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The Impact Factors of Industry 4.0 on ESG in the Energy Sector

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Abstract: Digital transformation refers to highly thought-out social, manufacturing, and organizational transitions driven by digital revolutions and emerging technologies. On the other hand, energy is a critical pillar of the economic growth of the country. Meanwhile, global interest in environmental, social, and governance (ESG) investment is growing. The conventional investment paradigm is being phased out in favor of investments that prioritize environmental, social, and corporate responsibility. The energy sector is one of the most significantly affected. Presently, the field of digital transformation is limited in its analysis about the sustainability factors and is still controversial, especially in the energy business. This paper identifies an in-corporation factor in Industry 4.0, taking into account the effect on ESG. The research papers and the World Economic Forum reports were investigated and identified the correlation factor using machine learning to analyze their contents. We spotlighted the documents relevant to the energy industry and sustainable development. To quantify the model, confirmatory factor analysis (CFA) is proposed to generate a valid model, followed by path analysis with latent variables to evaluate the structural equation modeling (SEM). The result provides the conceptual model with impact factors and their correlations. The goodness of fit value is acceptable for the agreed-upon condition, as well as a descriptive that incorporates Industry 4.0 and ESG in terms of business, industry, and ESG in relation to the energy sector's key issues.

Keywords: Industry 4.0; ESG; energy sector; digital transformation; sustainable development

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1. Introduction

Energy is one of the most important foundations for a country's economic growth. To fulfill their demands, expand their production potential, and improve their standard of living, all countries try to maximize their energy potential and purchase energy from other nations [1]. Over the last three decades, various states, regional, and worldwide organizations have been concerned with measures of sustainable energy. The report on the emission gap, which was released by the United Nations Environment Programme (UNEP), stated that most global greenhouse gas emissions are consumed and generated by energy [2], with fossil fuels accounting for the same proportion of the global energy mix as they did 30 years earlier. As a result, a shift to a more inclusive, sustainable, economic, and safe global energy platform that addresses global concerns while also creating value should be emphasized [3].

In recent years, industrial production processes have been transformed as a result of increased digitalization, leading to intelligent, interconnected, and decentralized production. The implementation of the Internet of Things (IoT) and cyber–physical network technologies has had a significant influence on industrial systems [4]. Additionally, the new level of organization is often referred to as the "fourth industrial revolution" or "Industry 4.0" [5,6]. The important component of Industry 4.0 is to utilize developing technology so that engineering and business processes are thoroughly integrated, allowing production to evolve in a scalable, effective, and sustainable manner that maintains continuously high quality and low cost [7]. Consequently, digital transformation (DT) enables a new approach to digitizing resources and generating value and revenue. The word "digital transformation" is commonly used in today's world. Meanwhile, Industry 4.0 has attracted the interest of academics and scholars all over the world [8]. Some researchers look at particular technologies to describe an "organizational transition to data driven" while others focus on technology as mostly a catalyst of fundamental change [9] and the effects of those changes on the organization [10].

The UNEP defines industrial development transition as a "new economic paradigm in which materialistic prosperity is not unavoidably given at the expense of increasing environmental challenges, ecological shortages, and social inequities" [11]. Consequently, there has been a growing understanding by individuals, states, and investors that firms have an important role to play in tackling society's most serious social issues, and the globe will still be on track to meet the UN Sustainable Development Goals (SDGs) for 2030. ESG elements are increasingly being integrated into investment and business management, demonstrating that they can generate greater performance and durability profit growth. Economic growth and social effect growth are intertwined. In 2004, 20 financial corporations introduced the term ESG in the public response to a statement from UN Secretary-General Kofi Anon [12]. This approach is organized around a wide range of suggestions addressed to various financial sector organizations, all of which aim to address the primary issue of incorporating environmental, social, and governance (ESG) value drivers into financial market research, analysis, and investment. Through the collaborative approach between the global compact office and partners such as the Swiss Government, the International Finance Corporation (IFC), and other mainstream financial institutions are helping mainstream financial institutions integrate environmental, social, and governance (ESG) issues into investment analysis, processes, and decision making [12]. As indicated, business models that take into account issues of sustainability, social responsibility, and good governance (ESG) are known as ESG models.

ESG is a methodology for assessing a company's environmental, social, and governance performance. Numerous companies publish ESG proof to indicate that their business model is not only profitable but also responsible or sustainable. This reporting helps to understand an organization's ESG issues, opportunities, and impacts. Meanwhile, MSCI (Morgan Stanley Capital International) has pioneered efforts to assist with and accelerate sustainable investing by offering data, research, and other resources to support the implementation of ESG. Moreover, support global ESG openness by publishing publicly the ESG ratings of the most widely held corporations in the world, as well as the ESG rating and ESG index construction methodology [13]. The MSCI ESG rating approach highlights the most serious ESG concerns, which are called "key issues" as well as creates the ESG industry materiality map [14]. MSCI developed a statistical approach to determine the most significant risks and opportunities for each sector by examining ranges and average values for externalized consequences such as emissions intensity, water severity, and accident rates for each sector. A company's primary risks and possibilities may be reduced or increased if its business plan is distinctive for its industry. There are several exceptions that can be made for firms that have a variety of business strategies, are in the middle of a controversy, or follow industry standards. Each industry and firm is allocated a set of key issues after they have been identified. With a worldwide team of over 200 professional research firms, MSCI analyzes thousands of alternative data including government, regulatory, and NGO data points across 35 ESG Key Issues, concentrating on the junction of a company's core business and industry issues that might provide substantial risks and/or opportunities. Companies are given a score from AAA to CCC based on their performance and standards in comparison to other companies in the sector [15].

As a consequence of COVID-19, several organizations have accelerated their pandemic planning processes. They could now strategize for the real-world consequences of a lack of digital technology. The Industry 4.0 enabling technologies supported digital transformation prior to COVID-19, but this epidemic has sped up attempts to produce more effective methods for implementing Industry 4.0 [16]. Correspondingly, digital innovations have rapidly pervaded manufacturing and production processes in recent years. Additionally, Industry 4.0 unfolds as a response to a number of critical global issues, including global warming, extreme poverty, affordable housing shortages, water contamination, ecological pollution, and resource depletion, all of which are being exacerbated by current and emerging global phenomena such as population growth, urbanization, and migration. The question of how Industry 4.0 may benefit in developing new solutions to world-changing social, economic, and environmental concerns becomes more pressing. This point raises the question of whether and how Industry 4.0 can be leveraged [17]. The interdependency and interconnection of the world are increasing exponentially. These major shifts necessitate new investment techniques that take sustainable finance seriously into account. A rapidly changing world provides exceptional investment opportunities. The dependence on fossil fuels could be transformed by the development of new energy alternatives. Technological advancements could help alleviate food and water shortages while allowing us to use resources more sustainably. The transition to sustainable energy and Industry 4.0 characterize the following key features: both are significantly influenced by technological innovations, rely on the development of new appropriate infrastructures and regulations, and have the potential to enable new business models. The Fourth Industrial Revolution, according to [18,19], targets sustainable growth but integrates digital transformation and sustainability remains. Sustainable and responsible investing (SRI) has grown significantly in the recent decade. Investors, shareholders, governments, and enterprises all benefit from credible information on financial and ESG aspects [20]. In recent years, the influence of corporate ESG on financial performance and risk management has been discussed extensively. ESG-related assets must be reviewed and assessed by ESG-specific rating organizations [21].

The annualized return comparisons of ESG and reference firms [22] indicate that stock performance was significantly correlated to ESG aspects. Strong ESG standards have the greatest influence on stock returns in the energy sector. Other industries, on the other hand, have shown a detrimental impact of ESG issues on returns. The existence of oil and gas energy could be a probable reason for the energy sector. In most cases, the oil and gas industry does not perform in a way that is environmentally friendly. Numerous studies have contributed to ESG growth, including performance evaluation and factors in the early-stage sector such as financials [23–27], port industry [28,29], healthcare [30], and information technology [31]. No research has been conducted to determine the ESG aspects and influencing criteria that will be incorporated into Industry 4.0 in the energy industry.

Industry 4.0 has the potential to be a significant opportunity for integrating sustainable development goals with advanced technology digital transformation, but it also has the potential to be a roadblock if sustainability goals are not addressed while implementing Industry 4.0. This study's objective is to develop the conceptual model of impact factors that correlates the notion of "Industry 4.0" to the MSCI ESG key issues from an energy sector perspective. In the introduction, we gave a comprehensive discussion of Industry 4.0 and sustainable development in the energy business, while the literature analysis highlighted the major topics examined by previous researchers and revealed the gap that necessitated our study. In the materials and methods section, the study dataset is collected based on its most frequently occurring text fragments and their associations using machine learning, and then the model of each cluster is assessed using confirmatory factor analysis (CFA) in the first order, and the aggregate model is evaluated using path analysis. In the results, the research model is constructed and the extent to which it integrates with the essential pillars of Industry 4.0 and ESG, with a particular emphasis on the energy industry, is outlined.

2. Theoretical Background

This section is intended to describe the concepts that have guided the selection and evaluation of papers, to sum up, the structure of the relationships in the energy sector between Industry 4.0 and ESG, identify major issues, and indicate research needs.

2.1. The Impact of Industry 4.0 and Sustainable Development

Digital technologies associated with Industry 4.0, including artificial intelligence (AI), big data analytics, and several others, benefit humanity and organization [32]. Additionally, the adoption of digital technologies in sustainable development is expanding. The energy sector, such as mining, oil, and gas industries, is all part of the broader linkage between digitization and sustainable development. Digitalization has considerable potential to contribute significantly to the aim of decarbonization. Feroz et al. [33] indicated the four primary areas in which digital technology can be applied to the environment, while Vrchota et al. [34] findings of the relationship between Industry 4.0 and greener processes. On the other hand, Beier et al. [19] study of the topic of Industry 4.0 in the sociotechnical context offered an initial description. Oláh et al. [35] and Burritt and Christ [36] have identified that the environment benefits from Industry 4.0, which enables comprehensive digitization. In another study by García-Muiña et al. [37], Braccini et al. [38], Müller and Hopf [39], the authors suggest the Triple Bottom Level Model (TBL), which incorporates possibilities and challenges related to Industry 4.0's adoption. In addition, the World Economic Forum (WEF) outlines the collective potential for action within the dynamic and diversified stakeholder group, provides impact reports on ESG, and emphasizes locations to take further measures to promote change in the system [40].

2.2. The Industry 4.0 and ESG in the Energy Sector

Energy business transitions through the introduction of more sustainable energy systems and Industry 4.0 would dramatically alter how people work, consume, manufacture, and trade. Previous literature has placed more importance on the correlation between technology and energy. Jin et al. [41] conducted a study on the impact of technology on energy, Du et al. [42] and Sohag et al. [43] indicated the reduction of energy consumption, while Aflaki et al. [44] highlighted the impact of renewable energy. Numerous studies have lately established various links between Industry 4.0 advancements and sustainable strategies. For example, Kamble et al. [45] discuss the impact of Industry 4.0 on sustainable business models, and Machado et al. [18] concentrate on the impact of Industry 4.0 innovations on Lean Manufacturing Practices for sustainable organizations Beier et al. [19] to comprehend how sustainable research from manufacturing helps to the establishment of an agenda for Industry 4.0 and the interconnectedness of all of those. In addition, the fourth industrial/revolution study, according to [46], targets sustainable growth but integrates digital transformation and sustainability remains [47].

Socially responsible investors place an emphasis on three major areas, often referred to as ESG. ESG stands for environmental, social, and governance, three essential criteria for investments in recent decades [23,48–51]. The energy business is already at the forefront of crucial issues such as climate change and indigenous rights, including reconciliation, economic prosperity, and sustainable energy usage in Canada [52]. The findings of the Yang et al. [53] study indicate the importance of clean energy, green investment, and the growth of a sustainable economy in the framework of the G7 countries as major and positive indicators, while Xie [21] examines how investors would influence policy on ESG awareness on energy sector performance through advocacy. Yu et al. [54] propose that Chinese energy companies utilize Industry 4.0 technology to automate their ESG reporting processes. In addition, the correlations between the ESG scores of businesses operating in the energy industry and their firm financial performance are shown by Baran et al. [55].

In summary, we examined many prior research threads connecting Industry 4.0 with ESG [19,33–35,56–59]. Recent research has taken a number of methodologies to the particular topic, including manufacturing surveys [60,61]; content analysis [62–69], and statistical data [19,41–44]. Recently, studies have identified ESG impact indicators that might affect a firm's performance and investor attractiveness in the early-stage industry [23–31]. In the energy industry, a few research indicated that Industry 4.0 can facilitate ESG by automating reporting [54], correlating financial performance [55], and influencing investor policy [70]. After examining all of this research, it is still unclear where the energy sector has the possibilities associated with Industry 4.0 and tree the majority of ESG; environmental [33,35,56,60], social [71,72], and governance [71,73,74]. As a result, there is still a disconnect between Industry 4.0 and ESG in the energy sector.

3. Materials and Methods

The methodology for the impact factor of Industry 4.0 on ESG in the energy business is based on three stages data collection; content analysis utilizing machine learning techniques using Leximancer software [67–69,75–78], and evaluation approach with structural equation modeling (SEM) [79–83] by first-order confirmatory factor analysis (CFA) and path analysis using IBM AMOS software. Finally, this research combined the topics of ESG [84] and the topics of Industry 4.0 in scaling and adopting digital [85–87] as well as a descriptive term that integrates Industry 4.0 and ESG in teams of business, industry, and ESG to address the energy sector's critical concerns.

3.1. Define the Pillars and Data Collection

In order to advocate for various points of view, this study identified the following two essential pillars: sustainability and digital transformation as key ingredients. This search query yielded a list of papers ranked by the following major indicator: the number of citations they received. To ensure that the study covers the concept's perception not just in academic publications but also in business and economic white papers and science databases were chosen (see Table 1).

In Figure 1, the first stage involves screening and gathering applicable documents and related topics from the World Economic Forum (WEF) Strategic Intelligence [3] and academic databases. The keyword in Table 1 was used according to the search query. Only articles in recent years that have been published from 2017 to 2021 were considered. A total of 583 were processed. This move included undertaking a wide literature review quest for abstracts, related topics, and key issues relating to Industry 4.0 and ESG.

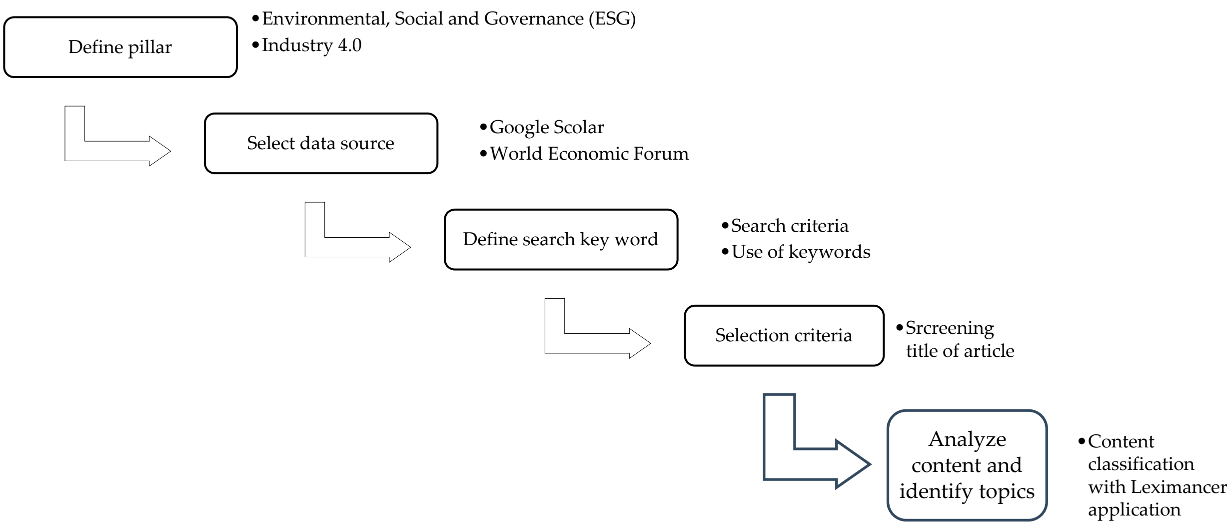

Figure 1. The overview of sample data selection process.

Table 1. The overview of keyword and selection criteria.

Datasource	Criteria	Content Type
Google Scholar	("Industry 4.0" OR "Digital Transformation") AND ("Sustainab*" OR "ESG")	Academic publication
World Economic Forum (WEF) Intelligent	Select article under "Future Energy"	Articles and Academic publication

3.2. Data Analysis

In the second point, the anthology items, as well as the theoretical and practical white papers, were included to incorporate (see Figure 2). However, in terms of quality, publications that violate fundamental scientific principles, such as reference handling, were removed from the analysis. As a result, our study is based on a content analysis of 255 publications to find the greatest correlation words as the concepts, and the top content categorization as the themes. The Leximancer software [67,69,75] gathered the most fragmented words and correlations based on Industry 4.0 and ESG. Finally, the papers were reviewed to find a positive impact on the key principles that were established on the research pillars. As a subject, the study dataset was collected from the highlights of Themes and Concepts (see Figure 3).

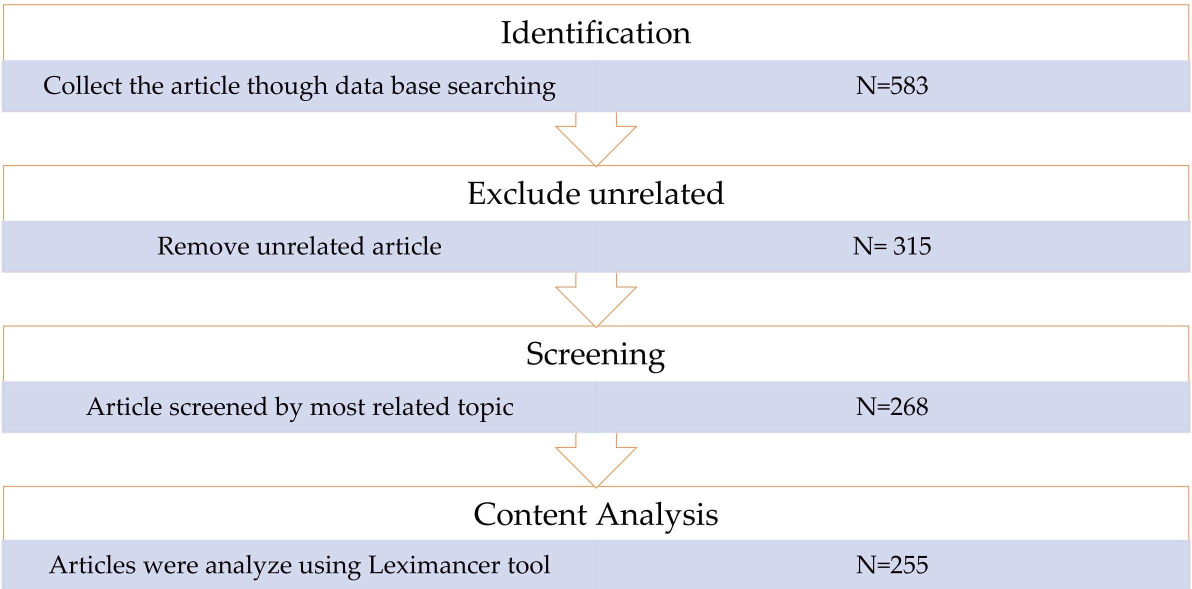

Figure 2. The overview step of topics selection.

3.3. Measurement of Variables and Evaluation of Structural Equation Modeling

To identify the impact factors related to ESG and the perspective of digital transformation. The reliability of the correlation dataset was evaluated by IBM SPSS (see dataset in S1). It found validity and appropriate [88–91] at Cronbach's Alpha = 0.969 and Kaiser–Meyer–Olkin (KMO) = 0.965, Bartlett's test = 695.378, Sig = 0.000 and measures of sampling adequacy (MSA) between 0.920 and 0.990 (see dataset in S2). This dataset was then utilized to validate the structural equation model in the next stage.

The CFA analysis is a strong method for exploring the underlying structure of latent variables and understanding interactions among them [92]. Furthermore, CFA is an essential part of the family of structural equation modeling (SEM) and is used in the path or structural analyses for model validation [79–82,93,94]. With respect to Dennis et al. [92] recommendation, this research included the standard formula for the χ^2 value, along with the degrees of freedom and probability value, which gives a better overall assessment of model fits, such as the Tucker–Lewis index (TLI), comparative fit index (CFI) and the root mean square error of approximation (RMSEA).

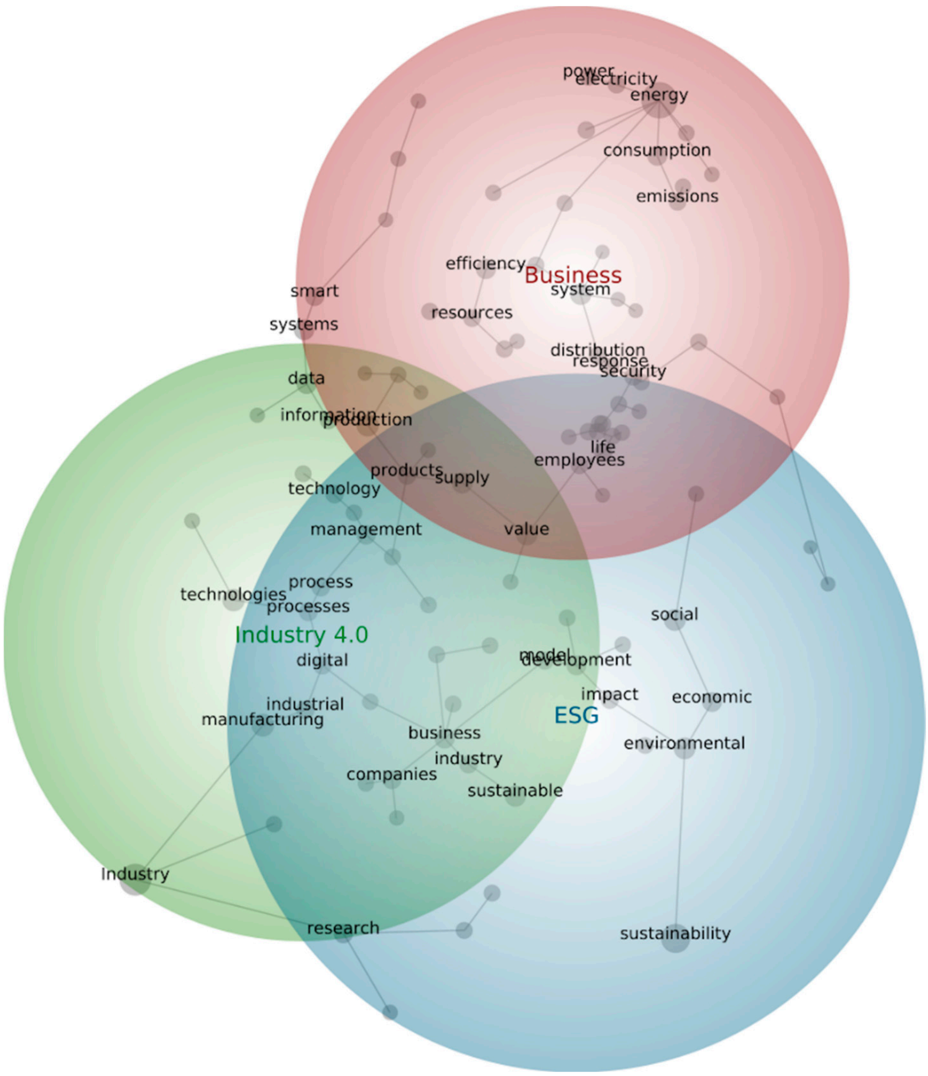

Figure 3. The content analysis using Leximancer application.

4. Results and Discussion

In particular, for each of the categories of business, Industry 4.0, and ESG. This section summarizes the themes that describe this particular. The detailed descriptions of essential aspects are based on information collected from the reviewed sources. Detailed descriptions highlight the impacts and relevance to the topic of Industry 4.0 and ESG from an energy perspective.

The following part discusses the most essential elements of Industry 4.0 and ESG, categorized by themes and concepts [67,69,75]. we provide these three themes and seventeen factors that were referenced in the majority of articles (see Figure 4). The term "goodness of fit" is defined as a metric for determining how well the data observed matches the model. The goodness of fit outcome in this experiment is consistent with the agreed-upon condition based on cutoffs and the two-index presentation strategy proposed by Hu and Bentler [95]. Cutoffs are 0.06 or lower for RMSEA, 0.09 or lower for the standardized root mean square residual (SRMR), and 0.96 or higher for TLI and CFI. For relative chi-square (X^2/df) based on cutoffs ranges from as high as 5.0 proposed by Wheaton et al. [96] to as low as 2.0 recommended by Tabachnick and Fidell [97].

The path analysis is shown in Table 2 and the result of the structural equation modeling analysis is explained for each of the themes, individually. This is the goodness of fit score for a path analysis model that shows the correlations between a dependent variable and independent variables, and it is used to validate models in structural analyses; probability level = 0.441, Chi-square (X^2) = 109.535, degree of freedom (df) = 108, relative chi-square (X^2/df) = 1.014, CFI = 0.998, TLI = 0.997, SRMR = 0.057, and RMSEA = 0.018. Consequently, first; the business has positive and significant direct effect to Industry 4.0 variable (β = 0.946, α < 0.001); second, ESG variable have positive and significant direct effect from Industry 4.0 (β = 0.968, α < 0.001) and indirect effect from business (β = 0.916). Table 2 describes the findings of the path analysis on Industry 4.0 and ESG.

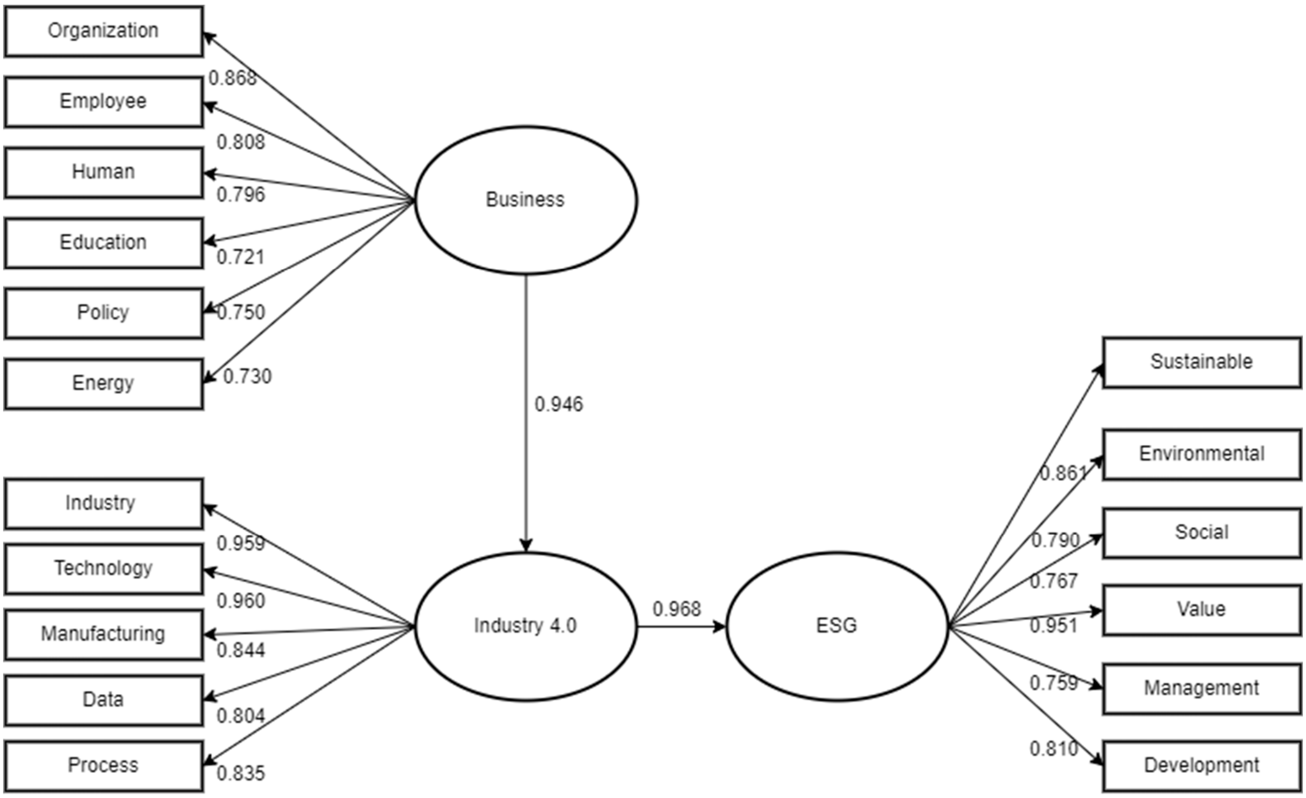

Figure 4. Structural equation modelling with path analysis. Chi-square (X^2) = 109.535, degree of freedom (df) = 108, relative chi-square (X^2/df) = 1.014, probability level = 0.441, CFI = 0.998, TLI = 0.997, SRMR = 0.057, and RMSEA = 0.018.

Table 2. The result of the second-order confirmatory factor analysis on Industry 4.0 and ESG.

Latent	Business			Industry 4.0			ESG			
Observe	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	r^2
Organization	0.868	0.868								0.754
Human	0.796	0.796								0.634
Employee	0.808	0.808								0.653
Policy	0.750	0.750								0.562
Education	0.721	0.721								0.520
Energy	0.730	0.730								0.533
Data	0.761		0.761	0.804	0.804					0.647
Technologies	0.908		0.908	0.960	0.960					0.921
Industry 4.0	0.907		0.907	0.959	0.959					0.919
Manufacturing	0.799		0.799	0.844	0.844					0.713
Process	0.790		0.790	0.835	0.835					0.697
Value	0.871		0.871	0.921		0.921	0.951	0.951		0.905
Management	0.695		0.695	0.735		0.735	0.759	0.759		0.576
Sustainable	0.788		0.788	0.833		0.833	0.861	0.861		0.741

Table 2. *Cont.*

Latent	**Business**			**Industry 4.0**			**ESG**			
Observe	**Total Effect**	**Direct Effect**	**Indirect Effect**	**Total Effect**	**Direct Effect**	**Indirect Effect**	**Total Effect**	**Direct Effect**	**Indirect Effect**	r^2
Development	0.742		0.742	0.784		0.784	0.810	0.810		0.657
Environmental	0.723		0.723	0.765		0.765	0.790	0.790		0.624
Social	0.702		0.702	0.742		0.742	0.767	0.767		0.588
Latent	Industry 4.0			ESG						
Dependent	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect				
Business	0.946	0.946		0.916		0.916				
Industry 4.0				0.968	0.968					
R^2	0.895			0.937						

Chi-square (X^2) = 109.535, degree of freedom (df) = 108, relative chi-square (X^2/df) = 1.014, probability level = 0.441, CFI = 0.998, TLI = 0.997, SRMR = 0.057, and RMSEA = 0.018.

4.1. Business

There are six factors in the theme business. The result of structural equation modeling analysis is as follows: business with the relative X^2 = 1.382, p-value = 0.227, TLI = 0.957, CFI = 0.986, and SRMR = 0.045 has positive and significant influence on variable employee (β = 0.903, α < 0.001), education (β = 0.814, α < 0.001), human (β = 0.709, α < 0.001), organization (β = 0.703, α < 0.001), policy (β = 0.628, α < 0.001), and energy (β = 0.576, α < 0.001). Table 3 describes the findings of the first-order confirmatory factor analysis on business.

Table 4 outlines the following business theme: According to our experimental findings, employee, education, human development, and organizational culture all have the potential to impact business growth as well as long-term growth policies in the energy sector, which is crucial. As a result of the study [98], when Industry 4.0 was introduced, the whole corporate sector started to deal with it. This shows that intervention methods are necessary for all other businesses that have not adopted them. Numerous businesses have already developed Industry 4.0 strategies, while a few others have begun implementing changes [38]. In addition, since the differences between companies or industries are no longer as distinct, it is possible to more broadly apply the capacities that are being used [99]. At the core of Industry 4.0, jobs for the unemployed Industrial reports indicate that Industry 4.0 has impacted the recruiting industry [100]. The following several driving elements were discovered: business model and competitiveness; performance and efficiency; worker requirements; customer needs [101]. In order to maximize the benefits of Industry 4.0 technology, an organization must plan to streamline all of its business operations [16]. For instance, an industrial IoT study for the mining industry offers improved mine operations, improved efficiency, more efficient use of energy, safety for mine personnel, visibility for mine equipment, and reduced labor costs [102].

The economy is becoming digitalized across all sectors, including upstream industries. Efforts to reduce greenhouse gas emissions through the use of digital technology have a high probability of success [103]. Throughout this, the question of organizational effectiveness is raised. Businesses that seek to incorporate environmental sustainability concepts into their business strategies will want to know if such activities can lead to higher performance independent of their social responsibility rankings [33]. In the meanwhile, the European Union has announced a set of supporting tools to assist businesses in achieving emission reductions [103]. Establishing a supply chain that utilizes renewable raw materials as well as being more environmentally conscious provides firms with an incentive to develop environmentally friendly products [104]. The digital, physical, and biological domains are converging. Having a strong ethical, legal, and safety policy should be a must. Robotic or automatic systems must be managed in conjunction with human labor in smart industrial environments that use robotics [105]. In China, this target of achieving peak carbon by

2030 and carbon neutrality by 2060 is extremely clear [106]. More investment will go to sustainable energy solutions as carbon-intensive energy sources and industrial techniques are phased out. All South Asian countries have adopted the policies, which include subsidies for energy, irrigation, seeds, and agrochemicals. They aimed at to raise the output of the primary food crops, primarily rice and wheat [107]. The regulatory engagement with the industry has increased [108].

4.2. Industry 4.0

There are five factors in the theme Industry 4.0. The result of structural equation modeling analysis is as follows: industry with the relative X^2 = 0.322, *p*-value = 0.863, RMSEA = 0.000, and SRMR = 0.009 has positive and significant influence on variable industry (β = 0.960, $\alpha < 0.001$), technology (β = 0.953, $\alpha < 0.001$), manufacturing (β = 0.864, $\alpha < 0.001$), process (β = 0.842, $\alpha < 0.001$) and data (β = 0.773, $\alpha < 0.001$). Table 5 describes the findings of the first-order confirmatory factor analysis on Industry 4.0.

Table 6 outlines the following Industry 4.0 theme: According to our research, we discovered that smart manufacturing and process optimization are essential. Environmental sustainability often uses digital technologies. Data-driven and traceable carbon footprints can lower CO2 emissions from industrial revolution 4.0 technologies [109]. Improved working conditions, less waste, and less use of energy and resources all contribute to a better situation in the workplace with the full implementation of Industry 4.0 [110]. Bányai et al. [111] demonstrate the integration of container equipment and wireless communications systems into industrial settings to show that the routes can be adjusted dependent on the waste level of the containers. To enable stakeholders to make dynamic real-time decisions, the entire firm should be digitally connected. the Internet of Things (IoT) enables enterprises to integrate their systems, equipment, sensors, and people [112]. Industry 4.0 presents numerous opportunities, both ecologically and socially. Additionally, data-driven and transparent carbon footprint evaluations, such as those enabled by Industry 4.0, make greenhouse gas emission reductions possible [113,114].

New technologies that form the fourth industrial revolution have the potential to strengthen our collective response to the pandemic. The revolution in Industry 4.0 is for enterprises to incorporate smart technology, but it is also an opportunity for people to adopt a new way of living styles, especially through the use of mobile devices [57]. Smart technologies that aid the elderly in creating friendly, mutual, and individualized interactions are being adopted in many countries [115]. The practical information provided here aims to help governments and industry to work together to provide good governance while also increasing flexibility and participation [116]. Data integration and analytics have been coupled with maintenance planning to assist clients in saving money and reducing emissions [117]. Design can be improved by directly integrating product usage data back to design [118]. Better product lifetime management includes reusing [119]. As a result, Industry 4.0 identifies and then mitigates greenhouse gas emissions. Additionally, Industry 4.0 can enable enterprises in minimizing wasteful material transfers and decreasing the volume of international and domestic shipping flow by helping companies in avoiding missed deliveries, waiting for delays, and damaged goods [120,121].

With the help of Industry 4.0 technology, smart products could produce considerable economic, environmental, and social advantages, thus helping the world fight climate change. The enterprise will collect untapped waste streams' value and turn it into profit [122].

4.3. Environmental, Social, and Governance (ESG)

There are six factors in the theme ESG. The result of structural equation modeling analysis is as follows: ESG with the relative X^2 = 1.168, *p*-value = 0.314, TLI = 0.987, CFI = 0.993, and SRMR = 0.030 has positive and significant influence on variable value (β = 0.917 $\alpha < 0.001$), sustainable (β = 0.887, $\alpha < 0.001$), environment (β = 0.831, $\alpha < 0.001$), development (β = 0.809, $\alpha < 0.001$), social (β = 0.786 $\alpha < 0.001$), and management (β = 0.733,

$\alpha < 0.001$). Table 7 describes the findings of the first-order confirmatory factor analysis on ESG.

Table 8 outlines the following environmental, social, and governance (ESG) theme: The World Economic Forum's Mission Possible Platform is a collaboration of corporations and experts committed to decreasing heavy industrial and mobility emissions by providing technological, regulatory, and financial solutions [123]. A recent analysis [124] across a range of high-emission companies has shown that top-quartile companies in specific ESG criteria such as emission intensity and environmental impact trade at a premium versus the industry median. Most organizations can do considerably more to decarbonize their supply chains. The Future of Nature and Business report [125] identifies effective means for industry to guide the transition towards a nature-positive economy. This is a win-win approach for nature, people, and business. However, a study was conducted on employment and personal fit in relation to Industry 4.0 and new business models, including participants from Poland, Slovakia, and Germany [126].

Additionally, the research indicated that digitally transformed enterprises in Serbia see human resources as a barrier to Industry 4.0 adoption and not as a driving force [101]. On the other hand, manufacturers should carefully evaluate elders' willingness, ability to accept, and affordability, as the benefits of sustainable products are to improve the quality of life for elders [115]. Combining environmental governance alongside technological progress has launched the introduction. Numerous international organizations have recognized the critical nature of a company's mission and the necessity for the best evidence-based value for its stakeholders [127]. It is important for the company to have a clear mission, and it is important for the company to evaluate all of its actions that contribute to a thriving, long-term society [127]. The case studies further indicate that Industry 4.0 increases production while also benefiting the environment [128] and is involved in organizational activities and marketing techniques that have a beneficial effect on the economy [129]. On the other hand, it is necessary to take into consideration cultural barriers when restructuring firm organizations and to build a culture that encourages the adoption of Industry 4.0 [77,130]. In practice, this will undoubtedly be faced with resistance, unwillingness to change, and emotional reactions within the company, all of which will likely have a negative influence on the adoption of smart manufacturing technologies [100].

Table 3. The result of the first-order confirmatory factor analysis on Business.

Latent	**Business**			r^2
Observe	β_i	b_i	**S.E.**	
Employee	0.903	1.000	-	0.815
Human	0.790	0.875	0.147	0.624
Organization	0.703	0.778	0.149	0.494
Policy	0.628	0.695	0.157	0.394
Education	0.814	0.901	0.147	0.662
Energy	0.576	0.632	0.159	0.332

Relative X^2 = 1.382, *p*-value = 0.227, TLI = 0.957, CFI = 0.986, and SRMR = 0.045.

Table 4. The selected factors of business.

Factors	**Main Related**	**Reference**
Organization	Govenance, communication relations	Butt [16] Tavares-Lehmann and Varum [58] Brozzi et al. [98] Santos at al. [128] Oesterreich at al. [129]
Employee	Labor Management, Human Capital Develoment	Schallmo et al. [99] Aziz et al. [102]

Table 4. *Cont.*

Factors	Main Related	Reference
Human	Labor Management, Human Capital Develoment, Health and Safety	Sung [100] Aziz et al. [102]
Education	Labor Management, Human Capital Develoment	Schallmo et al. [99] Herceg et al. [101]
Policy	Governance, Privacy and Data security	Bag et al. [105] Rasul G [107] WEF [108]
Energy	Opportunities in Renewable Energy	Feroz et al. [33] WEF [103] Manavalan et al. [104] WEF [106]

Table 5. The result of the first-order confirmatory factor analysis on Industry 4.0.

Latent	Industry 4.0			r^2
Observe	β_i	b_i	**S.E.**	
Industry	0.960	1.000	-	0.921
Technology	0.953	0.993	0.071	0.908
Manufacturing	0.864	0.901	0.093	0.747
Process	0.842	0.878	0.097	0.710
Data	0.773	0.806	0.112	0.598

Relative X^2 = 0.322, p-value = 0.863, RMSEA = 0.000, and SRMR = 0.009.

Table 6. The selected factors of Industry 4.0.

Factors	Main Related	Reference
Industry	Carbon Emission, Toxic Emission and Waste, Water Stress, Opportunities in Clean Tech, Human	WEF [103] Bai et al. [109] Bányai et al. [111]
Process	Carbon Emission, Opportunities in Clean Tech, Biodiversity	Bai et al. [109] Bányai et al. [111] Kettunen et al. [112] Müller et al. [110]
Manufactoring	Carbon Emission, Toxic Emission and Waste	Kettunen et al. [112] Werthmann [122] Peukert et al. [113]
Technologies	Opportunities in Clean Tech, Human	Meng et al. [115] WEF [116] Saniuk et al. [114]
Data	Privacy and Data Security	Peukert et al. [113] WEF [117] Chu et al. [118] Zhao et al. [119] Stock et al. [120] Parry et al. [121]

Table 7. The result of the first-order confirmatory factor analysis on ESG.

Latent	**Sustainability**			r^2
Observe	**β**	b_i	**S.E.**	
Value	0.917	1.000	-	0.842
Sustainable	0.887	0.967	0.108	0.787
Social	0.786	0.857	0.124	0.618
Environment	0.831	0.906	0.117	0.691
Development	0.809	0.882	0.120	0.654
Management	0.733	0.799	0.131	0.538

Relative X^2 = 1.168, *p*-value = 0.314, TLI = 0.987, CFI = 0.993, and SRMR = 0.030.

Table 8. The selected factors of ESG.

Factors	**Main Related**	**Reference**
Sustainability	Carbon Emission, Govenance	WEF [123–125]
Environmental	Carbon Emission, Toxic Emission and Waste, Water Stress, Opportunities in Clean Tech, Opportunities in Renewable Energy	WEF [123–125]
Social	Health and Saftyn Labor Management, Human Capital Development	WEF [125] Dobrowolska et al. [126] Herceg et al. [101] Meng at al. [115] WEF [127]
Management	Labor Management, Govenance	Müller et al. [130] Kiel et al. [77] Sung [100] Butt [16]
Development	Governance	WEF [123–125] WEF [127]
Value	Governance	Feroz et al. [33] WEF [103]

5. Conclusions

The study contributes to existing theory by developing a conceptual model that illustrates the relationship between digital transformations and the sustainable development of the energy sector. The dataset was gathered from academic and consortium journals and analyzed using machine learning. The confirmatory factor analysis (CFA) was used to develop a valid model, which was then assessed using path analysis using latent variables. Finally, the experimental conclusion comprises a conceptual model of impact factors and their connections, as well as a description that incorporates Industry 4.0 and sustainable development in business, industry, and ESG teams in relation to the energy sector's key issues. Corporate governance and technology are critical components of a business's adaptation to Industry 4.0. Digital technology and environmentally friendly products are key enablers of "Industry 4.0" in the energy sector. This impact factor benefits the organization that would be considering a digital transformation based on a foundation for sustainable development.

It should be seen as an area for improvement in order to accomplish sustainability in the energy sector, which requires industry participation. A further aspect in which ESG contributes to the value of Industry 4.0 is through sustainable development. The research gathered information on the basis of an academic article and was limited to the energy sector. The findings of this study will serve as the foundation for future research that will be conducted in a cross-cultural context in order to determine the business functions in the next technological paradigm, Industry 5.0, which will lead to economic growth and prosperity while protecting society and the environment through the adoption of new technologies.

Future research could focus on the assessment and impact of Industry 4.0 in other relevant sustainable sectors, such as agriculture, materials, production, and logistics, in an approach to invest in green producing energy and protect people and the environment through advancements in technology. Future research may include the collection of structured data from operational firms, such as the public dataset of the ESG annual report, as well as metadata and real-time ESG variables, a case study, and a questionnaire of operational businesses. As part of the framework's evaluation, consider using statistical methodologies such as construct validity and exploratory factor analysis in order to discover the extent to which a questionnaire assesses what it is designed to measure.

Supplementary Materials: S1 Dataset. The correlation coefficient matrix. https://github.com/theerasakn/PONE-D-22-03652/blob/e27449a8917e3bb3204ac84804004f385aac5373/ccmatrix-frequency.csv. S2 Dataset. The Measures of Sampling Adequacy (MSA). https://github.com/theerasakn/PONE-D-22-03652/blob/e27449a8917e3bb3204ac84804004f385aac5373/MSA.xlsx.

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