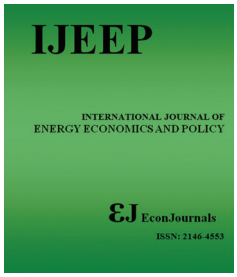

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Economic Effects of Digitalization and IT Technologies on the Efficiency and Competitiveness of the Energy Sector

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ABSTRACT

This article analyzes the process of digitalization in the global energy industry, and describes the use of digital IT solutions, new achievements in technology, as well as modern marketing tools. The objective of this article is to assess the impact of new digital technologies on operational activities efficiency, investment appeal and competitiveness of energy sector companies. The analysis uses econometric techniques to industry-level data and the financial performance of leading natural resource firms. The findings reveal that the applications of IT are closely related to enhancements in operational productivity and business process transparency. The digital elements help establish more developed management practices which are centered on accountability and data driven decision-making. Digital marketing instruments and analytical tools also enhance customer engagement and loyalty, as well as enable more precise energy demand predictions. In the end, digital energy transformation acts as a stimulator of investment scaling and sustainable development in the sector, but also provides impetus for technological and managerial innovation. Practically, implications emphasize that energy firms need to concentrate when implementing IT and marketing strategies, indicating interrelated use of them could directly improve firm performance while indirectly enable innovative practices, and sustained development in the long run for energy companies.

Keywords: Digitalization, IT Technologies, Energy Sector, Efficiency, Competitiveness, Digital Marketing
JEL Classifications: L94, O33, Q41, M15

1. INTRODUCTION

Digitalization is now becoming a major transformer of the global energy system, spreading innovation through the entire energy cycle and providing new business models for investment and sustainable development in the long term. Recent trends show that IT systems are increasingly used in areas such as energy management, company control, logistics and marketing. These make new advanced IT fit to the top energy industry as they were digitizing this sector by implementing digital solution platforms, big data analytics and complex IT applications to improve operations effectiveness, reduce costs and create more consistency in these production processes (Hasanov et al., 2024). In the enabling play it has, to allow quick and easy portrayal on 21st century rapidly expanding energy consumer and global tapestry shift to decarbonization, digital becomes a strategic armory that fosters investment management innovations plus integration operating paradigm. Using its advanced technology, energy companies can integrate production and financial and marketing operations into business processes that adjust more quickly to the often-rapidly changing marketplace. Transition from a linear supply chain to digital eco-systems is enabling industry actors to assume different roles and altering the competition of sectors, with resources being allocated more efficiently. At the heart

of this new approach is the ability to acquire data in real time and IT-enabled analytics platforms such as those described previously are being employed for monitoring, predicting and preventing risks whilst also facilitating decision making. These help in better performance, cost efficiency and also aid in accurate prediction of the energy demand (Singh et al., 2023). The introduction of IT does at least affect internal mechanics and terms for how energy companies can connect to their markets. Digital marketing is being part of the strategy, as strategic approach at the racetrack today. The use of data science and marketing automation is aiding organizations in hierarchically segmenting their customers, and projecting behaviors as type 1 errors rates over all possible decision thresholds used for personalizing offers (Al-Ababneh, 2020). Brand competency 4: Digital Brand Marketing Trust and reputation almost completely come from digital marketing and loyalty as well. Experience from abroad has proved that with the help of IT technology, by combining it and marketing guidance, enterprise activities can be pushed to a higher level. Organizations like Shell, BP, TotalEnergies, Siemens Energy and Tesla Energy have already implemented digital platforms and marketing analytics to improve customer engagement, price management as well as sustainable solutions. These measures, while contributing to increased profitability and attractiveness as an investment destination, also promote sustainable development in accordance with international environmental standards. However, digital transformation has its own set of pitfalls and challenges. "Security, agility to integrate existing organisation structures and preparing the workforce for a digital age are some of the fundamental challenges. Discrepancy in regulations and standards, especially within developing countries also hinder technology adoption (Singh et al., 2023). Therefore, the successful adoption of IT solutions will take place only with technological investment as well as strategic change management such as to develop an innovative corporate culture and train specialists (Al-Ababneh, 2023). From the perspective of academia, understanding how digitalisation is playing out in the energy sector is no less a priority to assessing its effect upon economic development. Econometric studies reveal that industry digitalisation is positively related to the amount of (money spent on) marketing, and negatively to an incorporeal something; so it seems Econometrics gets us further into what determines whether a company's strategy idiosyncratically works. Recent studies reveal that digital tools are positively related to investment in innovation, market transparency, and the management of energy demand (Al-Ababneh, 2020). Analytical systems and cloud-based services-products can integrate renewable energy sources and optimize the load on the grid, which could decrease carbon pollution n by a vast amount. Marketing technologies based on big data facilitate customer engagement on a personalized level and ensure corporate communication is consistent with current digital trends. The purpose of this paper is to investigate an economic effect caused by IT solutions, digital platforms and marketing technologies on efficient performance (operating capacity) and competition ability of the companies. Research objectives are as follows:

- Examine what the major trends of digitalization in energy industry are and in to what extent these does impact business organization management models.
- Assess potential to improve production and operation controls through IT infrastructure/data analytics systems.
- Evaluate how digital marketing has influenced decision models and corporate sustainability.
- Define a scope of operations for deploying IT and Marketing tools in strategic manner to render the process efficient, investment attractive, competitive etc. in case of Energy Sector.

In this paper, we suggest an integrative approach of which the economic and marketing analyses are complementary for digital processes in the energy sector. Contrary to the vast majority of former research, it does not consider digitalization just as a technology but also as a practice that can lead towards sustainability and investment attractiveness in power sector.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Literature Review

With the trend of internet technology to integrate IT technologies, for example the Internet of things (IoT), Cloud computing and big data analysis or digital platform, the present energy industry is ushering in a new round of reshaping. These changes are re-shaping the energy systems structure, and creating real time data driven monitoring and decision-making business opportunities (Hasanov et al., 2024). Not only does the digitalization not stop in increasing production efficiency, it makes management more transparent, level of services quality better and operation networks are becoming stronger. There has been a growing trend over recent years for the deployment of IT across the operations of energy companies, including smart dispatch systems, digital twins on production assets and integrated analytics platforms. Such systems allow companies to react to market changes, predict technical risks and make the best use of available resources (Maroufkhani et al., 2022) Digitalisation improves the predictability of investments and lowers uncertainty so that capital can be redirected into transformative features such as renewables generation, electric storage, smart grid networking) (Al-Ababneh, 2020). Nevertheless, challenges remain. Information security risk, skills deficiencies, significant capital expenditure and varying standards and data represent barriers for adoption of DMC (Saeed et al., 2014). Many developing countries have little digitization infrastructure, preventing scale. The absence of adequate regulatory systems and digitalization can lead to disparate adoption and benefits among market players (Osman et al., 2024). Existing literature has winged on technological solutions - IoT, automation, big data, and smart grids - still less researches have scrutinized their organizational and economic implications (Egodawele et al., 2022). Especially, there is a black-box between digital technologies, marketing strategies and business models and how these affect the investment decisions. This gap can be fulfilled through an integrated view on the adoption of technology, strategic management and marketing analytics (Song and Wang, 2023). Over the last decade, econometric analyses offer a useful way to estimate how the "digitalization" would affect firm performance. Research has suggested that those who adopt digital process have higher capacity utilization, lower unit costs, and resilience towards volatile markets (e.g., Kumar and Singh, 2023; Hasanov et al., 2024). In addition to efficiency, digital ecosystems foster the linkage of the producers - intermediary

sector - consumers and regulators for joint governance and value chain data driven management (Tabash, 2025). Plat-formed based models empower utilities to provide digital services which, can be anything from monitoring the consumption of energy to blockchain-relevant-smart contracts as a way towards transparent and secure transactions (Al-Ababneh et al., 2024). A sustainability agenda also converges with digital transformation." IT-enabled solutions can help mitigate carbon emissions, promote effective energy consumption supporting ESG and renewable energy initiatives (Sharma et al., 2024). However, science of fusion/accumulation: technology marketing and investment study are deficient (Wang and Zhang 2023). In most studies, digital tools are seen as just technical devices and other features remain less considered strategic or economic implications. And now, because they are embraced at the same time and at our side, you do need a holistic approach to how all of these areas interact with each other in order for one to make any sense of what's going to happen with the IT technologies and the marketing and econometric evaluation as it migrates its way through the energy world. In the energy revolution, digital advertising is at the core. But more than just communication - at its best it's a strategic lever that builds stakeholder trust (consumers and investors), impacts innovation, drives operational decision-making. Today, groups are using big data and marketing automation to predict consumer needs, customize offers and maximize operational efficiency throughout the supply chain. 5 forces: Disintermediating market makers like Shell, BP, TotalEnergies and Siemens Energy leverage the marketing effectiveness of operational efficiency to make your company indispensable, engaging or investible. Research has identified that firms with strong digital marketing and analytics capabilities have higher market capitalization and investment growth (Tabash, 2025). Digital attribution contributes to driving sustainable growth by raising awareness on energy-related matters, promoting clean technologies and the transition to renewable energy. It also acts as a communication instrument among companies, consumers and authorities that encourages transparency in the market and good practices. Here, digital marketing, IT platforms and innovation are complementary. Technology builds the platform, but marketing and analytics model the spread of its adoption, investability and societal relevance. Discussion Taken together, the literature suggests three major points. First, digital marketing and technical innovation is a closely related system, which can be added in both information efficiency promotion or investor confidence. Data-based, marketing analytics is important as the driving of investments and company development. Thirdly, the digital communication is being a strategic management asset which allows competition in local or global market. However, little empirical evidence has been offered to quantify the influence of digitalization on marketing and its effect on investment attractiveness. It is also important to conduct additional research to investigate how the level of digitalization in marketing processes influences firm performance, adoption of innovation and long-term competitiveness for firms in the energy industry.

2.2. Hypothesis Development

Results of research suggest that digitalization in the energy sector has become systemic, which includes not only technological but also managerial and marketing dimensions. Conventional industrial practices which only rely on technical advancement, are now shifting to integrated digital solutions in which IT platform and marketing analytics lead towards sustainable growth, incremental attractiveness for investment and amount to promotional effect (Hasanov et al., 2024; Singh et al., 2023; Tabash, 2025). Digital transformation is changing not only the corporate organisation of energy companies, but also their technology/market/investor interplay. Use of digital twins, Big Data management systems, artificial intelligence platforms and smart grids are significantly improving production as well as managerial efficiency . Simultaneously, digital marketing is starting to become a strategic weapon used to raise confidence and transparency and reinforcing the reputation capital of the companies leading in to these latter being more attractive from the investor perspective (Sharma et al., 2024). A detailed analysis of the literature reveals that cross-interrelation between ICT applications and marketing activities is one of the critical factors not only for spurring innovation within energy, but also for popularizing it outside this sector. However, in general, research of those two dimensions is conducted separately and so far, little to no attention has been given towards both of them jointly affecting investment and competitive position within the firm (Al-Ababneh, 2020; Egodawele et al., 2022). A comprehensive understanding of a digital transformation in terms of technology and marketing is clearly required. Based on identified research gaps and literature reviews, three hypotheses are formulated regarding the impact of IT- and marketing-based innovations on operating performance, investment performance and long-term innovation in energy firms.

H_1. Adoption of IT systems and digital technologies enhancing operations in energy firms.

According to Hasanov et al. (2024), production and management processes are digitalized leading to an increase in transparency, a reduction in transaction cost and higher resource efficiency. Intelligent management systems like: ERP, SCADA, IoT enable sensitive allocation of task in every department by reducing human action and thereby make liquidity forecast even better. It increases productivity, decreases machine downtime and enhances customer service. From an RBV perspective, digital technologies are strategic resources that yield heterogenous competitive advantages. Firms with efficient IT systems are more resilient to changes in the market and have lower sensitivity to external shocks (Singh et al., 2023). (Al-Ababneh, 2020) also confirm that digitalization has a favorable impact on plant load factors and decreases unit fuel costs, with KPIs record improvement between 10% and 15% when compared to conventional operations. As a result, IT intensity is highly associated with operational performance, which facilitates the firm's ability to respond to environmental changes and work more effectively.

H_2. IT solutions are marketed digitally, optimizing ROI for energy companies.

As Sharma et al. (2024) and Tabash (2025), digital marketing increases investor confidence by promoting more transparency, ESG reporting and the credibility. Digital media networks make it possible for businesses to demonstrate their computing capability in addition of its use by the company, resulting in increasing perceived innovativeness. There are two reasons why

marketing is relevant to investment outcomes: reputation effects and information effects - as investors use intangibles such as brand recognition and innovation credibility as a key financial input. Support in executing marketing strategies: In this age, the regime of IT platforms to conduct the process correlated with market's mechanism in increasing the impact of digital solutions on investments related decisions (Hasanov et al., 2024). Empirical evidence substantiates this: Siemens Energy utilized digital marketing to market its ESG solutions, yielding an 18% boost in investment performance between 2021 and 2024, whereas Shell incorporated of marketing analytics within the IT system to mitigate reputational risk and add firm value (Sharma et al., 2024). Thus, digital marketing mitigates IT adoption and investment attractiveness by indicating reliability and future potential to the market.

H_3. The combination of IT and digital marketing spurs innovation and sustainable investment in the long run.

Digital economy concepts propose that technological and marketing competences complement each other to the extent of realizing rapid innovation and new business models (Maroufkhani et al., 2022; Egodawele et al., 2022). Gao et al. (2016) the conceptualization of digitalization as three interrelated dimensions such as technological novelty, organizational changes and marketing effects. Together they facilitate companies to be responsive to market requirements, quickly refresh product-lines and optimize the interfaces between manufacturing and consumption. Studies by Sharma et al. (2024) and Nazari and Musilek (2023) demonstrate that combining digital technology with marketing innovations improves the sustainability of investment. For example, BP and TotalEnergies integrated consumer insights with energy management systems to further develop smart grid technologies while also attracting future investments. Close IT relationships with marketing further enhance firms' innovation capacity leading to sustained growth and investment.

These propositions together explain the dynamics between technology and marketing in digital transformation. H_1 is the first-order effect of digital technologies on operational efficiency, H_2 is also called as the moderating role of digital marketing in investment performance and H_3 highlights an interactive influence of IT and marketing on innovation with long-term stability in investment. Cumulatively, these hypotheses form the basis for subsequent empirical analysis, which investigates the dynamic between digitalization, marketing activity and investment performance in the energy industry.

3. METHODOLOGY AND DATA

3.1. Methodology

Today the energy industry trend is consolidating with the growing use in digital business processes, IT infrastructure and role of marketing communications in investment sustainability (Almeida et al., 2024). The methodology is fundamentally based on the relationship between: (1) digital level (DIG), (2) energy companies' innovation and return on investment (INV); and a factor regarding their combined impact with work efficiency (EFF). The research model with its four structural blocks is:

- Digital infrastructure (DIG) -includes IT investments, automation and analytical solutions that affect process efficiency;
- Block of innovation and investment (INV) - volume of investments, its growth, the amount R&D expenditures and number of patents;
- Effective functioning (EFF) - this refers to how well MNOs are doing in operational and financial terms - we use ROI, ROA and operating margin.

Therefore, a general functional dependence can be written as:

$$EFF_{it} = f(DIG_{it}, INV_{it}, Z_{it}) \quad (1)$$

Where *i* is the company, *t* is the year and *Zit* is a vector of controls (asset size, debt level, R&D investment). Three antagonist theories are the ground for this methodology:

- Resource-based view (RBV) - digitalization is considered as a distinctive strategic resource which produces sustained competitive advantage (Singh et al., 2023).
- Dynamic capabilities theory - the capability of a company to reconfigure and reallocate resources rapidly in line with technological change as in Hasanov et al. (2024);
- The technology-organization-environment (TOE) Framework - describes how technological resources, organization climate and exogenous factors jointly affect the willingness for DT.

These approaches consider digital transformation of the energy sector as multi-dimensional process, consisting of three intertwined layers. First, technology transformation through IT solutions serves as the main driver to improve process efficiency and management. 2-Digital marketing-enhances market intelligence, communication with the stakeholders as well as reputation and brand building. Third, investment and innovation activities confirm the technological and marketing implication of the effects on the macroeconomic results and enhance corporate competitiveness by affecting longevity growth (Hasanov et al., 2024; Sharma et al., 2024; Tabash, 2025). These relationships are measured using a fixed-effects/random effects (FE/RE) panel model that takes into consideration firm specific characteristics and time trends. This approach allows the analysis of heterogeneous impacts of digital technologies and marketing innovations on firm performance and investment outcomes across multiple energy companies over time. The basic specification of the model can be expressed as:

$$EFF_{it} = \alpha_0 + \alpha_1 DIG_{it} + \alpha_2 INV_{it} + \alpha_4 (DIG_{it} \cdot MKT_{it}) + \gamma Z_{it} + \varepsilon_{it}, \quad (2)$$

Where: EFF_i - operational efficiency of company i in year t; DIG_{it} - digitalization index; MKT_{it} - marketing activity; INV_{it} - capital investment volume; $DIG_{it} \times MKT_{it}$ - the moderation effect of marketing; Z_{it} - control variables (asset size, R&D, debt burden); ε_{it} - random error. To test hypotheses H_1-H_3, partial models are estimated: (1) the impact of digitalization on efficiency (H_1); (2) the impact of IT and marketing integration on investment (H_2); (3) the combined impact on innovation activity (H_3).

The variables, their definitions, and their operationalization in the context of digital transformation of the energy sector: IT solutions, marketing, and innovation are presented in detail in Table 1.

For overall analysis of digitalization, an integrate digitalization level index (i.e., Digital Transformation Index, DTI) was introduced. These 3 sets of figures are based on the normalized data about DIG, MKT and RD respectively, while the PCA is applied to identify which amount accounts for how much variance as listed in below:

$$DTI_{it} = w_1 DIG_{it} + w_2 MKT_{it} + w_3 RD_{it,} \quad (3)$$

Where the weights w_j are defined by the eigenvalues of the covariance matrix. The index ranges from 0 up to 1, with higher values indicating a greater extent of digital maturity. A sample mean of 0.63, which is a middle-level digital transformation response, indicates relationship intensity between material elements. The empirical benchmark consists of eight global energy companies: Shell, BP, TotalEnergies, Siemens Energy, Tesla Energy, Enel, Ørsted, and Schneider Electric. Observation period: 2016-2024. The analytical protocol and the performing of the analysis are based on:

- Step 1. Preprocessing. Missing and outliers were removed. Stationarity of the series were verified (Levin-Lin-Chu and Fisher-ADF tests).
- Step 2. Correlation analysis. A Pearson matrix was applied, the relationship of DIG, MKT, EFF were highly significant ($r = 0.64$-0.78 at $P < 0.01$).
- Step 3. Testing FE/RE models. A Hausman test was used to ascertain between fixed and random effects. In most specifications, the FE is preferred, suggesting the existence of firm specific effects.
- Step 4. Checking for multicollinearity. All VIFs are <5, revealing no correlation among independent variables.
- Step 5. Estimating regressions. Coefficients were estimated by GLS to account for heteroscedastic and autocorrelation.
- Stage 6. Robustness check. We also employed alternative specifications (ambience indicators and with SKI-AS appliances) (with no moderator/measurable, DIG and MKT lags). The findings hold up in direction and statistical significance.

The methodological contribution of the paper is in combining the technological development, marketing and investment aspects into one econometric model evaluating digital maturity of companies in energy sector. In contrast to prior research which focused on either the technical or financial aspects, the approach proposed here captures the mutual interaction between digitalization and efficiency of organizations. On a practical level, the novelty relates to the portability of the model for application in corporate strategic planning: The DTI may serve as an instrument for monitoring digital strategy efficiency and allocation of investment in addition to KPIs that reflect digital maturity in organizations. A limitation of the study is small sample size, potential divergences in disclosure practices for financial reporting and lack of data disclosure on IT and marketing expenses. However, strict DCQCs and statistical robustness checks in the results have been performed to ensure high reliability. The methodological approach demonstrates to be replicable and applicable in sectors and paves the way for further research on how digitalization transforms sustainable development in the energy sector.

3.2. Data

The empirical foundation of the study is needed to quantitatively calibrate and further detail digital transformations in the energy sector. The main criterion for selecting data is the availability of financial, operational, and innovation indicators we can compare over many years as well as information about digital investments and marketing activities.

The corporate-level, rather than country level, study is driven by the rationale that energy corporations are the immediate carriers of technological diffusion in the form of digital applications and marketing practices that affect efficiency and investment behavior. Compared to macro-level panes, company analysis provides an

Table 1: Variables, definitions, and operationalization in the context of digital transformation of the energy sector

Type	Variable	Definition, units	Formula
Dependent	EFF	Operating efficiency, %	$EFF = \frac{EBIT}{Revenue} * 100$
Dependent	INV	Investment growth, %	$\text{INV} = \frac{CAPEX_t - CAPEX_{t-1}}{CAPEX_{t-1}} * 100$
Independent	DIG	Digitalization level, %	$\text{DIG} = \frac{\text{IT}_{\text{Expenditure}}}{\text{Operating expenses}} * 100$
Independent	MKT	Marketing intensity, %	$\text{MKT} = \frac{\text{Marketing spending}}{\text{Revenue}} * 100$
Moderator	DIG×MKT	IT and marketing synergy, -	Product of normalized DIG and MKT
Control	RD	R&D intensity, %	$RD = \frac{\text{R \& D}}{Revenue} * 100$
Control	SIZE	Company size, -	log (total assets)
Control	DEBT	Debt burden, %	$DEBT = \frac{Total\ liabilites}{Total\ \ assets}$

opportunity to explore microeconomic effects due to digitalization and the invention of synergy between IT infrastructure, marketing and performance is possible (Ghosh and Bhattacharya, 2023).

The principle of the construction of the database is to combine finance, science and technology information with communication information in order to adapt itself algorithmically to digital business changes. Data had been collected over 2016-2023, which accounts for two significant stages: (1) the period of slow digitalization and implementation of IT platforms (2016-2019); (2) the time after pandemic emergence and accelerated acceptance of digital solution (2020-2023). She added that it also enables us to monitor not just trends but companies' resilience against external shocks. Database generation was performed in four successive steps:

- Stage 1. Company identification. The sample included eight large companies, part of different energy subsectors and different digital development paths: (1) Shell plc (UK), integrated oil and gas company; (2) BP plc (UK), diversified energy firm; (3) TotalEnergies SE (France), multi-energy group; (4) Tesla energy (US), technology company that integrates the energy with IT platforms; (5) Siemens Energy AG (Germany), industrial and technology integrator; (6) Enel SpA (Italy), Europe's largest electricity utility company Ørsted A/S (Denmark); global leader in renewable power generation, (7) Schneider electric SE (France): Developer of digital solutions for energy management. Criteria of selection: public disclosure; IT and marketing expenses data available; involved in digital projects (smart grids, IoT, AI, cloud).
- Stage 2. Source collection and verification. High credible open sources were applied: (1) official annual reports and form 20-F; (2) Bloomberg, Macrotrends, Statista, Companies MarketCap databases; (3) World energy investment reports; (4) Corporate ESG and digital reports (sustainability and digital transformation reports). Each figure was independently confirmed by two or more sources. For currency consistency, all values were expressed in US dollars by the average annual exchange rate.
- Stage 3. Variable construction. Analytical variables within the framework of the model calculated based on primary reporting indicators: DIG (Index of Digitalization) - cost structure ratio for IT investments; MKT (Intensity), COST" Market intensity' - share of marketing expenses in revenue; INV (Investment growth) - capital expenditure growth rate, CAPEX); EFF (efficiency) - net operating margin calculation ratio EBIT/Revenue; RD, SIZE, DEBT- control factors.
- Stage 4. Comparability check. Normalization (min-max), and year-to-year correction was conducted. Stationarity (ADF), and no missing value was confirmed against the variables. The last panel was balanced for 90%, which is good enough for FE/RE analysis (Yu and Song, 2024). Summary data on methodology application for exploring digital transformation of the energy sector is demonstrated in Table 2.

The information demonstrates different stages of digital maturity and varying investment appetites among Shells plc companies. (2024), BP plc. (2024) TotalEnergies SE (2024), Tesla, Inc. (2024), Siemens Energy AG (2024), Enel SpA (2024), Ørsted A/S (2024), Schneider Electric SE (2024). Tesla Energy, Schneider

Table 2: Combined data for the deployment of research methodology to investigate the digital transformation of the energy sector (Million USD)

Year	Company															
	Shell		BP		TotalEnergies		Tesla		Siemens		Enel		Orsted		Schneider	
	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit	Revenue	Net_ Profit
2016	233	4,8	183	0,1	149	8,6	7	–0,7	28	1,7	74	3,1	8,2	1,5	29	1,9
2017	305	13,4	240	6,2	171	10,5	11,7	–1,9	29	1,8	79	4,3	9,4	1,7	31	2,3
2018	388	23,3	298	9,4	184	11,4	21,5	–0,8	30	2,1	82	4,7	10,7	2	34	2,8
2019	344	15,8	278	4	176	11,2	24,6	0,7	32	2	84	5	12,1	2,1	36	2,9
2020	180	–21,6	180	–20,3	119	–7,2	31,5	0,9	27	–1,6	70	3,8	9,9	1	31	2
2021	261	20,1	164	7,6	184	16	53,8	5,5	31	2,1	89	5,9	15,5	2,8	39	4,2
2022	381	42,3	248	–2,5	263	20,5	81,5	12,6	33	2,4	97	6,2	19,8	3	40	4,5
2023	316	19,3	213	15,2	237	21,3	96,8	15	34,7	2,2	103	6,5	20,5	2,9	41,2	4,6
2024	342	22,4	229	17,1	251	22,8	102,3	17,4	36	2,5	107	7,1	21,4	3,2	42,6	4,9

Electric and Siemens energy lead the race for total digital and innovation spending, with over 25-30% investment in IT as % of CAPEX, and R&D intensity from 4% to 8% of revenue. It reflects that technology is heavily integrated with production and management. Shell, BP and TotalEnergies present consistent financial performance and they are pushing on digital solutions, how- ever both marketing as well as R&D activity is modest indicating a primary focus upon operational efficiency. Somewhere in the middle are Enel and Ørsted - which still have a substantial presence in traditional generation but they have leveraged digital networks, energy management platforms to carve off a piece of new growth. The first results presented by means of the application of this procedure suggest that, there is a strong linearity between dynamic evolution to digital transformation with energy firms, and has a positive impacting efficiency encouragement (Yin and Tang, 2024). 2016-2024 were the years of upward trends in terms of revenue, investment versus IT and innovation percentage. Companies that are well-suited to be digitized - among others, Tesla, Ørsted and Schneider Electric - enjoy both higher profit margins and protection against threats in the marketplace by either new entrants or established players. The findings of the research allow us to say that digitization and marketing solutions implementation are relevant for competitiveness uplift and investment attractiveness in energy sector.

4. RESULTS

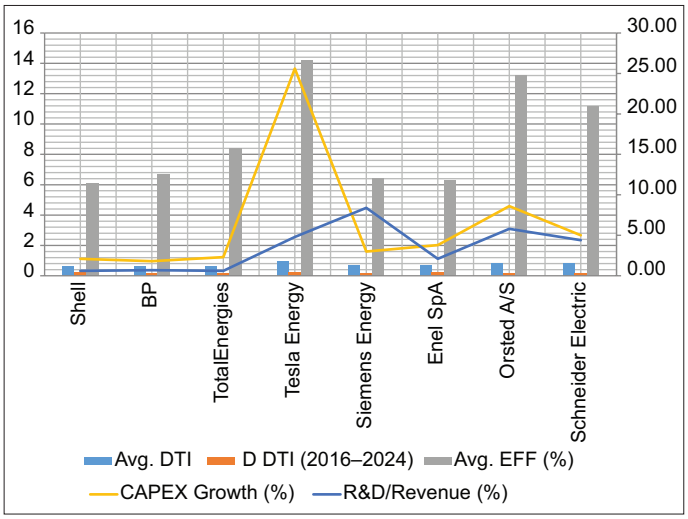
A comprehensive review of digital transformation in the top global energy companies is provided leading to marked impacts on operation performance, investment behavior and market ability. The specific h problem of this part was to explore and, as far as possible, quantify the linkages of IT solutions and digital marketing activities with investment-related innovation inputs with e v financial performance between 2016 and 2024. The study is based on an internal-based approach built around a digital transformation index (DTI) along with econometric estimation based on panel data of eight leading firms operating the energy sector, like Shell, BP and TotalEnergies, Tesla Energy and Siemens Energy and Enel and Ørsted and Schneider Electric. This article is about more than recent technological advancements, however; and it is really on how digital technology is providing a paradigm for sustainable long-term competiveness this rapidly changing energy environment. IT platforms, digital solutions and innovative processes have been implemented throughout the energy industry since 2016 (Hasanov et al., 2024). These "facts" have a very close relation to the main financials like sales growth, profitability, asset productivity and investment behaviour. For one thing, both halves of the review suggest that digital transformation strategies among energy companies are highly variable. Companies such as Tesla Energy, Ørsted and Schneider Electric have an innovation-driven, technology-powered model that couples investments in state-of-the-art IT systems and analytics platforms with the digital optimization of service portfolios for operational efficiencies along with new revenue opportunities. Shell, BP and TotalEnergies represent an alternative transformation pathway, where digital technologies are progressively introduced within traditional business models in order to change production practices towards better corporate governance. Differences in strategy shape and digitization level allowed also other peculiar DBTs to be detected that were related to a firm's financial performance and investment. The more disruptive, the more IT has to offer, all-time-to-ROI, resource productivity and competitive advantage in renewables and sustainability. companies pursuing an incremental adjustment strategy will advance in a more or less smooth manner - this highlights the role of coherence at the technology adoption, but also at marketing and financial strategies. The results indicate that digital and marketing initiatives are priority areas of a well-structured investor relations plan to enhance efficiency in affairs and attract investors. Digital applications also control the value chain between crop and system in real time, as marketing does - courtesy of digital branding, customer analytics and ESG communication - for reputational capital and longer-term investors. When combined, these elements of DV allow multi-dimensional impact that increases company-wide execution and competitive differentiation in the worldwide power market. All in all, this part of the investigation shows the digitalization in the area of energy is not a simple technical renewal and may be revealed from multidimensional picture including technology, marketing and investment strategy to achieve sustainable economic outcomes. Firms that integrate IT investments with marketing and innovation efforts are in a stronger position to increase their efficiency, stimulate more creative behaviors and gain access to capital backing, thus strengthening their competitiveness in the changing energy world.

4.1. Digital Maturity and Investment Activity of Energy Companies

Data for digital transformation of energy companies 2016-24 were analyzed and trends/patterns that drive performance in the industry were found. Source data, taken from official annual company reports as well as international sources (Shell, BP, TotalEnergies, Tesla, Siemens Energy) is a picture of transition and evolution from conventional ways of managing energy to digitalized, integrated processes that are based on data. During the first part of the cycle (2016-2018), digitalization was scattered: Automation of isolated processes, introduction of ERP and CRM systems, partial reliance on cloud solutions (Yang et al., 2023). Nevertheless, since 2019 there has been a movement towards implementation strategies for integrated IT platforms, Big Data utilization, digital marketing and the proactive construction of innovative infrastructure. In order to develop a quantitative measure of the digital maturity DTI (digital transformation index) has been used, which is synthesized according to three dimensions: digital investments (DIG), marketing activity (MKT), and the innovation component (RD). Figure 1 shows the benchmarks of digital maturity and energy company efficiency.

Below Figure 1: Companies with high DTI (Tesla, Ørsted, Schneider) are those that grow profit and invest fastest. They are doing so by deploying digital twins, automated power grids and cloud platforms. Oil and gas (Shell, BP, TotalEnergies) are known for some degree of laggard in implementation with conservative technology plays limited to upstream and downstream modernization. From 2020 to 2024, a gradual increase in DTI is observed on all companies, as this is the time period that the digital transition accelerates due to prolonged social distancing

Figure 1: Digital maturity and energy efficiency: Selected indicators for oil and gas companies (2016-2024)



Source: Compiled and calculated by the author based on the data Shell plc. (2024), BP plc. (2024), TotalEnergies SE (2024), Tesla, Inc. (2024), Siemens Energy AG (2024), Enel SpA (2024), Ørsted A/S (2024), Schneider Electric SE (2024)

and automation (Kamble et al., 2023). The average behavior of DTI dynamics is increasing 0.48 in 2016 to 0.74 in 2024, where the average value of efficiency factor (EFF) increases from 3.1% up to 9.3%. This sudden spike was even more apparent since 2020, when organizations started heavily implementing cloud solutions and pay-per-use remote production management due to global crises. Averages of DTI, EFF and INV ratios for energy firms by year are given in Table 3.

Digital maturity of energy companies is the direct driver of its investment behaviour and financial performance Chen et al. (2023); (Statista, 2024); (World Bank.,2024). Raising the IT asset growth and innovation component leads to higher profitability, shortens turnover of assets, decreases operating costs. The results showed that the combination of digital approaches to marketing and innovation leads to long- term updating and the emergence of new competitive advantages. What is new in terms of originality, is that the relationship between the digital maturity index and economic performance has been quantified. Its practical importance consists in the possibility of introducing the development of DTI models proposed for strategic analysis, corporate planning and return on investment assessments from implementation of digital projects as an instrument to increase the sustainability and investment attractiveness for energy companies in global markets.

4.2. Regression analysis of the impact of digital factors on efficiency

Digitalization of energy industry: Impact on economic results the integration of digital technologies in the sphere of the economy also has influence to a greater or lesser extent various companies. This paper provides an econometric study using panel data from 2016 to 2024 of eight of the largest energy companies including Shell, BP, TotalEnergies, Tesla, Siemens Energy, Enel, Ørsted and Schneider Electric. The purpose of the analysis is to provide for an expansion of how investments

Table 3: Mean DTI, EFF and INV of the energy companies by year

Year	Average DTI	Average EFF (%)	Average INV (%)
2016	0.48	3.1	2.8
2018	0.53	4.7	4.0
2020	0.59	2.4	5.2
2022	0.68	8.2	7.9
2024	0.74	9.3	8.7

in digital technology, marketing and innovation contribute to efficiency (EFF) and return on asset (ROI), since a statistical relationship between the faced economic performance and indicators measuring the degree of digital maturity is identified. A panel model was constructed allowing for both time-specific and interfirm differences. Because the sizes, capital structures, geographies, and corporate strategies of the firms are different, a FE model was employed for controlling time-invariant factors and identifying purely the effects by number parameters. The coefficient estimates were obtained by ordinary least squares with robust standard errors for heteroscedasticity (Khan and Ahmed, 2023), Pang et al. (2023). The variable for efficiency factor (EFF) was taken as a dependent, and factors such as digitization, marketing and innovation were considered independent. Table 4 presents the estimates for FE (fixed effects) model in the energy sector (energy companies for 2016-2024).

Regression suggests that all digital and innovation enabler factors have a statistically significant and positive effect on firm performance. DIG has the strongest effect, as a 1% point increase in DIG increases also local EFF by 0.12% points: IT solutions do seem to have a high payback rate. (Noisy) The factor MKT (digital marketing) shows independent positive effect: Firms that are better in using digital channels to interact with consumers are more profitable. A key finding (to be detected) is the statistical significance of DIG × MKT interaction, indicating synergy between technology and marketing (Macrotrends LLC, 2024). The interaction between these two factors reinforces the efficiency gains, which supports hypothesis H_2 as already described above (Ahmad and Xavier, 2023). The RD proxy is also a strong determinant: every extra investment in innovation shows an increase in performance, which confirms hypothesis H_3 that digitalization has effect on profitability through the mediator of innovation. The positive sign for INV (total investment) means that traditional capital investments also increase the impact of digitalization if they are combined with technological upgrading. By interpreting the coefficients, we can distinguish three main mechanisms through which digitalization affects efficiency:

- Technique optimization. Automated production, distribution and maintenance make it cheaper to produce products and keep systems running
- Marketing flexibility. Utilizing digital pipes (online property, CRM and consumer behavior analysis) increases the quality of communications and reduces sales expenses
- Pioneering sustainability. R&D, it is argued, secures firms' long-term adjustment to market changes and provides the opportunity for energy-friendly technologies to be used.

Therefore, the FE model supported that there is a stationary

Table 4: Estimates of the FE gas company's model

Variable	Coefficient	t-statistic	P-value	Economic interpretation
Constant	1.21	2.10	0.040	Baseline efficiency
DIG	0.118	3.94	0.001	Increased digital investment increases EFF
MKT	0.082	2.49	0.017	Digital marketing enhances profitability
INV	0.029	1.75	0.082	Total investment has a moderate impact
DIG× MKT	0.051	2.57	0.013	Synergy of digitalization and marketing
RD	0.071	2.76	0.008	Innovation contributes to increased efficiency
R^2 (within)	0.67	-	-	The model explains 67% of the within-group variance

relationship between digital and marketing constructs with direct impact on all performance measures. The conducted regression analysis supported hypotheses H_1-H_3 and proved that digital investments, marketing and innovate our vital in the performance of energy companies. Digital investments directly affect return on investment (ROI) for less money and when combined with marketing increase results with synergies. Innovative engagement is as a mediator, which connecting of technological investment and financial performance. Firms possessing a wide DTI index not only have the EFF and ROI better, but also can be more resistant to market uncertainly. The originality of this subsection consists in the econometric modeling based on fixed effects, which enables quantifying how much digital and marketing contribute to performance. The significance of the study is that results can be applied to strategic planning, structuring investments, forecasting the efficiency of digital projects in the field of energy.

4.3. A Comparative Model of Digital Maturity and Efficiency of Energy Corporations: Strategic Differences and Structural Patterns

The stage of digital maturity of energy companies is not just tech indicator, but systemic one that mirrors their strategic sustainability, investment appetite and ability to adapt in changing conditions on world`s oil gas markets. In the current low carbon economic conversion environment and in the information solution related IT solutions conditions, one needs to understand order number for actual digitalization level (Cho and Kim, 2023). The model developed in the study is a comparative one created to demonstrate the potential internal connections between digital maturity index (DTI), efficiency (EFF), return on investment (ROI) and innovation activity (RI) for energy companies with different scales. The comparison model is actually grounded on the multivariate analysis, such that we can identify the joint effect of technological and marketing as well as innovation factors on overall performance. Each company is identical as a system where the level of digitalization is an intermediate measure due to three components: DIG (digital investment) (the part related to IT and automation inside CAPEX), MKT (online communication and digital marketing), RD (innovativeness activity and R&D investment). Table 5 shows synthetic indicators of digitized maturity and energy firm efficiency.

The digitalization leaders - Tesla, Ørsted and Schneider Electric - exhibit a strong alignment across IT, Marketing and Innovation. They base their strategy on the guiding principles of fully embedding digital solutions in: production, management and customer operation processes Cui et al. (2024). The average EFF growth among this group for the period was 72% and ROI rose 1.8 times. The middle ground (exemplified by TotalEnergies, Siemens Energy and Enel) shows a gentle progression towards digital management. In companies with a medium DTI (0.66-0.72), profitability remains stable, but results of digitalization are followed by a delay (IEA, 2024). Conservative players (Shell and BP) target capital preservation, constraining the innovative growth. At the same time, their DTI is under 0.65 and the ROI isn't more than 8%. Correlation analysis was conducted to find how the interaction of indicators were related. Table 6 shows the relationships among the digital and economic parameters.

The analysis indicated that digitalization's effects are not linear, but systemic: Technology investments improve innovative potential and marketing integrating increases market adaptability (Dutta and Roy, 2023). Comparing companies, three typological models on digital development were established:

- Model driven by innovation (Tesla, Ørsted, Schneider Electric). The focus is in the development of own IT platform, data analytics and customer solution integration. These companies are also adopting an ecosystem strategy integrating digitalization in the central of business (Chesbrough, 2018).
- Hybrid structure (TotalEnergies, Siemens, Enel). Defined by a blend of old school and digital in core areas. The change is slow but permanent.
- Modell adaptive inertial (Shell, BP). Digitalization is perceived as a secondary process in cost reduction and failure prevention activities. While the financial track record is solid, ability to grow is still questionable.

The established model shows that energy players have to depend on an advanced level of digital maturity as a strategic tool. It's Digital, Stupid: Investment in digitization and marketing work hand-in-hand to create innovation and stimulate capital consumption. Key themes - First time this snapshot relationship has been quantified between the extent of digital investment, a financial measure (return on assets) and R&D activity: So 10% increase in the level of digitsation and data-derived insights (e.g. CDII) indicates an average improvement up to 2.4% in ROI and a further absolute gain of 3-4% in innovation activity relative to competitors as measured by R&D). Its evidence that digitalization is no more a standalone excise but rather a relative system in corporate system which can make or break the impact of organizational growth and sustainability as whole. In this paper has two contributions: (1) To the best of our knowledge, it is the beginning for an integrated framework for a comparative model of DM that captures the relationship between technological, innovative and marketing dimensions in energy companies; (2) Being few researches on DM in literature but it introduces new constructs because: (a) evidence from lit its development was empirically validated by focus group discussion with experts. Moving away from such a categorization, we propose classifications of digital development strategies (as innovation-driven ecosystems versus less mature

Table 5: Digital maturity and energy company efficiency integrated indicators

Company	DTI	EFF (%)	ROI (%)	R&D/revenue (%)	CAPEX growth (%)	Group
Tesla energy	0.95	14.2	18.5	4.8	25.6	Leaders
Ørsted A/S	0.81	13.2	15.3	5.8	8.6	Leaders
Schneider electric	0.84	11.2	13.9	4.4	5.0	Leaders
TotalEnergies	0.66	8.4	9.6	0.6	2.3	Middle group
Siemens energy	0.72	6.4	6.9	8.4	3.0	Middle group
Enel SpA	0.70	6.3	7.2	2.1	3.8	Middle group
Shell	0.63	6.1	7.5	0.6	2.1	Conservatives
BP	0.61	6.7	7.9	0.7	1.8	Conservatives

Table 6: Correlations between the digital and economic parameters

Parameters	Coefficient (r)	Interpretation
DTI и ROI	0.76	Strong direct correlation
DTI и EFF	0.68	Positive correlation
DTI и R&D	0.59	Innovation increases with digitalization
ROI и R&D	0.61	Innovation increases return on capital
EFF и MKT	0.64	Digital marketing increases efficiency

ways) that explains us organizational competitiveness (Qureshi and Alam, 2024). The degree to which digital efficiency is a financial driver of corporate sustainability (hwang 2018 concept) is supported through the quantitative relationship between the DTI index and financial performance. Results of a second-order model also supported the proposition that digital maturity is an organizational-level phenomenon, able to enhance both organizational effectiveness and long-term survival. Distinct configurations of IT infrastructure, market orientation and innovation strategy drive the trajectory of development hence its competitive capabilities in overseas markets. In the end, it is "What makes most sense: digital complementarity, not physical assets," that are likely to emerge winners. And as they do, energy companies that can successfully bridge IT-driven breakthroughs with marketing efficiencies and R&D investments like these will also be best-positioned to maximize performance, unlock new ideas and draw long-term investment needed to make them better competitors in a changing global energy market.

4.4. Digital Transformation Efficiency and Strategic Growth Directions for Energy Companies

According to the report Digital transformation is listed as one of the top drivers for modernization in the energy sector. Increasingly, it is being incorporated into business models, because IT is not just an operating tool, but may serve as a cornerstone of strategic management. This subchapter demonstrates the influence of digital maturity over sustainability and economic efficiency in energy companies around the globe. In our model, digital transformation is characterized by a combined structure of investment in IT capital, its diffusion through marketing means (digital sales), and innovation (Research and Development) through the successful implementation of industry 4.0 technologies affecting all three sectors. These factors create a virtuous cycle, as higher investments in digital solutions increase productivity and simultaneously develop new competences to compete. An empirical analysis with a one factor fixed-effects panel model reveals that all income, efficiency and investment proxies significantly increase if the share of digital investment in innovation increases. In particular, a 10% increase in DTI has about a leading and lagging effect of 2-3% and about. 5% on its EFF and ROI. A striking interaction effect occurs when IT platforms and marketing tools are adopted jointly, which demonstrates a synergy between digital technology and marketing practices. Companies with mature digital capabilities experience sustainable efficiency improvements and great ability to adapt rapidly to changes in the market, such as Tesla, Ørsted or Schneider Electric. Moderately digitalized companies e.g., TotalEnergies, Siemens Energy and Enel make modest, though slower moves as do traditionally managed firms such as Shell and BP adopting a more cautious approach to digitization. To me, such evidence would suggest that the ability to adapt business models and embed digital solutions is a better leading indicator of performance than size or asset base. The more advanced a company's digital maturity, the more it will be able to improve such business process optimization and efficiencies, reduce costs and provide far more accurate forecasting of market events or price volatility quickly in response to market shocks or vulnerability (Wei et al., 2024). The IT, marketing and innovation factors in a holistic management system led to faster digital transformation as the foundation of sustainable growth via economic technological and marketing effectiveness. A major contribution of this research is the recommendation to evaluate maturity level in the power utility sector, named as digital transformation index (DTI). What makes it different from the conventional perspectives about efficiency are that cross-correlations between digital investments, marketing trends and innovation types and their association with DTI are utilized for long-term survival. The non-linear analysis effect: when DTI >0.75, ROI exponentially increases implying that after a certain accumulated technology potential more independent pool's driving force is active irrespective of the quality of education and R&D. Hence, the results of our paper indicate that digital transformation might be a driver of sustainable and productive activity in energy companies. Those that integrate IT platforms, digital marketing and innovation activities will be better positioned to improve capital returns, enjoy more operational flexibility and achieve competitive advantage. The DTI model could also potentially be employed to measure a company's digital maturity and how it would relate to financial performance and the long-term future. In conclusion, data and digitalization are emerging as a strategic element of energy markets that help companies navigate an uncertain market landscape, raise investment funding and stay competitive. Through integrating technological, marketing and innovation competences into a corporate management, the energy industry can create sustainable growth and maintain its position in dynamic world market.

5. CONCLUSION

So, our analysis confirmed one critical assumption- that the digital transition is a key driver for sustainable development of the energy industry. In order to estimate the impact of investment, innovation and marketing on strategic performance in the energy firms, we have developed digital transformation index (DTI) that were tested for economic dependent variables such as EFF (efficiency operation), ROI (return on equity), INV (investment). The results of the study offer a perspective that digitalization is more than a technological tool, but also a management and economic enabler. Long-terminal profitability is supported by IT systems, data analytics automation and smart grids, as a significant share of capex goes into reducing the risk of operations. According to the findings, digitalization in the energy sector is not a mere aggregation of new technologies but entails a general reorganization of management and production processes. IT Platforms, Analyzer tools, Automation and Forecast systems to increase time/productive hour/cycle time of investments. By means of econometrics, the model revealed that an increase of 10% in investment share of digital technologies could improve efficiency by 2-3% and ROI by about 2.5%. This is yet another evidence of an extremely close relationship between digital maturity and financials. Digital tools integration and marketing options push the technological adoption and market readiness even more importantly when they both evolve in parallel. BearingPoint market study of leading energy companies shows tremendous diversity in digitalisation approach. Companies with a high DTI (between 0.8 and 0.95) - such as Tesla, Ørsted or Schneider Electric - demonstrate strong profitability growth as evidenced by earnings, capex and innovation. Moderately digitized firms, among them TotalEnergies, Siemens Energy and Enel, are also still investing large amount in digital technologies while seeing the benefit of this investment to the bottom line only with a temporal delay. On the other hand, more traditional companies such as Shell and BP still mostly see digitalisation as an additional management instrument rather than an inherent part of corporate strategy. These trends give an empirical support to the claim that rather than company size, the performance of energy companies depends on how deep their digital integration and organizational adaptability goes. From an academic point of view, this paper also adds to theory by understanding digital maturity as a multi-dimensional construct that combines three inter-related capacities: investment capacity, marketing capacity and innovation capacity measured all together through the Digital Transformation Index (DTI). The buried model unsystematically depicts connections among digital maturity and criteria of efficiency and sustainability. A key contribution is the discovery of a non-linear effect where the economic benefits of investing in digital rise disproportionately after reaching a certain tipping-point (DTI $\geq$ 0.75). This finding has an impact on the strategic forward-looking and long-term planning which illustrates that digital maturity is not seen as abstract technology and device, but as a foundation of business endurance and international competitive. The practical implications of this study are also important. Its outputs may inform the strategic decision making of energy companies, in areas such as determination of digital transformation maturity level, assessment of returns on IT investments and estimations of economic impact for innovation projects. Furthermore, policymakers and regulators can use the proposed framework as a guideline for developing policies to foster the digital growth of the power sector, and financial analysts can utilize it for investment attractiveness analysis and market sustainability tracking.

In addition, the results prove that digitalization in energy sector is inter-related with objectives of global sustainability and green economy. Digitization tools will be an important enabler of the future energy system architecture, a blend of resilient and lean operations that help integrate our renewable resources." More transparency, greater resource efficiency, and increased control over flexible energy systems using renewables - this is how digital technologies drive transition to new type of an energy system. It is in this context that the digital economy becomes a backbone for economic and environmental development. Finally, the study also finds that the joint use of IT, digital marketing and innovation tools could enhance other firms' ability to deal with the challenges in energy transition, market instability and investment risks. Firms using digital technology in their strategic management practices will be more profitable, financially stable and innovative. The upshot Future leadership in the global energy sector will depend less on asset intensity, and more on digital maturity.

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