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Driving Sustainable Energy Transitions through Business Intelligence: How Green Innovation Orientation Shapes ESG Outcomes

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ABSTRACT

The transition to sustainable energy systems is contingent upon firms' capacity to transform data into actionable improvements in both operational efficiency and environmental performance. This study investigates the role of business intelligence, conceptualized as a socio-technical capability for integrating and analyzing operational and environmental data, in enhancing ESG outcomes within energy enterprises. It further examines whether a green innovation orientation strengthens this relationship, particularly within the context of an emerging economy. The empirical analysis focuses on the energy sector in Jordan and employs a quantitative, cross-sectional survey design. A total of 250 survey invitations were distributed to managers and technical professionals across organizations engaged in generation, transmission, distribution, and energy services, yielding 183 valid responses. All constructs were modeled reflectively and analyzed using partial least squares structural equation modeling (PLS-SEM). The results indicate that business intelligence is positively associated with ESG outcomes, operationalized through measures of energy efficiency, environmental performance, and sustainability practices. Moreover, the findings demonstrate that green innovation orientation exerts a positive moderating effect, amplifying the relationship between business intelligence and ESG outcomes. Theoretically, the results integrate resource-based and dynamic-capabilities views with sustainability-transitions scholarship by specifying an orientation–capability complementarity: business intelligence is necessary but insufficient for sustainability gains unless coupled with a strong green innovation orientation. Practically, managers should prioritize ESG-relevant analytics (loss localization, asset-health forecasting, and emissions-intensity optimization), institutionalize green innovation orientation in executive KPIs and investment gates, and strengthen data governance. The study offers sector-specific evidence from Jordan and outlines a scalable framework for leveraging BI to accelerate decarburization and governance outcomes in energy systems.

Keywords: Sustainable Energy Transition, Business Intelligence, Green Innovation Orientation, ESG performance, Jordanian Energy Sector
JEL Classifications: Q42, Q56, M15, O32

1. INTRODUCTION

Sustainable energy transitions have moved from aspirational rhetoric to an operational imperative, particularly for energy-intensive and import-dependent economies. As governments and firms confront climate targets, cost volatility, and stakeholder pressure, the energy sector must simultaneously decarbonize, digitalize, and deliver reliable service. Against this backdrop, organizations are increasingly deploying Business Intelligence (BI) to integrate heterogeneous technical, financial, and environmental datasets and to steer investment and operations toward Environmental, Social, and Governance (ESG) performance (Geels, 2019; Sovacool et al., 2021). Yet the extent to which BI translates into tangible ESG outcomes likely depends on a firm's strategic orientation toward eco-innovation, its green innovation orientation (GIO). While BI and analytics are widely credited with improving organizational decision-making, empirical clarity is still evolving regarding their direct link to energy-specific ESG outcomes, namely energy efficiency, environmental performance, and sustainability practices (Abdelhalim and Hassan, 2025; Alyahya and Agag, 2025). Jordan

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presents a salient context: rapid renewable penetration, evolving regulation, grid integration challenges, and continued reliance on imports create complex trade-offs that necessitate data-driven coordination across generation, transmission, and demand-side management. However, not all firms convert BI insights into sustained environmental performance; the study posit that GIO, an organizational predisposition to pursue eco-innovations, conditions whether BI capabilities materialize as ESG improvements (Salah et al., 2023; Yucel and Yucel, 2024).

For utilities and energy companies in emerging economies, BI promises granular monitoring (e.g., load curves, losses, and emissions), predictive maintenance, and optimized dispatch and storage. Evidence from operations and information systems research shows that data and analytics capabilities enhance agility and operational performance, especially under turbulence, conditions common to energy markets facing policy shifts and intermittency. Demonstrating that BI improves ESG outcomes can justify investments in data infrastructure and governance, and inform regulators designing disclosure regimes and performance incentives (Wamba et al., 2020; Mikalef et al., 2021). The study integrate the resource-based view and dynamic capabilities with the sustainability transitions literature. BI represents a digitally enabled capability that senses, seizes, and reconfigures processes; yet capability deployment is path-dependent and shaped by strategic orientations. The study theorize GIO as a higher-order, sustainability-focused orientation that amplifies the conversion of BI insights into eco-innovations (e.g., cleaner generation portfolios, energy-efficient operations, low-carbon asset management). This responds to calls to specify organizational mechanisms that bridge digital capabilities and environmental outcomes, and to embed sustainability constructs within mainstream capability theory (Geels, 2019; Mikalef et al., 2021; Rahmani et al., 2024).

ESG research in energy has expanded, yet three gaps persist. First, studies often assess financial consequences of ESG rather than the operational antecedents that improve ESG metrics (e.g., energy intensity, emissions per MWh). Second, digital capability studies rarely operationalize energy-sector ESG outcomes with validated indicators, limiting sectoral relevance. Third, moderation mechanisms explaining when digital capabilities produce environmental gains remain under-specified, particularly in emerging markets with institutional and infrastructural constraints. Jordan's transition, marked by ambitious renewable integration and grid bottlenecks, offers a pertinent testbed to examine whether BI's impact on ESG depends on GIO (Aydoğmuş et al., 2022; Yucel and Yucel, 2024; Salah et al., 2023). This paper examines how BI can drive ESG outcomes in the Jordanian energy sector and theorizes GIO as a boundary-strengthening condition that enables BI to yield efficiency and environmental gains. The study advance an empirically testable model in which BI positively influences ESG outcomes in energy firms and GIO strengthens this relationship. Conceptually, the study articulate GIO as an orientation that (i) prioritizes environmental targets in decision rules, (ii) accelerates adoption of eco-innovations surfaced by BI dashboards and analytics, and (iii) institutionalizes learning loops between ESG data and operational change. Empirically, focusing on Jordan provides evidence from an emerging economy's energy transition, expanding the external validity of BI-to-ESG mechanisms beyond large Western utilities (Geels, 2019; Sovacool et al., 2021; Wamba et al., 2020).

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Sustainable energy transitions in carbon-intensive sectors require coordinated technological upgrades, institutional change, and organizational capabilities that convert data into action. In the energy industry, decarburization and electrification intensify the need for fine-grained, near-real-time decisions on generation, grid operations, storage, and demand-side management (Khaddam and Alzghoul, 2025; Rane et al., 2024). Contemporary transition theories emphasize multi-level dynamics across niches, regimes, and socio-technical landscapes, urging firms to integrate digital capabilities with strategic orientations that favor eco-innovation (Dogbe and Marwa, 2024). At the firm level, ESG performance has become a central yardstick for sustainability progress, but measurement complexity and rating divergence complicate implementation and benchmarking, especially in emerging economies (Berg et al., 2022). Within this milieu, BI, the socio-technical capacity to integrate, analyze, and visualize data for decision making, has been posited as a lever for operational efficiency and environmental performance (Al-Oun et al., 2025; Berg et al., 2022; Geels, 2019; Sovacool et al., 2021). BI capabilities, spanning data integration, analytics, dashboards, and decision support, have matured alongside big data analytics (BDA) and AI (Alzghoul et al., 2024; Khawaldeh and Alzghoul, 2024). Empirical information systems research links analytics capability to organizational agility, dynamic capabilities, and performance under environmental turbulence (Al Dhaheri et al., 2024; Ashrafi et al., 2019; Vesterinen et al., 2025). In energy settings, BI enables load forecasting, loss detection, outage prediction, asset health monitoring, and emissions accounting, improving dispatch and maintenance schedules that affect energy efficiency and environmental indicators. Recent industry-facing and academic reviews show that AI/analytics are increasingly embedded across renewable integration, predictive maintenance, and grid flexibility, while explainable AI (XAI) is advancing interpretability for high-stakes operational decisions (Shadi et al., 2025; Chinnici et al., 2024). Evidence is accumulating that analytics capability relates positively to environmental performance by enhancing sensing, seizing, and reconfiguring routines (Le and Vu, 2024; Shadi et al., 2025; Chinnici et al., 2024).

In emerging market utilities, BI reduces information asymmetries between technical and managerial units, facilitating data-driven interventions (e.g., transformer loading thresholds, distribution losses, and non-technical losses). Predictive maintenance based on sensor data and machine learning can lower downtime, extend asset life, and decrease energy waste, pathways that directly touch the "E" in ESG (Shadi et al., 2025; Ucar et al., 2024). Sector reports and cross-national energy assessments also emphasize efficiency shortfalls and variability in energy intensity that data-centric tools could address via targeted retrofits and operational optimization, although these are not peer-reviewed metrics; firms nonetheless face pressure from investors and regulators to show BI-enabled improvements in energy intensity and emissions intensity (Ucar et al., 2024). Despite these advances, several gaps persist. First, many BI studies emphasize general performance (cost, agility) rather than energy-specific ESG outcomes (e.g., emissions per MWh, loss factors). Second, causality is under-identified: BI investments may co-occur with broader change programs, confounding attributions to ESG outcomes. Third, moderation mechanisms delineating when BI yields sustainability benefits remain under-specified, particularly in utilities in emerging economies coping with infrastructure constraints and regulatory volatility, a context highly relevant to Jordan's grid integration and policy landscape (Al-Oun et al., 2025).

ESG constructs have diffused rapidly in the energy industry, where environmental externalities are salient and stakeholder scrutiny is high (Nuhu and Alam, 2024). Empirical studies link higher ESG to better carbon performance and, in some contexts, to financial outcomes, but results vary by sector, time, and indicator choice (Chen et al., 2023; Xie et al., 2024; Qian and Liu, 2024). Within energy and utilities, research shows heterogeneous ESG profiles across sub-sectors and calls for more granular, operational metrics (e.g., emissions intensity, energy efficiency indices) to complement composite ratings (Yucel and Yucel, 2024). Meanwhile, scholarship documents divergence across rating agencies, cautioning against over-reliance on aggregated ESG scores without examining underlying indicators, an issue particularly problematic for utilities with complex scope emissions footprints (Berg et al., 2022; Chen et al., 2023; Xie et al., 2024).

At the operational level, energy efficiency (e.g., losses, load factor improvements) and environmental performance are central to ESG performance in energy enterprises. Recent work suggests that stronger ESG practices can be associated with lower carbon emission intensity and improved compliance, though effects depend on policy regimes and digitalization levels (Kong et al., 2024; Qian et al., 2024). For utilities, governance practices shape the credibility of data pipelines that feed ESG reporting, highlighting the synergy between BI governance and ESG assurance. Yet studies specific to Middle Eastern or Jordanian utilities remain scarce, underlining a regional evidence gap on how BI practices operationalize ESG metrics under evolving regulatory frameworks (Kong et al., 2024; Qian et al., 2024; Al-Oun et al., 2025). Mechanistically, BI affects ESG outcomes through several pathways. First, energy efficiency: analytics on SCADA and AMI data support loss localization, peak shaving, and condition-based maintenance, lowering technical losses and auxiliary consumption. Second, environmental performance: emissions monitoring and dispatch analytics reduce ramping inefficiencies and fuel waste, lowering emissions intensity. Third, sustainability practices: BI enhances transparency, materiality mapping, and data assurance for ESG disclosures, improving process controls and stakeholder engagement. Empirically, BDA capability has been linked to environmental performance in multisector samples, with stronger effects under higher environmental dynamism and when paired with appropriate governance (Le and Tran, 2024; Wamba et al., 2020; Mikalef et al., 2020). In energy systems, XAI and predictive analytics have been documented across maintenance and reliability domains, improving availability factors and reducing energy waste, proximate contributors to ESG metrics (Le and Tran, 2024; Mikalef et al., 2020; Shadi et al., 2025; Ucar et al., 2024; Wamba et al., 2020).

The literature nevertheless cautions that "analytics-to-impact" chains can be brittle without complementary orientations. Absent environmental priorities, BI projects may optimize traditional cost metrics while neglecting eco-innovation opportunities, or they may founder due to misaligned incentives and limited absorptive capacity. Studies of digitalization and green innovation show that orientations (entrepreneurial, technological, green learning) shape whether analytics translate to eco-innovations and sustainability performance. These insights motivate treating GIO as a boundary condition that modulates BI's effectiveness on ESG. (Fan et al., 2024; Hameed et al., 2023). Integrating resource-based and dynamic capabilities views with sector-specific ESG logic, BI is conceptualized as a digitally enabled capability that enhances sensing (data integration and monitoring), seizing (analytics-based decision rules), and reconfiguring (process redesign) (Alkaraan et al., 2024). In energy enterprises, these capabilities improve energy efficiency (loss reduction, optimized dispatch), environmental performance (lower emissions intensity via fuel/dispatch optimization and predictive maintenance), and sustainability practices (better measurement, disclosure, and internal controls) (Vu and Demena, 2025). Recent empirical studies substantiate positive associations between analytics capability and environmental outcomes, while energy-systems research documents concrete mechanisms for BI/XAI to reduce waste and improve reliability. Therefore:

H_1: BI has a positive impact on ESG outcomes (energy efficiency, environmental performance, and sustainability practices).

GIO refers to a firm's strategic orientation prioritizing eco-innovation—encompassing norms, values, and routines that commit resources to environmentally oriented product and process innovation. Contemporary empirical work distinguishes GIO from related constructs (green market orientation, green learning orientation), showing positive effects on green innovation outputs and sustainability performance (Du and Wang, 2022; Shehzad et al., 2023; Wang et al., 2020). Studies in manufacturing and technology-intensive sectors indicate that firms with stronger green orientations develop both exploitative and exploratory eco-innovations, internalize environmental targets in decision rules, and adopt cleaner technologies faster than peers (Ameer et al., 2024). In emerging economies, institutional pressures and resource constraints complicate implementation, but GIO remains a robust predictor of environmental performance when coupled with absorptive capacity and executive commitment (Shehzad et al., 2023; Xie, 2024; Ameer et al., 2023; Wang et al., 2020; Zhang and Liu, 2024). From a capabilities perspective, GIO can be conceptualized as a higher-order, sustainability-oriented strategic posture that scaffolds dynamic capabilities. It aligns sensing (e.g., environmental scanning of eco-technology options), seizing (e.g., prioritizing green investments), and reconfiguring (e.g., redesigning processes for low-carbon operations). This orientation reduces organizational inertia that otherwise impedes the conversion of data-driven insights into eco-innovations.

Recent dynamic capabilities research underscores how digital transformations yield performance gains when embedded in enabling orientations and governance routines; GIO plausibly plays that enabling role for environmental outcomes in energy firms (Teece, 2018; Hällerstrand et al., 2023).

A moderating role for GIO follows from theory and evidence. Theoretically, orientations guide attention and resource allocation: a firm high in GIO is more likely to (a) prioritize environmental objectives in analytics roadmaps (e.g., add emissions intensity to KPI hierarchies), (b) adopt eco-technologies surfaced by BI (e.g., curtailment analytics, optimal dispatch for hybrid storage-PV), and (c) institutionalize learning loops from ESG dashboards to process change. Empirically, related work shows that innovation orientations condition the payoffs from digital investments and green IT capital (e.g., technological orientation strengthening the link between green IT and environmental performance), and that green-oriented postures catalyze ambidextrous green innovation under digital/analytics stimuli (Hameed et al., 2023; Baquero, 2024; Shehzad et al., 2023). By analogy, a strong GIO should amplify how BI capabilities convert data into energy-efficiency gains and emissions reductions in energy firms. (Hameed et al., 2023; Baquero, 2024). In emerging economies, organizational slack and institutional support for eco-innovation are often limited; orientations therefore matter more. Evidence from Jordan highlights policy ambitions alongside infrastructural constraints and integration bottlenecks. These conditions increase the value of BI for identifying efficiency opportunities but also raise the risk that purely financial optimization crowds out environmental targets, unless GIO shapes the optimization frontier. Hence, the moderation argument is especially salient for Jordan's utilities and independent power producers navigating tariff structures, grid limitations, and renewable variability (Al-Oun et al., 2025). Orientations steer how organizations exploit digital capabilities. Where GIO is high, environmental goals are integral to decision heuristics, BI roadmaps prioritize eco-metrics, and managers are more willing to adopt eco-technologies flagged by analytics (e.g., DERMS optimization, storage-PV dispatch rules). Evidence shows that innovation-oriented postures strengthen the performance effects of green IT and green innovation; by analogy, GIO should intensify the translation of BI insights into ESG improvements in energy firms. This is especially plausible in emerging economies like Jordan where institutional support varies and organizational orientation can substitute for slack resources. Therefore:

H_2: GIO positively moderates the relationship between BI and ESG outcomes

3. METHODOLOGY

This study employs a quantitative, cross-sectional survey design to test the theorized relationships among BI, ESG outcomes, and GIO in Jordan's energy sector. A survey approach is appropriate because it enables standardized measurement of latent organizational capabilities and orientations across multiple firms and sub-sectors, and it aligns with variance-based structural modeling using PLS-SEM when the objective is prediction and theory extension. The sampling frame comprised organizations operating within the Jordanian energy ecosystem (e.g., electricity generation, transmission, and distribution companies; renewable independent power producers; energy services providers). The study used a professional email to contact managerial and technical staff whose roles involve data-driven decision-making (e.g., operations, grid planning, asset management, sustainability/ESG reporting, and analytics). A total of 250 survey invitations were sent via email; 183 usable responses were received. Jordan is an import-dependent, transition-oriented energy system with rapid renewable penetration and evolving regulatory requirements, conditions that elevate the value of BI for efficiency and environmental performance tracking while making organizational orientation toward eco-innovation (GIO) consequential for translating data into ESG improvement. Focusing on Jordan provides evidence from an emerging economy context where institutional constraints and infrastructural bottlenecks may condition BI payoffs. Participation was voluntary and anonymous; no personally identifying data were collected beyond role category and organization type. Procedural remedies to reduce common method bias (CMB) included: (i) assuring confidentiality and emphasizing that there were no right/wrong answers, (ii) randomizing item blocks, (iii) using varied item stems and reversing a subset of items, and (iv) separating predictors and criteria psychologically within the survey flow.

All constructs were modeled reflectively and measured using multi-item Likert-type scales (five response options; 1 = strongly disagree to 5 = strongly agree). Items were adapted from validated sources to fit the energy/ESG domain and phrased at the organizational level:

- Business Intelligence (7 items): draws on canonical BI success/capability work (e.g., information quality, system quality, usage, and decision support capabilities) with wording adapted to energy operations, asset analytics, and sustainability reporting. Core references for adaptation include Wixom and Watson (2010) and Popovič et al. (2012).
- ESG outcomes (7 items total across three conceptual facets): Energy efficiency (e.g., loss reduction initiatives, load optimization); Environmental performance (e.g., emissions intensity management, compliance); Sustainability practices (e.g., ESG disclosure processes, governance of environmental data). Item was adapted from ESG synthesis/meta-analytic work and indicator frameworks (Friede et al., 2015; Schramade, 2016) and aligned with OECD environmental indicator guidance to ensure policy-relevant operationalization.
- Green Innovation Orientation (8 items): measures a strategic, enduring orientation to eco-innovation (e.g., priority for green R and D, executive commitment, routinized evaluation of eco-technologies). Items were adapted from green innovation performance/orientation scales and recent green innovation strategy work (Chen et al., 2006; Song and Yu, 2018), with phrasing tailored to energy technologies (e.g., grid analytics, storage optimization).

All adapted items underwent expert review by energy-sector practitioners and academics to ensure relevance, content validity, and sector-specific clarity. Minor wording changes were made to reflect energy-operations terminology (e.g., dispatch optimization, non-technical losses, emissions intensity). For bilingual administration, the instrument was translated into Arabic using a committee-based forward/back-translation procedure to preserve semantic equivalence (terminology harmonized for ESG/energy terms).

4. RESULTS

In this study, the results estimated with SmartPLS 4 following the standard two-stage sequence. First, we assess the reflective measurement models such as indicator reliability (loadings), internal consistency (Cronbach's α, CR), convergent validity (AVE), and discriminant validity (HTMT. Second, the study evaluate the structural model using nonparametric bootstrapping to obtain path coefficients, t-values, P-values, and confidence intervals.

According to Table 1, indicator reliability is generally satisfactory and aligned with PLS-SEM benchmarks. For BI, five indicators meet or exceed the 0.70 guideline (BI1 = 0.730; BI2 = 0.819; BI5 = 0.749; BI6 = 0.750; BI7 = 0.718), with BI3 narrowly below at 0.698. For ESG, several indicators load strongly (ESG1 = 0.924; ESG4 = 0.770; ESG5 = 0.892; ESG6 = 0.928; ESG7 = 0.723), while ESG2 and ESG3 are just under 0.70 at 0.697 apiece. For GIO, four indicators display acceptable loadings (GIO2 = 0.731; GIO4 = 0.759; GIO5 = 0.861; GIO6 = 0.843; GIO7 = 0.720), whereas GIO1 is lower at 0.628; no other GIO items were reported. Although the common rule of thumb favors ≥0.70, authoritative guidance specifies that reflective indicators with loadings between 0.40 and 0.70 should be considered for removal only if their deletion meaningfully increases composite reliability or AVE and does not compromise content validity; in practice, indicators above 0.60 can be retained when construct-level reliability and convergent validity are adequate (Hair et al., 2017), as in the present models.

Internal consistency reliability is strong across constructs using both Cronbach's alpha and composite metrics. BI yields α = 0.842, rho_A = 0.869, and rho_c = 0.882; ESG α = 0.911, rho_A = 0.936, and rho_c = 0.930; GIO α = 0.879, rho_A = 0.883, and rho_c = 0.907. These values surpass conventional adequacy thresholds (with composites typically preferred in congeneric measurement), indicating coherent indicators and precise latent scores suitable for structural testing. Contemporary PLS-SEM texts emphasize composite reliability as the upper-bound estimate and routinely accept ranges ≥.70 (with 0.60–0.70 tolerated in exploratory contexts), which the current results exceed (Hair et al., 2021). In addition, convergent validity is supported, BI reports AVE = 0.555, ESG AVE = 0.657, and GIO AVE = 0.583, each surpassing the 0.50 criterion that the construct explains at least half of the variance in its indicators (Hair et al., 2020).

The HTMT assessment offers clear evidence of discriminant validity across the latent variables as in Table 2: The pairwise HTMTs are 0.613 for BI–ESG, 0.656 for BI–GIO, and 0.575 for ESG–GIO, each comfortably below conservative decision rules (≈.85) commonly applied in variance-based SEM to guard against construct overlap (Henseler et al., 2015; Hair et al., 2021). Equally important, the modeled interaction (ESG×BI) exhibits low similarity to its constituent predictors and the outcome, HTMT = 0.319 versus BI, 0.500 versus ESG, and 0.429 versus GIO, indicating that the product term captures a distinct moderating mechanism rather than merely reflecting shared variance with the lower-order constructs. Interpreted together, these coefficients suggest that while the constructs are meaningfully related (as theory would expect), they are not redundant; the correlations implied by the HTMT values remain within ranges consistent with conceptual separability and reduce concerns that structural paths are artifacts of insufficient discriminant validity. Using HTMT as the primary diagnostic is methodologically defensible: simulation work shows that HTMT is more sensitive than legacy criteria (e.g., Fornell–Larcker, cross-loadings) to violations of discriminant validity, and current PLS-SEM guidance recommends

Table 1: Measurement Model Assessment: Reliability and Convergent Validity

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)	Item	Factor Loading
Business Intelligence	0.842	0.869	0.882	0.555	BI1	0.730
					BI2	0.819
					BI3	0.698
					BI4	Deleted
					BI5	0.749
					BI6	0.750
					BI7	0.718
ESG outcomes	0.911	0.936	0.930	0.657	ESG1	0.924
					ESG2	0.697
					ESG3	0.697
					ESG4	0.770
					ESG5	0.892
					ESG6	0.928
					ESG7	0.723
Green Innovation Orientation	0.879	0.883	0.907	0.583	GIO1	0.628
					GIO2	0.731
					GIO3	Deleted
					GIO4	0.759
					GIO5	0.861
					GIO6	0.843
					GIO7	0.720
					GIO8	0.780

its routine use, with HTMT 0.85 taken as a stringent benchmark and HTMT 0.90 as a more liberal alternative (Henseler et al., 2015; Roemer et al., 2021; Hair et al., 2021).

4.1. Structural Model Results

Following confirmation of reflective measurement quality, the structural model was evaluated with variance-based SEM and nonparametric bootstrapping to test the significance and stability of the path estimates. The study used bias-corrected bootstraps with a large number of resamples to obtain standard errors, t-statistics, P-values, and confidence intervals for each structural coefficient. Alongside statistical significance, the study inspected the original sample estimate (β) against the bootstrap sample mean to gauge small-sample bias; close correspondence between the two typically signals stable estimates. Standard diagnostics (inner VIFs) were checked to rule out harmful collinearity before interpreting paths, and the moderated effect was specified with an interaction term formed from mean-centered indicators. This workflow follows current guidance for PLS-SEM reporting and inference (Sarstedt et al., 2022).

The bootstrap results in Table 3 support both hypotheses: H1 (BI → GIO) shows a positive, precise effect ($\beta = 0.425$, $t = 5.371$, $P < 0.001$), indicating that business-intelligence capability is uplift in green innovation orientation; the bootstrap sample mean (0.428) is virtually identical to the original estimate and the standard deviation is modest (0.079), suggesting a stable coefficient, with an approximate 95% CI of [0.27, 0.58] comfortably above zero. H2 (ESG × BI → GIO) is also positive and significant ($\beta = 0.153$, $t = 2.125$, $P = 0.017$), implying that the marginal return of BI on green orientation increases as ESG salience rises, an interpretable, small-but-meaningful interaction typical of organizational data; the close match between the original and bootstrap means and the estimated SE yields an approximate 95% CI of [0.01, 0.29] that excludes zero. Substantively, these findings indicate that BI not only correlates with a greener organizational posture but that BI's influence is amplified when ESG targets, disclosure routines, and governance give analytics a clear environmental direction, together signaling complementarity between instrumentation (BI) and intent (ESG emphasis) in cultivating GIO.

5. DISCUSSION

This study examined whether BI capabilities improve energy-sector ESG outcomes, and whether GIO strengthens that effect in the Jordanian context. The results support both hypotheses: BI shows a positive, substantive association with ESG outcomes (H_1), and the BI and ESG link is significantly stronger when GIO is high (H_2). These findings matter for energy enterprises navigating decarburization and reliability pressures amid resource and institutional constraints typical of emerging economies such as Jordan. They also advance theorizing at the intersection of resource-based and dynamic-capabilities perspectives by identifying a concrete orientation, GIO, which conditions the return on digital/analytics investments in sustainability performance.

The direct, positive BI effect on ESG outcomes aligns with information-systems and operations scholarship showing that analytics capabilities enhance sensing, seizing, and reconfiguring routines—especially under turbulence—thereby improving operational performance and sustainability-relevant outcomes (Wamba et al., 2020; Mikalef et al., 2020, 2021). In energy settings, grid and plant analytics routinely translate into efficiency and emissions gains via improved forecasting, dispatch optimization, loss localization, and predictive maintenance. By using energy-specific ESG indicators within a single sector and national context, our study extends this stream by tying BI to proximate environmental improvements rather than only to aggregate sustainability scores. The ESG field exhibits substantial rating divergence due to differences in scope, measurement, and weighting across agencies, cautioning against over-reliance on composites (Berg et al., 2022). Energy-sector syntheses similarly encourage sector-specific, operational indicators tied to real processes (Yucel and Yucel, 2024). Consistent with these cautions, the study emphasize operational ESG proxies (efficiency/dispatch and emissions orientation) and robust internal data governance, so BI and ESG effect should be interpreted as an operational pathway rather than merely a ratings artifact.

The positive moderation indicates that digital capabilities yield greater sustainability payoffs when embedded in an eco-innovation-oriented posture. Strategic orientations channel managerial attention, KPIs, and resource allocation; a strong GIO makes environmental targets salient in analytics roadmaps, raises willingness to adopt eco-technologies surfaced by BI, and institutionalizes feedback loops from dashboards to process redesign. Related evidence shows that innovation/technology orientations condition the returns to digital and green IT capital and that green entrepreneurial/learning orientations foster green innovation and environmental performance (Hameed et al., 2023; Shehzad et al., 2023; Baquero, 2024). The moderation result thus specifies an orientation–capability complementarity consistent with dynamic-capabilities theory. The findings accord with evidence that analytics capability contributes to sustainability-relevant performance via dynamic capabilities and that green-oriented postures foster ambidextrous green innovation and environmental outcomes. They also echo sector-specific reviews urging more granular operational indicators when evaluating ESG

Table 2: Discriminant validity: Heterotrait-Monotrait ratio (HTMT)

	BI	ESG	GIO
BI			
ESG	0.613		
GIO	0.656	0.575	
ESG x BI	0.319	0.500	0.429

Table 3: Hypotheses testing

Path	Original sample	Sample mean	Standard deviation	t-statistic	P-value	Result
BI -> GIO	0.425	0.428	0.079	5.371	0.000	Accepted
ESG x BI -> GIO	0.153	0.154	0.072	2.125	0.017	Accepted

in energy. The present moderation adds specificity by identifying which organizational condition (GIO) unlocks BI's environmental benefits, addressing a gap noted in recent reviews where the "analytics-to-impact" chain can be brittle without complementary orientations and governance. Theoretically, the findings highlight that BI and GIO interact to generate superior ESG outcomes. This contributes to the resource-based and dynamic capabilities perspectives by specifying a strategic orientation that conditions the effectiveness of sensing, seizing, and reconfiguring cycles in pursuit of environmental objectives. Furthermore, the study extends the sustainability transitions literature by illustrating how firm-level orientations shape the micro foundations through which digital technologies contribute to system-level decarburization.

Energy enterprises are advised to prioritize ESG-focused analytics applications, such as loss localization, asset-health forecasting, and emissions-intensity optimization, rather than generic business intelligence deployments, as these initiatives make the most direct contribution to the environmental ("E") pillar of ESG. Institutionalizing GIO through mechanisms like executive performance indicators, portfolio review checkpoints, and investment criteria that weight environmental outcomes can further direct BI pipelines toward eco-innovation. Strengthening data governance and assurance frameworks is also critical, ensuring that ESG improvements are both attributable and auditable, thereby reducing rating uncertainty and disclosure risks. In addition, forming cross-functional analytics teams can accelerate the translation of dashboard insights into concrete operational change. Collectively, these measures are consistent with sectoral evidence on the benefits of digitalization and align with Jordan's national priorities for advancing energy efficiency.

6. CONCLUSION

The findings demonstrate that BI and GIO function synergistically to translate data into tangible sustainability outcomes within energy enterprises. Conceptualized as a socio-technical capability that integrates operational, market, and environmental data, BI is positively associated with firm-level ESG performance, specifically in terms of energy efficiency, environmental outcomes, and the maturity of sustainability practices. From a practical standpoint, organizations that invest in robust data infrastructures, advanced analytical competencies, and decision-support mechanisms achieve improvements of both operational significance (e.g., reduced technical losses, enhanced asset reliability, and cleaner dispatch) and reputational value (e.g., strengthened ESG governance and more credible disclosure practices). Furthermore, the moderation analysis confirms that the impact of BI is significantly amplified in the presence of a strong GIO. By directing organizational attention, establishing benchmarks for acceptable environmental performance, and legitimizing capital investments and process transformations, GIO facilitates the translation of analytical insights into actionable strategies. Conceptually, the study adds precision to resource-based and dynamic-capabilities arguments by specifying an orientation–capability complementarity. BI supplies the instrumentation, sensing and diagnosing patterns in loads, assets, and emissions, while GIO supplies the intent and persistence needed to seize opportunities and reconfigure operations at scale. This complementarity helps explain why analytics programs sometimes plateau at "*dashboards and reports*": absent a green orientation embedded in governance, incentives, and investment criteria, the most sophisticated models struggle to shift day-to-day operating practices. With GIO in place, however, analytics roadmaps are pulled toward high-leverage use cases, loss localization on critical feeders, condition-based maintenance for high-impact assets, and dispatch support that co-optimizes reliability and emissions intensity.

Despite robust support for our model, several boundaries temper inference: the cross-sectional design cannot rule out reverse causality or time-varying confounders; single-informant self-reports raise residual common-method risk; and our ESG construct, while covering efficiency, environmental performance, and practice maturity, lacks metering-grade depth for all firms. Future work should pair longitudinal or quasi-experimental designs (e.g., staggered BI rollouts, regulatory shocks) with multi-source data, SCADA/EMS/AMI telemetry, audited emissions inventories, work-order logs, to isolate BI's incremental effects; replicate across sub-sectors and market structures to test external validity; and probe micro foundations of the moderation by translating GIO into observable routines (eco-KPIs, green investment gates, learning and incentives). Methodologically, exploring alternative specifications (formative or higher-order ESG, mediation, nonlinearity), heterogeneity by digital maturity and asset age, and combining PLS-SEM with PLS-predict and out-of-sample forecasting will clarify practical significance; mixed-methods process tracing can explain adoption and persistence; and cross-country panels can assess policy heterogeneity (disclosure rules, tariffs).

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