{11}, and H_{12}, the specific indirect effects reported by SmartPLS were analyzed, as shown in Table 7. The results indicate that RIC mediates the relationship between DET and DP, supporting H_{10}. Additionally, EEC was found to mediate the relationship between DET and DP, supporting H_{11}. Lastly, CRC also mediates the relationship between DET and DP, confirming support for H_{12}. According to Javed et al. (2026), mediation is considered complementary partial mediation when both the direct and indirect effects are statistically significant. Since both effects were significant for all three mediators—RIC, EEC, and CRC—it can be concluded that each of these constructs exhibits a complementary partial mediation effect in the DET–DP relationship.

4.3. Discussion

This research results offer in-depth information about the effects of DET on DP via the mediating effect of RIC, EEC and CRC. The findings affirm that DET has a positive effect on all three energy transition capabilities and DP, which illustrate the critical importance of Digitalization in promoting sustainable energy results. In particular, the fact that DET has a key effect on RIC (H_1) makes it clear that digital technologies, including smart grids, energy management systems based on AI, and predictive analytics, can make intensive firms in Jordan incorporate renewable energy sources more efficiently. This result supports the previous literature on the importance of the digital systems in supporting the implementation of renewable and resource distribution optimization Yu et al. (2024); Li and Allen (2025) as well as complements the results reported by Baloch et al. (2024) that digital monitoring promotes the efficiency of the adoption of renewable energy. On the same note, the constructive impact of DET on EEC (H_2) depicts that digitalisation of energy not only facilitates integration of renewable energy, but also operational efficiency is enhanced. DET allow real-time monitoring of energy and predictive maintenance, as well as automation. Increases the capability of the firms to minimise energy wastage and maximise the efficiency. The finding is aligns with previous studies that indicate that digital energy technologies are associated with efficiency improvement in industrial sectors (Ji and Chen, 2025; Tufail et al., 2025). Funny enough, although certain sources have indicated a lesser role of digital tools in energy efficiency of smaller businesses Qi et al. (2025), the current results indicated that even the medium-sized businesses could gain more through specific DET intervention, which is a positive reflection of the increasing availability of energy digital solutions. The positive impact of DET on CRC (H_3) is also significant, which makes digital interventions show the direct positive effect on the ability of firms to undertake carbon reduction measures. This observation is in line with the previous literature that highlights the significance of energy data analytics, emission management, and digital reporting systems in deriving carbon mitigation goals (Huang et al., 2024; Shen et al., 2025). Conversely, prior economies of developing markets observed that the only means of reducing emissions is with the help of technology without other organisational capabilities EEC, and CRC as it was argued that the mediating factor of the two is essential to achieving the full potential of DP results Kemala et al. (2026). The fact that DET has a direct impact on DP (H_4) demonstrates that the digital energy strategies have a positive impact on low-carbon performance that goes beyond the capacity of mediation. This is aligns with Rizwan and Iqbal (2025) and Alvi et al. (2025) results that indicated that digitalization leads to decarbonization through process optimization, advanced monitoring, and decision-making. Nevertheless, the present study builds on previous works as it explicitly expands on the former. Investigating the mediating potentials, and, as a result, proving that digital tools can be the most efficient when they contribute to the integration of renewables, efficiency, and carbon reduction at the same time. In terms of the relationships between the mediators, the CRC has a positive impact on the EEC and DP (H_5 and H_6) and means that the more a company has a decent carbon reduction strategy, the higher the energy efficiency and decarbonization positive results are likely to be obtained. This is in line with the dynamic capabilities literature Javed et al. (2026); Sarabdeen et al. (2024) which postulates that the creation of certain environmental capabilities strengthens overall sustainability performance. Likewise, EEC has a positive influence on RIC and DP (H_7 and H_8), which proves that the enhancement of efficiency leads to the integration of renewable energy and subsequent decarbonization. Duong (2026) and Qamri et al. (2025) also support these findings by pointing out that Operational efficiency increases the ability of firms to embrace the use of low carbon technologies. Lastly, the positive impact of RIC on DP (H_9) reveals the significance of renewable integration

Table 6: Direct path coefficients (H_1-H_9)

Hypothesized paths	β	t-statistic	Percentile 95% CI	Support
H_1: DET→RIC	0.291***	4.632	0.180–0.395	Yes
H_2: DET→EEC	0.442***	6.101	0.320–0.558	Yes
H_3: DET→CRC	0.665***	15.982	0.595–0.730	Yes
H_4: DET→DP	0.336***	3.914	0.195–0.472	Yes
H_5: CRC→EEC	0.341***	4.812	0.228–0.466	Yes
H_6: CRC→DP	0.168**	2.442	0.055–0.279	Yes
H_7: EEC→RIC	0.596***	11.487	0.509–0.680	Yes
H_8: EEC→DP	0.142*	1.911	0.015–0.262	Yes
H_9: RIC→DP	0.289***	0.289	0.164–0.414	Yes

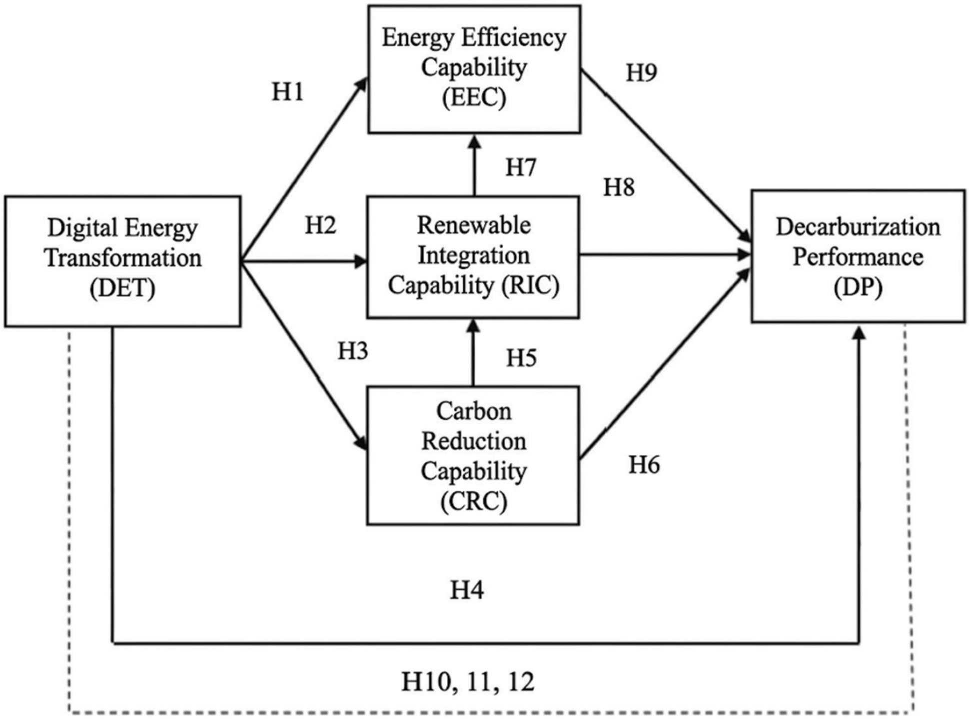
*P<0.05, **P<0.01, **P<0.001. CI: Confidence interval, DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance

Table 7: Mediation analysis

Specific indirect effect	β	*t*-statistic	Percentile 95% CI	Decision
H_{10}: DET→RIC→DP	0.082	2.642	0.037–0.138	Complementary partial mediation
H_{11}: DET→EEC→DP	0.061	1.805	0.007–0.116	Complementary partial mediation
H_{12}: DET→CRC→DP	0.113	2.361	0.036–0.192	Complementary partial mediation

*P<0.05, *P<0.01. CI: Confidence interval, DET: Digital energy transformation, RIC: Renewable integration capability, EEC: Energy efficiency capability, CRC: Carbon reduction capability, DP: Decarbonization performance

Figure 1: Conceptual model



as one of the major pathways toward low-carbon performance that is consistent with previous research results about the strategic value of renewables in industrial decarbonization (Javed et al., 2026; Tufail et al., 2025). The mediation analyses also help to understand how DET mediates DP. RIC, EEC and CRC were established to mediate the association between DET and DP in a partial way (H_{10-12}), implying a complementary partial mediation. These results imply that although the transformation of digital energy influences decarbonization directly, its full potential is achieved in case internal capabilities are reinforced. This is in line with previous studies conducted on STS and DCT, which hold that adoption of technology only works well when it is done in tandem with organisational capabilities. Whether the energy transition ability is complementary to digital investments, this study results can be corroborated by the findings of Li and Allen (2025), and Shen et al. (2025), who state that energy transition capabilities are central to the translation of digital investments into actual decarbonization effects. Intriguingly, most of the previous works have focused on the direct technological impacts on decarbonization Qi et al. (2025); Yu et al. (2024), this paper shows that the impacts are mediated by capabilities, which provides a detailed insight into the dynamics of digital transformation of energy in an intricate industrial setting. In general, the results indicate a consistent trend, namely, DET enhances renewable integration, efficiency, and carbon reduction potential, which, in turn, and directly improve the performance of decarbonization, which is the synergistic interaction between digitalization and the power of energy transition in achieving low-carbon effects.

4.3.1. Theoretical contributions

Within this study, a number of good theoretical contributions are made on the energy transition and sustainability literature. To start with, the combination of RBV theory and DCT with STS views provides a solid framework of the research on how DET can stimulate DP. The RBV theory is developed further by showing that DET is a strategic asset that can create sustainable competitive advantage when it is exploited using certain organisational competencies, such as RIC, EEC and CRC. Second, the study goes further by empirically confirming that these energy transition capabilities are dynamic capabilities that mediate the DETDP relationship and the processes by which firms in response to environmental pressures and energy policy requirements adapt, integrate and reconfigure their resources. Third, the use of STS is characterized by focusing on the interaction between technological systems and organisational processes showing that the implementation of DET is only not enough without the presence of human and operational capabilities. Taken together, the study is able to close gaps in previous studies that have widely focused on the effects of decarbonization on direct effects on technology Javed et al. (2026); Rizwan and Iqbal (2025), which presents empirical data of the mediating action of energy transition capabilities. This combination highlights a multidimensional perspective of sustainable energy management, which is a more powerful theoretical insight into how digital transformation can lead to quantifiable low-carbon results in energy-jury industries.

5. CONCLUSION

The current research was empirical investigation of the effects of DET on DP with the help of mediating variables of RIC, EEC and CRC in energy-intensive sectors in Jordan. The findings establish the positive role of DET in exerting a direct and indirect impact on DP because of these energy transition abilities, and the key role of coordinating technological investments with internally-developed capabilities in this respect. The study incorporating RBV, DCT, and STS insights offers a multi-dimensional perspective on the contribution of digitalization to the sustainability outcomes to fill the gap in the existing studies, which largely concentrated on direct technological impacts. The results also indicate that companies may gain substantial decarbonization opportunities when they enhance the integration of renewable sources, energy efficiency, and reduction of carbon at the same time. Together, this work highlights the strategic importance of DET in aiding the process of low-carbon transitions, providing evidence-based advice to managers and policymakers concerned with improving their environmental performance without losing competitive edge. Finally, the research paper can assist in a more specific and practical approach towards sustainable energy management and offers the direction in which companies can use digital technologies and organisational strengths to achieve global sustainability objectives.

5.1. Practical Implications

The results of this research have a number of practical implications on policymakers, energy managers, and industrial practitioners. To begin with, the positive contribution of DET towards energy transition capacities and DP is substantial, which indicates that companies need to focus on investments in digital energy technologies, such as smart grids, predictive analytics, and automation systems to enhance renewable integration, efficiency, and carbon reduction. Second, the mediating effect of RIC, EEC, and CRC shed light on the significance of developing internal capabilities and technological acceptance; companies are to address the need to train the staff, redesign the processes, and create. Cross-functional teams to maximize on digital platforms. Third, these insights can help industrial managers develop integrated energy strategies that would facilitate balancing the operational efficiency and decarbonization objectives, so that digital tools can be transformed into quantifiable environmental values. Fourth, such transitions can be facilitated by the policymakers offering incentive to use digital energy, promoting data openness, and networks of knowledge sharing, which complement the capabilities of firms. Lastly, digitalization and ability building can be discussed as two complementary factors in the emerging markets, including Jordan, which can be used to strategically tackle the sustainability goals, environmental policies, and competitiveness in the low-carbon markets. Overall, these real-world implications give a clear idea of how technological investments can be aligned with the capability building to bring about effective decarbonization results.

5.2. Limitations and Future Research Directions

Irrespective of its contributions, this study is limited in a number of ways which indicate the future research avenues. First, the cross-sectional research design restricts the possibility of causal inference; longitudinal research might give more insights into how DET and energy transition capabilities change over time to determine the impact on the outcome of decarbonization. Second, the research is concentrated on energy-intensive sectors in Jordan that might restrict the applicability of the results to other areas or sectors, further studies might apply the model to various industrial environments or different countries with various regulatory and technological settings. Third, data were gathered through self-reported surveys which may be prone to response bias, using mixed methods or a combination of survey data with operational energy performance measures would make validity stronger. Fourth, although the research tested three main mediators, other organisational or external variables such as organizational culture, pressure on stakeholders or other governmental policy stimuli can moderate or mediate the DET/DP relationship. Future research may consider such variables as they attempt to offer a much bigger picture of how digital transformation of energy contributes to sustainability. Finally, the new technologies like blockchain or IoT-enabled energy trading were not implicitly mentioned; it is possible to introduce them into the research in the future that would further broaden the theoretical and practical applicability of DET to DP.

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