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The global ESG trend and adaptation opportunities in the emerging hydrogen economy: A corporate governance perspective

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ABSTRACT

The development of the hydrogen economy (HE) has become the main direction of climate-focused economic progress. Although the gap between the potential impact of energy companies and their actual willingness or ability needs to be bridged by corporate governance and economic policy, these dynamics are underrepresented in the literature. As environmental, social, and corporate governance (ESG) considerations could foster adaptation and developing hydrogen technologies, the goal of this systematic literature review is to explore the specific environmental and energy aspects of ESG and the adaptation opportunities which could contribute to HE development. Findings suggest that ESG as a new institution in the economy might be in line with national and international policies, but corporate efforts at improving environmental performance could be further oriented directly or indirectly toward hydrogen technologies, for example, through cost reduction initiatives, favourable taxation, or specific requirements for sustainability reporting. On the corporate level, external and internal change drivers could lead to strategic and governance adaptation measures in line with HE development policy. The study contributes to the literature through the intersection analysis of the global ESG trend and the development policy of the HE, which has been overlooked to date, especially from a corporate governance perspective.

KEYWORDS

hydrogen economy, corporate governance, strategic adaptation, ESG

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1. INTRODUCTION

Ensuring economic, environmental, and social sustainability has become a priority for corporate governance (CG) in different industries, e.g., banking (Aras et al. 2018) or logistics (Karaman et al. 2020). Most recently, ESG, i.e., environmental, social, and corporate governance aspects, have become more important, including in the traditional (Behl et al. 2021) and the renewable (Liu 2020) energy sector, or regarding the expected environmental (Shive – Forster 2020), reporting (Lagasio – Cucari 2019) or innovation efforts (Filatotchev et al. 2020) of companies.

As a potential topic of ESG in the energy sector, the hydrogen economy (HE) has also attracted a lot of attention in the international literature, and some databases show that the number of articles on HE doubled from 2019 to 2020 (Csedő et al. 2021). The field of HE research is mainly dominated by techno-economic analyses, such as the development of new technologies, e.g. power-to-gas (Csedő 2020c) concerning wastewater treatment (Csedő 2020b, 2020c) and solar energy (Pintér 2020) or new energy systems (Nolting et al. 2019). Nevertheless, one should consider that the governance of energy companies and the regulatory environment also play a crucial role in the development and deployment of hydrogen technologies.

HE development as an innovation activity, however, might require organisational changes to increase competitiveness in smaller companies (Endrődi-Kovács – Stukovszky 2022) and larger ones as well (Stocker – Várkonyi 2022), overcome structural (Csedő 2006), resource-based (Csedő 2020a) or behavioural challenges (Sára et al. 2014), or foster collaborations (Baksa – Branyiczki 2023) and knowledge sharing (Baksa – Báder 2020). Specific characteristics of the energy sector (e.g., external institutional and internal organisational rigidities) (Nisar et al. 2016), and turbulent macroeconomic environments that increase the number of operational risks, however, can also overshadow ESG considerations, while crises and conflictual institutional environments can lead to perceptual blindness among decision-makers (Shi – Li 2020) and only symbolic actions instead of substantial change (Luo et al. 2017). Consequently, HE development may mean adaptation challenges; studying these perspectives, however, seems to be a research gap. The main questions of this study therefore are *(1) what changes are generated by ESG aspects regarding the environmental and energy context,* and *(2) what adaptation opportunities could be outlined to improve environmental performance in the emerging HE*?

The study approaches the issue of economic development policy from the perspective of CG while considering the objectives of relevant international and Hungarian hydrogen energy and climate strategies. The integrative nature of the study, which emphasizes analysing the intersections of ESG and HE, is relevant due to the adaptation pressure (or opportunity) generated by these trends which is apparent on different economic levels. Accordingly, national economic development and the transforming energy sector could benefit from hydrogen technologies (Demirbas 2017), while corporate governance must integrate ESG aspects, e.g., fighting climate change, into strategic decisions to meet the expectations of investors and the general public (Bose et al. 2018).

The contribution of this research is to provide an initial understanding for regulators and decision-makers of energy companies on (1) the background of ESG and its specific

environmental and energy aspects, and (2) possible adaptation opportunities which could accelerate HE development. The main findings suggest that ESG might be a new institution, i.e., a new "rule" in the game of economic activities which could and should be used by policies in favour of the HE development by regulatory interventions. Furthermore, not only external, but internal changes could also drive HE development, as ESG affects stakeholder management, organisational resource allocation, decision-making patterns of directors, and the structure and composition of the board toward increased environmental performance through hydrogen energy.

2. METHODOLOGY

The research is based on a systematic literature review (SLR), which can be defined as a research method that aims at answering a research question by collecting all relevant research that meets specific screening (inclusion) criteria (Snyder 2019). SLR can provide a basis for identifying focal points for future empirical research (Snyder 2019). SLR methods are widespread in many disciplines (Aguinis et al. 2018), including management sciences (Hiebl 2021) and hydrogen energy research (Fonseca et al. 2019). Considering the recommendations in the literature, for related areas such as business research (Fisch – Block 2018) and operations management research (Thomé et al. 2016), the SLR process was as follows:

1. Developing a research protocol: fixing two research focus points (external factors (e.g., economic history, economic development aspects) and internal factors (e.g., CG practices, organisational changes)) and assign search keywords to them.
2. Searching literature in an electronic database: Web of Science (WoS).
3. Expanding search results according to search possibilities that arise later, by re-running the search.
4. Content relevance-based filtering by title, abstract and keywords, according to the central theme of the research.
5. Data extraction and inductive, quantitative, and qualitative analysis.
6. Interpretation of the results: comparison with the content of European and Hungarian strategy documents and literature directly dealing with the development of the HE, also based on quantitative and qualitative analysis.

Table 1 shows the details of the data collection and analysis process.

The abstracts ($n = 90$) and other basic data (e.g., publication year, keywords) of the relevant journal articles and the text of the eight strategy documents (English versions in the case of Hungarian documents) were entered into the JMP statistical software for quantitative text analysis. Before the text analysis, data cleaning was carried out, including, for example, the merging of terms with the same meaning (e.g., European Union and EU) and the removal of irrelevant words (e.g., "based"). In line with the "change" theme of the research questions, the quantitative tools focused on exploring different approaches and trends. For the most relevant journal articles on ESG ($n = 28$), a qualitative analysis was conducted, which involved extracting, interpreting, and categorising findings related to the research question from the full texts.

Table 1. Details of the SLR

Focus points	– External change drivers: the background and relevance of the environmental dimension of ESG for economic development – Internal change drivers: CG and organisational aspects
First-round search criteria	ESG + econom* / histor* / economic development ESG + CG / change management / organizational change
Second-round filtering, categorisation criteria	– Content matching by research focus – Studies across specific sectors and regions – Selection of studies (also) dealing with environmental aspects
Full list of results	$n = 1.114$
Not relevant, excluded	$n = 1.024$
Selected for high-level quantitative analysis	$n = 90$ (see the list in the Appendix)
Selected for in-depth qualitative analysis	$n = 28$
Supplementary data sources	Relevant strategies, $n = 8$, from which Hungarian: 2 (ITM 2021; ITM 2019), EU: 6 (European Parlament 2019; European Commission 2020a; European Commission 2022; European Commission 2021; European Clean Hydrogen Alliance 2020; European Commission 2020b)
	International literature on HE development, $n = 21$, from which most relevant: 5

Source: author.

3. RESULTS

3.1. Contextual factors

3.1.1. Policy aspects of the HE development. Looking at HE from a historical perspective, Goltsov and Goltsova (2014) argued that after "hydrogen as energy", it is worth talking not only about the transition to a "hydrogen economy", but also about a "hydrogen civilisation". According to the authors, the first hydrogen-based technology cycle in this context will be between 2030 and 2090, in which hydrogen as an environmentally friendly energy carrier will be dominant and hydrogen production technologies, storage, transport and consumption will be the "core of the lifestyle". Nuclear and thermal power are both present in the electricity and hydrogen value chains. Fuel cells, water electrolysis, platinum metals, hydrogen-fuelled passenger vehicles and hydrogen refuelling stations are key elements of the cycle (Goltsov – Goltsova 2014). These predictions are also in line with current strategic plans

for the development of the HE. For example, among the main EU strategies for the development of the HE, the latest REPowerEU Plans aims to produce 10 million tonnes of green hydrogen by 2030 (European Commission 2022).

The expected impacts of the HE can be interpreted in several dimensions. According to Demirbas (2017), in addition to environmental impacts (e.g., lower GHG emissions), hydrogen also improves energy security. From an economic perspective, hydrogen will lead to resource abundance and adequate availability, sustainability, and fuel diversity, increased rural manufacturing jobs, increased investment in plants and equipment; international competitiveness, and reduced dependence on fossil fuel imports (Demirbas 2017). Similarly, Ambrose et al. (2017) highlight that HE development can link energy security and environmental sustainability, and the new energy system could promote growth and competitiveness from an economic perspective, climate neutrality and zero emissions from an environmental perspective, and equality, security, and health from a social perspective.

Nevertheless, there are also major challenges to HE development. These often include the limited ability of hydrogen to be injected into the natural gas grid and the need for new tools on the end-user side, hence some researchers argue that the development of new infrastructure and applications seems necessary (Ogden et al., 2018). Another technological barrier may be that some hydrogen technologies, for example in the transport sector, are still considered backstop technologies, which could be environmentally friendly, important for energy security and substitute existing solutions, but have not yet been widely deployed because of their high cost (Demirbas 2017).

There are also region-specific opportunities and challenges to HE development. According to Sadik-Zada (2021), countries that already have a significant share of renewables in their energy mix and an extensive natural gas grid have a competitive advantage in the production of green hydrogen, as the existing grid can allow the deployment of hydrogen infrastructure at a lower cost than in places where it does not exist. Ambrose et al. (2017) also note that developing countries face challenges of R&D and investing but would benefit from a HE as much as developed countries, as the former typically have more energy-intensive industries and higher levels of air pollution. According to Sadik-Zada (2021), it is not preferable for developing countries to invest in green hydrogen production in the current situation. In contrast, first they need to increase renewable energy production capacity, which will later provide the basis for the cheaper production of green hydrogen. Furthermore, in countries where nuclear energy is dominant, the production of pink hydrogen is a promising direction, as the infrastructure will be also suitable for green hydrogen as renewable energy production continues to grow (Sadik-Zada 2021). This finding is in line with Hungary's National Hydrogen Strategy, which targets the production of 20,000 tonnes of low-carbon and 16,000 tonnes of green and nuclear energy-based carbon-free hydrogen by 2030 and emphasizes the decarbonisation of industrial consumption, the greening of transport, and supporting infrastructure and seasonal energy storage (ITM 2021). Moreover, the natural gas infrastructure of Hungary is also beneficial for hydrogen blending, grid balancing, and seasonal energy storage (ITM 2019).

Although HE development could be faster in developed economies such as Hungary and other EU countries, practical experience with hydrogen is scarce even there, so R&D of hydrogen technologies should be actively promoted and international cooperation should be fostered (Demirbas 2017). Furthermore, the literature suggests that a critical regulatory task is to develop guidelines for hydrogen utilisation and related operational measures, in particular a

favourable taxation system for hydrogen (Demirbas 2017). Furthermore, energy policy and regulation have the potential to support the R&D of hydrogen technologies and infrastructure development, such as hydrogen refuelling stations and hydrogen storage solutions in the medium term, thereby reducing the cost of hydrogen technologies (Ambrose et al. 2017). Based on Lee et al. (2011), regulatory support strategy for hydrogen should be determined by a long-term energy technology roadmap that prioritizes technologies according to (1) economic impact, (2) commercial potential, (3) internal capacity, (4) technology spin-off, and (5) development cost.

3.1.2. Different approaches of ESG research from the aspect of HE development. Although the 90 relevant articles selected from the first list (n = 1.114) represent a wide range of topics based on the WoS categories, e.g., agriculture, computer science, or ethics, a significant number of the articles fall into similar categories. Three main approaches have been outlined based on the combination of the most frequent categories:

1. business, management, and finance studies;
2. environmental, energy, and technological studies;
3. integrated studies, i.e., which take account of the business, management, and financial aspects as well as the environmental, energy, and technological aspects.

Figure 1 shows that the first category, business, leads in the distribution of articles, which is not surprising given the ESG background (investment and evaluation strategy, see chapter 3.2.). An influential but less dominant direction is the environmental, energy, and technology approach to ESG and economic development. The integrated approach is rare based on the SLR, indicating a clear separation between business and engineering, and possible future research in this area.

Among the 2.876 terms used in the abstracts of the relevant articles, the most frequent are ESG (n = 249), social (n = 159), corporate governance (n = 151), environmental (n = 139), companies (n = 106/ firms, n = 81; corporate, n = 85), financial (n = 104), performance (n = 98), sustainability (n = 88), board (n = 80), investment (n = 68), reporting (n = 52/

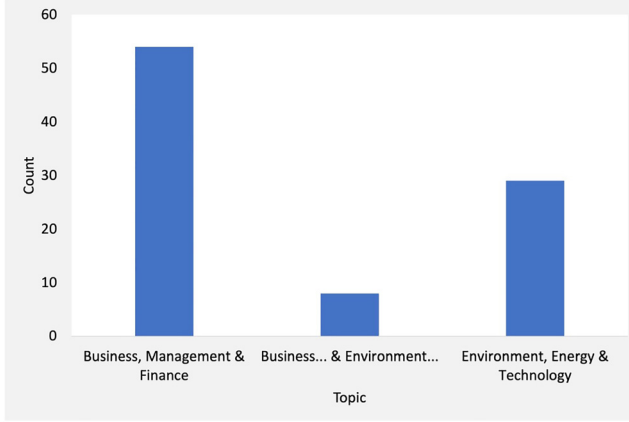

Fig. 1. Thematic distribution of relevant articles
Source: author.

disclosure, $n = 67$). Figure 2 shows the 30 most frequent terms in the abstracts of the relevant articles in 2016, 2019 and 2022. On the one hand, the appearance rates also show that most of the articles in the focus of the research were published in 2022, which, since no date-based pre-screening was applied, indicates how current the topic is. On the other hand, among the most frequent key terms, for example, *sustainability, ESG reporting,* and *environmental aspects* show a significant increase; *market* and *investment* show a significant decrease, while *performance* and *countries* seem to be recurrently important terms. The contrasting trend between the terms *ESG* and *CSR* is particularly noticeable, i.e., the marginalisation of CSR compared to ESG.

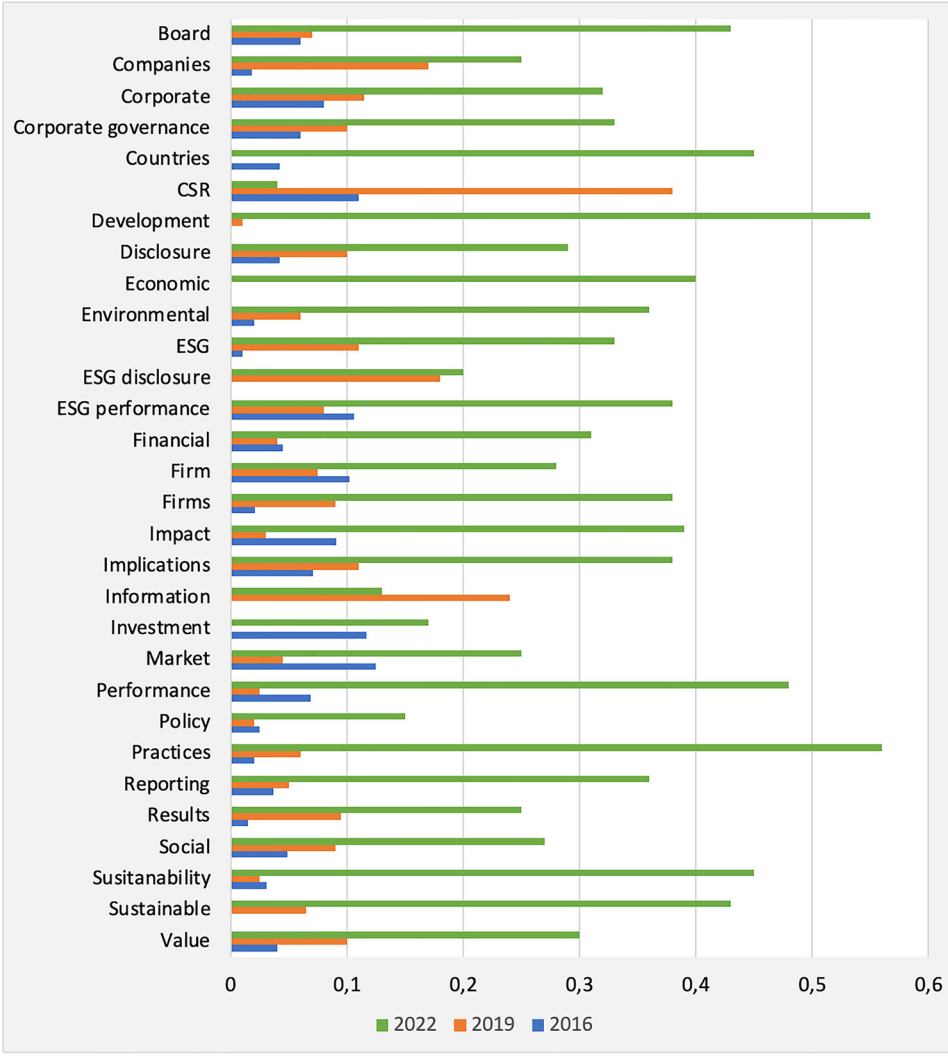

Fig. 2. Appearance rate of the 30 most frequent terms in relevant articles in 2016 2019 and 2022
Source: author.

These results could be compared with the content of the Hungarian and EU strategy documents. Figure 3 shows a word cloud based on the most common terms used in the documents. Given the focus of these documents on energy and climate, it is not surprising that there is little overlap between the most common words – however, *investment* and *development* can be important aspects to interconnect public and market mechanisms. The figure also indicates which terms are more dominant in EU documents and which in Hungarian documents. For example, capacity (n = 363), price (n = 239), natural gas (n = 211), energy consumption (n = 174), and source (n = 204) appear predominantly in the Hungarian documents – which could refer, e.g., to the large capacitates of the natural gas system, the need for affordability or to decrease energy imports. However, there is a high degree of fit on the most common terms, which include, for example, (renewable) electricity, targets for 2030, market, production, system, technology, development, or emissions. The dominance of renewable energy (n = 734), hydrogen (n = 359) and fuel (n = 344) in the EU documents could be mainly explained by the larger number and length of EU documents in the sample.

The combinations of the most common ESG and HE terms (based on the HE policy topics) could highlight potential key areas that are likely to influence the governance of energy companies. For example:

1. The different levels of economic development in different countries (countries = 49, economic = 58, development = 45) may justify different degrees of consideration of environmental, social and CG aspects (environmental = 139, social = 159, corporate governance = 151) and the preparation of sustainability reports (sustainability = 88, disclosure = 67/ reporting = 52).
2. The board of directors can have a direct impact on ESG performance (board = 80, impact = 53, ESG performance = 44) and corporate financial performance (companies = 106, financial = 104, performance = 98).
3. From an energy perspective, the long-term ESG strategy can address support for national targets for 2030 (2030 = 385, national = 243, target = 238, support = 269), reducing emissions in the

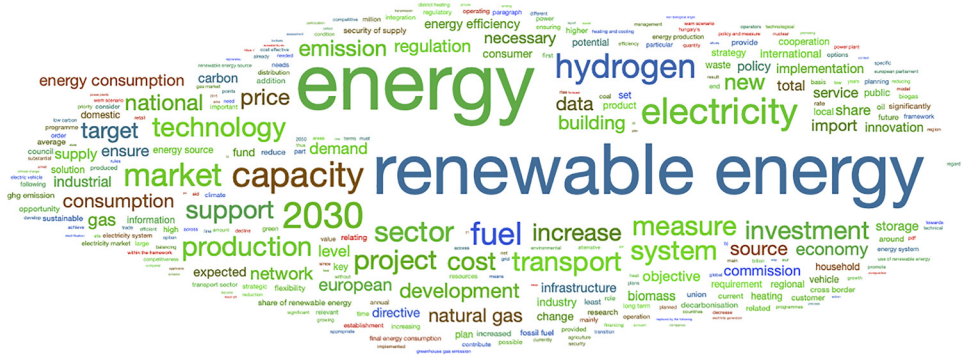

Fig. 3. Word cloud of strategic documents related to the development of the HE in Europe and Hungary (red: Hungarian documents, blue: EU documents)
Source: author.

electricity sector (electricity = 394, sector = 312, emission = 233) and increasing renewable energy capacity (renewable energy = 734, capacity = 363, increase = 251).
4. Moreover, by investing in technology development projects (technology = 286, development = 226, project = 295, investment = 266) the cost of hydrogen and hydrogen-based fuel production (hydrogen = 359, fuel = 344, production = 283, cost = 266) might be decreased.

These areas indeed appear in the selected ESG literature, as detailed below.

3.2. Drivers of ESG-based change toward the improved environmental performance

3.2.1. External drivers of change: the background of ESG and the importance of the environmental dimension. An in-depth analysis of the literature suggests that the ESG trend is so new that only a few studies have begun to analyse its background from a historical perspective. Interestingly, the first study was published in 2011, in which Eccles and Viviers (2011) focused on the terms and meanings used to categorize investment practices. According to their study, "environmentally responsible investment" is one of the vague terms used in the literature. The authors refer to Sparkes' even earlier work from 2001, which argues that it is worth distinguishing between "ethical investment" and "socially responsible investment". The former includes value-based organisations (e.g., a church), while the latter represents social and environmental goals combined with financial goals (Sparkes 2001). However, based on Fan et al. (2022), the so-called sustainability-themed strategy, with an emphasis on investing in clean energy, has become a separate version of the newer ESG investment strategies.

Later, Eccles et al. (2020) focus on the social context of ESG. The authors point out how the environment as a social issue has shaped the investment decisions of individuals in the past century, and highlight the activities of Innovest. In the second half of the 1990s, Innovest sought to establish a link between environmental and financial performance, by the green analogy of Moody's and an eco-industrial revolution. The concept was that eco-efficiency and environmental performance would be critical to competitiveness, profitability and even survival. An important milestone in this regard was the UN's Environmental Program Finance Initiative's "Freshfields" report, which demonstrated that ESG issues have financial relevance. This financial relevance is a major theme in the ESG literature, as research often shows contradictory results (Shahrokhi et al. 2022).

The literature on the background of ESG suggests that environmental considerations have often been and continue to be a focus of attention. For example, Barman (2018), approaching sustainability reporting from the perspective of the Global Reporting Initiative (GRI), points out that it was created as a standard for companies to report on environmental performance first. The GRI and GISR (Global Initiative for Sustainability Reporting) also emphasise that ESG issues are relevant because of their social and environmental consequences rather than their financial value (Barman 2018).

The contrast between financial and non-financial aspects and corporate responsibility can also be analysed based on the differences in certain economic perspectives. According to Bhandari et al. (2022), the traditional view of economics is that the environment is embedded in the economy, but a more recent, unorthodox view suggests that the economy should be embedded in nature, as this will provide enough attention to biodiversity and maintaining rational limits to growth. However, based on the work of Gillan et al. (2021), some scholars emphasise the need for state/government intervention in addressing environmental and social issues, as this is where the

"superior capability" (e.g., regulation, resources) is available, and this is why prior research found that state-owned enterprises improve their environmental performance more than other enterprises. A similar contrast is outlined by Daugard and Ding (2022), who argue that the former mainstream literature believes that business and management decisions should be made according to the principles of the free market, in which governments should not interfere. However, this suggests that a country could prioritise either social outcomes or a prosperous economy, but not at the same time. In contrast, the more recent literature now emphasises the need to encourage and hold for-profit companies accountable beyond business interests (Daugaard – Ding 2022).

In line with recent trends in scientific approaches, a change in the attitudes of market actors can also be identified. For example, Baldini et al. (2018) point out that while previously environmental protection tasks were regulated only by government initiatives (in addition to labour and governance) and institutional investors and analysts were not interested in environmental reporting before 2010, they now demand sustainability reporting. Furthermore, focusing on the changing ESG trends in 2020, Raman et al. (2020) found that social factors have been gaining attention in recent years, while environmental factors have peaked and stagnated.

Concerning environmental factors, Walter (2019) points out that developing sustainability metrics and estimating costs for the natural environment is a difficult task, as environmental resources have costs and benefits that are difficult to measure, are unevenly distributed and cross political boundaries. E-scoring, however, is a fashionable approach to business valuation, focusing primarily on climate change (Walter 2019). The ESG literature often mentions environmental issues such as reducing greenhouse gas emissions and carbon footprint (Singhania et al. 2022), the use of renewable energy sources (Umar et al. 2020), efficient waste management (Raman et al. 2020), energy consumption and energy efficiency (Li et al. 2021), and corporate resilience to climate change (Walter 2019).

Another direction of the literature deals with indicators and assessment systems for environmental performance and ESG performance in general. Some of the methodologies focus directly on climate change (including carbon footprint and alignment with pathways to carbon neutrality), while others focus on social and environmental impacts together (Popescu et al. 2021). These include mainly ESG assessments, sustainability labels, and sustainability-based impact assessments based on the SDGs (UN Sustainable Development Goals) and LCAs (Life Cycle Assessments). Novel ESG assessment methodologies are also exploring alignment with the Paris Agreement, such as the Carbon Impact Analytics tool, which measures the compatibility of electricity-related assets with climate change/mitigation scenarios (Popescu et al. 2021).

Among the works on the background of ESG, the study by Yang et al. (2022) is particularly relevant to the development of the HE, highlighting the role of clean energy and green economy development in all three pillars of ESG. By definition, a green economy improves human well-being, reduces environmental risks and ecological scarcity, promotes social equity, protects the natural environment, and also provides fundamental economic benefits such as stability or the creation of "green" jobs (Yang et al. 2022). However, certain contextual factors must also be considered, such as regional, industry, and institutional environments.

1. From a regional perspective, the work of Pineau et al. (2022) suggests that environmental (green) aspects are not developed in the same way everywhere. From the point of view of creditworthiness, which can be a driver of development, CG aspects are more important in

developed economies, environmental aspects in agriculture-focused economies (e.g., Sub-Saharan Africa), and social aspects are important in the Middle East and North Africa.

2. From an industry perspective, Andersen and Bams (2022) point out that in industries that are particularly visible to consumers and the general public, companies use environmental management to obtain consumer sympathy; however, these companies also tend to feel pressure to overspend in this area. In contrast, for less visible but polluting and capital-intensive companies (cf. the traditional energy industry), environmental management is only relevant for risk management and regulatory compliance purposes.
3. From an institutional perspective, Daugard and Ding (2022) argue that ESG performance can be affected by institutional isomorphism. Institutional isomorphism is a framework that describes three mechanisms to potentially enhance ESG performance. Coercive isomorphism is achieved through the need for legitimacy in policy regulation and society. Mimetic isomorphism operates when strategies that support ESG become the standard choice for risk management in an industry, market, or country. Normative isomorphism is achieved through the recognition of CSR, ESG and SRI activities as separate professions.

3.2.2. Internal drivers for change: corporate aspects of improving environmental performance. Since external factors naturally influence CG responses, many of the themes presented in the previous chapter are also relevant at the company level. For example, increasing regulatory pressure means external pressure for ESG reporting. However, Aureli et al. (2020) also point out that these pressures act in parallel with other influences, i.e., in addition to regulation, employees, local communities, competitors, auditors and shareholders also exert a push towards sustainability on companies. However, these influences may change over time, for example, the regulatory side and the audit department may first drive ESG reporting, while other stakeholders, such as investors, may later have a stronger influence on the direction of change (Aureli et al. 2020). Concerning investor activism, Kruitwagen et al. (2017) have shown that the long-term interests of investors generally increase the sustainability performance of the portfolio companies, as they foster reduced environmental risks. However, among investors who want to actively influence company operations and decisions, and among boards of directors, sometimes the short-term focus of directors can often make cooperation difficult. This phenomenon, in turn, may – on a game-theoretic basis – affect investor expectations and lead to less committed, passive investor behaviour (Kruitwagen et al. 2017).

Consequently, the performance evaluation system of directors may be subject to change to improve ESG performance, especially because the implementation of long-term sustainability projects and their financial return on investment may be challenged by short-term contextual factors (Csedő et al. 2022). However, the literature suggests that other tools can be also used to ensure long-term planning as a success factor. For example, Arslan et al. (2022) argue that senior managers who are also shareholders of the company, and new CEOs typically pay more attention to improving sustainability performance, because of their motivation to think over longer time horizons. Haque's (2017) research suggests that board independence and diversity can also be important, as these have a positive impact on carbon footprint reduction initiatives. The author also points out, however, that although ESG-based incentives can help senior management improve process-based carbon reduction performance (starting a project), this is often only to improve financial performance (e.g., through an increase in share price) and does not result in actual GHG emission reductions (Haque 2017). According to

Tanthanongsakkun et al. (2022), board member turnover is also a relevant factor. Their research shows that staggered boards (in which only a few directors leave, and a few new directors join from time to time) perform much worse in terms of carbon emissions than traditional boards (in which directors' terms expire at the same time). Although staggered boards do protect directors from short-term market effects (challengers must win in several cycles to take over the control), the principal-agent problem becomes amplified. This means that the number of outcomes that are favourable to shareholders is also declining, which would nowadays include carbon emissions as well (Tanthanongsakkun et al. 2022).

There are other concrete opportunities to improve environmental and reporting performance. For example, according to Cormier et al. (2015), environmental reporting is more detailed in cases where there is an environmental committee composed of individual board members. Where no reporting is required by regulators, CG plays a critical role in properly informing markets and financial analysts about environmental performance (Cormier et al. 2015). Qian et al. (2022) argue that changes towards sustainability can be induced by the implementation of a carbon management system. According to Ge et al. (2022), rethinking innovation strategy appears to be a promising tool, as good ESG performance contributes to investment in innovation and further increases the pace of "high-quality development", characterised by innovation, environmental friendliness, coordination, openness and sharing, in line with the international consensus on sustainable and global development (Ge et al. 2022). Finally, Ortas et al. (2015) argue that strategic change can be environmentally and financially beneficial. Indeed, their research shows that voluntary CSR initiatives systematically improve both corporate ESG performance and financial performance, but ESG performance improvements necessarily involve organisational changes (Ortas et al. 2015).

4. DISCUSSION: ESG-BASED ADAPTATION OPPORTUNITIES

Based on quantitative and qualitative analyses, ESG appears to be a key factor in achieving climate goals and addressing the challenges of developing the HE at the level of energy companies. ESG can be interpreted in at least three ways.

1. From a societal perspective, ESG is a new economic institution, representing a new set of rules and guidelines for economic life, as North (1990: 3) describes institutions as "the rules of the game in the society".
2. From an energy economics perspective, ESG can be interpreted as a driver for the development of the HE, as environmental concerns point to environmentally friendly technologies and applications, of which hydrogen is one of the most promising areas. For example, hydrogen can be applied in several areas in the energy sector through the so-called power-to-hydrogen and hydrogen-to-X processes, e.g., electricity, heat, methane, and methanol (Chehade et al. 2019).
3. From a corporate perspective, however, ESG could generate a change in the board and the organization (cf. dynamic CG with new strategies, incentives, or systems) (Csedő et al. 2022). Tables 2 and 3 classify and interpret external and internal changes from a CG perspective, concerning improving environmental performance and/or directly developing the HE (where relevant). Different drivers of change could induce different adaptation mechanisms, as external factors influence the direction of strategic decision-making at the CG level, while internal factors affect the CG structure and the organisational systems.

Table 2. Strategic changes to improve environmental performance in the emerging HE

External factors	Drivers of change	Adaptation for environmental benefits/ HE
Investment strategies and attention	ESG-based investment strategies (Eccles – Viviers 2011: 389–390)	Meeting new investor expectations by taking ESG aspects into account
	Sustainability-themed investment strategy (Fan et al. 2022: 6)	Investing in hydrogen technologies
	Turbulent periods which reduce the benefits of portfolio diversification through ESG investments (Umar et al. 2020: 122–123)	Combining ESG with conventional or alternative energy activities to reduce risk
	Increased interest in sustainability reporting (Baldini et al. 2018: 80)	Sustainability reporting considering HE aspects
	Increasing importance of social factors (Raman et al. 2020: 454)	Fostering the social acceptance of hydrogen technologies
Institutional environment	Environmental protection as a key social issue (Eccles et al. 2020: 577, 585)	ESG strategy development considering green hydrogen opportunities
	ESG, CSR, sustainability and socio-environmental governance are synonymous (Li et al. 2021: 19)	Conscious ESG communication according to trends
	Institutional isomorphism mechanisms (Daugaard – Ding 2022: 18)	Following and/or proactively shaping industry standards through strategic decisions - investing in the widespread use of hydrogen technologies
Evaluation methods	Strategic importance of social and environmental topics (Barman 2018: 306)	Meeting new reporting standards
	E-scoring trend (Walter 2019: 23)	Resilience building to climate change based on hydrogen technologies
	New ESG evaluation methods (Popescu et al. 2021: 3)	Following climate change-focused or holistic social-environmental evaluation methods
Industry practices	Polluting nature of the industry and resource constraints (Gillan et al. 2021: 3)	Reaching external financial resources for hydrogen technology development/ diversification to improve environmental performance

(continued)

Table 2. Continued

External factors	Drivers of change	Adaptation for environmental benefits/ HE
	(In)visibility to consumers and the general public in certain segments (Andersen – Bams 2022: 1)	Balancing environmental management approach (no over- or underspending)
Economic development and regulation	Green economy development with ESG pillars (Yang et al. 2022: 2)	Production and/or utilization of carbon-neutral or green hydrogen
	ESG regulatory framework of a country (Singhania et al. 2022: 169)	Proactive development of environmental and management dimensions in developed economies
	Regulatory pressure to responsible operations, ESG-friendliness of resources (Bhandari et al. 2022: 1532)	Development and/or acquisition of hydrogen technology resources
	Regional differences regarding ESG factors (Pineau et al. 2022: 7)	Improving governance performance for reaching favourable financial sources

Table 3. Governance changes to improve environmental performance in the emerging HE

Internal factors	Drivers of change	Adaptation for environmental benefits/ HE
Stakeholder management	Cooperation or conflict with active investors (Kruitwagen et al. 2017: 12–13)	Modifying the incentive scheme in line with a long-term hydrogen strategy
	Various stakeholder effects on sustainability reporting (Aureli et al. 2020: 2400)	Ensuring consistency of the content with strategic goals, controlling compliance with regulatory requirements
Decision-making patterns	Long-term motivations of shareholder managers and new CEOs to improve sustainability (Aureli et al. 2020: 2400)	Stock options and careful planning of CEO succession
	Short-term factors which challenge the financial returns of ESG projects (Csedő et al. 2022: 15)	Analysis of the return on investment of hydrogen technology projects under several long-term scenarios

(continued)

Table 3. Continued

Internal factors	Drivers of change	Adaptation for environmental benefits/ HE
Structure and composition of the board	More detailed sustainability report if an environmental committee exits (Cormier et al. 2015: 920–921)	Establishment of an Environmental/ Hydrogen Technology Committee
	Diversity and independence of directors improve carbon footprint, but actual GHG emissions might not decrease (Haque 2017: 362)	Establishment of an independent and diverse board of directors; monitor not only initiatives and financial performance but also actual GHG emissions
	Staggered boards underperform in CO_2 emissions (Tanthanongsakkun et al. 2022: 9)	Avoid staggered boards or manage the resulting principal-agent conflict with new incentives
Initiating organizational changes	Voluntary CSR improves financial and environmental performance, and ESG performance improvement needs organizational changes (Ortas et al. 2015: 1951)	Initiating organisational changes that strengthen stakeholder involvement and engagement, sustainable development and the public good
	Good ESG performance induces investment in innovation, innovation drives quality growth (Ge et al. 2022: 21)	A strategic analysis of the intersections of hydrogen technology innovation and ESG
	Carbon management systems could drive sustainability-oriented changes (Qian et al. 2022: 9)	Introducing a carbon management system

5. CONCLUSIONS

This study aimed to explore changes which are generated by the global ESG trend and outline adaptation opportunities to improve the environmental performance of companies in the emerging HE, based on a systematic literature review (SLR). The theoretical contribution of the study is that it provides a collection, categorization, and reinterpretation of prior literature, focusing on environmental, economic, and CG development. Moreover, the results suggest practical contributions to policymakers and energy companies.

1. The results highlighted that external ESG changes are related to investment strategies and attention, institutional environment, corporate evaluation methods, industry practices, and economic development and regulation, and ESG as a new institution could mean a new "rule" in the game of economic activities.
2. From a policy perspective, this "rule" could and should be used by policies in favour of HE development, which would orient and amplify the increasing environmental performance of companies, incited by other external forces (e.g., stock markets) and internal pressures

(e.g., incentive systems, responsible leadership). Based on the specificities of HE development, regulatory interventions could incite investment into technology development projects focusing on cost reduction, and favourable taxation systems supporting the large-scale production and utilization of green or low-carbon hydrogen (e.g., by power-to-X processes). Besides, regulators could also indirectly affect hydrogen technology development by making sustainability reporting mandatory or recommended and orienting the attention toward substantive HE topics.

3. From a CG perspective, beyond the external factors which drive environmental performance, stakeholder management, decision-making patterns, structure and composition of the board, and initiating organizational changes were identified as key governance areas. Based on the reinterpretation of the literature from CG aspects 27 strategic- and governance-related adaptation opportunities were elaborated to support the environmental performance in the emerging HE.

In a broader sense, the results suggest that HE development could affect corporate ESG performance and vice versa. On the one hand, national HE development could be facilitated by inciting corporate governance to integrate ESG, especially their environmental aspects into strategic decisions. On the other hand, contributing to the HE development inherently improves ESG, especially the environmental performance of companies. Finally, while policymakers and corporate directors can follow decision-making patterns which do not challenge each other, additional socio-economic, sectoral, and corporate benefits could come from the top-down coordination of HE development, which could lead to a more resilient, competitive, and climate-neutral energy sector based on hydrogen energy.

Even though the study was built on a systematic process and a hybrid, quantitative-qualitative approach, there are some limitations which induce future research. For example, as the selection and the analysis of the selected journal articles were mainly influenced by dominantly environmental and governance perspectives, the social aspects remained in the background. In line with the expected technological diffusion, however, social aspects might generate interesting research topics as well. Furthermore, as this study aimed to lay the foundations for empirical research, the elaborated governance interventions could be in the scope of further studies.

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