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AI-Based Solution for Sustainability Tracing for Companies

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ABSTRACT

Many companies look for novel ways to trace their operational sustainability. The application of AI to analyze and make sense of the big data the company holds represents one promising approach for this aim. The authors study how one can set and design an AI-based solution for improving the sustainability of complex business processes and decision-making in companies of different types. First, they provide a general analysis of current frameworks for measuring adherence to sustainability goals for companies, then they present a conceptual framework and architecture design for an AI-enabled sustainability service for companies. The implications of our research suggest that AI can provide distinct functions: (a) automation: taking big data from different departments and analyzing them with the aim of tracing the sustainability of the company; (b) support: to help decision-making and create relevant insights for stakeholders that are coherent with defined sustainability decision criteria. To the authors' knowledge, no previous research has provided analysis and design of such AI solution for companies.

KEYWORDS

Artificial Intelligence, ESG (Environment, Social, and Governance), Information System, Information System Design, Knowledge Management

INTRODUCTION

Sustainability as a concept has gained momentum in recent years. Firms increasingly commit to sustainability in their business processes and operations. Media attention puts even more pressure on businesses to pursue sustainability, raising questions on how to establish and measure progress towards sustainability goals.

Companies have been adopting environment, social, and governance (ESG) rules to measure adherence to sustainability in their existing business operations and keep up with these changes. ESG means adopting and incorporating environmental, social, and governance principles into company decisions (Van Duuren et al., 2016; Ertz, 2020; Hahn & Lülfs, 2014). Why is ESG so important?

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According to recent research (Unruh et al., 2016), ESG-focused companies are more highly valued, and ESG aspects contribute heavily to financial sustainability and performance. Companies focusing on ESG issues have a better reputation and brand image, and they also have improved risk management and control of long-term risks (Xie, 2019; Pedersen, 2020).

The United Nations (UN) and an international group of institutional investors introduced the ESG process. Responding to the increased relevance of environmental, social, and corporate governance issues in business practices, they proposed creating, by 2030, a world free of poverty, hunger, and disease. These efforts align with European Union (EU) directives that work to establish standards and benchmarks to improve company transparency in ESG reporting (Arvidsson & Dumay, 2021). Businesses understand the importance of tackling ESG goals, yet ESG remains a relatively new area, so companies need time to discern how to integrate ESG into their functioning.

On a strategic level, it is difficult for a company to tackle every aspect in all categories of ESG at a time. Thus, decision-makers must prioritize areas to focus on at any given time and determine what threshold points they should start with. Therefore, they must select the most essential aspects and ESG rules.

Several barriers to ESG have been identified. The most important is limited knowledge and expertise on ESG issues since the concept is relatively new (Hedstrom, 2018; Porter et al., 2020). Moreover, businesses sometimes fail to consider ESG aspects that may significantly impact them, and they may see a limited short-term return as a disadvantage. The EU is now moving to improve transparency obligations. Publicly quoted companies must disclose specific information about their approach to integrating sustainability risks and considering adverse impacts on sustainability (van Oostrum, 2021). Yet, these companies barely do this, and even when they do, they do not provide evidence that the presented results apply to their operation.

The role of journalism and reporting on ESG should not be underestimated. Findings from a recent cross-country study show that journalists play an essential role as informants and educators when writing about sustainable finance (Strauß, 2021). The research finds that the reporting is event-driven, putting even greater pressure on companies since such events put their brand at stake.

Greenwashing is another crucial aspect in this context. The ESG data provided by companies are often unaudited, and sustainability report data may not be reliable. Several studies have examined various greenwashing behaviors within the ESG dimensions and the circumstances under which companies engage in greenwashing (Del Bosco & Misani, 2016; King Andrew & Lenox Michael, 2001; Yu et al., 2020). These studies agree that companies exposed to greater scrutiny—that is, adequate supervision of their working operations—are less likely to engage in ESG greenwashing.

At the same time, businesses have begun to devote effort to exploiting big data as a novel opportunity to gather insights into the state of their enterprise from data in their possession (Manyika et al., 2011). Although artificial intelligence (AI) has gained popularity, the use of machine learning (ML) and AI in ESG is not well researched. Many organizations want to use AI to improve their decision-making, but few have managed to do so effectively (Macpherson et al., 2021). The problem of how to do this properly for various industries in different domains is a challenging one. The question of how to analyze unstructured data, compare ESG-relevant information for each company categorized by ESG-special classifications (with the help of ML and AI), and thus generate insight for ESG goals adherence has, to our knowledge, yet to be researched.

One of the challenges is how to tune "sensitivity" to different E, S, or G metrics for the particular domain and effectively translate this into ML and AI decisions (Macpherson et al., 2021). Machine learning can better spot and identify the E, S, and G indicators, or at least detect them from priory data. However, the next concern is classifying the conformance indicators for relevant industries (Crona, 2021). Another issue involves company culture and whether it focuses on ESG compliance. This may represent a hurdle where intention for ESG compliance is lacking (Tang, 2020).

On the analytical side, advances in AI have revolutionized the way businesses operate and work with data. AI, ML, and automation have become ubiquitous and essential to organizational

operations. Over the past few years, AI capabilities have proven helpful in providing companies with the means and tools for analysis. Previously, enterprises often relied on manual search and selection tasks that used information from self-disclosure and annual business operations subject to inherent data challenges and biases.

Given the evidence discussed above, we will address the following research questions in this paper:

RQ1. What are the current approaches for measuring adherence to ESG criteria for companies in different domains, and how can AI help in this respect?
RQ2. How can companies design AI-based services and solution architectures to assist business processes and decision-making for sustainability?

Previous research has highlighted the need to develop analytics-driven approaches, understand mechanisms to collect and use data for tracking companies' behavior, and design decision-support systems for this aim (Ketter et al., 2020). In this paper, we build on this need, presenting a spectrum of activities companies should implement, from collecting relevant data about their ESG metrics to designing information system architecture and services that can provide such insights for ESG data decision-making. We use a purpose multisector approach in the analysis to develop a design for a generic decision support system that can respond to the needs of various industries. This will help the companies automate the process of collecting data from different departments, analyze these data to trace the company's sustainability, and obtain relevant insights for their sustainability decision criteria. To our knowledge, no previous research has tackled this problem.

The paper is organized as follows. In Section 2, we review what ESG data are and analyze the use of AI on big data for tracing sustainability. We focus on the company's total supply chain, as it is vital to understand not only the operations within the company but all the operations needed to produce the final product or service. Afterward, in Section 3, we discuss a selected set of data points collected from different industries and suggest how companies can use them, with AI, to better understand the adherence to sustainability goals of the companies in the fields analyzed. Our paper focuses on a process and information system design that helps us understand the levels of company sustainability in different sectors, such as the tech, health, energy, and food industries, presented in this article. The idea consists of integrating (through AI) many data points specifically developed for each company and then attributing a single score—based on available data collected from the operations—to serve as input for analyzing the companies' level of ESG activities. Lastly, we provide a suitable architecture design that companies can use to implement such IT services. We conclude the paper by discussing the strengths and weaknesses of our proposed approach and our next steps.

ESG

ESG Goals: What Are They?

The ESG method entails researching environmental, social, and governance factors in addition to the usual financials of a company (Amel-Zadeh & Serafeim, 2018). ESG criteria can be analyzed together or individually.

Environmental factors consider the company's positive and negative impact on the earth, such as their climate change policies, plans, disclosures of motivation, greenhouse gas emissions goals, or usage of renewable energy. These factors include the company's actions towards climate change through greenhouse gas emissions, along with waste management, treatment of animals, and energy efficiency. Sustainability reports such as the Global Reporting Initiative (GRI) (Amel-Zadeh & Serafeim, 2018) reveal the company's engagement towards these aims.

The social factors consist of people-related elements, including company culture and factors that impact employees, customers, consumers, and suppliers (Gillan et al., 2010; Pelosi & Adamson, 2016).

The topics to analyze include, for example, employee pay, employee engagement and staff turnover, employee training and development, diversity and inclusion in hiring, and granting advancement opportunities and raises. For such information regarding companies, decision-makers can find media reports on how companies treat their employees and their efforts for or against social justice issues or reviews the employees leave on websites such as Glassdoor.com.

The governance factors consist of concerns regarding how the company is governed, how the company relates to different stakeholders, and whether the corporate incentives align with the business's success (Gillan et al., 2010; Khan, 2019). Issues to analyze include executive compensation, bonuses, diversity of the corporate boards and management team, and transparency in communicating with shareholders. Such information can be found in the company's generic reports to shareholders.

ESG and Their Importance for Companies

Previous literature has also provided heterogeneous views about stakeholder roles, that is, the primacy of shareholder value and how it acts as the main barrier to sustainability (Sjåfjell et al., 2015; Stout, 2013). Existing research studies the potential for companies to reorientate themselves to sustainability and how to better achieve this through reforming the existing company legal sustainability infrastructure (Sjåfjell et al., 2015). Many times, ESG rule satisfaction depends on the industry. For example, a company specializing in weapons production that scores highly on environmental sustainability, employee treatment, corporate governance, and diversity may also score highly on ESG, even though there may be questions about their social performance.

Undeniably, ESG is good for business, too. Obvious revenues can be earned through specific product developments. Investors will withdraw from financially risky firms, and these market dynamics can be sensed if companies are not using ESG metrics.

By their nature, ESG criteria allow us to consider the environmental and societal benefits companies provide through ESG-compliant activities since the impact of activities creates advantages in economic performance. ESG investors do not have to make performance compromises because, beyond their ability to help society, they have a role in reducing risk. ESG integration can, in fact, expand the scope of material information relevant to the company's strengths and weaknesses, and therefore should potentially result in better company operations and decisions (Chen & Mussalli, 2020). Specifically, it has been found that ESG practices enhance operational performance in firms and that stock price performance is positively affected by good sustainability practices adopted by the company (Clark et al., 2015). Therefore, "based on the economic impact, it is in the best interest of company managers to incorporate sustainability considerations into their decision-making processes" (Clark et al., 2015, p. 9).

Supply Chain, Technology, and ESG

While a growing number of companies have set ambitious supply chain goals over the last decade—from achieving zero deforestation to ending child labor—progress toward these goals has been inconsistent. AI, blockchain, the use of satellite images, and supply chain data digitization will continue to grow in sophistication, advancing end-to-end supply chain transparency. These technologies will be essential for companies to keep pace with increasingly stringent regulations and expectations from consumers and large customers for increased transparency and disclosure.

Instead of focusing on the importance of the supply chain in tracking the various operations, it is essential to respect the ESG commitments of all third-party providers. The solution offered by companies to respect their ESG commitments through the supply chain is to adopt supply chain standards, such as the Code of Business Conduct and Ethics (Quintana-García et al., 2021). These companies require all third-party providers to respect not only basic ESG requirements but also to make further implementations to achieve future objectives set by the company. The need to trace ESG compliance across the whole value chain is critical. For companies to score higher on rankings aggregating a myriad of ESG metrics, they often must address non-ESG behavior in their supply

chains or measure ESG compliance in other countries, where the scope and measures can diverge from those in the company's country of origin (Porter, 2019).

AI allows investors to collect and analyze more information than ever when accounting for ESG risks and opportunities. Different sources of data hold the potential for using AI in tracing ESG scores, such as sentiment analysis algorithms, satellite data monitoring physical and financial risks, or even fine-grained textual data analysis (e.g., topic modeling, language use, data comparison; Macpherson et al. 2021; O'Donoghue et al., 2016; Schmidt, 2019; Van de Kauter et al., 2015). General ethical and legal concerns about the use of data by AI technologies are relevant for any company that supervises and maintains vast amounts of highly personal data.

METHODOLOGY

Research Design

The method for analyzing frameworks in the four industries of interest (health, oil and energy, IT, and food) and answering RQ1 is based on the established procedure for conducting systematic literature reviews (Popay et al., 2006). We began by formulating search keywords for the four industries of interest, after which we formulated and refined our exclusion criteria and read all relevant articles thoroughly.

We analyzed the existing literature on the i) health care, ii) oil and energy, iii) IT, and iv) food sectors.

We decided to use the SCOPUS database as it covers important publication venues, including sources that do not necessarily come from the academic communities around the domains, for all four sectors. SCOPUS is a widely used search engine for conducting bibliometric analysis of scholarly literature, and it has comprehensive coverage of peer-reviewed literature.

Data Collection

Both authors reviewed the papers, excluding those that were false positives or less relevant to the aim of the research. We used the advanced search and looked for the specific keywords only in the title of the publications. In alignment with the research objectives, keywords related to ESG and the respective domains were used in the search. We used as general search keywords "ESG" and "AI," while we used the subdomain-specific search terms (i) "health care," ii) "oil" or "energy," iii) "IT systems," and iv) "food" for each subdomain sequentially.

We restricted the search to articles in the English language. The search was completed in January 2023, and we did not set a starting year. The last step included a thorough check of complete manuscripts by both authors to ensure the inclusion of only those papers that met the inclusion criteria. A total of 195 papers remained for examination. We cross-examined the search results for inclusion and reached a consensus on the final list. We did this individually for each of the four subdomains and then finalized the list of articles to be included in this paper. This led to a final review size of 105 papers.

For the RQ2 and conceptual framework part of the paper for AI-empowered sustainable finance service and solution architectures, we relied on data and practices from existing studies regarding the design of such services and know-how from the design of similar services in adjacent industries.

For this part of the research, we analyze AI analytics opportunities and the steps that should be taken to build such an AI system to develop an AI framework composed of research rules and criteria on how to handle and score different ESG data for companies from diverse sources. Then, we take a systems perspective and describe how such ESG data should be gathered on a company level and how to create a functional infrastructure. For this part, we take an information systems theory approach (Dwivedi et al., 2011) and define the components and characteristics of such a system.

RESULTS

In this section, we answer RQ1 and RQ2 using empirical analysis.

Adherence to ESG for Different Industries and the Role of AI

In this subsection, we answer RQ1: What are the current approaches for measuring adherence to ESG criteria for companies in different domains, and how can AI help in this respect?

Analysis of ESG for Different Industries

We focus on the health, information technology, food, and energy sectors. Because each sustainability issue tends to have a different impact or consequence depending on the context in which it arises, sustainable corporate activities vary from one industry to another, meaning each sector has its unique sustainability profile (Clark et al., 2015). For this reason, we summarized the knowledge about companies in the four industries mentioned above and built frameworks for each, including some sector-specific sustainability topics that can have a material impact on the business performance of companies in the particular industry.

The following presents a brief overview of the selected sectors and the relative ESG frameworks we built. We recommend updating the presented ESG frameworks and the data for each company every year or more frequently, if necessary, to take into account the most significant changes in the sustainability strategies pursued by the companies.

Healthcare Sector. Since the pandemic broke out, the health industry has seen a significant increase in the burden of social responsibility. These extra tasks originated from the assistance it had to provide governments to fight the global pandemic. However, once things subside, the health sector might observe a long-term boost in demand because COVID-19 has left the masses well aware of the significance of focusing on health and wellness issues.

In Figure 1, we show summarized ESG characteristics for the healthcare sector to consider, based on reports from S&P Global and associated literature (Ferreira & Loures, 2020; Gregoriou & Hudson, 2020; Gyönyörová et al., 2021), the SASB Materiality Map (Madison & Schiehll, 2021; Wu et al., 2018), and Edwards Lifesciences Corporation (2024). Social factors are a prevalent constituent in our analysis of healthcare companies because they often play a crucial role in the communities they serve and derive a portion of their revenue from the government. A healthcare company's supply chain portrays product operations and distribution processes; for this reason, payment tracking can improve the traceability of products and, for example, help prevent counterfeiting. Having excellent control over the chain of custody of medical goods—identifying only those medicines whose origins

Figure 1. ESG Framework for the Healthcare Sector (Note. Based on reports from S&P Global and related literature (Ferreira & Loures, 2020; Gregoriou & Hudson, 2020; Gyönyörová et al., 2021), the SASB Materiality Map (Madison & Schiehll, 2021; Wu et al., 2018), and Edwards Lifesciences Corporation, 2024)

ENVIRONMENTAL	SOCIAL	GOVERNANCE
Energy usage	Employee relations	Accountability
Total energy consumed	Voluntary and involuntary turnover rate	Monetary losses as a result of legal proceedings
Percentage renewable	Presence of compensation and benefits to employees	
Waste and recycling	Responsible marketing and R&D	Corporate governance
Amount of medical and pharmaceutical waste	Adequate information to patients about risks	Practises and policies by which a company is directed
Percentage incinerated	Strategies to reduce the environmental impact	
	Processes to manage health considerations	
Supply chain management	Customer relations/products	
Participation to audits for integrity of supply chain	Policies to secure customer information	
Traceability within distribution chain	Traceability of products/services	
	Process to alert customers for defective/counterfeit products	

and ownership are known to be authentic and safe—increases the social performance of a healthcare company since counterfeit products put patients' lives at risk.

The details of reporting requirements in different countries represent the biggest obstacle in performing the analysis, which is the aim of this paper. There is a strong need for standardization in how healthcare companies report in terms of ESG; our study finds that the problem regarding healthcare companies is not that they fail to disclose information but that they disclose information in different formats and to various extents (El Khoury et al., 2023).

Oil and Energy Sector. From the moment environmental awareness started to increase, the oil and energy sector has been the center of attention regarding the sustainability and societal impact that they exert. Sustainable development initiatives have been thoroughly explored since the mid-1980s. This broad concept binds economic investment to sustainability, which means that in every economic reality, policymakers have a crucial role to play in addressing the global crises we continue to face. The oil and energy sector comprises major players that can positively or negatively affect the world's environment as an ecosystem. The environmental factors stood out in our research due to the major focus on the best-in-class companies in this sector to address environmental concerns due to the potential impact of their activities. In addition to environmental awareness, a noticeable focus is on disclosing documents and information that otherwise could amount to corruption and bribery schemes, even with governments and lobbying, to elevate the transparency within the companies' corporate governance. Figure 2 shows which ESG characteristics we see as most financially relevant in the energy industry and the metrics to account for them based on ExxonMobil (2018), BP (2019), and the associated literature (Hasz, 2021; Krzus & Tomlinson, 2019).

The oil and energy sector places great importance on promoting transparency to prevent corruption and provide citizens with a basis for demanding the fair use of revenue streams (Sovacool et al., 2016). Besides being a sector that operates mainly in parts of the world with widespread bribery and corruption, to which major companies have considerable exposure, its operations take on the risk of creating poor working conditions and breaches of human rights. Therefore, within a complex supply chain, through assessing a wide range of risks and opportunities to mitigate and responsibilities to manage, they can set standards with suppliers and contractors and encourage improved ethical performance. This can drive the sector to meet a better sustainability performance within the ESG index. This information can be obtained from the companies' websites, independent audits, or assessments, which can be internal or provided by initiatives in which the leading oil and energy sector players are active participants (e.g., the Extractive Industries Transparency Initiative [EITI]).

Figure 2. ESG Framework for the Oil and Energy Sector (Note. Based on BP (2019), ExxonMobil (2018), Hasz (2021), and Krzus & Tomlinson (2019))

ENVIRONMENTAL	SOCIAL	GOVERNANCE
Carbon emissions	Working conditions	Board structure
Percentage of low carbon activities	Workplace with equal opportunities	Board diversity
Percentage of carbon removal technologies used	Assistance and fitness programs	
Energy use	Human capital	Transparency and risk control
Percentage of renewable energy	Presence of guides and purpose in work	Revenue transparency
Percentage of wind and solar energy	Human capital development initiatives	
Percentage of new sources of energy	Reporting or escalation procedures	
Biodiversity	Community relations	Anti-bribery and lobbying initiatives
Percentage of spill prevention	Percentage of local hiring and development	Anti-bribery and corruption trainings
Biodiversity surveys	Percentage of sustainable development projects	Lobbying expenses
Management and restauration of habitats		

Despite being one of the most researched domains, the oil and energy sector seems to be missing guidelines for companies to implement a good ESG strategy; thus, this is the most challenging task oil and energy companies face (Gungor & Seker, 2022; Wanday et al., 2022).

IT Sector. The biggest concerns for IT companies relate to privacy and security, namely how companies use sensitive information, if and how they monetize them, and the risk of misuse of personal information. Energy concerns are also relevant for IT companies, as data centers consume significant energy and thus present an environmental threat. Yet, these concerns have been softened due to companies' efforts to improve energy efficiency. Previous violations have occurred in the hardware and semiconductor sub-sectors regarding their labor management, as some companies offer poor working conditions and low occupational safety standards. In addition, these sub-sectors use metals and rare earth elements to produce electronic components and generate waste that contains metals and toxic chemicals, which pose threats from an environmental point of view.

Figure 3 shows the relevant ESG characteristics in the IT industry and the metrics to consider based on findings from S&P Global and the related literature (Ferreira & Loures, 2020; Gregoriou & Hudson, 2020; Gyönyörová et al., 2021) as well as ESG and sustainability reports from some of the major companies in this industry: Google (2023), Apple (2023), and Amazon (2020).

Finally, tracking the tech company supply chain can help us understand the accurate evaluation of the ESG index. Complex software products comprise hundreds of components, usually compiled from many companies' products and integrated as a unique service by the leading integrator technology company. Analyzing the entire operations flow, we can better understand who the company cooperates with and analyze the ESG performance of the partner companies that are essential in delivering the final product.

IT companies appear to have low E and S scores, mainly due to the actions of sub-contractors and suppliers. We did not find such evidence; however, we consider this to be due to the different company levels we observed in the literature (Egorova et al., 2022; Nau & Breuer, 2014; Teor et al., 2022).

Food Sector. Sustainability is critical in the food industry because food production impacts the environment and human life. Regarding the environment, while food companies usually do not have high carbon emissions, supply chains often do (Batini & Pointereau, 2020). Quite frequently in this industry, it may be unclear whether the companies in the supply chains are food companies. In addition, intensive cultivation damages biodiversity, causes deforestation, and affects future land use. Finally, the use of water for crops must not be forgotten. Concerning human life, human health (specifically malnutrition and obesity) strongly depends on food availability, quality, and characteristics (Barrett et al., 2020). Companies in the food industry are generally not required to

Figure 3. ESG Framework for the IT Sector (Note. Based on S&P Global and related literature (Ferreira & Loures, 2020; Gregoriou & Hudson, 2020; Gyönyörová et al., 2021), as well as ESG and sustainability reports from the major companies in this industry (Apple, 2023; Amazon, 2020; Google, 2023))

ENVIRONMENTAL	SOCIAL	GOVERNANCE
Energy usage	Benefit to society initiatives	Shareholder rights
Smart power consumption	Initiatives to promote access to the Internet	Number of annual shareholders meetings
Personage of renewable energy	Percentage of sustainable development projects	Information scheme for companies shareholders
Raw material sourcing	Products and services	Accountability
Raw materials usage report	Process to alert customers for defective/counterfeit products	Monetary losses
Waste and recycling	Diversity, equality	
Products recycling processes	Diversity and equality in all aspects of work	
Recycled materials present in the products	Diversity report	

disclose specific information regarding ESG aspects, so investors have difficulty distinguishing companies based on their environmental impact (Barrett et al., 2020).

For these reasons, companies face growing pressure to disclose more information because consumers want to be informed about the origin of the food they consume and its environmental impact (Batini & Pointereau, 2020).

Figure 4 shows which ESG characteristics are most financially relevant in the food industry and the metrics to account for them, based on data from Nestlé (2020) and Coca-Cola (2022).

Finally, we must also consider supply chains in the food industry as they make it possible to know the origin of the food and how it is cultivated (e.g., in terms of the number of natural resources used and what workforce has been employed). This information can be retrieved from the sustainability report, company websites, and product labels.

According to our analysis, one of the most critical aspects for the food industry is waste reduction and opportunities to reuse waste wisely. Some of the possibilities discussed in the literature include reusing the waste in the production processes of the product or turning the waste into a renewable resource that can be used by other partners in the supply chain or companies unrelated to the industry (Grinberga-Zalite & Zvirbule, 2022).

Conceptual Framework for AI-Enabled Sustainability Service for Companies

In this section, we reflect on how AI can help with ESG data detection and analysis so companies can put the frameworks described above into practice.

Based on our frameworks and ESG criteria, we can establish research rules, begin the research process, and determine whether information exists about an industry or individual company. If information exists, we check whether we can decide if it is positive or negative information about sustainability challenges. A lack of information about a company's sustainability practices, a negative piece of information or ESG parameter about an industry or a company, or a more precise analysis of the sustainability metrics that are most relevant for each industry can help investors screen sectors and companies and decide where to put their money.

AI is used to collect and process data; different information is combined and analyzed to calculate the company's completive ESG index.

The envisioned automation is performed through a three-step process:

1. Data point extraction thought principles. The first step is to define the principles of ESG criteria. Some starting points could be hard and soft laws from international organizations (e.g., Universal Declaration of Human Rights, UN Sustainable Development Goals), international standards (SASB), and ideas from same-sector companies and think tanks.

Figure 4. ESG Framework for the Food Sector (Note. Based on data from Nestlé (2022) and Coca-Cola (2022))

ENVIRONMENTAL	SOCIAL	GOVERNANCE
Energy usage	Benefit to society initiatives	Shareholder rights
Energy use efficiency	Percentage of factories situated in developing	Ensure that all investors are updated on developments
Personage of renewable energy	Amount of jobs created	Answer to all shareholders' questions/doubts
Global energy consumption per tonne of product		
CO2 emissions	Products and services	Board structure
CO2 emissions per tonne of product	Provide easy-to-find nutrition information on packages	Board diversity
Water management	Diversity, equality	
Total water consumption per tonne of product	Diversity and equality in all aspects of work	
Water use efficiency	Diversity report	
Raw materials	Responsible marketing and R&D	
Incentives to grow ingredients in sustainable ways	Advertise in a responsible way	
Percentage of ingredients sourced sustainably	Innovation for food safety, quality, and enhanced well-being	
	Not target advertising to children under age 12	

2. Classifying the importance of the various ESG criteria for specific industry sectors. The second step is to analyze the various ESG criteria to determine which are most relevant for the sector's stakeholders. This step is conducted through surveys and interviews with stakeholders (e.g., executive managers, investment experts, NGOs, employees, and consumers).
3. Search for specific data points of companies engaged in ESG key points, goals, and objectives. The third step is to search for companies' particular data points related to the ESG key points. This is done by analyzing the companies' non-financial statements or global reports.

Figure 5 presents a summary of our research agenda.

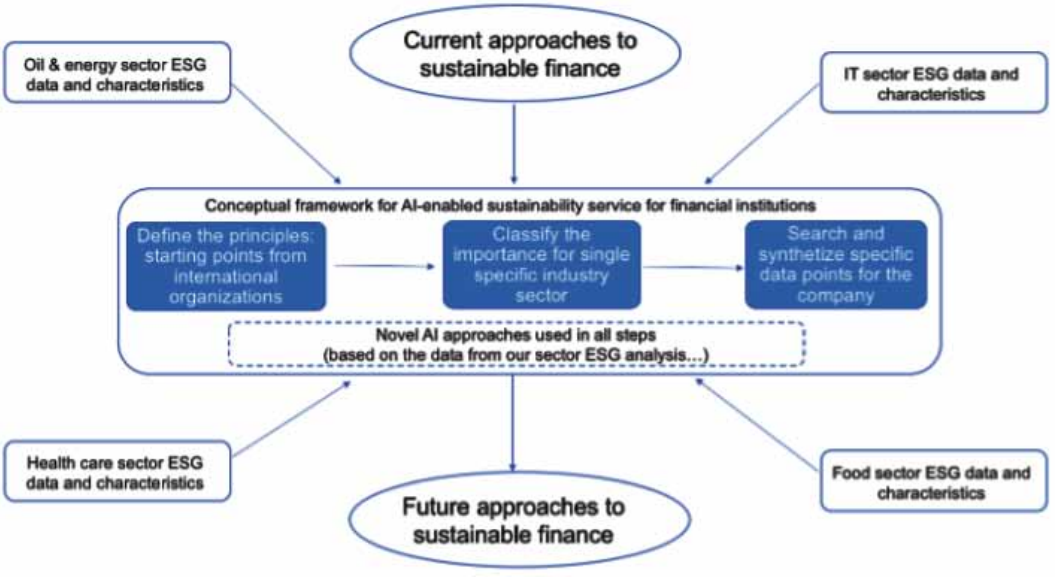
So far, in this analysis, we have used AI to collect and analyze data for the companies. However, in the future, AI will also be able to use collected data to change and update the underlying frameworks for different industries. This can, however, result in unintended system behaviors; hence, special care should be taken to design and implement preventive mechanisms to deal with the different sociotechnical implications of such self-feeding systems. Organizations and institutions are paying more and more attention to these issues in technology development, with various stakeholders demanding responsibility, fairness, transparency, and bias-free decisions from algorithmic systems. In our view, this will be the next challenge in AI systems. We believe that in this direction, interdisciplinary research will be critical.

Architecture Solution for Tracing ESG Criteria for Companies

In this subsection, we answer RQ2: How can companies design AI-based services and solution architectures to assist business processes and decision-making for sustainability? We reflect on how companies can design information system architectures to help business processes and decision-making regarding sustainability.

The collection and analysis of big data through different sources for companies, as explained above, has become the standard mode of working. The efficient and effective utilization of big data companies in their possessions has become an important issue. The process of data collection and

Figure 5. A Conceptual Framework for AI-Enabled Sustainability Service for Companies, Based on Our Analysis of Healthcare, Oil, Energy, IT, and Food Sectors



transformation requires the use of well-established processes and should be treated systematically. The most famous such process is the Cross-Industry Standard Process for Data Mining (CRISP-DM). It uses different data sources, such as data from company operations, external data, and data originating from sources like IoT-s, web channels, company CRM, and electronic images. These data types are heterogeneous; we either consider their structure or content. Meta-data describes all the data coming from different sources, and it can be used to construct a so-called data catalog to have a better overview of various data and possibilities for the use of advanced data analytics.

Data warehouses are commonly used to store and integrate data from various sources and support companies' storage and decision-making (Golfarelli & Rizzi, 2009; Kimball, 2010). All information stored in the data warehouse is non-volatile; the aim is to give companies fast answers to questions. First, unstructured data is processed by cleansing it and putting data from different sources in the same format; this creates a single source of truth, that is, reliable and trusted data for prediction and prescription. The abovementioned different types of data can be gathered into an appropriate data architecture that would provide step-by-step instructions for transforming and using such data (see Figure 6).

The left-hand side of the diagram in Figure 6 contains the potential data sources that can be used to detect and apply ESG rules for the company.

A data lake is another type of storage that should be considered in this scenario. Compared to a data warehouse that stores structured/tabular data, the data lake contains unstructured data that must be processed (structured) before usage. In our architecture design (Figure 6), we count on having a data warehouse and a data lake. The latter provides a smaller version of the data for making day-to-day operation decisions, separate from data collection devoted to long-term reporting and retrieving.

Most commonly, data are collected from different systems of the company, such as enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM; Figure 7). The data warehouse and data lake serve as places to store data in structured or unstructured formats, respectively, to support decision-making on a long-term or daily basis (Molnár et al., 2020; Pisoni et al., 2021). Different business intelligence tools can be used on both datasets

Figure 6. Data Sources and Their Utilization for Analysis and Prediction of ESG-Rules Adherence for Companies

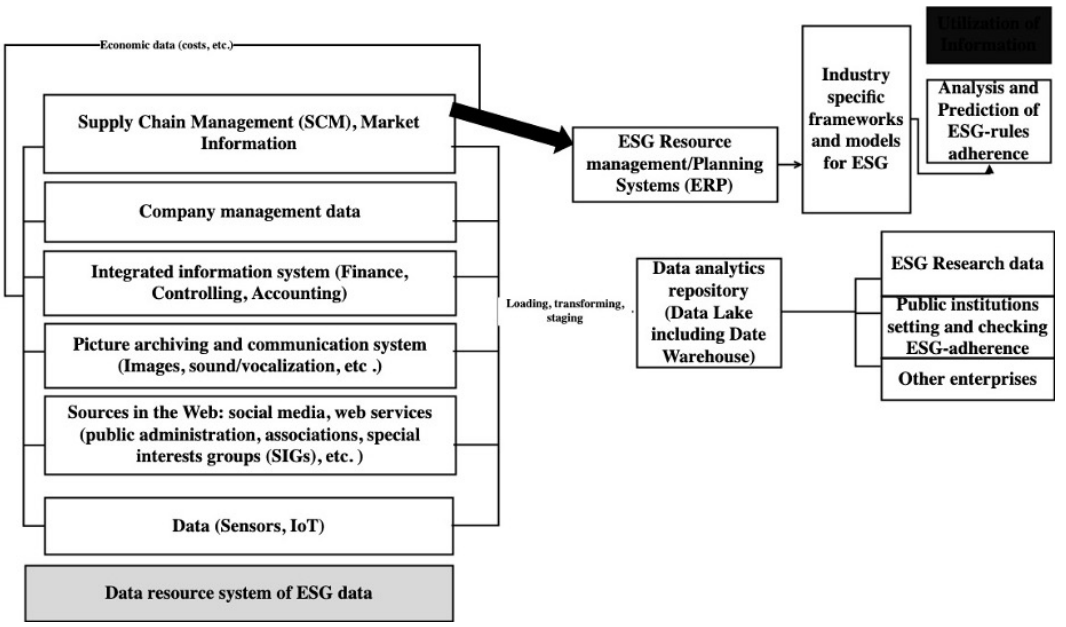
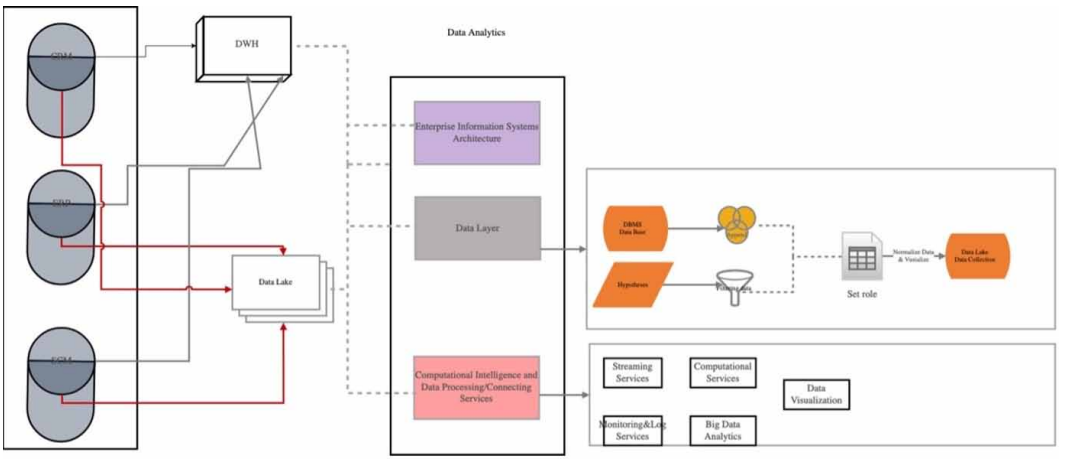


Figure 7. Enterprise Resource Planning (ERP), Customer Relationships Management (CRM), Supply Chain Management (SCM) Systems, Data Warehouse (DWH), and Data Lake Architecture for Data Analytics on ESG Data



to provide insights. Companies define the key performance indicators (KPIs) they want to monitor and track regarding ESG components. An application of dashboards can also give a cleaner and easier-to-understand visualization of the state of the different ESG components of the enterprise. The dashboard will lay the foundation for effective decision-making.

In the data lake, the data should be handled in a secure environment, considering the data protection and GDPR requirements. Adequate libraries and workbenches are needed for data analytics tools and machine learning. A catalog of different ML and AI tools should be stored so the data lake and data warehouse can use them (Figure 7). Strict access rights to data should be implemented through sophisticated sign-on and multi-factor authorization and authentication methods.

DISCUSSION

General Discussion and Limitations

Current approaches to tracing companies' sustainability using AI are limited in scope and application (Ebinger & Omondi, 2020; Hofmann & Langner, 2020; Lee et al., 2021). Big data promises to help financial companies develop more suitable approaches to automate measuring sustainability adherence through financial data for stakeholders and support decision-making by providing insights, alerts, and notifications based on well-defined criteria for company decision-makers. Therefore, the potential and applicability of such financial services are significant.

It is essential to underline the limitations of our work in several aspects. First, the developments in this area are relatively fast, so our paper might soon need an extended version outlining steps for AI researchers to implement and set in place, such as ESG tracing practices. Second, we did not outline deployment models for our proposed architecture; therefore, further research is needed. Such research can focus on the ease of adapting existing systems to work on sustainability or potential value created by deploying such new services for companies and even further detail the new roles, activities, and business models that will be needed. Third, our work did not include all possible sectors (we focused only on the oil and energy, IT, health, and food sectors), so in future work, we may need to complement our work with an analysis of other sectors.

Our study offering a framework for AI-empowered sustainability finance services is a first and significant step in such a direction. The paper contributes a disciplined, literature-grounded architecture approach for ESG criteria tracing for companies and the first framework for implementing the service.

Therefore, we first investigate how investment service providers should set up an infrastructure that would enable companies to become aware of their ESG criteria and provide services that would help them improve their scores. This can be extremely useful for enterprises: By taking advantage of this infrastructure, they can determine their ESG criteria score and focus on improving those data points where they are not doing their best.

Managerial and Practical Implications

This article explores how AI can trace companies' adherence to sustainability goals through their financial data and how companies can set up relevant data warehouses and data lakes to provide decision-makers with ESG-relevant KPIs. The knowledge presented in this article will help companies create decision-support systems for tracing ESG values on characteristics of interest and trace and predict future ESG values in areas important to them. Companies' existing information architectures are complex and require further attention to developing new data science-based services; therefore, this article aims to pave the way for implementing such sustainability tracing services. Practitioners can use these findings to analyze changing finance data informatics practices for financial companies and understand how they can implement new reasoning and services on their data, in this case, to trace sustainability. A company's AI research team would need to assess their current data processes within their systems and map how the framework described in our article can be implemented for their data.

As our work indicates, and as previous research has pointed out (Sun et al., 2020), examining companies' ESG practices through big data is critical for effective sustainability analysis. The most challenging point is the lack of transparency and standardization in ESG reporting and scoring. Moreover, there are limitations with the data provided by ESG third parties, especially concerning differences in strategies that could bring about differences in scores. Most data providers treat their methodologies as proprietary information without fully explaining how scores are evaluated. Therefore, by relying on an ESG data provider's score, we help companies become more transparent. The result is increased transparency towards companies regarding their evaluation for ESG scoring.

Future Work

We conducted a literature review on four industry domains and proposed an AI application framework that can be used in practice. In future work, we aim to ground this theoretical framework in empirical case studies and qualitative literature research in situ. Future improvement will include the study of the main indicators (ESG) and their sub-categories (e.g., board structure, work conditions, biodiversity) and whether some of these should be employed in all sectors. If one sector has more difficulty adapting to, for example, social/environmental aspects (e.g., food production, pollution, emitting CO2, methane, nitrates), this does not mean that one must be less critical when assessing it.

CONCLUSION

In this paper, we defined four different (industry-specific) ESG frameworks for measuring adherence to sustainability for companies in these industries, and we reviewed the corresponding open questions and necessary steps toward designing and implementing an AI-supported sustainability service. We outlined the steps the sustainable AI financial service should perform, how it should be designed, and how it can be used by practitioners, as well as the potential sociotechnical implications of developing a self-learning AI system. We performed a complete analysis and considered different regulatory standards regarding ESG metrics.

We answered the research questions we set at the beginning by defining industry-specific ESG criteria for companies in these domains; we outlined an AI framework comprising research rules and criteria on how to handle and score different ESG aspects for companies coming from these industries; and, lastly, we outlined how companies can design information systems solutions to assists business operations with the knowledge obtained.

Overall, while there is an increasing awareness of these questions in the community, more research is still needed to develop future techniques for AI-supported sustainability finance. Many financial companies are currently making a coordinated effort, and this is a subject of many research projects with EU funding, especially regarding the transparency of AI for financial services.

One main objective of the project is to study and tackle transparency issues of FinTech AI technologies and increase the transparency of financial intelligence applications.

COMPETING INTERESTS

The authors of this publication declare there are no competing interests.

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