

# THE IMPACT OF ENERGY EFFICIENCY ON CORPORATE PERFORMANCE: GLOBAL ACADEMIC REVIEW

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## Abstract:

*The paper aims to explore the current literature about the performance duality, energy efficiency (EE) and corporate financial performance. An increased pressure from international organizations and regulators to internalize environmental mechanisms and sustainability processes into the business strategies of the companies impose to quantify such initiatives on corporate financial performance. Using a unique technic for text-analysis of articles published in the last 15 years we identified four clusters of keywords (Energy Efficiency, Economic Analysis, Performance assessment, Optimization and waste heat) that indicate the way the current academic contribution is structured. It was found that yet, the relationships between energy efficiency and corporate financial performance are still not enough studied mainly because of the lack of data disclosed through ESG reporting. Moreover, the energy efficiency research topics are dominated by engineering academic undertakings, which started to be approached by researchers in the earlies 2000. This aspect indicates that topic of energy efficiency at the beginning was considered the in context of corporate sustainable development through innovation. Our results demonstrates that most of the authors found a positive relationship between energy efficiency (measured through energy intensity) and corporate financial performance, but still there were also contradictory opinions.*

**Keywords:** corporate performance, economic analysis, energy efficiency, environmental performance, performance assessment, sustainable development

**JEL classification:** G31, G38, Q43, Q56, P28

## 1. INTRODUCTION

Sustainable development implies complex processes at micro and macro level to achieve the climate targets in 2030 and 2050. The most influential aspect of sustainable development, which also determines the change in the global economic model, is the energy factor. For this reason, it is a core research scope for both academia and professional organizations. The global economy is in the process of transition from fossil fuel-based economy to circular and renewable energy-based economy. An important component of the transition process is the energy efficiency factor which currently is extensively regulated by many countries and regions: EU energy efficiency plan is set-up in the context of National Energy Efficiency Action Plan (EU level), 20-Year Energy Efficiency Development Plan (Thailand), Strategic Energy Efficiency Plan (Turkey) etc. (Rasoulinezhad and Taghizadeh-Hesary, 2022). The International Energy Agency is one of the leading organizations which actively promotes the energy efficiency by stating that “We consider energy efficiency to be the ‘first fuel’ as it still represents the cleanest and, in most cases, the cheapest way to meet our energy needs.” (Fatih Birol, IEA Executive Director). The scope of the research is to reveal the academic contribution and research tracks on the role of energy efficiency (EE) within corporate performance, which is the main subject in achieving the net zero emissions by 2050. The energy efficiency has a complex and dual role for sustainable development; it is a transitory mechanism to green economy which depends consistently on financial resources and brings visible results on the short and medium term. Moreover, the energy efficiency is a mechanism that forego the energy intensity. Methodologically, we used a unique hybrid technique for textual analysis of articles published between 2010 and 2022. The process consisted of six steps. First, we defined the specific research questions. Second, we examined Scopus database using the relevant keywords through

titles, abstract and keywords of the papers. Third, we created three selections criteria (set period 2010-2022, academic articles, and English language papers) to get the batch of selected academic documents. Fourth, information retrieved from the Scopus was processed with the help of VOSviewer software to identify keywords clusters (*Energy Efficiency, Economic Analysis, Performance assessment, Optimization and waste heat*). Fifth, Online Analytical Processing (OLAP) principles for data management were applied with the help of spreadsheets to retrieve the most relevant research papers. To increase the representativeness of the selected papers we combined citations index and the number of identified keywords per each cluster. Finally, at the sixth step the identified relevant articles are critically assessed to determine the academic contribution of the impact of Energy efficiency initiatives on the corporate financial and operational performance.

The grounds for setting and internalizing sustainability and implicitly of the energy efficiency mechanisms into the corporate strategy lies in the commitment of the top board of directors and executive team, reflected through corporate governance mechanisms. In academic literature, there are three theories that consider the sustainability internalization process into corporate strategy and its effect on the short and long term corporate financial performance. First is the agency theory that is focusing more on the financial/economic side of the organization and implies that there is a negative relationship between environmental and corporate financial performance mainly from the point of cost efficiency (Friedman, 1970). Second is the resource-based theory according to which companies should “pay to be green”. Within this theory, companies undertake actions to internalize environmentally friendly mechanism (implicitly energy efficient solutions) in the production process in order to stay competitive in the market and enhance the firms value creation process (e.g. increase the corporate environmental performance (Orlitzky et. al., 2003). Third theory is called behavioral theory of corporate governance, which embed the aspects of positive agency theory and behavioral view of the companies that require business organizations to adopt “practices addressing larger societal issues”. This means that top management should consider the human-behavioral view of a firm when participating in the decision-making process for resources allocation (e.g. the economic aspects of the decision making process are inter-linked with the human behavioral vectors) (Dubey et. al., 2018).

## 2. METHODOLOGY AND CONCEPT DEFINITIONS

To identify the academic contribution about the impact of energy efficiency on the corporate performance we use the functionalities of VOSviewer for text mining and data processing. For this reason, several steps were taken to identify the main research trends. Initially, we define the specific research questions with regards to the duality: energy efficiency and corporate financial performance. Secondly, we examine the citation database Scopus using specific key words through the titles, abstract and keywords of the papers. The following keywords refer to the full spectrum of the relationship between energy efficiency and corporate performance: “energy efficiency” AND “financial performance” AND “Economic performance” AND “organizational performance” AND “corporate performance” AND “ESG performance”. Thirdly, we filter the database and get the batch of selected academic research papers by selecting the following subject areas: environmental science, business management and accounting, social sciences, economics econometrics and finance, multidisciplinary; only research papers and English language. In the fourth step information extracted from Scopus was processed through VOSviewer software to identify the keywords clusters. Applying ‘Online Analytical Processing’ (OLAP) principles with the help of Visual Basic Programming through the spreadsheets, the most representative research papers were extracted, by combining the number of keywords per each cluster and citation index. At the final step of our methodology the relevant articles were extracted and critically assessed to identify the main research trends of the relationship between energy efficiency and corporate financial performance of companies acting in the EU.

At this stage it is also relevant to identify how the academic community is defining the concept of energy efficiency, as apparently it has a generic character. Among the first regulators which brought the energy efficiency concept at the regional regulatory level was the EU. According to the EU Energy Efficiency Directive the “*energy efficiency means the ratio of output of performance, service, goods or energy, to input of energy*” (EPRS, 2015). In other words, the directive refers to a wide spectrum of issues that impact a multitude of stakeholders and perspectives: energy consumption targets and savings, energy poverty and consumers, audit obligations, technical competence requirements and other elements (EC, 2022). The EU regulatory initiatives are transposed at the level of business organizations, this in fact should identify the economic benefits of implementing EE rules. Moreover, it will ensure the implementation of an important milestone towards organizational sustainable development. The International Energy Agency, being the most advanced organization that monitors complex aspects and global energy flows is stating that “*Energy efficiency is called the “first fuel” in clean energy transitions, as it provides some of the quickest and most cost-effective CO2 mitigation options while lowering energy bills and strengthening energy security. .... Energy efficiency is the single largest measure to avoid energy demand ....., along with the closely related measures of electrification, behavioral change, digitalization and material efficiency.*”(IEA, 2022). The US Department of Energy has a simpler view about the energy efficiency, where the level of importance is the same as other organizations have, according to their approach the energy efficiency “*... is the use of less energy to perform the same task or produce the same result. Energy efficiency is one of the easiest and most cost-effective ways to combat climate change, reduce energy costs for consumers, and improve the competitiveness of U.S. businesses. Energy efficiency is also a vital component in achieving net-zero emissions of carbon dioxide through decarbonization.*” There are common views in different organizations about the same climate issue, which do not create any geographical or stakeholder segmentation. As mentioned before, for business organization, the concept itself has a double implication - financial and sustainability performance. Moreover, ESG rating organizations already included the energy efficiency metrics in the methodology for index calculation (e.g. Thomson Reuters is using the following metrics: *Policy EE score, targets EE score, total energy use / million revenue score, energy use total, energy purchased direct, energy produced direct, indirect energy used*).

### 3. RESEARCH QUESTIONS AND DISCUSSIONS

Considering the complexity of the energy efficiency topic from the perspective of environmental impact, sustainable development transition mechanism, achieving the climate targets by 2030 and 2050, also considering the UN initiatives reflected through SDG, the following research questions are drawn in this paper:

- What are the research clusters of the duality energy efficiency vs corporate performance?
- ***Which companies should focus on performance duality energy efficiency corporate performance?***
- What is the impact and magnitude of the duality energy efficiency and corporate performance?
- How to measure the impact of the EE on the corporate financial performance (CFP)?

Due to the importance and magnitude of the topic, EE is extensively researched in the academic literature, from a wide range of perspectives. A simple key word findings of “energy efficiency” will bring about 250.000 document results which requires a different approach for structuring the academic literature clustering process. After interrogating the data at the 3<sup>rd</sup> and 4<sup>th</sup> steps by following our research methodology 420 articles were identified. Then, data retrieved from Scopus was processed through VOSviewer and 4 keywords clusters were obtained as shown on the keywords map (see Figure no. 1): cluster 1 - energy efficiency; cluster 2 - economic analysis; cluster 3 - performance assessment; cluster 4 - optimization.



elements (important for country's sustainable development): CO<sub>2</sub> emissions schemes, macroeconomic and financial instruments (e.g. FDI, country Fiscal system, GDP), trade openness and renewable energy utilization etc. Indeed, the implementation of sustainable development initiatives have different dynamics in developed and developing countries. This is directly related to the access to investment capitals and access to the innovation projects. These two are constraints for developing countries especially considering the energy efficiency policy initiatives. (Godil et. al., 2021) analyzed the impact of country's R&D, financial development, globalization, and institutional quality on the energy utilization in India and subsequently its propensity to the energy efficiency initiatives and renewable energy sources. They found that, developing country like India is struggling with factor limitations that affect its engagement towards sustainable development, a weak financial system will reduce the energy consumption and will cease the development of economy (and vice-versa). Moreover, an increase in the institutional quality and outcome of R&D (especially in energy sector) negatively influence the energy consumption through the implementation of energy-efficient technologies that contribute towards the decline of energy usage. Similar results were achieved by (Chandra Deb et. al., 2022) about Bangladesh companies in the general research context about environmental corporate financial performance. European Union is a region that has the most advanced economic system design towards sustainable development. The implementation at the European Union of the Emissions Trading Scheme (EU ETS) in 2005 is a strong example of this aspect. (Makridou et. al., 2019) in their research are analyzing the impact of EU EST on the performance of companies from 19 EU countries. As the regulatory system is designed including also the functionality of EU ETS it was found that both economic and energy related variables (e.g. Energy efficiency policies score for industry, the number of electricity retailers etc.) significantly and positively impacts the organizational profitability. Indeed, the CO<sub>2</sub> / EU ETS adherence to the corporate operations can only be done through energy efficiency mechanisms and policy efficiency (Martin et. al., 2012; Jaraite et. al., 2016).

With the same academic intensity, the energy efficiency aspects are approached at micro level. In the "Energy Efficiency" cluster, authors are mostly focused on the liaison between energy efficiency and corporate financial performance. In a more extensive academic vain, energy efficiency belongs to the corporate sustainability development strategy and its performance (especially environmental component). An interesting paper was published by (Friede et. al., 2015) where they did a meta-analysis of approximately 2200 research papers about the relationship between ESG performance and corporate performance. They found overall a positive link between sustainability performance and corporate financial performance. For companies, energy efficiency represents a win-win undertaking considering the following: companies improve their financial performance through a better cost management (Moon and Min, 2020), its consolidate environmental performance position (including also the corporate image) (Bergmann et. al., 2017), and ultimately companies are consolidating its competitiveness (Lui et. al., 2021) in the market through its development. The energy efficiency mechanisms will be implemented by companies which ultimately will bring financial performance then and only then at national or regional level will be implemented a functional environmental regulatory framework and policies system. Moreover, the regulatory system should consider all the stakeholders, because they are the direct and indirect beneficiaries of these resource and because energy efficiency is a "low-hanging fruit" that is "creating good jobs and saving businesses and consumer's money. So it's a win-win" (Barack Obama, 2015).

There are also contrary academic views about the magnitude of energy efficiency on the corporate financial performance. (Carmen-Pilar and Martí-Ballester, 2017) undertook a complex and multidimensional research about the impact of EE on CFP. Comparing with other studies, their analysis comprise data across 36 countries (both developed and developing) which shows that energy efficiency and the use of renewable energy (RE) sources do not significantly influence the corporate financial performance. The reasons behind their results might be that costs savings obtained from EE solutions and renewable energy use compensate the financial spendings utilized to implement these sustainable solutions. Moreover, not having a significant and visible impact,

investors might not be willing to invest in such solutions. In the analysis the authors used the combination of two concepts Rational use of Energy (RUE) and Renewable Energy sources (RES) (Peura, 2013), which show significant impact on CFP only when companies have installed sustainable energy management systems (and only in the short term). In the long term the impact is not significant which strengthens the hypothesis that EE solutions are “low-hanging fruits” but only on the short term.

Countries’ specifics should be considered in the analysis, as each country has a different mixture of energy sources, different levels of national energy market interconnectivity compared to the international energy market and different pricing systems. The characteristics of the national energy market should be embedded in the analysis of performance duality EE-CFP when the research refers to cross country data (research gap).

The time frame considered for the analysis is also an important indicator whether companies should implement EE and RE solutions or not. The low demand for energy sources will determine a low price, therefore companies prefer to use traditional sources of energy as the price is low. Such sustainable development initiative is beneficial when the energy market is turbulent from the supply, price and demand perspectives including the structural changes in the energy market (e.g. military conflicts, pandemic cases etc.). The above ideas bring us to the conclusion that time is important while considering EE and RE solutions. At the EU level the energy efficiency and renewable undertakings play an important role in the implementation of the climate agenda, therefore, companies should implement EE and RE solution only through innovation mechanisms in order to stay competitive in the market.

The performance duality of EE-CFP should be analyzed in a wider variety of influential factors: energy efficiency practices, greenhouse gases, material, and resource efficiency (Boakye et. al., 2020), FDI, R&D, fiscal policies, CO2 emissions (EU ETS) etc.

The concept of energy efficiency, as it is defined, refers more to non-financial aspects related to the organizational functioning. It encompasses technical aspects with indirect economic implications. For this reason, the rest of the clusters will refer more to non-financial aspects of energy efficiency - same research discoveries and/or innovative solutions on how to obtain these benefits.

### **Economic analysis cluster**

To identify articles that are the most relevant for the “Economic Analysis” cluster we combined two sets of information: the most cited articles and the co-occurrences of the depicted keywords. The Economic Analysis cluster brings research papers which study a wide variety of technical solutions, mainly in the energy sectors that impact the environmental performance of companies positively through CO2 reduction, increasing the energy efficiency rates, etc. In most of the papers the authors research and present the technological solutions which also includes the impact assessment and the analysis of the economic viability of the project. Interestingly, the most cited and relevant articles are published in two dominant journals - “Energy” and “Applied energy” which are not financial-economical profiles. CO2 reduction and energy efficiency can be obtained by researching a wide spectrum of disciplines and technical solutions from area such as: fuel cells with carbon capture (Wang et. al., 2020); Gasification process for power plants (Salman et. al., 2018; Carvalho et. al., 2018), Jatropha biodiesel-fired power plants vs other types of power plants (Somorin and Kolios, 2017), electricity production solutions with low level of CO2 emissions (Campanari et. al., 2014). All the technical solutions researched in the papers of the Economic analysis cluster also include the analysis of the economic impact of the presented solution. Indeed, this is the lowest level of granularity where technical specialists are extracting the environmental benefits out of CO2 reduction, increasing the energy efficiency etc. Even though the cluster “economic analysis” is dominated by technical solutions for CO2 emissions reduction and different alternative ways to produce energy, every solution has assigned the economic impact analysis. Such projects indirectly influence the corporate financial performance; in case the technical sustainable initiatives are implemented in practice. Moreover, all the solutions contain an important part of R&D, and these are academic examples related to the earlier R&D proxies and innovations

analyzed in connection to energy efficiency and corporate financial performance. Critically speaking this cluster envisage the transposition of the “Energy efficiency cluster” but with a lower technical and informational granularity. To create research initiatives in such areas the authors should also have a certain non-academic motivation. Considering the years of publications of the articles we conclude that the regulatory frameworks and policies are strong non-academic motivation drivers and stimulus for academia to find solutions to reduce CO2 emissions, increase the energy efficiency etc., which ultimately impacts the competitiveness of the business organizations and the countries.

#### **Performance assessment cluster**

To identify the articles that are the most relevant for the “Performance Assessment” cluster we combined two sets of information: the most cited articles and the co-occurrences of the depicted keywords. The performance assessment cluster brings research papers which study wide variety of technical solutions, mainly in the alternative electrical and thermal energy sources for civil and residential contractions. As the title of the cluster is indicating, it is about the performance assessment, which mostly refers to the technical projects. This cluster gathers research papers which approach technical engineering aspects in the energy field to find optimal solutions to reduce the carbon footprint. Considering the selection criteria, all papers were published after 2015 which is interesting, meaning that academia started to find solutions after Paris Agreement in 2015.

As the energy efficiency is a “low-hanging fruit” that represents one of the pathways towards reducing CO2 emissions and mitigating climate change, it was found that about 25% of it can be reached by using current technologies and other 20% can be reached through innovations (IPCC, 2014). The research topics in this cluster combine renewable energy solutions with energy efficiency as follows: solar vs heat pumps as energy source for different purposes (Calise, et. al., 2016; Liu et. al., 2021; Fan et. al., 2020), the efficiency of using geothermal heating as an alternative source of energy (Nian and Cheng, 2018; Buonomano et. al., 2015), innovative solutions of thermal energy for residential buildings (Ruan et. al., 2016; Sorace et. al., 2017) etc. Most of the papers research the impact of engineering solutions from the perspective of their performance as an important part of energy efficiency. Moreover, energy efficiency has a technical matrix approach, it refers to both electrical and thermal energy including also heating and cooling parts.

To succeed with energy efficiency solutions through end-to-end implementation, governments and policymakers should provide a proper support at different levels: for academia and companies in R&D to promote innovative solutions, to provide financial assistance to prototype the inventions, to provide regulatory support authorizing the usage of unconventional sources of energy etc. In this sense, an important initiative was completed by EU through the National Recovery and Resilience plans which account investment for energy sector of about EUR 88.49 billion (17.9% of their resources) in the policy area. Thus, EUR 54.85 billion is earmarked only for energy efficiency measures and the rest for clean energy (mainly devoted to finance the renovation of buildings especially in residential sector). For example, in Romania the funds will be directed towards energy renovation of private and public buildings, the mechanisms for improving EE in industry (e.g., reducing energy consumption and enhancing energy self-consumption) and financial support in EE areas for SME (EPRS | European Parliamentary Research Service, oct 2022).

#### **Optimization and waste heat cluster**

To identify articles that are the most relevant for the “Optimization and Waste Heat” cluster we combined two sets of information: the most cited articles and the co-occurrences of the depicted keywords. The optimization and waste heat cluster brings research papers which focus on a narrow topic, obviously connected with the previous clusters but this time focused on the optimization and waste heat. Indeed, waste heat is one of the core components of the Energy Efficiency area and this is the reason why EU is allocating huge financial resources to mitigate these issues, especially for buildings in the residential sectors. Different technical aspects connected to the optimization and waste heat are researched, including the assessment of financial and economic impact of these solutions. It is worth mentioning certain articles that reflect better on the specifics of this cluster. CO2 reduction is the main target and research topic through optimization and recovery of waste

heat especially in the case of (diesel) engines which ultimately bring economic and environmental advantages (Shu et. al., 2017; Yang and Yeh, 2015). Other aspect which was researched is the management of waste heat in the context of electricity production which again has an impact of CO2 emission reduction (Xu et. al., 2015; Feng et. al., 2015).

Energy efficiency is not about electric or thermal energies, it is a complex mechanism that requires huge resources (e.g. financial, intellectual, legal, policies etc.) in order to reap the benefits and to further achieve the climatic targets. Moreover, energy efficiency is about improving competitiveness through sustainable development therefore the focus on this topic (both financial and non-financial) is crucial.

### **Which companies should focus on performance duality energy efficiency and corporate performance?**

Energy efficiency concerns multitude of “stakeholders” which are divided in two categories, producers, and consumers. On top of this, there are also regulators who are creating political and regulatory prerequisites to implement the mechanisms of EE. Their common goal is to contribute to the achievement of climate targets and the Nationally Determined Contributions (NDCs). Moreover, the EE undertakings play an important role in stabilizing the possible shortages of energy supplies in the times of crisis (e.g. COVID19, military conflicts etc.) (IEA, 2022). At the global level, United Nations, International Energy Agency, and European Commission play key roles in supporting the development of EE initiatives as an important pillar for global sustainable development. Also, the cooperation between these organizations is a strong signal of importance of their roles. For example, IEA and EU Commission work together on raising awareness and providing measures to national governments in the EU helping SME make the energy use and expenses more efficient, mainly in the current energy crisis (IEA, 2022). (Boakye et. al., 2020) academically found a strong relationship between financial performance and environmental practices through energy efficiency for listed SME from United Kingdom including the effect per industry. From the current literature research, we can identify different types of actors which are involved directly or indirectly in the process of adopting, implementing, and innovating the energy efficiency solutions. Firstly, industrial producers and consumers of energy resources are impacted as the energy factors influence, consistently and directly, their environmental and corporate financial performance. The classification of industries is made by IEA where the CO2 emissions are considered as primary factor, which in the end is highly related to the energy consumption (IEA, 2015). Thus, according to their classification, they have: electricity and heat production companies, other energy industry own use, manufacturing industry and construction, transport and other sectors, and residential. (Carmen-Pilar and Martí-Ballester, 2017) in their research include companies from 36 countries which activate in industries with high, medium, and low environmental impact. Surprisingly they found no relationship between types of industries and corporate financial performance. Moreover, the correlation coefficients between industry types and EE are low. An empirical analysis was conducted by (Moon and Min, 2020) on Korean companies from non-metal and food industries. These types of companies were chosen because of the regulatory requirements imposed by the Korean government through the “Target Management System in Korea”. Besides industry, the energy efficiency impact was divided into pure energy efficiency and subsequent impact which is economic efficiency. The authors concluded that energy intensive companies which increase/improve the pure energy efficiency factors will improve significantly the corporate financial performance. In our research area the inclusion of sector activity is an important driver for: energy consumption, CO2 emission and impact of energy efficiency on financial performance. The contrast: low energy intensity vs high energy efficiency with positive impact on corporate financial performance was revealed to Chinese companies from the following sectors of activity: electricity production, steel, chemical, and aviation (Fan et. al., 2020). These results strongly contradict those critics on the lack of financial benefits for those companies that improve the energy intensity through efficiency. As shown before, the manufacturing energy intensive industries are benefiting mostly from energy efficiency

implementation mechanisms no matter if companies are acting in developing or developed countries (Bergmann et. al., 2017; Lui et. al., 2021).

Concluding, in the literature the evidence on the level of development of the regulatory framework regarding the energy efficiency policies in developed and developing countries was not found – this aspect represents a research gap which should be approached in the future. The importance of this research gap consists of the dynamics and spillover effect of sustainable finances and innovations from developed countries to developing ones to achieve the climate targets through energy efficiency. The sensitivity of energy efficiency towards corporate financial performance was shown to be higher for EU companies in the period when European Union Emissions Trading Scheme was launched in Europe. The pressure of reducing CO2 emissions through EU ETS for energy intensive companies determined them to trigger the EE mechanisms through innovations from the following perspectives: increasing the competitiveness of companies through sustainability, increasing the company's agility through cost reduction, higher energy prices and risk for energy shortages (Makridou et. al., 2019).

### **How to measure the impact of the energy efficiency on the corporate financial performance?**

Energy efficiency is a generic concept that derived from the humanity willingness to mitigate the climate change. Due to its abstract and generalized character, it is difficult to find the best fit measurement mechanism to quantify the level of connectedness between energy efficiency environmental performance and corporate financial performance. The energy efficiency measurement is also an important subject and metric for non-financial/ESG reporting which might raise questions about the comparability and transparency. Moreover, the abstract character of the EE creates difficulties in defining methodologies for empirical research and creating comparability of the results. Nevertheless, the researchers made attempts and proposed research methodologies to reveal the impact and relationships between EE, environmental performance, and corporate financial performance. There are two important elements in the current questions: how to measure the EE and which methodology to use to discover its impact on corporate performance. In the identified literature two streams of metrics and methodologies were identified to quantify the dynamics and sensitivity of EE towards corporate financial performance. The classical approach, much simpler, where energy efficiency is researched through the lenses of energy intensity. While the second approach refers to the DEA (Data Envelopment Analysis) which include output and input approaches in terms of energy consumption.

(Carmen-Pilar and Martí-Ballester, 2017) were among the first (within energy intensity theme) to reveal the influence of EE on the CFP. The key formula they used is shown below.

$$EE = \frac{\frac{EC_t}{Sales_t} - \frac{EC_{t-1}}{Sales_{t-1}}}{\frac{EC_{t-1}}{Sales_{t-1}}}$$

Thus, EC denotes the total energy consumption in gigajoules (GJ) divided by net sales of company *f* at time *t* or at time *t-1*. The EE represents the reduction or growth in energy efficiency for a period which is adjusted by sales (yearly variables). A negative value for the indicator means lower energy consumption which is higher energy efficiency. Renewable energy sources in the *t-1* are an instrument that defines the level of integration of energy efficiency system and renewable energy and shows the quantity of renewable energy used. To test the hypothesis, the authors used the dynamic panel data model, which is basically trying to capture the continuous improvement character of Energy Efficiency mechanisms. Similar research approach was used by (Bergmann et. al., 2017) where the EE factor was quantified as an indicator of energy consumption in (GJ) to net sales revenue, depicting a proxy for the volume of activity (Anderson et al., 2003).

(Moon and Min, 2020) in their research analyzed the limitations of different methods to measure the energy efficiency. For example, measuring the EE based on energy intensity will be insufficient, because it depends on the industry, company size, production process, etc. The energy

intensity measures the consumption of energy per unit of output compared to the changes in the energy consumption (Bergmann et. al., 2017) which further is correlated with the company's net sales.

The authors proposed a more complex and representative approach which takes into consideration the limitations of measuring the EE by using other methods. They use two-stage DEA model for a multiperiod scenarios to identify the changes of EE during each period which can be further compared econometrically with corporate financial performance. This method is also considering the conditions of multiple variables "without any statistical distributional residual noise" (Mohammadi et al., 2013). The two-stage structure refers to the following: in the first stage it measures the pure-energy efficiency and in the second stage it measures the economy efficiency. Additionally, the pure energy efficiency will include the energy factor utilized by companies as input in the production process and cost of goods sold (COGS) as output factors (primary factor) and greenhouse gas (GHG) emissions as secondary undesirable output factor. For the second stage of efficiency the annual sales volume was used as output factors. A slightly different DEA methodology was applied by (Haider et. al., 2019) who researched the impact of EE on the performance of Indian companies acting in paper industry by using DEA model. Their research approach on the DEA model is different as they use two variants of DEA based on proportional and non-proportional reduction in inputs. The following expression to calculate the energy efficiency factor was used:  $EE = \frac{OEU}{AEU} = \frac{AEU - ES}{AEU}$ . OEU is optimal energy use, AEU is actual energy use, ES is energy slack. Further, with the obtained results the panel regression across firms and periods was used to reveal the influencing factors of EE.

(Boakye et. al., 2020) use methodological approach that aims to reveal the relationship between environmental performance and practices (divided in structural factors) and corporate financial performance. Energy Efficiency is a structural component of corporate environmental performance that is extracted from non-financial performance reports of UK listed SMEs. Companies should disclose the following information about EE measures (Energy): reduction in energy use/savings, cost savings in energy use (Gas and electricity), fuel savings for using light weight cars and plants, efficient use of energy/energy saving devices, improved use of alternative energy/others. Further this information is regressed (OLS) towards financial performance indicators – ROA and Tobin's Q.

In addition, the academic literature has discovered a different research mechanism regarding the relationship between corporate energy efficiency systems and corporate financial performance. For example (Lui et. al., 2021) do not reveal anything interesting about the environmental performance through the lenses of energy efficiency. The aim of the research is to show the direct effect of energy efficiency systems on corporate financial performance from the perspective of institutional/stakeholder's pressure (e.g. government, NGO, etc.). The propensity of company for energy efficiency system was created by using the text analysis throughout news articles in Factiva database. Methodologically, (Lui et. al., 2021) employed long-horizon event study to reveal the causal link between energy efficiency system (EES) implementation and corporate financial performance – used mainly to examine the impact of corporate initiatives in relation to external factors (Lui et. al., 2016).

The metrics for corporate financial performance refers to both, accounting, and capital markets measurement. The authors use these two approaches to capture the full spectrum of influences of environmental performance (measured through energy efficiency) on corporate financial performance. In our research we already mentioned some metrics that belong to both classes (e.g. return on assets, return on capital employed, Tobin's Q etc.)

Concluding, the EE measurement needs more research for refinement and calibration of performance duality of EE and CFP. We found the dominating quantification mechanisms are energy intensity factors and energy efficiency measurement through DEA. The development of non-financial reporting where companies will be required to disclose more non-financial information, especially ESG, will allow academic community to run more accurate analysis on the impact of environmental performance on the process of corporate value creation.

### **What is the impact and magnitude of the duality energy efficiency and corporate performance?**

Due to the recent world crisis contexts (e.g. COVID 19, military conflicts in Europe, Asia etc.) the EE became an instrument which (besides economic and environmental roles) is playing a role in energy security especially for EU. This means that additional accelerators for energy efficiency mechanisms attracted more investments and brought more benefits. According to the latest market report issued by International Energy Agency, global investments spendings in energy efficiency reached about USD 560 billion in 2022 representing an increase of 16% compared with 2021 (e.g., investments in building renovations, public transport electric cars infrastructure etc.). In addition, according to the IEA report issued in 2022, since 2000 the total energy savings in IEA countries are set to be USD 680 Billion less than it would be otherwise (compared to 2022). In 2022 the global economy used energy more efficiently by 2% than in 2021, which is the best energy consumption achievement in the last 5 years. It seems that the impact of energy efficiency mechanism is huge, meaning that these undertakings should continue further.

These achievements were possible because of the following factors: more commitments from companies towards complying with environmental performance, the reconfiguration of the global energy market from the past 4 years, the development and progress of global energy efficiency policies which accelerated the implementation of energy efficiency initiatives, and the evolution and disbalances of the global energy prices.

The economics of energy efficiency have the following functional pattern: the implementation is directly related to the price of energy factor. If the price goes up so does the attraction of economic agents to initiate investment programs for energy efficiency purposes. The consumer for the EE effect will not be willing to pay extra to internalize EE mechanism into their consumption patterns, therefore, the regulators should intervene to rebalance this aspect. (Brennan, 2013) analyzed the economics of energy efficiency and energy use in the context of dynamics of market price. When referring to the EE policies including policies for renewable energy facility production the following aspects should be considered: the internalization of the environmental protection initiatives in the unit production costs of electrical energy, the main premises for setting up the EE policies should be that EE output should not be treated as a substitute but rather a complement in the consumption process, rebalancing the energy costs for both producers and consumers through EE regulatory mechanisms.

To provide a smooth and efficient transitory mechanism from fossil fuel to clean sources of energy production central authorities should provide economic and financial support to achieve the climate and energy targets. As mentioned above, the EU has allocated enormous budget for energy efficiency set up at different levels across the European region. The quality and policy efficiency will ensure either success or failure in implementing the Energy Efficiency initiatives – their aspects were analyzed by (Aste et. al., 2018) using Lombardian region in Italy, looking at public and private sector entities for a period of 15 years. For example, an analysis performed by (Caragliu, 2021) across Italian firms acting in paper and glass industries showed that there is a positive association between EE policies support and firms' performance. This means that companies which receive government support to reduce energy consumption (higher EE) will be more productive and efficient.

Besides financial support from central and local authorities to ensure the transition towards green economy through energy efficiency mechanisms, the private financial sector should also be efficiently connected to this process through sustainable finances. China was among the first countries in the world to understand the importance of sustainable finances for transition towards green economy. They took actions in creating the baseline for "financial inclusion". Chinese succeed through fast-expanding technology banking system that optimizes the communication and the value chain of country financial system building a healthy association between state, banking institutions, and business. Empirically it was proved that financial inclusion can significantly influence the green economy efficiency especially for energy and climate change performance (e.g., through energy efficiency mechanisms). Financial inclusion means tightening credit restrictions for

pollution companies and increasing financial benefits for companies willing to become green through innovation and structural revolution (Liu et. al., 2022).

#### 4. RESULTS AND CONCLUSIONS

Energy efficiency is an important component for environmental protection and sustainable development both at micro and macro levels. As illustrated in the analyzed academic literature, this is due to a “low-hanging fruit” in transition towards green economy. In the analysis of the current literature, we used a unique methodology that combined machine-based content analysis and OLAP principles identifying the most relevant research articles for each identified cluster of keywords as follows: Energy Efficiency, Economic Analysis, Performance assessment, Optimization, and waste heat. The energy efficiency is not a new mechanism for mitigating the climate change proposed by researchers. Initially, energy efficiency was used as a mechanism for companies to increase its competitiveness through a better management of energy factors, in other words increasing the organizational competitiveness via innovation and sustainability. It was found that the research topic about the relationship between corporate financial performance and energy efficiency is relatively new, indeed, more extensively the focus of academic community was on the relationship between corporate performance and sustainability/environmental performance of the company. Today, as the topic of sustainable development and environmental protection becomes more complex the academic research approach requires a more detailed and disseminated analysis of the structural factors of sustainability (e.g. ESG index vs environmental social governance analysis as standalone components). Moreover, the energy factor has a double role, it is the most important existentiality factor of development of many economies in the world the structure of which will create competitive advantage for micro and macro levels of economic systems development. Secondly, the energy factor is tightly connected to the CO<sub>2</sub> emissions. These are the reasons why energy efficiency mechanism is important, as through energy efficiency additional energy factor is released without eliminating additional CO<sub>2</sub> quantities.

Considering these arguments, the energy efficiency mechanisms were included in the problematics of environmental protection and climate change mitigation. This area is a strategic direction for International Energy Agency, which is actively promoting energy efficiency from the perspective of innovation technologies, policies development and economic and financial impact for those economies that embrace it. In the current literature review it was found that Energy Efficiency as an influential factor for micro and macro level should be considered in relation with other structural components which might affect either the macroeconomic development of the country or corporate financial performance. At macro level Energy efficiency was analyzed in the context of the quality of the regulatory framework, or level of R&D or structure of fiscal policies, or level of renewable energy production development. At micro level, energy efficiency was analyzed together with environmental performance of the company, structure of corporate governance and its influential power, the industry the company is acting in (e.g. energy intensive industry), the level of ESG reporting etc.

The global economy will change its structure soon, considering the environmental commitments of many countries for 2030 and for 2050. Besides environmental aspects social and corporate governance aspects are treated separately based on Paris Agreement from 2015, moreover sustainable development goals per each country should be achieved. For this reason, non-financial reporting is getting more and more popular in the global business and financial community. However, non-financial reporting requires more details to be disclosed about energy efficiency mechanisms companies implemented and metrics they were supposed to achieve. Concluding, this is an important prerequisite for further and more accurate research about the performance relationship between energy efficiency and corporate financial results and value-added creation.

Although, we interrogated only social and economic areas looking for the most relevant articles for our research topic most of the articles were technical (e.g., clusters: Economic Analysis, Performance Assessment, Optimization and Waste Heat). Until recently, the analysis of the

relationship between energy efficiency and corporate financial performance was not so popular because of the stability in the regional and global energy markets. Due to the recent global pandemic crises the regional and global energy stability was broken and the academic community became more interested in the impact of energy factors on corporate financial performance - therefore most of the papers were published in the last 5 years.

The main opposing academic opinions about the lack of impact of energy efficiency refer to the level of investment to achieve a certain energy saving benefits, and that the impact is only for short term. Moreover, the energy efficiency is very sensitive to the energy prices: lower energy prices will not stimulate investments in energy efficiency mechanisms or renewable energy production. For this reason, in the academic literature, it was found that a strong policy regulation in the field of environmental protection through energy efficiency is needed. At the EU level the regulatory framework and policies set for this purpose are solid which consequently attracted important investment resources for implementation of energy efficiency mechanisms (e.g. through the National Recovery and Resilience plans for energy efficiency problematics were allocated EUR 54.85 billion).

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