Hacettepe University Graduate School Of Social Sciences

Department of Economics

ESSAYS ON THE REBOUND EFFECTS OF THE ENERGY EFFICIENCY

Songül TEKELİ

Ph. D. Dissertation

Ankara, 2022

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ABSTRACT

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The industry contributes the most to the world's energy savings in all sectors through more efficient energy use (IEA, 2018). Yet, the literature provides evidences that the potential Energy Efficiency (EE) savings in the industry are not fully achieved. The gap between the potential EE measures and the actual implemented measures is called "energy efficiency gap" and might offset the increase in energy savings. In this thesis, we firstly measure the size of energy efficiency gap, resulted from the energy efficiency improvements (EEI) aiming to save electricity and heat within the fourteen sub-sectors in the Turkish industry. Secondly, we reveal the reasons for the energy efficiency gap by focusing on behavioural and organizational responses to EEI the Turkish industry. To this end, we developed a questionnaire, which consists of questions that if the implementer of an EEI considers a factor as a barrier and driver. We conducted a questionnaire survey with 135 industrial enterprises that have completed at least one state-funded Efficiency Improvement Project (EIP). 86 of them responded to the survey. The results show that the energy intensity level and scale of enterprises take the lead in the importance of perceived barriers and drivers. The findings also suggest that the average scores of the perceived barriers in Small and Medium-sized Enterprises [SMEs] are mostly higher than those in Large-sized enterprises [LEs]. This finding reveals that the tendency of considering a factor as a barrier diminishes as the scale becomes larger. Finally, we applied the PLS-SEM methodology to the primary data. Specifically, the results demonstrate that increasing awareness, improving techno-economic capability, reinforcing subsidies and incentives, mitigating economy, information, and competence-related issues would result in improving EE. If the performances of EIPs, sectoral experiences, and good practices about them, energy conservation opportunities through them are shared among the firms, EE improves.

Keywords

Industrial energy efficiency, Rebound effect, Barriers, Motivations, Drivers, SMLEs, PLS-SEM

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ABBREVIATIONS AND SYMBOLS LIST

AS	Actual Energy Savings
AVE	Average Variance Extracted
BE	Backfire Effect
CA	Cronbach's Alpha
CH_4	Methane
CO_2	Carbon Dioxide
COP	Conference of the Parties
CR	Composite Reliability
CS	Calculated Energy Savings
EB	External Barriers
EE	Energy Efficiency
EEED	Energy Efficiency and Environment Department
EEI	Energy Efficiency Implementations
EIP	Energy Improvement Project
EIS	Energy Intensive Sectors
EM	External Motivations or Drivers
ESCO	Energy Service Company
GHG	Greenhouse Gases
HOC	Higher Order Construct
HTMT	Heterotrait-Monotrait Ratio
IB	Internal Barriers
IEA	International Energy Agency
IM	Internal Motivations or Drivers
ISO 50001	International Organization for Standardization 50001
LE	Large-Sized Enterprise
LOC	Lower Order Construct
PLS-SEM	Partial Least Square Structural Equation Modeling

NEIS	Non-Energy Intensive Sectors
N_2O	Nitrous Oxide
MENR	Ministry of Energy and Natural Resources
QS	Questionnaire Survey
RE	Rebound Effect
R&D	Research and Development
SEF	Stochastic Energy Demand Frontier Model
SME	Small-sized and Medium-sized Enterprise
TMMOB	Chamber of Mechanical Engineers
TOE	Tons of Oil Equivalent
UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor
YEGM	General Directorate of Renewable Energy

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PREFACE

I am very grateful to the Scientific and Technological Research Council of Turkey (TUBITAK) for supporting this thesis between 2019 and 2022 with Grant No 119K204. In this regard, I acknowledge that this thesis is prepared with the support of the TUBITAK 1001 project titled "The Direct Rebound Effects of Energy Efficiency Improvement Projects and Barriers and Drivers of Energy Efficiency in Turkish Industry Sector".

INTRODUCTION

Climate change due to global warming has become one of the major challenges of the world. It is an unfortunate consequence of the increasing amount of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere since late 1800s. This problem has been arising mainly because of human activity, more specifically, fossil fuel consumption, i.e. energy use. More than 70 countries account for more than 80 percent of carbon dioxide (CO_2) emissions which is the main gases responsible for the GHG (McKinsey, 2022). In order to handle global climate change, many countries determine common goals and road maps to reach these goals. In this regard, the Paris Agreement, which is an international treaty adopted by 196 parties in 2015, constituted to keep the mean global temperature increase below 2, preferable 1.5, degrees Celsius by 2100 compared to pre-industrial levels. In line with these goals, the Parties adopted the Glasgow Climate Pact in 2021 with a specific reference to energy efficiency (EE) in the process of the Conference of the Parties (COP). This was the first time EE has been explicitly cited. Article 36 calls on Parties to "accelerate the development, deployment and dissemination" of actions including "rapidly scaling up" EE measures.

The industry sector accounts for a large share of the world's final energy consumption. Therefore, improving industrial EE is one of the most efficient (also cost-effective) approaches to diminishing global energy use, fossil fuel consumption and CO_2 emissions (Trianni et al. 2016). According to Intergovernmental Panel on Climate Change, if the industrial enterprises use energy more efficiently, they can reduce CO_2 emissions by 61% in 2050 compared to 2018 (IPCC, 2022). Moreover, Sorrell et al. (2004), Sardinanou (2007), and Thollander and Dotzauer (2010) also claim that energy efficient applications in industry sector have a bigger impact on global energy consumption and CO_2 emissions than in other sectors.

Nevertheless, there is a gap between potential EE measures and the actual implemented EE measures (also tools and investments, EEI hereafter as short) (Sorrell et al., 2004;

Sardinanou, 2007; Thollander and Dotzauer, 2010). This is referred to as ‘the rebound (or take-back) effect (RE)’, ’Jevons Paradox’, ‘the energy-efficiency gap’ or ‘the energy paradox’ in the related literature (Jevons, 1865; Jaffe and Stavins, 1994). RE or the energy-efficiency gap occurs when the real unit price of energy service decreases through replacement or usage of more efficient technology, leading to both substitution and income effects which could lower or neutralize the full energy-savings based on engineering type of calculations (Amjadi et al., 2018). In order to fully benefit from the EEI, it is essential to measure the size and explore the factors affecting the EE gap.

The goal of this thesis is to investigate the size of EE gap and barriers and drivers (instead, the term “motivations” is also used) causing or reducing the EE gap from the perspective of the small, medium and large size firms. We use data calculated by the engineers on site and primary data from the Turkish industry. This thesis consists of three related studies. In particular, these three studies examine the results of a specific supporting mechanism financed by the state for improving EE in terms of energy savings’ level, the size of EE gap, the reasons and their importance for the EE gap by focusing on behavioral and organizational responses to EEI. Therefore, our main contribution to the literature is that we reveal the production-side EE gap and its reasons by using broad and detailed classifications as well as the responses of the energy experts on-site in the process of EEI.

In the first study, we measure the size of direct REs, resulted from the EE improvements aiming to save electricity and heat within the fourteen sub-sectors in the Turkish industry. We prefer to investigate the direct REs of production-side of Turkish industry sector for several reasons. Although RE has been investigated by numerous studies and categorized in two main separate forms: direct RE and indirect RE (Greening et al., 2000), the direct RE is used to show the case of an increased level of consumption of energy service where the EE enhancement occurs. Besides a large number of studies have measured the consumer-side REs for energy demand on transportation, space heating, and space cooling. However, there are few studies considering the production-side REs of EE improvements. In order to fill this gap, we aimed to calculate the production-side REs of Efficiency Improvement Projects (EIPs) completed by industrial enterprises since 2009. We raise a special focus on Turkey because it initiated a transformation process to decrease energy intensity through efficiency improvements in primary and end-use energy consumption in industry, housing, and transport sectors since adoption of The Energy Efficiency Law in 2007. The Turkish government has been financing up to 30% of the cost of EIPs, which are proposed by the firms in the industrial sectors since 2009. The total amount of subsidies via completed 175 EIPs has reached approximately 5 million US Dollars ($). However, despite the allocation of a significant amount of financial support via the EIPs, the direct REs have arised from these EIPs have not yet been measured in the literature. In this study, therefore, we calculate direct REs by using the firm-based data of the 30 completed EIPs to save heat and 145 completed EIPs to save electricity, by fourteen sub-sectors in the Turkish industry. The results of this study show the potentials of energy-savings amounts due to EIPs based on the fuel type and the sub industry sectors.

In the second study, we examine the factors and the relative importance of them from the perspective of the energy experts who work at the enterprises that have implemented at least one EE improvement. Several disciplines, namely engineering, economics, behavioural and organizational studies have made contributions to EE literature by means of investigating barriers (Soepardi et al.,2018; Cagno et al., 2013; Trianni and Cagno, 2012; Kostka et al., 2011; Okazaki and Yamaguchi, 2011; Palm and Thollander, 2010; Oikonomou et al., 2009; Schleich et al., 2008; Shi et al., 2008; Sardianou et al., 2008; Schleich and Gruber, 2007; Anderson and Newell, 2004; De Groot et al., 2001; Harris et al., 2000). They have concentrated on the barriers and failures (Hassan et al., 2017; Trianni et al., 2013a) due to the large potential in that sector for further EE improvements. Wang et al. (2018) pointed out that the scholars have paid less attention to drivers compared to the number of the studies investigating potential barriers in the industry sector. However, promoting the driving forces that lead enterprises to adopt EE measures might be as effective as mitigating barriers to close the EE gap. In addition, since there are a variety of tools, measures and investment opportunities to enhance EE, it is important to identify the most highly prioritized factors that affect them. In order to fill this gap, we develop a questionnaire survey (QS) consisting of many factors for barriers and drivers based on the literature review. By doing so, we include more broad and detailed classifications for better understanding of the empirical factors and building a sound and viable policy recommendation. This study uses primary data from the Turkish industry. The responses are gathered from 14 sub-sectors and represent 63.7% (86 out of 135) of the population of all industrial enterprises completed EIPs. This study reveals the top ranked and significant barriers and drivers based on the energy intensity levels as well as firm-size. This study also provides some insights into improving work and experience related with EEI.

In the third study, we shift our focus to whether industrial barriers and/or drivers have significant effects on EEI in a developing country such as Turkey. To this end, we apply a broad approach to modelling while simultaneously analyzing all possible barriers and drivers from the QS which include 9 categorical barriers with 51 indicators and 8 categorical drivers with 37 indicators. To deal with such a complex model with many constructs, indicators and structural paths; we employ Partial Least Square Structural Equation Modeling (PLS-SEM) method by using a higher order construct model with Dis-joint Two-Stage Approach to modelling and the Repeated Indicator Approach for the higher order constructs to test the research hypotheses. Building such a complex model by taking into account both barriers to and drivers for EEI is important as the recent literature mostly considers barriers to and drivers for EE separately (Kostka et al., 2013; Du et al., 2016; Backman, 2017). Nevertheless, the studies that investigate both barriers to and drivers for EE (Hasan et al., 2019; Lawrence et al., 2019) have a limited scope in terms of the sub-industrial sectors and/or the sizes of the enterprises (Trianni et al., 2014; Hrovatin et al., 2021). In this study, we include the enterprises of any size from all sub-industrial sectors while investigating both barriers and drivers. Thus, we fill the gap of limited scope of similar studies by applying PLS-SEM to investigate both barriers and drivers in a very comprehensive approach. Finally, we suggest some recommendations on how to raise the willingness of EEI by the industrial enterprises.

The dissertation continues in Chapters 2, 3 and 4 with the three studies described above. In Conclusion, we summarize the main findings of the three study, and discuss limitations for future research.

CHAPTER 1

THE REBOUND EFFECTS OF ENERGY EFFICIENCY IMPROVEMENTS IN THE INDUSTRY: EVIDENCE FROM TURKEY

ABSTRACT

The major part of the energy savings made in the world is done by the industry sectors through energy efficiency improvements. However, the behavioral responses to them, called rebound effects (RE), might offset the increase in energy savings. In this study, we measure the size of REs, resulted from the energy efficiency improvements aiming to save electricity and heat within the fourteen sub-sectors in the Turkish industry. The novelty of this study is twofold. The first is to measure the production-side RE by applying the energy savings approach. The second is to use the firm-based data of the completed 175 Energy Improvement Projects (EIPs), financed by the government between 2009 and 2019. The results of this study reveal that RE range from a very high negative backfire effects to a very small partial rebound. The rebound effects are negative in 86 out of 175 EIPs. Therefore, we find unexpected efficiency gains rather than efficiency losses. The results of this study suggest that promoting energy efficiency improvements has proved to be an effective tool to increase the overall energy savings, and to diminish industrial energy intensity and CO_2 emissions.

Keywords: Industrial energy efficiency; Energy efficiency improvement; Rebound effect; Prebound effect; Negative Backfire Effect.

1.1. INTRODUCTION

Increasing energy demand, climate change, and environmental issues have recently led EE improvement to be a major energy policy target in many countries since it is considered as a costless approach to conserving energy (Gillingham et al., 2009). In particular, the International Energy Agency reported that EE gains saved an additional 12 percent of final energy use in major economies between 2000 and 2017 (IEA, 2018). However, despite the widespread implementation of EE policies over the last two decades throughout the world, energy consumption has grown (Saunders, 2013). This has raised the question of whether the increased level of energy consumption can be compensated by the increase in energy savings. This paper aims to address this issue by focusing on the energy savings of the industry sectors through the EE improvements.

The major part of the energy savings made in the world is done by the industry sectors through more efficient energy use (IEA, 2018). In particular, the EE gains in the industry has caused more than half of the savings since 2000. Therefore, diminishing the overall energy demand of a country, and maximizing the energy savings depends on efficiency gains in the industry, which makes promoting EE policies in this sector to be very crucial. Besides, initiating new efficiency policies, evaluating EE programs, and analyzing their outcomes require to take into account the discrepancies between actual and foreseen savings due to behavioral responses to EE improvements. This is called the “the rebound (or take-back) effect (RE)”.

RE occurs when the real unit price of energy service decreases through replacement or usage of more efficient technology, leading to both substitution and income effects which could lower or neutralize the full energy-savings based on engineering type of calculations (Amjadi et al., 2018). A RE of 0 percent means the full achievement of planned energy savings, whereas 100 percent means complete loss of planned energy savings (Jin, 2007).

RE was first introduced to the energy economics literature by Jevons (1865) while discussing whether the efficient use of fuel was necessarily equivalent to a diminished consumption of fuel in Britain. This concept is also known as "Jevons Paradox". Since Jevons (1865), RE has been investigated by numerous studies and categorized in two main separate forms: direct RE and indirect RE (Greening et al., 2000).[1] Direct RE is the case of an increased level of consumption of energy service where the EE enhancement occurs. It can be linked to a price effect of an increase in EE, which eventually increases the demand for energy. Therefore, the direct RE stems from the substitution effect of the decrease in the real unit price of energy service. The indirect RE, or secondary effect, is the case of an increased level of other energy services with the money saved as a consequence of an EE increase in some energy services. Namely, it concerns further impacts on energy demand for other energy products and services. Hence, indirect RE occurs because of the income effect that is yielded via the decrease in the real unit price of energy service.

In the literature, even though Jevons (1865) initiated RE discussions for industrial EE, a large number of studies have measured the consumer-side REs for energy demand on transportation, space heating, and space cooling. Unlike the number of studies investigating the consumer-related REs, there are few studies considering the production-side REs of EE improvements.

As a pioneer, Saunders (1992) established the first known theory of the production-side RE by using the neoclassical growth theory and demonstrated the possibility of backfire as a result of EE improvements. Bentzen (2004) estimated the direct RE in the US manufacturing sector by applying the translog cost function for the period of 1949-1999. The study revealed approximately 24 percent for the direct RE for the US manufacturing industry. Saunders (2013) measured the size of RE for the US economy and 30 different sectors using data covering 1960-2005. He estimated the average size of REs as 121% for 1980-1985; 75% for 1985-1990 and 60% for 1990-1995 for 30 US sectors, respectively. Zhang et al. (2017) estimated RE for the Chinese aggregate

[1] In the literature, apart from direct and indirect RE, two more categorizations of RE are also coined: Economy-wide RE and transformational RE (Greening et al., 2000). The economy-wide RE is a measure of the total rebound throughout a country's whole economy, as a result of all the energy efficiency improvements in that country. The transformational RE occurs when an energy efficiency increase results in social and organizational change, increasing the need or demand for a more energy-efficient product.

industry by adopting the Logarithmic Mean Divisia Index (LMDI) method and found an energy RE of Chinese heavy industry ranging from 20 percent to 76 percent between 1995 and 2012. However, the energy RE in the manufacturing sector is calculated approximately 28 percent on average.

To the best of our knowledge, only two studies have been conducted on energy REs for Turkey. Topallı (2012) examined the direct RE of households' electricity consumption by employing autoregressive distributed lag (ARDL) model for the period of 1964-2009 and found that the direct RE is 18 percent. Somuncu (2016) estimated economy-wide RE, a measure of the total rebound throughout the country's whole economy. Somuncu (2016) used a computable general equilibrium model based on the 2002 Turkey Input-Output table from the Turkish Statistical Institute. In the study, two EE policies are introduced to the model: energy certification for buildings and mandatory energy labeling for household appliances. The simulations for both scenarios indicate economy-wide RE ranging between 18-19 percent. Hence, Topallı (2012) and Somuncu (2016) took into consideration merely the consumer-side RE for Turkey.

Nevertheless, Turkey is a very good candidate to examine production-side RE. By launching The Energy Efficiency Law in 2007, Turkey initiated a transformation process to decrease energy intensity through efficiency improvements in primary and end-use energy consumption in industry, housing, and transport sectors. The Turkish government has been financing up to 30% of the cost of Efficiency Improvement Projects (EIPs), which are proposed by the firms in the industrial sectors since 2009. The total amount of subsidies via completed 175 EIPs has reached approximately 5 million US Dollars ($). However, despite the allocation of a significant amount of financial support via the EIPs, the direct REs arised from these EIPs have not yet been measured in the literature.

Measuring the direct REs of the energy improvements in the industry has several advantageous. First of all, it reveals the extent of the potential level of energy savings through the efficiency improvements. Moreover, if negative RE occurs, the energy cost per unit output diminishes through the decrease in energy use, which helps firms to be more advantageous in terms of reduced manufacturing costs and thereby to raise selling and marketing options of their product both domestically and internationally. Furthermore, the EIPs with more energy-saving potentials have respectively shorter payback time and higher profitability than the others. This leads the firms to initiate new EE improvement projects. The prevalence of industrial efficiency investments could increase without state support, which may be the ultimate target of any policy-makers in designing successful polices. All in all, the policy-makers might benefit more from the funds that they allocate if they take into consideration the sizes of the direct REs of efficiency improvements.

This study aims to measure direct REs in the Turkish industry. For this aim, we utilize firm-based data of the 30 completed EIPs to save heat and 145 completed EIPs to save electricity, by fourteen sub-sectors in the Turkish industry.

The main novelty of this paper is to calculate the production-side RE related to actual electricity and heat savings of the completed EIPs for the first time. Secondly, this study contributes to the literature by using a reliable data set that enables us to use the definition of RE in terms of energy savings. This approach requires the information of the calculated and the actual energy savings of the firms as a result of replacement or usage of more efficient technology in their facilities. The calculated and the actual energy savings are measured by the energy experts on-site in the process of the preparation and implementation of the EIPs. As another contribution, we utilize a detailed firm-level dataset for Turkish firms within fourteen sub-industrial sectors. Therefore, the calculation of RE of the EIPs allows us to reveal the discrepancies among them according to the energy-saving potentials.

The remainder of the paper is structured as follows. In Section 2, we briefly explain the theoretical concept of RE. We examine the descriptive statistics for EE improvement projects in each industrial sub-sector of Turkey in Section 3. Section 4 provides the calculation and the classification of REs for each EIP. Finally, we present the main conclusions and some policy implications in the last section.

1.2. THEORETICAL BACKGROUND

RE occurs when the consumption level of energy services changes as a response to the changes in EE. In the literature, it is widely estimated either by using the elasticities of the demand for energy services with respect to EE and energy prices or by using stochastic energy demand frontier models (Saunders, 2008; Sorell, 2009; Orea et al., 2015). Apart from them, the definition of RE in terms of energy savings is also used to calculate RE (Roy 2000; Berkhout et al., 2000; Haas and Biermayr, 2000; Jin, 2007; Druckman et al., 2011).

By definition, RE can be written as (Saunders, 2008):

$$RE = \frac{dS}{de}\frac{e}{S} \tag{1}$$

where e is the variable representing EE and S is the consumption level of energy service. Energy efficiency of an energy service is defined as $e = S/E$ (Sorrell and Dimitropoulos, 2008). S is proportional to the actual energy consumption (E) and the proportion is reflected by EE gains:

$$S = eE \tag{2}$$

By taking partial derivative of S with respect to e and substituting it into (1), we get RE as:

$$RE = 1 + \frac{d \ln E}{d \ln e} \tag{3}$$

The second term of the right side of (3) refers to the efficiency elasticity of energy demand. RE in (3) ranges from $-\infty \; to \; +\infty$. Based on (3), the empirical procedure to obtain RE starts with the estimation of (4), where X is a vector of control variables consisting of level of output, energy price, and other variables.

$$\ln E = \alpha_0 + \alpha_1 \ln e + \alpha_2 X + v \tag{4}$$

where α_i for i=0,1,2 are the coefficients, v is assumed to be random noise and normally distributed. The efficiency elasticity of energy demand is captured by the estimate of the coefficient α_1 ($\hat{\alpha}_1$), which is used to calculate RE as follows:

$$RE = 1 + \hat{\alpha}_1 \tag{5}$$

The approach to measuring RE utilizing the price elasticity of energy demand is based on the relationship between the energy cost of energy service, P_S, and energy price, P_E, given in (6). When energy prices are constant, an increase in e has the same effect as a decrease in the energy cost of energy service does or vice versa (Sorrell and Dimitropoulos, 2008). Therefore, the efficiency elasticity of energy demand might be replaced by the efficiency elasticity of energy demand.

$$P_S = P_E / e \tag{6}$$

The empirical procedure requires that one estimate (7) and use the estimate of $\alpha_{1,S}$ ($\hat{\alpha}_{1,S}$) as in (8) to find RE.

$$\ln E = \alpha_0 + \alpha_{1,S} \ln P_S + \alpha_2 X + v \qquad (7)$$

$$RE = 1 - \hat{\alpha}_{1,S} \qquad (8)$$

Adopting the energy demand elasticities to obtain the size of RE relies on two restrictive assumptions which lead RE to be overestimated (Sorrell and Dimitropoulos, 2008; Binswanger, 2001; Sorell, 2009; Hunt and Ryan, 2014; Chan and Gillingham, 2015). The first assumption states that the responses of energy demand to a same-size decrease and increase in energy prices are symmetric. However, Bentzen (2004) argues that energy demand responses to an increase in energy prices are higher than to a same-size decrease. The second assumption is that EE improvements are exogenous. But, RE cannot be isolated from EE since EE gains are a result of technological change, which leads to EE to be endogenous.

To address the issues stemming from the aforementioned assumptions, the stochastic energy demand frontier model (SEF) is used to measure RE. SEF is based on actual EE changes where the actual energy demand for a firm depends on not only deterministic but also stochastic components, which includes energy inefficiency (Filippini and Hunt, 2011, 2012):

$$\ln E = \ln f(X, \alpha) + v + u \qquad (9)$$

where X is the deterministic component of the model whereas the error terms v and u are stochastic components. v is assumed to be a random noise and normally distributed while u is one-sided error term and distributed half normal. u measures the distance between the observed and potential energy use, thus it is used to represent the level of underlying energy inefficiency for a firm.

For SEF, EE score is calculated using u from (9) as in (10):

$$\mathrm{e} = \exp(-\mathrm{u}) \tag{10}$$

where e takes a value between 0 and 1. When $\mathrm{u} = 0$, then $\mathrm{e} = 1$, indicating that potential efficiency gains is fully achieved. Since $\ln e = -u$, and by replacing it in (3), RE can be written in terms of u as in (11):

$$RE = 1 - \frac{d \ln E}{du} \tag{11}$$

Orea et al. (2015) claim that the elasticity of demand for energy use with respect to changes in EE is -1 in standart stocastic energy demand frontier given in (9). This implies that RE is equal to zero. In order to allow the size of RE to be other than zero, Orea et al. (2015) propose to modify SEF by incorporating $(1 - RE)$ as a correction factor. Then, the model becomes:

$$\ln E = \ln f(X, \alpha) + v + (1 - RE)u \tag{12}$$

Equation (12), however, excludes the case $RE = 1$ in which EE (u) is not identified. Moreover, Orea et al. (2015) point out that the value of $(1 - RE)$ must be positive, therefore RE to be less than 1 due to the methodological limitations. Orea et al. (2015), then, define RE as a function of economic and policy variables Z. Consistent with the possible ranges, RE might have the functional forms given in (13a) and (13b). To obtain RE, Equation (12) and $\lambda' Z$ are estimated simultaneously.

$$RE = \frac{\exp(\lambda' Z)}{1 + \exp(\lambda' Z)} \tag{13a}$$

$$RE = \frac{\exp(\lambda' Z) - 1}{\exp(\lambda' Z)} \tag{13b}$$

Even though SEF is able to cope with the issues raised by the assumptions that are imposed in the elasticity approaches, it hinges upon its restrictive assumption, namely $RE < 1$.

However, any size of RE irrespective of intuitive or counterintuitive might be taken into consideration due to the fact that RE stems from the behavioral responses to EE improvements. Different from the aforementioned approaches, the energy savings approach to measuring RE does not impose any restrictions on the size of RE. This represents an advantage over the competent approaches.

The energy savings approach uses the definition of RE in terms of energy savings, given in (14), where CS and AS are the calculated and the actual energy savings, respectively (Roy 2000; Berkhout et al., 2000; Haas and Biermayr, 2000; Jin, 2007; Druckman et al., 2011):

$$RE = \frac{CS - AS}{CS} \tag{14}$$

Nevertheless, despite being straightforward, the energy savings approach relies on having information on energy savings due to the more efficient technology. Thanks to data availability, we employ this approach to measure RE in the Turkish industry sector.

1.3. THE ENERGY USE AND THE FINANCIAL SUPPORTS FOR ENERGY EFFICIENCY IMPROVEMENTS IN TURKEY

Turkey targets reducing energy intensity[2] at both sectoral and economy-wide levels by increasing efficiency from production to final consumption. Figure 1 shows the changes in energy intensities of the Turkish economy. As can be observed from Figure 1, the primary energy intensity index decreased cumulatively by 23.1 percent between 2000 and 2016 (YEGM, 2018). The energy intensity improved annually by the rate of 1.8 percent in the industry, 1.9 percent in the housing sector, and 2.7 percent in the transportation sector. An annual improvement of the whole economy has occurred at 2.1 percent.

[2] Energy intensity index is defined as the measure of inverse energy efficiency (Cantore et al., 2016).

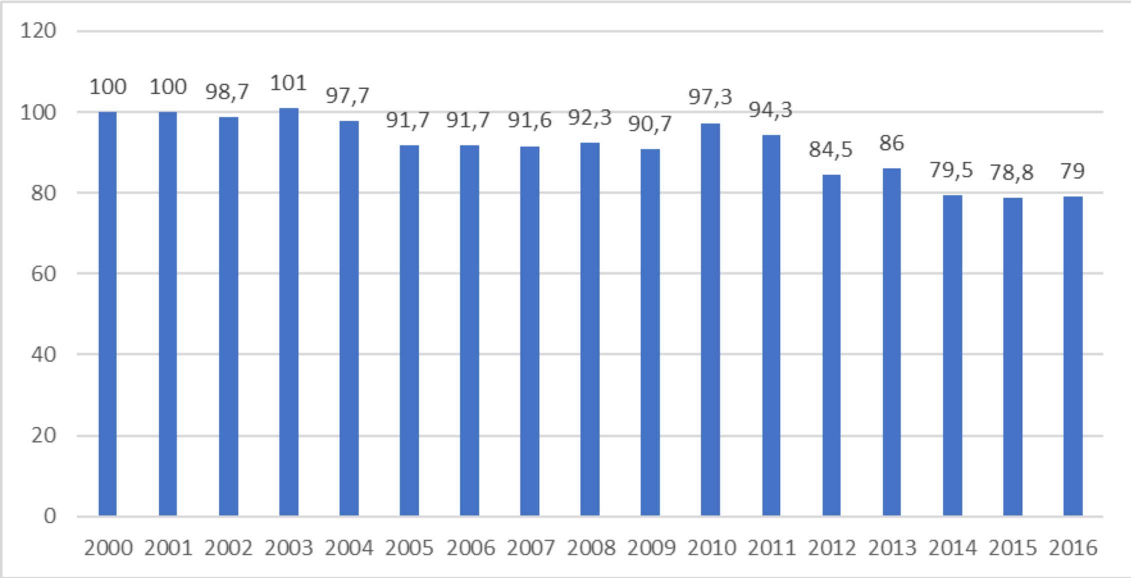

Figure 1: The decline in energy intensity of Turkish economy. Source: EEED,2018

While energy intensity has decreased, energy consumption has increased since 2000. Figure 2 demonstrates the sectoral energy consumption between 2000 and 2018. Figure 2 also indicates that the energy consumption in the industry is higher than the one in any other sector. We calculate that the Turkish industry's energy consumption share has increased by 2.3 percent since 2009 and accounted for 25.3 percent of total energy consumption in 2018. Since the industry is the leading sector in energy use, the decline in energy consumption per unit production is likely to be contributed the most by adopted EE policies in the industry. For this reason, industrial EE is considered as the best cost-effective ways of reducing fossil fuel consumption, thus it helps to mitigate greenhouse gas emissions (Trianni et al. 2016).

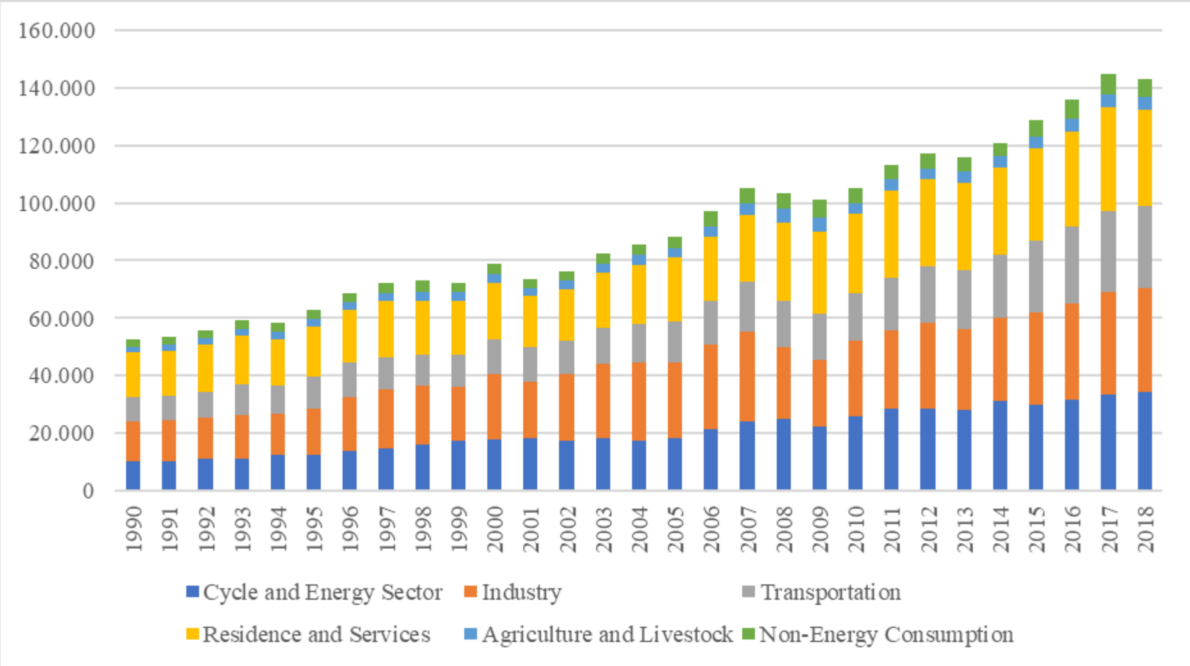

Figure 2: Sectoral energy consumption in Turkey 1990–2018. Data source: MENR, 2020

In order to create awareness concerning the efficient use of energy in industry sector and to accelerate the EE implementations, the Turkish government launched the energy efficiency-enhancing policies via energy improvement projects (EIPs) in 2009. In particular, EIPs are the projects which are prepared for the implementation of necessary measures to eliminate energy waste, losses, and inefficiencies in industrial firms. Energy efficiency improvement activities and policies are performed and designed by the Ministry of Energy and Natural Resources (MENR). Energy Efficiency and Environment Department (EEED) is one of the affiliated directorates of MENR calls for EIPs proposal that any firms in the industry can submit up to two times in a year. Each industrial firm, having an energy efficiency project's proposal related to its process and/or facility can apply for the support of up to 5 million Turkish Liras. In case of the approval of proposals, the Turkish government funds up to 20 percent for electricity projects and 30 percent for heat projects of EIPs' cost. Figure 3 shows the number of applications versus the numbers of approved and supported projects by the end of 2019. As can be seen, there have been a total of 683 project applications; 526 of them have been approved and 234 of them have been completed by the end of 2019 (Figure 3).

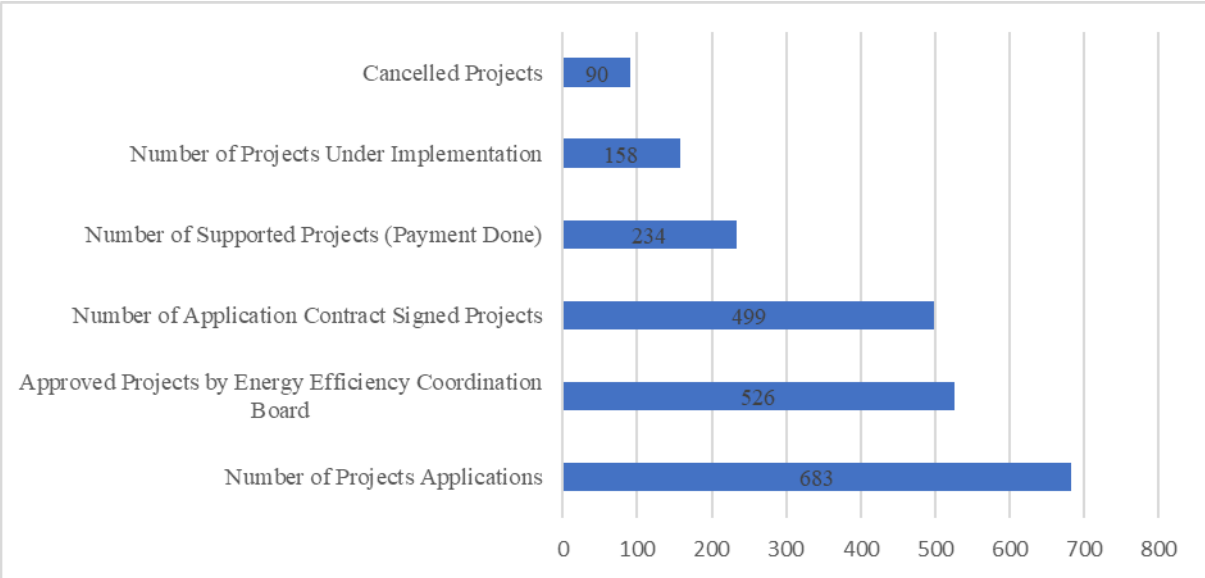

Figure 3: Summary of EIPs between 2009 -2019 Data Source: EEED, 2020.

Figure 4 shows the summary of financially supported EIPs between 2009 and 2019. Approximately 5 million United States Dollars ($) have been paid for the successfully completed 175 EIPs since 2009 and the annual saving is almost $23 million. With the implementation of the completed EIPs, about 35 thousand tonnes of oil equivalent (toe) was initially planned to be saved. However, more than 50 thousand toe has been saved. It is also foreseen that more than 17 thousand toe will be saved when 158 EIPs, which are currently under the implementation phase, are completed.

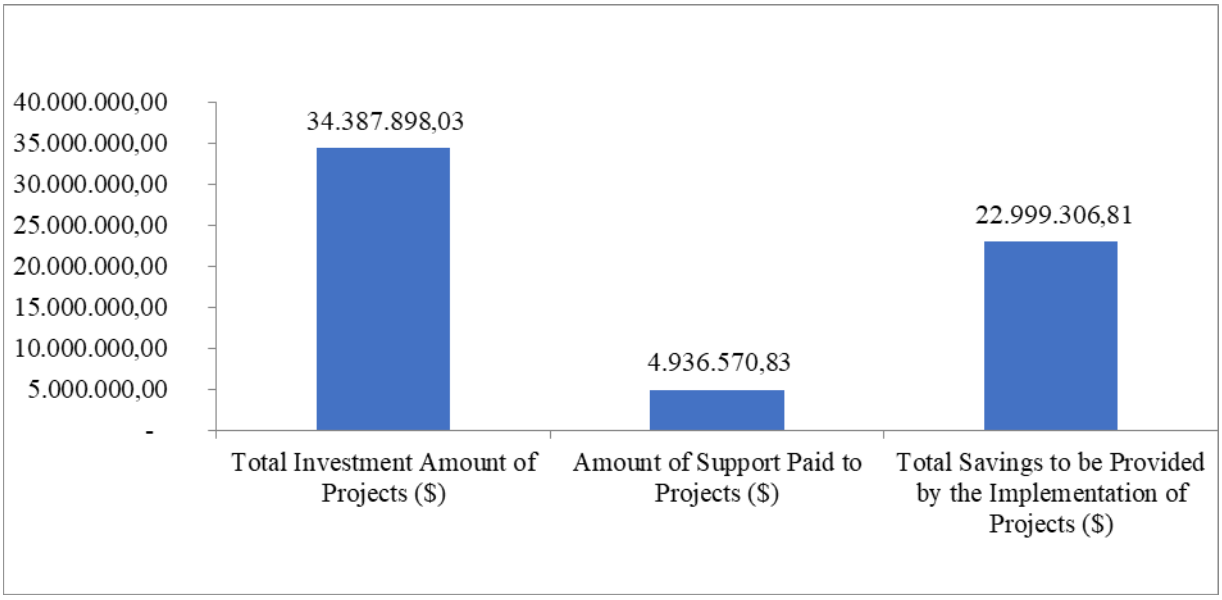

Figure 4: Summary of Financially Supported EIPs between 2009 and 2019. Data source: EEED, 2020.

1.4. DATA, METHODOLOGY AND RESULTS

1.4.1. Data

To analyze industrial EE measures in Turkey, we utilize the firm-level dataset of Turkish firms within fourteen industrial sub-sectors based on NACE Rev 2, comprising the period 2009-2019. We select the firms based on the completion of EIPs since the Turkish government started to financially support EIPs in 2009. Our data set consists of 175 completed EIPs' observations which are derived mostly from the medium and large-scale industrial firms.[3] 145 of the completed EIPs are designed to save electricity, 30 of them are designed to save heat.[4] Based on division number and NACE Rev. 2 sub-sector descriptions, Table 1 reports the number of the completed EIPs that we utilize in this study.[5]

[3] 158 of EIPs are still under implementation; therefore, they are not included in our data set since actual electricity and heat savings cannot be estimated for after-efficiency enhancement.
[4] Although we have the energy savings data of 59 EIPs which are also completed successfully, they are not included in this analysis since the saved energy types of these projects are unknown.
[5] The data set has a variety of cross-sections and time dimensions. In particular, firms that have completed EIPs are very different in scale and each EIPs is completed in different months and years even if they are approved at the same term of the year by state.

Table 1: Number of observations of fourteen sub-industries with reference to NACE Rev.2

Division Number	Division Description	Number of Observation
10	Manufacture of food products	11
13	Manufacture of textiles	16
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	27
17	Manufacture of paper and paper products	7
19	Manufacture of coke and refined petroleum products	13
20	Manufacture of chemicals and chemical products	25
22	Manufacture of rubber and plastic products	6
23	Manufacture of other non-metallic mineral products	17
24	Manufacture of basic metals	19
25	Manufacture of fabricated metal products, except machinery and equipment	7
26	Manufacture of computer, electronic and optical product	1
27	Manufacture of electrical equipment	11
28	Manufacture of machineryand equipment n.e.c.	3
29	Manufacture of motor vehicles, trailers and semi-trailers	12
	Total	175

The data set consists of both general information about EIPs (application term, type of saved energy, description of EIPs, projected application cost in TL, actual application cost in TL, planned investment support cost by state in TL, actual investment support cost by state in TL, planned energy savings in toe, planned monetary savings in TL, actual energy savings in toe and actual monetary savings in TL for each completed EIP) and the planned (calculated) and the actual energy savings via EIPs. The planned savings for each EIPs are calculated by an Energy Efficiency Consultancy Company (ESCO) during the preparation process of each EIPs' application. The actual savings are measured by the expert team of MENR on-site when firms submit the completion reports of EIPs. We use general information to reveal the framework of EIPs related to costs and savings according to the sub-sectors of the industry. The observations about the calculated and the actual energy savings are used to measure REs of each EIPs.

As a preliminary analysis, we plot the potential energy savings against the actual savings for all EIPs (Figure 5). The plot indicates that the actual and the calculated savings for EIPs differ widely, which implies the existence of significant direct RE.

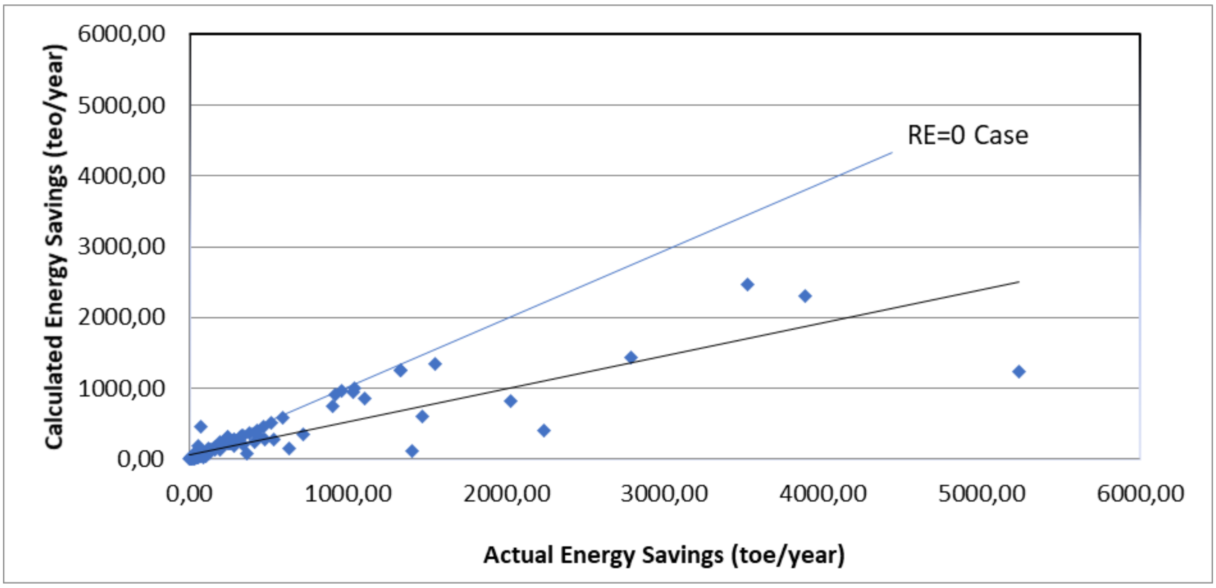

Figure 5: Actual and Calculated Energy savings for 175 EIPs in toe, with best-fit savings curve. Data source: EEED, 2020.

1.4.2. Methodology and Results

In this study, we use Equation (14) to calculate the direct RE for each EIP. The calculated savings are obtained from the application forms of the firms, which are calculated during the application for state funding of EIPs. Actual savings are calculated by EEED's inspectors right after the notification of projects' completion.

The calculated REs are sorted according to the scale of RE consisting of five separate categories (Table 2). The first category is a size of RE greater than 100 percent, which is called "the backfire effect (BE)". BE indicates that the level of energy consumption increases after the improvement in efficiency. In the presence of BE, the efficiency improvement measures may be used to explain other policies such as welfare policies in the consumer side and labor policies in the production side rather than energy policies (Jin, 2007). The second category is "partial conservation of energy savings", partial RE as short, which occurs when RE is between 0 and 100 percent. In the presence of partial RE, potential savings are not fully reached. The third category is described as "zero rebound effect (zero RE)", meaning that the actual savings equal to the calculated savings. The fourth category is called "prebound effect (pre-RE)", which refers to the case of decreased level of consumption of energy service comparing to the pre-efficiency enhancement situation (Sunikka-Blank and Galvin, 2012). In the case of prebound effect, RE is between -100 and 0 percent. The last category represents the case where RE is estimated less than -100 percent. We name this case as "the negative backfire effect" as it has not been coined in the literature to the best of our knowledge. The occurrence of the negative backfire effect is unique to special circumstances and rarely observed in EE enhancement situation. Table 2 also relates the change in energy use from 1% efficiency gain to RE.

Table 2. The Scale of Rebound Effect

Rebound Effects	**Negative Backfire Effect**	**Prebound Effect**	**Zero Rebound Effect**	**Partial Rebound Effect**	**Backfire Effect**
	RE≤-100%	**-100%<RE<0%**	**RE=0%**	**0% <RE<100%**	**RE≥100%**
Change in	**ΔE≤-1**	**-1<ΔE<0**	**ΔE=0**	**0<ΔE<1**	**ΔE≥1**

Energy Use from 1% Efficiency Gain

We tabulate the number of cases for each industrial sub-sector with respect to the scale of the calculated RE in Table 3.[6] RE estimates of all 174 EIPs are also shown in Figure 6, classified by sub-sectors with an exception of RE estimate of an EIP in manufacture of coke and refined petroleum products sub-sector due to its extreme value (-1116,40).

The results reveal several facts about the energy-saving realizations of the completed EIPs according to the industrial sub-sectors. First of all, none of the 175 EIPs exhibits BE. This is consistent with the data since it consists of the observations belonging to the successfully completed EIPs and the financial support of the Turkish government is conditional on both the completion of the project and the achievement of the proposed EE gains in the firms' application. Second, for 61 EIPs, RE is calculated zero in fourteen industrial sub-sectors, suggesting that for 61 EIPs potential energy savings are equal to actual energy savings. Third, for 28 EIPs the partial RE has been observed, indicating that actual energy consumption exceeds the calculated energy consumption. Thus, the EE gains are less than what is initially proposed. However, the firms partially benefit from the EIPs comparing to the consumption level of pre-implementation. Fourth, there are 14 EIPs with negative backfire effects, which suggests that actual savings are more than twice the calculated savings. The EIPs in the manufacture of coke and refined petroleum products sub-sector have the highest negative backfire effects, therefore this sector takes the most advantages from the completed EIPs. Fifth, there are 60 cases of prebound effect. Prebound effects are especially accumulated in manufacture of wood and of products of wood and cork, except furniture and manufacture of articles of straw and plaiting materials sub-sector. Last, comparing to

[6] We round up or down the estimates between -1 and 1 percent to zero while calculating the number of EIPs with zero RE.

the numbers of positive REs (28), there are more EIPs with negative REs (86), which suggest unexpected efficiency gains rather than unexpected efficiency losses because of the EIPs aiming to save electricity and heat. These results imply that the implementations of the EE policy have not only achieved the foreseen energy savings but also lead the firms to save more energy than what is initially planned.

Table 3: Number of REs of 175 EIPs by industrial sub-sectors

Sub-sectors	**Number of Cases**				
	Negative Backfire Effect	**Prebound Effect**	**Zero Rebound Effect**	**Partial Rebound Effect**	**Backfire Effect**
Manufacture of food products	0	6	1	4	0
Manufacture of textiles	0	6	8	2	0
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	1	10	15	1	0
Manufacture of paper and paper products	0	7	0	0	0
Manufacture of coke and refined petroleum products	6	6	0	1	0
Manufacture of chemicals and chemical products	2	7	11	5	0
Manufacture of rubber and plastic products	0	4	0	2	0
Manufacture of other non-metallic mineral products	1	6	4	6	0
Manufacture of basic metals	3	6	9	1	0
Manufacture of fabricated metal products, except machinery and equipment	0	4	1	2	0

Manufacture of computer, electronic and optical product	0	1	0	0	0
Manufacture of electrical equipment	1	1	7	2	0
Manufacture of machineryand equipment n.e.c.	0	3	0	0	0
Manufacture of motor vehicles, trailers and semi-trailers	0	4	5	1	0
TOTAL	14	72	61	28	0

We, then, calculate REs for heat and electricity savings derived from EIPs separately in the Turkish industry. Table 4 reports REs for 145 EIPs using electricity savings and Table 5 shows REs for 30 EIPs using heat savings, classified by the sub-industries. We find extreme sizes according to their absolute values.

Table 4: Summary statistics of electricity rebound effects

Sub-sectors	**# of Obs.**	**Mean.**	**Std. Dev.**	**Min**	**Max**
Manufacture of food products	10	13,96	39,10	-51,29	71,12
Manufacture of textiles	14	-2,23	13,10	-36,47	25,00
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	23	-14,58	42,93	-165,75	59,84
Manufacture of paper and paper products	5	-35,09	29,14	-74,59	-6,05
Manufacture of coke and refined petroleum products	4	-27,30	61,23	-87,41	47,54

Manufacture of chemicals and chemical products	21	-15,97	84,63	-157,42	32,74
Manufacture of rubber and plastic products	5	7,70	19,45	-7,82	38,84
Manufacture of other non-metallic mineral products	14	5,73	38,80	-134,11	25,29
Manufacture of basic metals	18	-0,31	51,04	-180,51	8,91
Manufacture of fabricated metal products, except machinery and equipment	6	-7,22	29,31	-47,33	33,47
Manufacture of computer, electronic and optical product	1	-1,00	-	-	-1,00
Manufacture of electrical equipment	11	-5,61	36,49	-109,14	38,49
Manufacture of machinery and equipment n.e.c.	3	-10,80	5,01	-16,53	-7,29
Manufacture of motor vehicles, trailers and semi-trailers	10	1,58	31,68	-47,59	81,38

As shown in Table 4, we find that the average electricity RE ranges between -35.09 percent (for the manufacture of paper and paper products) and 13.96 percent (for the manufacture of food products). Regarding the values of electricity RE in the manufacture of paper and paper products industrial sub-sector, calculated electricity savings are 35.09 percent less than actual electricity savings. That is, 35.09 percent is extra and unexpectedly saved from 5 completed EIPs in the manufacture of paper and paper products sub-sector on average. Nevertheless, in the manufacture of food products sub-sector, for 4 EIPs, average electricity savings are 13.96 percent less than actual electricity savings.

The standard deviation of the electricity RE shows the range of behavioral responses to efficiency improvements by the firms. We find that 84,63 percent is the highest figure, indicating that 21 firms in the manufacture of chemicals and chemical products sub-sector are the most heterogeneous sub-sector in terms of behavioral response to electricity efficiency improvement. Whereas 3 firms' behavioral response to electricity efficiency projects in the manufacture of machinery and equipment n.e.c. sub-sector is the lowest (5,01) among the completed electricity efficiency projects by sub-sectors. Thus, the manufacture of machinery and equipment n.e.c. is the most homogeneous sector in terms of behavioral responses to efficiency improvements.

Table 5: Summary statistics of heat rebound effects

Sub-sectors	# of Obs.	Mean.	Std. Dev.	Min	Max
Manufacture of food products	1	2,77	-	2,77	2,77
Manufacture of textiles	2	-42,71	40,19	-71,12	-14,29
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	4	-10,17	8,56	-20,93	-1,15
Manufacture of paper and paper products	2	-79,74	96,70	-148,12	-11,37
Manufacture of coke and refined petroleum products	9	-288,40	347,48	-1116,4	-5,99
Manufacture of chemicals and chemical products	4	-10,03	12,52	-28,06	-0,24
Manufacture of rubber and plastic products	1	-22,75	-	-22,75	-22,75
Manufacture of other non-metallic mineral products	3	-15,45	32,89	-68,55	-3,29
Manufacture of basic metals	1	-291,50	-	-291,50	-291,50
Manufacture of fabricated metal products, except machinery and equipment	1	-1,05	-	-1,05	-1,05
Manufacture of computer, electronic and optical	0	-	-	-	-

product					
Manufacture of electrical equipment	0	-	-	-	-
Manufacture of machineryand equipment n.e.c.	0	-	-	-	-
Manufacture of motor vehicles, trailers and semi-trailers	2	-20,35	81,19	-30,17	84,66

On the purpose of heat savings, there are only 30 completed EIPs, whose average REs are reported in Table 5. The results suggest that the average heat RE ranges between -288.40 percent (for the manufacture of coke and refined petroleum products) and 84.66 percent (for electrical machinery and equipment). Regarding the values of heat RE in refined petroleum products sub-sector, the calculated heat savings are 288.40 percent less than actual heat savings. That is, 288.40 percent is extra and unexpectedly saved by 9 EIPs in refined petroleum products sector. When we exclude one of the EIPs in this sub-sector due to its extreme result (-1116.40), we calculate the average heat RE as -184.90 percent for the manufacture of coke and refined petroleum products, indicating that 184.90 percent is saved more from 8 EIPs done in this sub-sector. However, in the manufacture of chemicals and chemical products sub-sector, the calculated heat savings are 10.03 percent more than the actual heat savings on average.

We also use the standard deviation of the heat RE as a range of behavioral responses to efficiency improvements by firms. As can be seen in Table 4, 347.48 percent is the highest figure, indicating that 9 firms in the manufacture of coke and refined petroleum products sub-sector are the most heterogeneous in terms of behavioral response to heat efficiency improvement.[7] Nonetheless, 4 firms' behavioral response to heat efficiency projects in the manufacture of wood and of products of wood and cork, except furniture; the manufacture of articles of straw and plaiting materials sub-sector is the lowest (8.56)

[7] If we exclude the EIP with the extreme RE (-1116.40), we can calculate the standard deviation of the heat RE as 166.77 percent by using the remaining 8 firms. This finding indicates that the manufacture of coke and refined petroleum products sub-sector is the most heterogeneous sub-sector in terms of behavioral response to heat efficiency improvement irrespective of outliers.

among the completed heat efficiency projects by sub-sectors, meaning that this sub-sector is the most homogeneous.

The results of this study also reveals that REs that arise from EIPs are strongly subjective to the fuel type and the sub-sectors. On the one hand, zero or negative RE are observed in 29 of the 30 completed EIPs aiming to save heat, which indicates the success of extra energy-saving potential of heat projects. More specifically, we calculate the average heat RE as -110 percent for all 30 EIPs aiming to save heat. This finding points out that the average actual heat savings are more than two times the planned initial average heat savings. Since the manufacture of coke and refined petroleum products sub-sector has the lowest average heat RE (-288.40 percent) in all the sub-sectors, allocating financial state support to the firms that operate in the manufacture of coke and refined petroleum products sub-sector and perform the EIPs aiming to save heat might lead the highest level of the energy savings on average in return.

On the other hand, the 60 EIPs demonstrate zero RE and the 58 EIPs show negative RE among the 145 EIPs aiming to save electricity. Besides, only 27 out of the 145 EIPs have partial electricity RE. These results for electricity RE show that 81.38 percent of the EIPs have either equal actual electricity savings to planned electricity savings or more actual electricity savings than the planned electricity savings. We calculate the average electricity RE as -9.32 percent for all 145 EIPs aiming to save electricity, which indicates that average actual electricity savings exceed planned initial average electricity savings. The lowest average electricity RE is calculated from 5 completed EIPs in the manufacture of paper and paper products sub-sector as -35.09 percent on average. Hence, this finding suggests that the firms operating in the manufacture of paper and paper products sub-sector might achieve the highest level of energy savings on average in return while implementing EIPs aiming to save electricity.

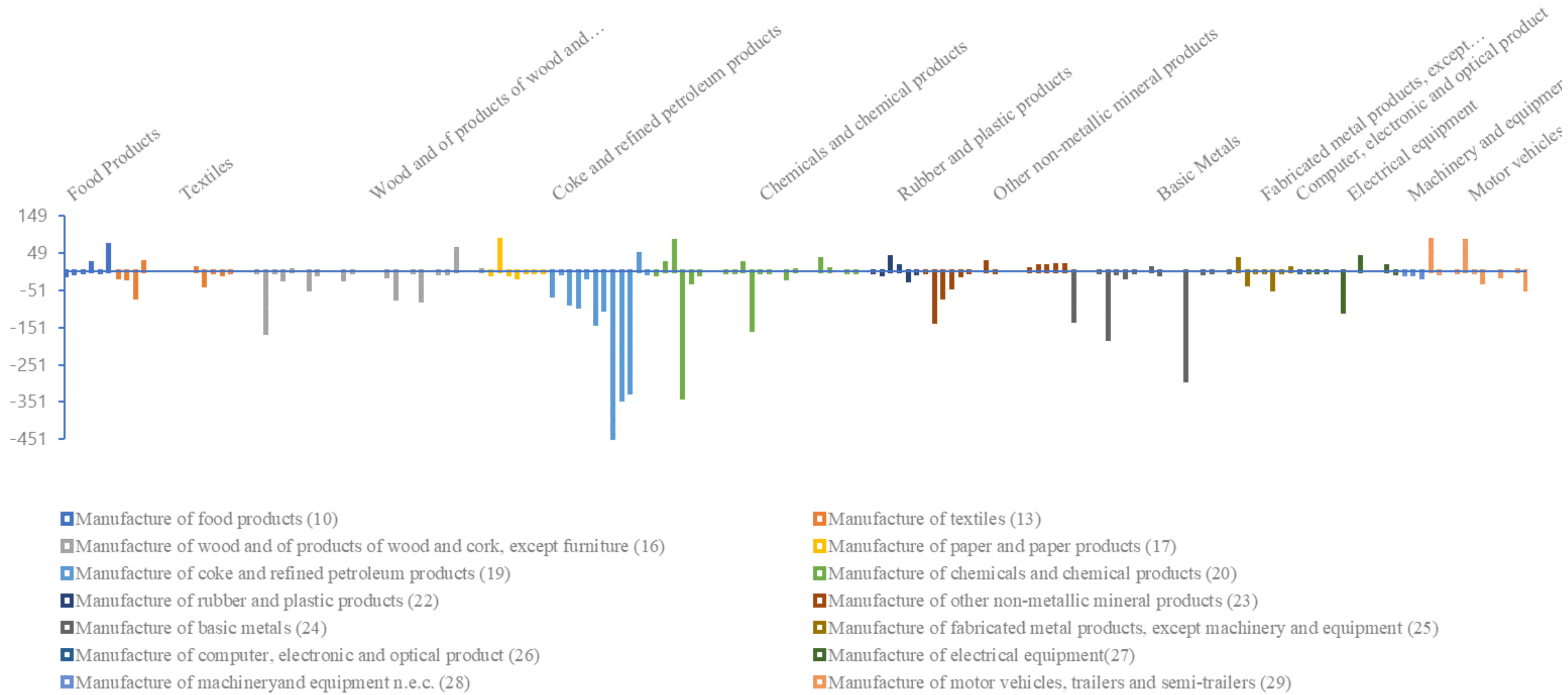

Figure 6: Direct REs for 174 EIPs. Source: Own calculation.

1.5. CONCLUSION AND POLICY IMPLICATIONS

In this study, the direct rebound effects (REs) for the Turkish industry are calculated for the first time. To this end, we have used the completed 175 energy improvement projects (EIPs), partially financed by the Turkish government between the period 2009-2019. The calculated REs range from a very high negative backfire effect to partial RE, which indicates that all EIPs cause energy conservation. In 86 out of the 175 EIPs, RE is negative; therefore, the expected energy conservation amount is not only achieved but also exceeds the proposed energy conservation amount in almost half of the EIPs. In particular, negative backfire effect is observed in 14 EIPs and prebound effect is observed in the 72 EIPs. Negative REs range from -1 percent to -1116.4 percent. These results suggest unexpected EE gains rather than efficiency losses due to the behavioral responses to the EIPs. Therefore, energy improvements enable most of the firms to save more energy than they initially expected. This indicates the super-conservative response to EE improvements in most of the EIPs.

The findings of this study are highly counter-intuitive for developing countries for which several studies in the literature have estimated partial REs (Orea et al., 2015; Lin and Zhao, 2016; Lin and Tan, 2017; Lin et al., 2017, Labidi and Abdessalem, 2018) In particular, we have calculated partial REs for only 28 EIPs out of the 175 EIPs, ranging between 4.85 percent and 84.65 percent. There are zero REs in 61 EIPs, meaning that 35 percent of all completed EIPs have caused neither unexpected efficiency losses nor unexpected efficiency gains. The inconsistency with the literature on the results might stem from the approach we have adopted to measuring RE of energy improvements. As we have discussed in Section 4, most of the approaches used in the literature impose restrictive assumptions on the size of RE. However, we have used the energy savings approach, which has enabled us to measure any size of the RE.

The results of this study also imply that the amount of energy-savings potentials due to EIPs are strongly subjective to the fuel type and the sub-sectors. For instance, 93.33 percent of the completed EIPs aiming to save heat exhibit negative RE; whereas, only 40 percent of the completed EIPs aiming to save electricity exhibit negative RE.

Specifically, in the manufacture of coke and refined petroleum products sub-sector, 92 percent of the EIPs display negative REs, whereas only 8 percent of them exhibit partial RE. Besides, annually 4,426 tonnes of oil equivalent (toe) have been saved extra from the 13 completed EIPs in this industrial sub-sector. On the other hand, 36 percent of the EIPs exhibit partial RE in the manufacture of food products sub-sector. The cumulative efficiency gains are actualized 280.32 toe less than what initially planned via 11 completed EIPs in this sub-sector.

Our study also reveals that the highest level of average actual energy savings derived from the EIPs are in three sub-sectors: the manufacture of coke and refined petroleum products, the manufacture of paper and paper products, and the manufacture of computer, electronic and optical product sub-sectors. Actual energy savings per EIP in these three sub-sectors are calculated ninety, twenty-nine and fifteen times greater than the average energy savings of per EIP completed in the manufacture of motor vehicles, trailers and semi-trailers sub-sector, respectively.

This study has clear policy implications. First of all, this study reveals the energy-saving potentials of the industrial sub-sectors through the EIPs. If the energy policy-makers allocate the funds among the industrial sub-sectors by taking into account their energy-savings potential, they might increase the overall energy savings from the EIPs. Moreover, the EIPs with more energy-saving potentials have respectively shorter payback time, which might cause the firms to initiate new EE improvement projects. In addition, the less ultimate consumption of energy by the industry causes more energy security and less CO_2 emissions. Thereby, the policy-maker's goal of reducing energy intensity and emissions of greenhouse gases at both sectoral and macro level will be achieved via the efficiency gains and awareness arisen from EE improvements. Hence, this study suggests that promoting EE improvements has proved to be an effective tool to increase the overall energy savings, and to diminish industrial energy intensity and CO_2 emissions.

This study brings new questions to the floor such as a novel discussion on the existence of super-conservation response based on the sub-sectors in the industry sector of a developing country. Further research might focus on the determinants of the super-conservation response and the reasons of the variations based on the sub-industry sector of this super-conservation response. Moreover, dependent upon the data availability, the effects of the business cycle fluctuations, and a change in the output levels of the firms on their energy consumption and energy savings during the implementation period of EE improvements might be taken into account to get a better insight.

CHAPTER 2

CHALLENGES AND OPPORTUNITIES FOR MAINSTREAMING INDUSTRIAL ENERGY EFFICIENCY IN SMES AND LES: THE CASE OF TURKEY

ABSTRACT

The industry contributes the most to the world's energy savings in all sectors through more efficient energy use (IEA, 2018). Yet, the literature provides evidences that the potential EE gains in the industry are not fully achieved. The gap between the potential EE measures and the actual implemented measures is called "energy efficiency gap". This study aims to reveal the reasons for the energy efficiency gap by focusing on behavioral and organizational responses to EE improvements in the Turkish industry. To this end, we developed a questionnaire, which consists of questions that if the implementer of an EE improvement considers a factor as hampering or promoting. The list of the factors is based on the literature review. We conducted a questionnaire survey with 135 industrial enterprises that have completed at least one state-funded Efficiency Improvement Project (EIP). 86 of them responded to the survey. We separately ranked their responses according to the average responses. The results show that the energy intensity level and scale of enterprises take the lead in the importance of perceived barriers and drivers. This study also suggests that the average scores of the perceived barriers in small and medium-sized enterprises [SMEs] are mostly higher than those in Large-sized enterprises [LEs]. This finding reveals that the tendency of considering a factor as a barrier diminishes as the scale becomes larger.

Keywords: Industry sector, Energy efficiency barriers, Energy efficiency drivers, SMLEs,

JEL Codes: A13, C83, Q55, Q48

2.1. INTRODUCTION

Improving industrial energy efficiency has been recognized as one of the most significant and cost-effective approaches to diminishing global energy consumption and CO_2 emissions for many governments due to its highest shares in total energy consumption. It also provides benefits to industrial enterprises in terms of increasing their profitability and productivity while reducing their energy-related costs. In this context, industrial EE has allured a special interest in managers as well as policy-makers.

On the other hand, despite the need and desire for increased industrial EE, studies indicate that cost-effective EE measures (also tools and investments) might not be effectively implemented by enterprises (Brunke et al. 2014). Several studies have provided evidence about a gap between potential and actual EE measures (Sorrell et al., 2004; Sardinanou, 2007; Thollander and Dotzauer, 2010). This issue has been named by many different terms in the literature such as ‘the rebound (or take-back) effect (RE)’, ’Jevons Paradox’, ‘the energy-efficiency gap’ or ‘the energy paradox’ (Jevons, 1865; Jaffe and Stavins, 1994).

Initiating, promoting and, re-evaluating EE polices by governments requires taking into account the energy efficiency gap and its reasons. Even though several studies have investigated the size of the industrial energy efficiency gap, the reasons and circumstances causing it are still ambiguous. Moreover, no operational outcomes for industry practitioners exist (Lee, K. H., 2015). A set of barriers namely economic, financial, regulatory, organizational, informational, or knowledge-related factors (Rohdin et al., 2007; Thollander et al., 2007; Trianni et al., 2013a) can lead energy-efficiency gap (Reddy, 2013). On the other hand, there are also economic, financial, organizational, competence-related, awareness-related, and policy-related factors that promote the adoption of energy efficient technologies and decrease the energy-efficiency gap (Rohdin and Thollander, 2006; Thollander and Ottosson, 2008; Nehler et al., 2018). They are called motivations or drivers by the literature. It is quite essential to explore the main reasons why cost-effective EE measures (also tools and investments, hereafter EEI) could not be implemented and what factors affect enterprises' energy efficiency gap by considering the hampering and promoting factors encountered during the application of cost-effective EE measures by the implementers.

Several disciplines, namely engineering, economics, behavioural and organizational studies have made contributions to EE literature by means of investigating barriers (Soepardi et al.,2018; Cagno et al., 2013; Trianni and Cagno, 2012; Kostka et al., 2011; Okazaki and Yamaguchi, 2011; Palm and Thollander, 2010; Oikonomou et al., 2009; Schleich et al., 2008; Shi et al., 2008; Sardianou et al., 2008; Schleich and Gruber, 2007; Anderson and Newell, 2004; De Groot et al., 2001; Harris et al., 2000). They have concentrated on the barriers and failures (Hassan et al., 2017; Trianni et al., 2013a) due to the large potential in that sector for further EE improvements. Wang et al. (2018) pointed out that the scholars have paid less attention to drivers compared to the number of the studies investigating potential barriers in the industry sector. However, promoting the driving forces that lead enterprises to adopt EE measures might be as effective as mitigating barriers to close the energy efficiency gap. In addition, since there are a variety of tools, measures and investment opportunities to enhance EE, it is important to identify the most highly prioritized factors that affect them.

This study aims to find out those factors and the relative importance of them from the perspective of the energy experts who work at the enterprises that have implemented at least one EE improvement. To this end, we developed a questionnaire survey (QS), which gathers their potential attitudes and feedback on EE measures and EE policies.

This study uses primary data from the Turkish industry. We prefered the Turkish case, which is because the Turkish government initiated a special financial subsidy mechanism for Efficiency Improvement Project (EIP)s in 2009. Since then, approximately 5 million US Dollars ($) financial support has been paid to the completed EIPs. Despite the allocation of a significant amount of financial support via the EIPs, the factors affecting the implementation of EIPs in terms of real and potential barriers and drivers for them have never been studied so far in the Turkish context. There is only one study considering Turkey as a case for simultaneously investigating barriers to and drivers for EE. However, its scope is limited by 3 sub-industrial sectors. Besides, in his study, Kalangos (2017) investigated barriers to and the policy drivers for EEI with the data derived from only 30 industrial enterprises. Therefore, our study is different from it because of its scope over 14 Turkish sub-industrial sectors with 135 industrial enterprises as well as including all possible drivers for EEI along with policy drivers.

This study has several novelties. One is that we developed a questionnaire, consisting of many factors for barriers and drivers based on the literature review. This broad approach to the factors affecting industrial EEI can be used for future research. Moreover, more broad and detailed classifications is not only necessary for better understanding of the empirical factors but also required to build a sound and viable policy recommendation. Furthermore, this study reveals the importance rankings of the perceived barriers and drivers for EEI in a developing country. Therefore, the findings of this study can be used for developing energy policies in other developing countries. They can also be compared with similar studies conducted for different sectors and different development levels of countries to enlarge the knowledge on the issues related to the energy efficiency gap in the industry.

The other novelty of this study is that it examines and aggregates the answers of enterprises at the level of energy-intensive and non-energy-intensive sectors. We also addressed the top ranked and significant barriers and drivers based on the energy intensity levels as well as scale of enterprises. By having a special focus to energy intensity levels and firm sizes, this study suggests better operational outcomes to practitioners for enhancing EE, while taking into account the attitudes towards EE policies for the industry.

Moreover, in this study, we utilized the experiences and perceptions of the energy managers and/or experts who work at the industrial enterprises that implemented at least one EIP. By using such an experienced group of sample on EE, this study provides a deeper insight into the actual and potential barriers to and drivers for the practices and policies in the industrial EE implementation.

Last but not least, improving EE is one of the essential ways to combat global climate change. The Glasgow Climate Pact in 2021 highlighted EE in the process of the Conference of the Parties (COP). In fact, the parties of the Paris Agreement might make use of the EE improvements to achieve their net-zero emissions target. This study brings together the perspectives of the experienced group of EE implementers to reveal the importance level of the actual and potential barriers and drivers. Therefore, this study suggests a deep insight into how the humanity can take the most advantage of the EE measures in the process of the COP.

The organization of this paper is as follows: the next section gives some review of the most relevant literature on the study of barriers and drivers of EE as well as the targeted sample group description. In section 2.3, empirical survey findings are presented. Finally, we conclude and explain the implications of this study.

2.2. RESEARCH METHODOLOGY, THEORETICAL FRAMEWORK AND DATA

This study aims to introduce the potential and perceived barriers to and drivers for EE in an industry sector by applying descriptive and exploratory approach. The study covers all Turkish enterprises in industry sector that has completed EIPs partially financed by the state. However, the number of the enterprises which completed EIPs is limited to 135.

We developed a questionnaire survey (QS) based on the related literature. The QS consists of two main parts: Descriptive and explorative parts. The descriptive part was used to obtain the characteristics of the enterprises that completed EIPs in the Turkish industry. The explorative part was used to determine whether the perceived and real barriers to and drivers for EE improvements put forwarded in the literature perceived as suggested in the fourteen sub-industrial sector of Turkey.

The extant literature suggests that barriers to and drivers for EE investments for enterprises might be economic, financial, organizational, behavioral, technical, information, knowledge, material, market, regulation and policy related. A list of common barriers and drivers along with categorical differentiation are given Table 6 and Table 7, respectively. The tables also list the studies that they have investigated barriers to and motivations/drivers for improving EE and/or cost-efficient industrial EE measures.

Table 6: Major operational and empirical barriers

Category	Variable Abbreviation	Statement for Variable	Source
Economic	Low Capital	Low capital availability	(Thollander and Ottosson, 2008), (Trianni et al., 2013a), (Rohdin et al., 2007),
	Costs of Interrupted Production	Hidden cost of production interruption/disruption/inconvenience	Cagno et al., 2013
	Low Energy Cost in Total	Low share of energy costs	Trianni et al. (2013a)
	Long Payback	Long payback periods	(Soepardi et al.,2018), (Schleich et al., 2008), (Shi et al., 2008), (Cagno et al., 2013), (Harris et al., 2000),(De Groot et al., 2001), (Anderson and Newell, 2004),(Sardianou et al., 2008),(Oikonomou et al., 2009), (Kostka et al., 2011)
	High Education Cost of EE Tech	Unwillingness of employers to bear the cost of educating their employees about new energy efficient technology	(Thollander and Ottosson, 2008), (Trianni et al., 2013a), (Rohdin et al., 2007)
	Less Profit Perception	EE projects are not seen profitable enough /not considered worth the costs	Lawrence et al., 2019
Behavioral	Other Priorities	Other Priorities (Other investments are more important)	Cagno et al., 2013
	Inertia	Inertia	Cagno et al., 2013
	Focus Daily Problems	Managers and employees focus their attention to daily manufacturing problems	(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou et al., 2008), (Fleiter et al., 2012), (Meath et al., 2016)
	Long Decision Making	Long decision-making process	(Soepardi et al.,2018), (Shi et al., 2008), (Cagno et al., 2013), (Olsthoorn et al., 2015), (Sorrell et al., 2000),
	Firm Imperfect Evaluation	Imperfect evaluation criteria	Cagno et al., 2013
	Having Different Objectives	Lack of sharing the objectives	Cagno et al., 2013
	No Benefit Perception	Perception or thought of EE is not beneficial	Trianni et al. (2013a)
	Lack of Measure Awareness	Lack of interest and awareness	Cagno et al., 2013
Organizational	Low Efficiency Status	Low status of EE	Cagno et al., 2013
	Complex Decision Chain	Complex decision chain	Cagno et al., 2013; Thollander et al. (2013)
	Poor Physical Conditions	Lack of industrial space or unsuitable physical conditions for EEI	Own contribution

	Lack of Time	Lack of time	Cagno et al., 2013; Thollander and Ottosson, 2008), (Rohdin et al., 2007)
	Resistance to change	Resistance to change in managerial levels	Lawrence et al., 2019
	Limited Authority	Limited authority of the energy management department and its personnel within the enterprise for EEI is not strong enough and its authority is limited	(Thollander and Ottosson, 2008), (Rohdin et al., 2007)
	No Inspection	Industrial establishment is characterised as energy-efficient	Own contribution
Competences	Poor Equipment	Difficulties in identifying opportunities and inefficiencies	Lee, K. H,. 2015
	Poor Technical Characteristics	Current technical characteristics of process is not adequate to implement EEI	Cagno et al., 2013
	Lack of Qualified Staff	Lack of staff/skilled technical personnel	(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou et al., 2008), (Fleiter et al., 2012), (Meath et al., 2016)
	Need for Consultancy	Lack of staff for implementation interventions and analysis	(Rohdin et al., 2007);(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou et al., 2008), (Fleiter et al., 2012), (Meath et al., 2016)
Awereness	Lack of EE Awareness	Lack of information with regard to energy conservation opportunities	Lawrence et al., 2019
	Lack of Knowhow	Lack of	Lawrence et al., 2019; Rohdin et al., 2007
	Lack of Profitability Awareness	Lack of information with regard to the profitability of energy saving measures	Lawrence et al., 2019
	No Trust on Info Source	Lack of reliance on the information source for EEI Lack of awerness/ignorence to EEI	Cagno et al., 2013
Market	Cost of Finding Capital	High cost for investing capital availability for the operating sector	(Soepardi et al.,2018), (Schleich et al., 2008), (Shi et al., 2008), (Cagno et al., 2013), (Harris et al., 2000),(De Groot et al., 2001),
	Low Technology Diffusion	Low diffiusion of technology/Inadequate energy-efficient technologies	(Soepardi et al.,2018), (Shi et al., 2008), (Cagno et al., 2013), (Olsthoorn et al., 2015),(Oikonomou et al., 2009), (Fleiter et al., 2012)
	High Market Risk	High market risks	Rohdin et al. (2007); Cagno et al., 2013
	Limited Access to Capital	Limited access to capital	Thollander and Ottosson, 2008), (Trianni et al., 2013a), (Rohdin et al., 2007),
	Uncertain Future Prices	The uncertainty about future energy prices	Rohdin et al. (2007)

	High Transaction Cost	High transaction costs	Lawrence et al., 2019
	Difficulty of Determining Parameters	Difficulty in identification quality parameters of investment/Uncertainty of how energy management improves EE	Lawrence et al., 2019
Policy	Lack of Government Audit	Lack of audit for EE by Government	Cagno et al., 2013
	Incorrect Auditor Assessments	Inaccurate assessment for EEI by auditors	Cagno et al., 2013
	Lack Incentive Mechanisms	Absence of economic incentive regulation for implementing the EEI.	(Soepardi et al.,2018), (Oikonomou et al., 2009), (Okazaki and Yamaguchi, 2011), (Shi et al., 2008),(Olsthoorn et al., 2015),(Reddy, 2001)
	Long Bureaucratic Procedures	Lots of paper work and bureaucratic procedure for getting incentive and Complex bureaucratic procedures	Wang et al., 2018
	Time Limits of Completing Projects	Strict time limitation for EEI supported by state	Own contribution
	Limited Incentivized Sectors	Lack of incentive or less amount of incentive	(Soepardi et al.,2018), (Oikonomou et al., 2009), (Okazaki and Yamaguchi, 2011), (Shi et al., 2008),(Olsthoorn et al., 2015),(Reddy, 2001)
	Energy Tax on Equipment	Taxes on energy efficient technology and equipment	(Apeaning and Thollander, 2013), (Brunke et al., 2014),
Information	No Technology Performance Informing	ESCOs and their suppliers not sufficiently informing the market about the performance of energy efficient technologies	Thollander et al., 2013
	No Sectoral Information Sharing	Failure to share sectoral experiences and good practices for EE improvements	Wang et al., 2018
	No External Communication	Lack of external corporate communications	Cagno et al., 2013
Technical	No Current Techno Information	Inadequate energy-efficient technologies	Cagno et al., 2013
	Only Marketing Available Tech	Marketing of existing technologies by suppliers instead of the most efficient and up-to-date technologies	Cagno et al., 2013
	Difficulty of Finding Appropriate Technology	difficulty in identification of efficient and appropriate technology for the business process	Cagno et al., 2013
	Unavailability of Advance Technology	Unavailability of more advanced technologies related to the operating sector of activity	Own contribution
	Lack of Technology Experts	Difficulty in gatering external technical skills in the market	Cagno et al., 2013

Table 7: Major operational and empirical drivers

Category	Variable Abbreviation	Statement for Variable	Source
Economic	Longterm Strategy	Long-term energy consumption and management strategy of firm	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014) , (Wang et al., 2018)
	Cost Reduction	Cost reduction resulting from lower energy consumption	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013) ,(Wang et al., 2018)
	High Investment Return	High rate of return on the investment	Own Contribution
Informational	Priorities To EEI	Priorities given to EEI	Sorrell et al., 2000
	Information From Networks	Acquaintances and networks within the energy sector	(Thollander and Ottosson, 2008), (Brunke et al., 2014)
	Local Consultancy	Local authority energy consultancy	Lee, K. H., (2015)
	Expert Support	Support from energy experts	Lee, K. H., (2015)
	Owner Demand	Demand from owner, Owner's requirement	Brunke et al. (2014)
	Sector Support	Support from the sector organisation	Lee, K. H., (2015)
	Ambitious Employee	People with real ambition/highly motivated employee	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014);
Organizational	Operating ISO50001	Operating a Energy management system ISO 50001	Lawrence et al., 2019
	Priorities To EEI	Priorities of EEI projects	Own Contribution
	Committed Management	Management with ambition/Assurance from preeminent management	(Brunke et al., 2014), (Thollander et al., 2013), (Wang et al., 2018)
Competences	High Motivated Employees	Highly motivated employee	Thollander and Ottosson, 2008), (Trianni et al., 2013a), (Rohdin et al., 2007),
	Advanced Analysis Capability	Advanced capabilitiy in identifying opportunities and inefficiencies in the process	Lawrence et al., 2019
	Qualified Analyst	Advanced technical capabilitiy in analysis and implementation of EE projects	Thollander et al. (2013a)
Awereness	Environmental Benefits of EE	Environmental benefits (other than CO_2…	Lee, K. H., (2015)

	Competitive Awareness	Competitive awareness	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013),
	Energy Plan	Energy Plan	(Rohdin et al., 2007), (Brunke et al., 2014)
	Emission Reduction Target	Viable reduction in carbon emissions	Lee, K. H., (2015)
	Awareness on Gains	Awerness on EEI Gains	Trianni et al., (2013)
Economic	Domestic Competitiveness	Competing with other domestic firms in the sector	Wang et al., (2018)
	Equipment Subsidy	Energy-efficient equipment subsidies	Wang et al., (2018)
	Financing Loans	Beneficial international loans for EE investment / Favorable loans for efficient energy financing	Lee, K. H., (2015)
	Third Party Financing	Third-party financing	Thollander et al. (2013); Lee, K. H., (2015)
	Threat Of Rising Price	Menace of rising energy prices	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013)
Informative	Technical Consultancy	Locally available energy consultancy /Technical support	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013)
	Professionals Assistance	Assistance from energy professionals	Own Contribution
	Training Programs	Programs of education and training	(Lawrence et al., 2019); (Wang et al., 2018)
	Energy Saving Culture	Energy-saving culture	Wang et al., (2018)
Policy	Domestic Incentives	Beneficial national/domestic incentives for EEI (Enerji Bakanlığı)	Lee, K. H., (2015)
	Techno Invest Substitution	Subsidies for EE investments, technologies and schemes	Wang et al., (2018)
	Tax Exemption Agreements	Long-term agreements with tax exemption	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014), (Wang et al., 2018)
	Voluntary Agreements	Voluntary agreements	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Wang et al., 2018)
	Energy Carbon Taxes	Taxes (e.g. energy, CO_2)	(Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013)
	Legal Restr Standards	Legal restrictions/standards	Wang et al., (2018)

	Customer NGOs Press	Pressure from customers and NGOs	Brunke et al. (2014)

The most common empirical and theoretical barriers and drivers (and motivations) in the literature are usually clustered into two groups: Internal barriers/drivers and external barriers/drivers based on Table 6 and 7. On the one hand, Internal Barriers (IB) are categorized as economic, behavioral, organizational, competence and awareness related barriers while External Barriers (EB) as market-related, policy-related, information-related, and technical-related. On the other hand, Internal Motivations or Drivers (IM) are grouped into economic, informational, organizational, competence and awareness related drivers whereas External Motivations or Drivers (EM) are economic, informative, and policy related ones.

The barriers and drivers included in the questionnaire we surveyed were built using the classification given in Table 6 and Table 7. The respondents were asked to rate the significance of 51 potential barriers and 37 potential drivers for EE measures for their enterprises using a scale: 1 (strongly disagree); 2 (disagree); neutral (3); 4 (agree); 5 (strongly agree).

We conducted the QS with the enterprises, which are small-sized, medium-sized enterprises (SMEs), and large-sized enterprises (LEs), in the Turkish industry. We contacted 135 manufacturing SMEs and LEs from the 14 industrial sub-sector by using contact information obtained from The Energy Efficiency and Environment Department within the Ministry of Energy and Natural Resources. The QS was conducted between March 2020 and January 2022 by applying the web-based approach. The surveyed data were mostly filled by the energy managers who are responsible for the EIPs and other energy related tasks and issues at their enterprises. We received 86 responses. The overall response rate was 63.7%, which may be regarded as a high rate of response compared with similar studies (Thollander and Ottosson, 2008; Hassan et al., 2017).

We categorized the enterprises that completed the QS according to Nace rev. 2 codes in order to determine each enterprise’s sub-industrial sector. The number of enterprises responded our QS based on their sub-sectors and Nace rev. 2 codes are shown in Table 8.

Table 8: Profile of respondents based on Nace rev. 2 codes and sub-sectors

NACE Code	Division, Group or Class Description of Sub-Sectors	# of Enterprises	% of Enterprises
C24	Manufacture of basic metals	19	22
C20	Manufacture of chemicals and chemical products	6	7
C19	Manufacture of coke and refined petroleum products	1	1
C27	Manufacture of electrical equipment	3	3
C25	Manufacture of fabricated metal products, except machinery and equipment	2	2
C10	Manufacture of food products	6	7
C29	Manufacture of motor vehicles, trailers and semi-trailers	7	8
C23	Manufacture of other non-metallic mineral products	11	13
C17	Manufacture of paper and paper products	4	5
C22	Manufacture of rubber and plastic products	3	3
C13	Manufacture of textiles	12	14
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	9	10
B8	Other mining and quarrying	1	1
G46	Wholesale trade, except of motor vehicles and motorcycles	2	2
	TOTAL	**86**	**100**

The sample includes 14 sub-sectors and represents 63.7% (86 out of 135) of the population of all industrial enterprises completed EIPs. Therefore, the sample assures the generalization of results for all Turkish industrial enterprises.

2.3. RESULTS AND DISCUSSION

This section shows the results obtained from the quantitative parts via the QS. Subsection 2.3.1 represents the results on respondents' characteristics, subsection 2.3.2 presents the findings on barriers to EE implementations and subsection 2.3.3 presents the results on drivers to EE implementations.

2.3.1. Enterprises' and Respondents' Profile and Qualification

The respondents' profile, shown by Table 9, is very important to deduce whether the QS can retrieve usable data. EIPs were submitted by mostly energy managers of the enterprises. As expected, the 53 of the QS was filled by them, which is the 61% of the overall responses. 31% of the QS was completed by the staff positioned as “other” which are Business Director, General manager, Mechanical Maintenance Manager, Technical Personnel/ Energy Manager, R&D Center Officer, Quality Assurance Chief, Energy Manager, Group Energy Director, R&D Engineer, Refinery and Energy Production Technology Manager, Electrical and Maintenance Manager, Energy and Electricity Department Manager, Technical and Energy Manager, Electrical Maintenance Engineer, Quality Documentation Officer, Energy and Maintenance Manager, Mechatronics Chief and Energy manager and so on. Hence, the profile implies that this study reached the respondents who have experience and knowledge of EE practices and energy issues.

Table 9: Profile of Respondents

Position	**Frequency**	**Percentage**
Energy Manager	53	61%
Factory Manager	1	1%
Technical Staff	5	6%
Production and Planning Engineer	1	1%
Other	26	31%
Total	86	100%

The frequency of the employee number is given in Table 10. The enterprises are subdivided into the categories in terms of the firm size. The enterprises with 1 to 9 employees are classified as micro enterprises, the ones with 10 to 49 employees as small enterprises, the ones with 50 to 249 employees as medium enterprises, and the one with more than 250 employees as large enterprises. The table 10 shows that 82% of the enterprises are large scale whereas 14 % of them are medium-sized scale and only 2 % of the respondents are small-sized enterprises. Therefore, the repartition of the firm size in our sample is right-skewed towards enterprises with more than 250 employees.

Table 10: Number of Employees

Number of Employees	**Frequency**	**Percentage**
Less than 10	1	1%
Less than 50	1	1%
Less than 250	13	15%
More than 250	59	69%

Other	12	14%
Total	86	100%

The willingness of implementing EE measures may also be alterable with respect to the energy intensity level status of the enterprises. Basically, energy intensive industries refer to industrial sectors which use high amount of energy and therefore their energy costs are usually a large portion of their production costs (Hutton et al., 2021). In this regard, we sub-sized the sample whether they are energy intensive or non-energy intensive. The energy intensity profile of the respondent enterprises is given in Table 11.

Table 11: Energy intensity levels of the respondent enterprises with Nace rev. 2 descriptions

	Manufacturing Sectors	**% of Enterprises**
Energy-Intensive	Food products - C10	7
	Textiles - C13	14
	Wood and of products of wood and cork, except furniture; Articles of straw and plaiting materials - C16	10
	Paper and paper products - C17	5
	Coke and refined petroleum products - C19	1
	Chemicals and chemical products - C20	7
	Rubber and plastic products - C22	3
	Other non-metallic mineral products - C23	13
	Basic metals - C24	22
Non-Energy Intensive	Fabricated metal products, except machinery and equipment - C25	2
	Electrical equipment - C27	3
	Motor vehicles, trailers and semi-trailers - C29	8
	Other mining and quarrying - B8	1
	Wholesale trade, except of motor vehicles and motorcycles - B46	2

Almost 83% of the sample belongs to Energy Intensive Sectors (EIS), i.e. basic metals 22%, textiles 14%, mineral products 13%, wood products 10%, other 34%. On the other hand, 17 % of the respondents belongs to the Non-energy Intensive Sectors (NEIS).

2.3.2. Barriers to energy efficiency measures

Since this study aims to explore barriers to and drivers for industrial EE improvement in industrial SMEs and LEs, we analysed the derived data from the QS for barrier-related factors and driver-related factors separately in order to make sound deduction between these categories. Therefore, we sub-divided them to examine the influence of perceived barriers and drivers on EE separately.

In Table 7, the results of the all barriers derived from the QS according to the ranking made by 86 respondents along with their respective average scores and responses in percentage are represented. The barriers with average score equal or greater than 3 are considered more important while the rest of the barriers having score less than 3 may be regarded as less important since we used 5 point Likert scale ranking in our survey.

Table 12: All enterprises' ranking of barriers to Energy Efficiency Improvement and responses in percentages

Barriers	**Average Score**	**Strongly Disagree (%)**	**Disagree (%)**	**Neutral (%)**	**Agree (%)**	**Strongly Agree (%)**
LongPayback	3,55	7	17	7	51	17
LongBureaucraticProcedures	3,24	13	19	16	36	16
LackIncentiveMechanisms	3,1	7	36	12	30	15
NoSectoralInformationSharing	3,09	8	29	17	36	9
NoTechnologyPerformanceInforming	2,94	13	27	22	30	8
NoExternalCommunication	2,94	14	29	17	28	12
EnergyTaxonEquipments	2,9	12	26	30	27	6
LimitedIncentivizedSectors	2,85	10	34	24	23	8
NoCurrentTechnInformation	2,8	6	38	28	26	2
OnlyMarketingAvailableTechnology	2,78	12	26	16	18	4
TimeLimitsofCompletingProjects	2,78	12	34	28	19	8
CostsofInterruptedProduction	2,77	10	44	10	28	7
HighTransactionCost	2,76	8	42	19	29	2
HighMarketRisk	2,72	14	35	22	23	6
UncertainFuturePrices	2,67	15	37	22	16	9
DifficultyofFindingAppropriateTechnology	2,67	9	47	17	21	6
LackofTechnologyExperts	2,65	14	40	16	28	2
LongDecisionMaking	2,6	19	35	17	26	3
Inertia	2,58	10	50	14	22	3

FocusDailyProblems	2,57	15	41	21	19	5
LimitedAuthority	2,52	17	47	10	17	8
OtherPriorities	2,48	19	45	13	16	7
CostofFindingCapital	2,48	19	44	13	20	5
LackofQualifiedStaff	2,47	24	37	14	16	8
ComplexDecisionChain	2,45	17	47	14	17	5
UnavailabilityofAdvanceTech	2,44	15	47	19	19	1
LimitedAccesstoCapital	2,4	20	42	20	16	2
HavingDifferentObjectives	2,38	20	44	19	13	5
LackofEEAwareness	2,37	26	41	12	15	7
LackofMeasureAwereness	2,36	22	44	13	17	3
LackofProfitabilityAwareness	2,36	26	40	14	15	6
DifficultyofDeterminingParameters	2,36	19	44	22	13	2
PoorPhysicalConditions	2,33	30	35	13	16	6
LackofTime	2,33	22	51	5	16	6
IncorrectAuditorAssessments	2,33	16	56	12	12	5
PoorEquipment	2,31	26	44	9	15	6
NoTrustonInfoSource	2,3	23	47	9	19	2
LowTechnologyDiffusion	2,28	21	51	10	14	3
ResistancetoChange	2,26	22	48	15	13	2
LowCapital	2,24	24	49	7	17	2
PoorTechnicalCharacteristics	2,23	24	48	12	13	3
LackofKnow-How	2,19	27	47	10	14	2
NeedforConsultancy	2,07	30	49	7	12	2
LackofGovernmentAudit	2,06	34	44	9	8	5
NoInspection	2,05	33	48	6	10	3
FirmImperfectEvaluation	2	37	43	6	10	3
LessProfitPerception	1,99	28	52	13	7	0
HighEducationCost	1,85	34	55	6	5	1
LowEfficiencyStatus	1,72	49	40	3	7	1
LowEnergyCostinTotal	1,67	51	40	2	2	4
NoBenefitPerception	1,6	55	37	2	5	1

The results reveal that the more important barriers are “Long Payback”, “Long Bureaucratic Procedures”, “Lack Incentive Mechanisms”, “No Sectoral Information Sharing”, “No External Communication” and “No Technology Performance Informing”. The majority of the respondents considered “Long Payback”, which refers to the longer payback periods of projects for replacement of more efficienct technology, as the most important barrier to industrial energy efficiency improvement (EEI) with an average score of 3.55. This barrier is theoretically related to the “Economic Barriers” of enterprises, which is interior to the enterprises. Furthermore, this barrier was also ranked the most important barrier among SMEs with a slightly higher average score of 3.64 and among larger enterprises with 3.54 average score. “Long Bureaucratic Procedures”, which was elaborated in the QS as lots of paper work and bureaucratic procedure to obtain state incentives, was considered by the respondents as the second major barrier with average score of 3.24. It is followed by “Lack Incentive Mechanisms”, referring to the absence of economic incentive regulation for implementing the EEI, with average score of 3.1. These two barriers are both related to “Policy Related External Barriers” category and also ranked as the second and third highest barriers among all enterprises. “No Sectoral Information Sharing” was perceived as the next most important barrier with an average score of 3.13. This barrier is related to “Informational Barriers” and stated as failure to share sectoral experiences and good practices for EEI in the QS, which is an external barrier to the enterprises. “No Sectoral Information Sharing” was seen as the fourth most important barrier among LEs whereas it was ranked as the fifth most important barrier among SMEs. The next most ranked barriers by the respondents were “No External Communication”, which is lack of external corporate communications between the enterprises in their sectors, and “No Technology Performance Informing”, which is linked to the Energy Service Companies (ESCOs) and their suppliers for not sufficiently informing the market about the performance of energy efficient technologies. Their average scores are 2.94, slightly less than 3.

In sum, the results reveal that the top four barriers, which include a policy-based (i.e. Long Bureaucratic Procedures and Lack Incentive Mechanisms), external information-based such as “No Sectoral Information Sharing” and an internal economic behavioural perspective namely “Long Payback” play important roles in implementing energy efficiency investment projects in general. Therefore, focusing on these categories (both the external policy and information related, and internally origined economic related perspectives) might mitigate the barriers to EE investment.

2.3.2.1. Barriers By Size Of Organization

The scale of enterprises is claimed as one of the most important factors affecting EE (e.g. Rohdin and Thollander, 2006; Schleich, 2009; Trianni et al., 2013b). We, therefore, report the average scores of the highest-ranked 15 barriers according to the firm sizes in Figure 7 and the average scores of all barriers for SMEs and LEs with differences in Table 13.

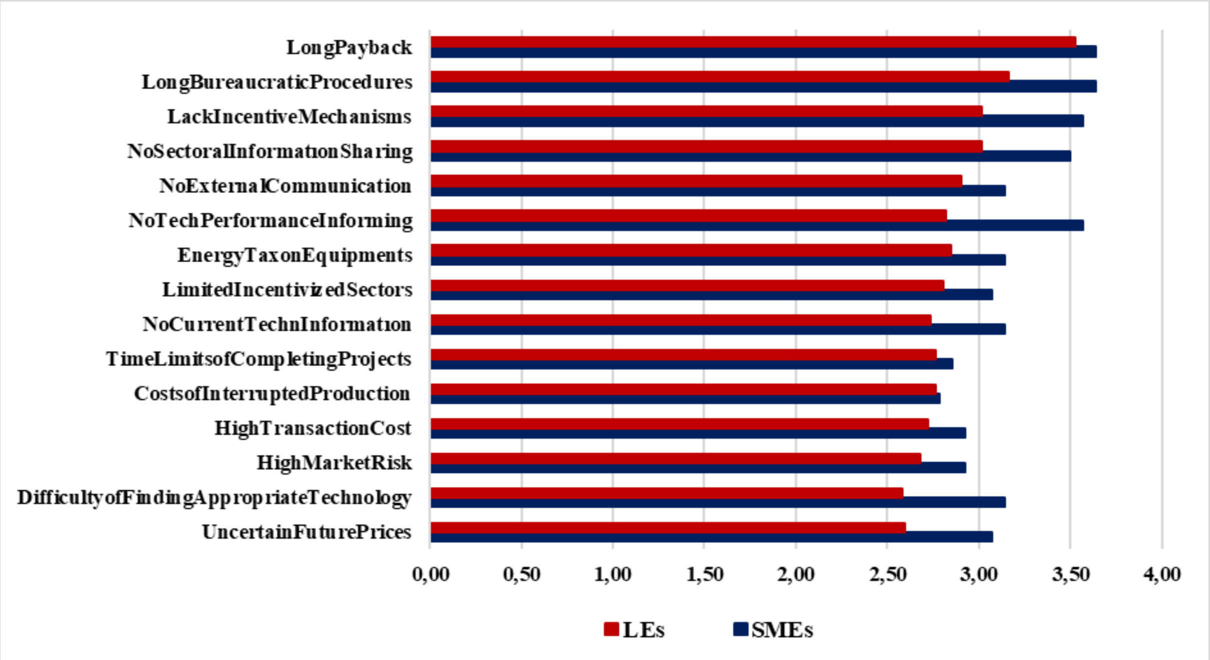

Figure 7: Top 15 highest-ranked barriers based by firm sizes

We detected several differences between the barriers perceived by SMEs and LEs. Specifically, the average scores of the the barriers in SMEs are mostly higher than those in LEs. The highest difference of average scores among the top 15 highest ranked barriers is 0,76 for the barrier called *"No Technology Performance Informing"*, which is linked to the ESCOs and their suppliers for not sufficiently informing the market about the performance of energy efficient technologies. This finding highlights that the larger the enterprise is, the lower the need to be informed about the performance of the efficient technologies. Most of the respondents of SMEs perceived this barrier as an important barrier with the average score of 3.57, whereas most of the LEs considered this barrier as much less important with the average score of 2.82. The second highest difference score (0.56) is for *"Difficulty of Finding Appropriate Technology"* barrier, refering to difficulty in identification of efficient and appropriate technology for the business process, which is associated with *"No Tech Performance Informing"*. This high difference score may be because of the fact that SMEs might not have enough information about the performance of energy saving measures compared to LEs. As shown in Table 8, these findings suggest that the tendency of perceiving the items as barriers diminishes as the enterprises' scale becomes larger.

Table 13: Average scores and their difference for the barriers against firm sizes

Barriers	**All Enterprises**	**Small&Medium (SM)**	**Large (L)**	**Difference in SMs and Ls**
	86	**14**	**72**	
LongPayback	3,55	3,64	3,53	0,12
LongBureaucraticProcedures	3,24	3,64	3,17	0,48
LackIncentiveMechanisms	3,1	3,57	3,01	0,56
NoSectoralInformationSharing	3,09	3,5	3,01	0,49
NoTechnologyPerformanceInforming	2,94	3,57	2,82	0,75
NoExternalCommunication	2,94	3,14	2,9	0,24
EnergyTaxonEquipments	2,9	3,14	2,85	0,3
LimitedIncentivizedSectors	2,85	3,07	2,81	0,27
NoCurrentTechnologyInformation	2,8	3,14	2,74	0,41
OnlyMarketingAvailableTechnology	2,78	2,64	2,81	-0,17
TimeLimitsofCompletingProjects	2,78	2,86	2,76	0,09
CostsofInterruptedProduction	2,77	2,79	2,76	0,02
HighTransactionCost	2,76	2,93	2,72	0,21
HighMarketRisk	2,72	2,93	2,68	0,25
UncertainFuturePrices	2,67	3,07	2,6	0,47
DifficultyofFindingAppropriateTechnology	2,67	3,14	2,58	0,56
LackofTechnologyExperts	2,65	3,29	2,53	0,76
LongDecisionMaking	2,6	2,21	2,68	-0,47
Inertia	2,58	3,07	2,49	0,59
FocusDailyProblems	2,57	2,71	2,54	0,17
LimitedAuthority	2,52	2,36	2,56	-0,2
OtherPriorities	2,48	2,71	2,43	0,28
CostofFindingCapital	2,48	2,86	2,4	0,45
LackofQualifiedStaff	2,47	2,79	2,4	0,38
ComplexDecisionChain	2,45	2,43	2,46	-0,03
UnavailabilityofAdvanceTechnology	2,44	2,43	2,44	-0,02
LimitedAccesstoCapital	2,4	2,29	2,42	-0,13

HavingDifferentObjectives	2,38	2,21	2,42	-0,2
LackofEEAwareness	2,37	2,86	2,28	0,58
LackofMeasureAwereness	2,36	2,71	2,29	0,42
LackofProfitabilityAwareness	2,36	3	2,24	0,76
DifficultyofDeterminingParameters	2,36	2,64	2,31	0,34
PoorPhysicalConditions	2,33	2,36	2,32	0,04
LackofTime	2,33	3,07	2,18	0,89
IncorrectAuditorAssessments	2,33	2,43	2,31	0,12
PoorEquipment	2,31	2,79	2,22	0,56
NoTrustonInformationSource	2,3	2,71	2,22	0,49
LowTechnologyDiffusion	2,28	2,43	2,25	0,18
ResistancetoChange	2,26	2,79	2,15	0,63
LowCapital	2,24	2,07	2,28	-0,21
PoorTechnicalCharacteristics	2,23	2,21	2,24	-0,02
LackofKnow-How	2,19	2,5	2,13	0,38
NeedforConsultancy	2,07	2,57	1,97	0,6
LackofGovernmentAudit	2,06	1,79	2,11	-0,33
NoInspection	2,05	2	2,06	-0,06
FirmImperfectEvaluation	2	2,14	1,97	0,17
LessProfitPerception	1,99	2	1,99	0,01
HighEducationCostofEETechnology	1,85	1,86	1,85	0,01
LowEfficiencyStatus	1,72	1,57	1,75	-0,18
LowEnergyCostinTotal	1,67	1,36	1,74	-0,38
NoBenefitPerception	1,6	1,71	1,58	0,13

However, the economic related barriers such as *"Less Profit Perception"* due to EIPs, *"High Education Cost",* which refers to the unwillingness of employers to bear the cost of educating their employees about new energy efficient technology, and *"Costs of Interrupted Production"*, namely hidden cost of production interruption and disruption, were considered in a similar manner by both SMEs and LEs since their average ranking scores are almost same. Their average score is also low, approximately 2. These results suggest that SMEs and LEs do not consider them as important barriers.

The highest difference of average scores (0,89) is for the barrier called "*Lack of Time*". Hence, lack of time was differently perceived by SMEs and LEs. Most of the respondents of SMEs perceived this barrier as an important barrier with the average score of 3.07, whereas most of the LEs considered this barrier as much less significance since its average score value is 2.18. This finding highlights that the larger the enterprise is, the lower the time management issues related to implementing EE measures are. This barrier might be linked with the second highest difference score (0.76) of “*Lack of Technology Experts*” and “*Lack of Profitability Awareness*” barriers since lack of technical skills and awereness of profitability opportunities of energy saving measures in SMEs might affect the decision of allocating time for EE improvements compared to LEs.

2.3.2.2. Barriers By Energy Intensity Level Of The Sector

Next, we explored if there are commonalities or differences with respect to the energy intensive levels of the sectors that the surveyed enterprises were in operation. Figure 2 represents the perceived barriers according to the ranking made by the respondents based on their energy intensity levels along with their respective average scores.

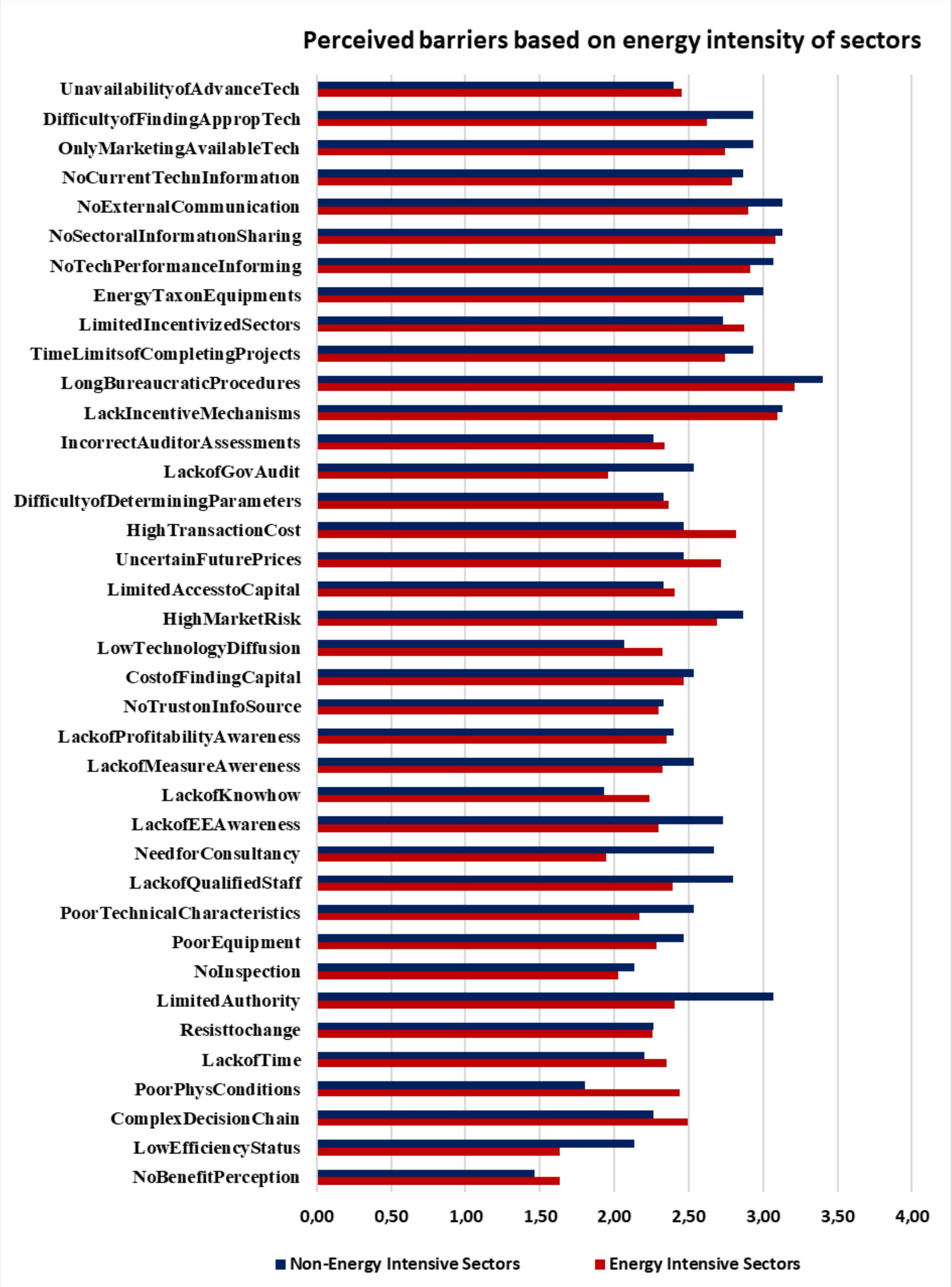

Figure 8: Barriers based on EIS versus NEIS.

The results indicate that the more important barriers for both EIS and NEIS are *"Long Bureaucratic Procedures"*, "*Lack Incentive Mechanisms*", *"No Sectoral Information Sharing".* The majority of the respondents considered "*Long Bureaucratic Procedures*" as the most important barrier to industrial EE with an average score of 3.40 for NEIS and 3.21 for energy intensive sectors. On the one hand, "*No External Communication*", *"Limited Authority"* of the energy management department and its personnel within the enterprise for EEI and *"No Technology Performance Informing"* are the barriers which were considered as important by the respondents from NEIS due to their average score bigger than 3. On the other hand, these three barriers were ranked less than 3 on average by the respondents from energy intensive sectors; therefore, they were not considered as significant barriers.

2.3.3. Drivers for energy efficiency measures

Table 9 shows the rank of the perceived drivers. In general, since we used 5 point Likert scale ranking in our QS for drivers as well as barriers, all of the drivers included in the QS were considered as important by the respondents due to their average score of over 3. 26 out of 37 drivers were ranked over 4 on average, which indicates strong perception of these drivers for EEI. This result suggests that the drivers are perceived important in reducing the energy efficiency gap (or energy paradox).

Table 14: All enterprises' ranking of drivers to Energy Efficiency Improvement and responses in percentages

Drivers	**Average Score**	**Strongly Disagree (%)**	**Disagree (%)**	**Neutral (%)**	**Agree (%)**	**Strongly Agree (%)**
OperatingISO50001	4,36	1	1	3	49	45
CommittedManagement	4,34	0	2	5	50	43
DomesticCompetitivenes	4,34	0	1	5	53	41
HighInvestReturn	4,33	0	2	8	44	45
AmbitiousEmployee	4,31	0	2	6	50	42
EnergyPlan	4,27	1	1	2	60	35
ThreatOfRisingPrice	4,27	1	3	3	51	41
CompetitiveAwareness	4,24	0	1	7	58	34
PrioritiesToEEI	4,23	0	1	7	59	33
AdvancedAnalysisCapability	4,23	0	3	5	57	35

DomesticIncentives	4,23	1	1	8	52	37
InvestmentSubsidyforEETechnologies	4,22	1	3	8	47	41
MotivatedEmployee	4,20	0	3	12	47	38
EnvironmentalBenefits	4,20	0	1	6	65	28
AdvanceKnowHowCapability	4,19	0	1	8	62	29
LongtermStrategy	4,17	0	3	5	63	29
PrioritiesToEEI	4,16	0	5	8	53	34
Awareness	4,15	0	1	12	58	29
EquipmentSubsidy	4,15	1	5	8	50	36
OwnerDemand	4,13	0	2	10	59	28
CostReduction	4,12	2	5	12	42	40
EmissionReductionTarget	4,10	0	6	8	56	30
EnergySavingCulture	4,09	0	1	10	66	22
Taxes	4,08	0	6	13	49	33
TaxExemptionAgreements	4,06	1	5	12	52	30
TrainingPrograms	3,98	0	3	16	59	21
VoluntaryAgreements	3,77	3	6	24	43	23
InformationFromNetworks	3,73	1	14	14	52	19
FinancingLoans	3,73	5	12	17	38	28
ExpertSupport	3,71	3	7	17	59	13
ProfessionalsAssistance	3,71	2	8	22	51	16
ThirdPartyFinancing	3,66	1	14	21	45	19
LegalRestrictionStandards	3,64	1	15	20	47	17
CustomerNGOsPress	3,64	1	9	29	45	15
SectorSupport	3,53	1	19	20	47	14
TechicalConsultancy	3,22	13	13	30	28	16
LocalConsultancy	3,05	8	26	30	26	10

As shown in Table 14, we found that *"Operating ISO50001"* was the most important driver by the majority of the respondents with an average score of 4.36. This driver is theoretically related to the organizational perspective of enterprises, which refers to operating an energy management system of ISO 50001. Furthermore, this driver was also ranked as the most important driver among LEs with a slightly higher average score of 4.38 and among SMEs with 4.29 average score. The drivers *"Committed Management"* and *"Domestic Competitivenes"* were considered as the second major drivers with same average score of 4.34. The driver *"Domestic Competitivenes"* refers to competing with other domestic enterprises. The other second importantly ranked driver *"Committed Management",* was elaborated in the survey as top management's determination, enthusiasm and assurance about the realization of EE projects and it is also categorized under the organizational drivers as well as *"Operating ISO50001"*. From an organizational perspective, the results show that operating a ISO50001 and committed top management are the main drivers for adoption of EE projects. The third top-ranked driver by the respondents was *"High Investment Return"*. This might be related to the fact that enterprises expect high returns in energy efficiency-enhancing projects, as in other investment decisions. The next most ranked drivers were *"High Investment Return", "Ambitious Employee"* could be categorised as the culture within the rather than outside. To be more specific, promoting an energy efficient culture within the company could improve EE implementation. On the other hand, the drivers *"Energy Plan",* that refers having plans on energy measuring, and *"Threat Of Rising Price",* that refers to the menace of rising energy prices, could be linked with the awereness and market related categorical drivers.

2.3.3.1. Drivers By Size Of Organization

Figure 9 demonstrates the average scores of the ranked drivers according to size of the enterprises. The figure reveals that SMEs and LEs perceive drivers differently. Specifically, the average scores of the perceived drivers in SMEs are mostly higher than those in LEs. This finding suggests that the likelihood of ranking the drivers with a higher score increases as the firm size becomes smaller.

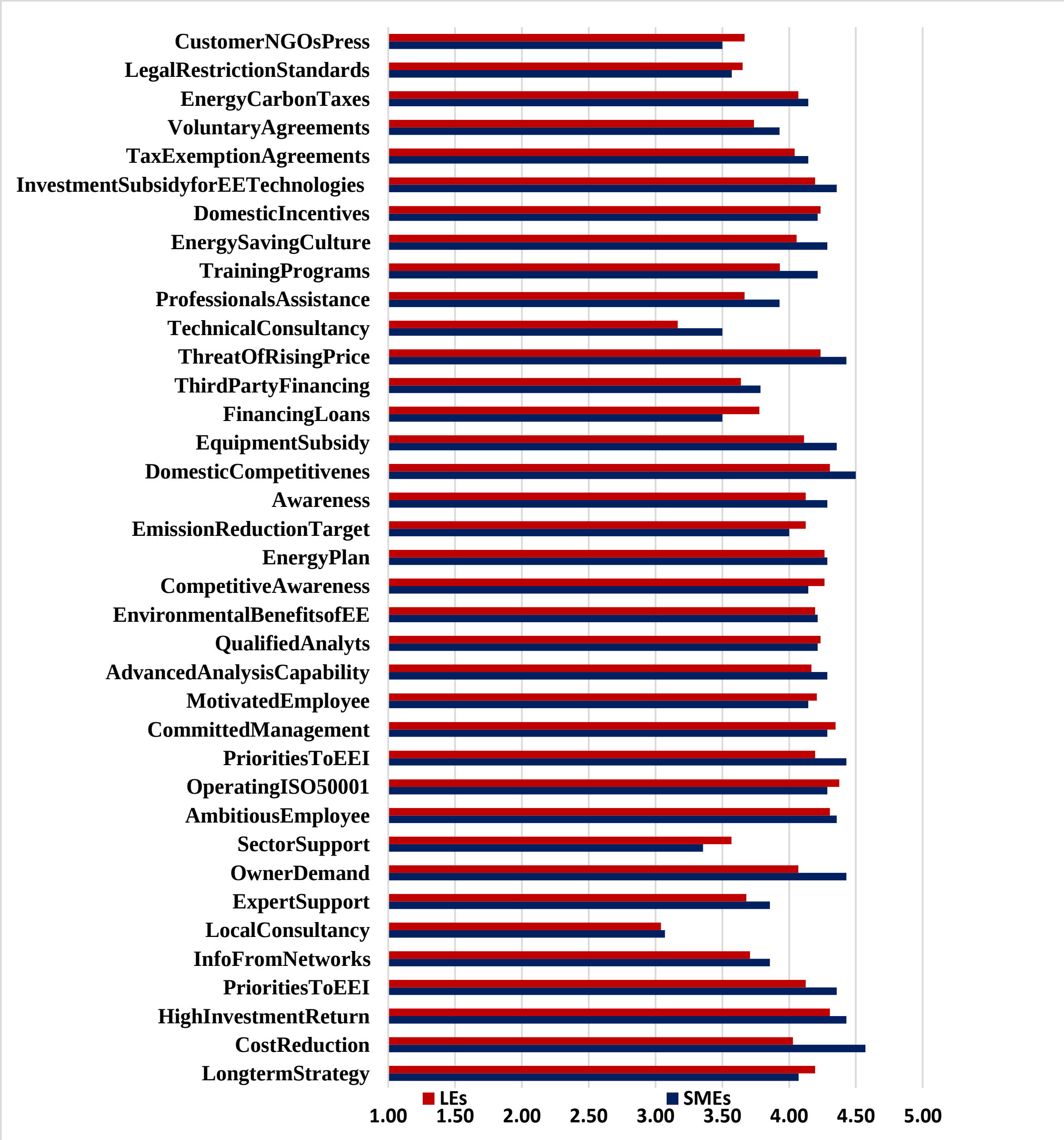

Figure 9: Drivers for energy efficiency based by firm sizes

We report the average scores of the highest-ranked 15 drivers according to firm sizes in Figure 9 and average scores of all drivers for SMEs and LEs with differences in Table 15. As can be seen from Figure 4, the drivers of SMEs and LEs were perceived differently in terms of their imporatance level. The majority of the respondents from SMEs considered "Cost Reduction", which was elaborated in the QS as cost reduction resulting from lower energy consumption due to EEI, as the most important driver since it has an average score of 4.57 whereas it was ranked as an average score of 4.03 by the respondents from LEs.

Moreover, the average scores of the perceived drivers in SMEs are mostly higher than those in LEs. Table 15 shows the drivers with significant differences in the SMEs and the LEs, which are equal or greater than 0.30. The highest difference of average scores (0,54) is for the driver called *"Cost Reduction"*. This finding shows that the larger the enterprise is, the lower the cost reduction issues related to implementing energy efficiency measures are. This may happen because LEs are already taking many measures to reduce the costs comparing to SMEs. The second highest difference of average scores is 0,36 for the driver called *"Owner Demand",* referring demand from owner for EEI. This driver, which is linked to the owner's requirement and demand for EE improvement, was considered very important but with a minor different perception by SMEs and LEs.

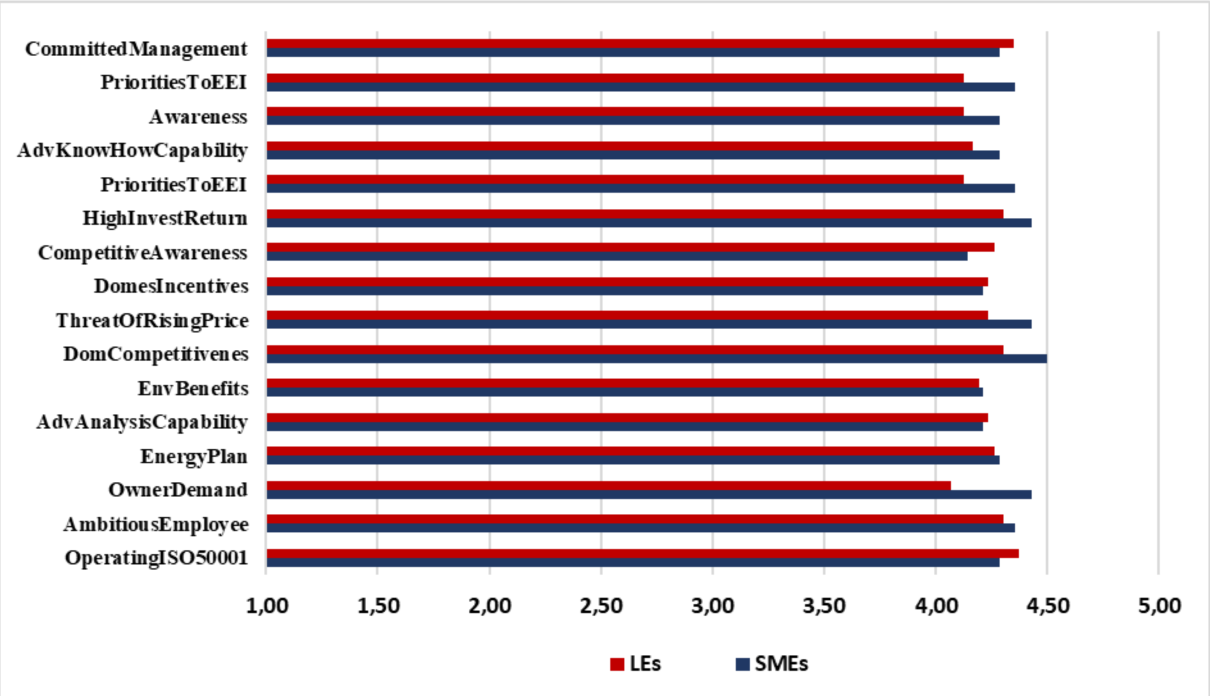

Figure 10: Top 15 highest-ranked drivers based by firm sizes

Table 15: Perceived drivers with significant differences in the SMe and the LEs.

Drivers	**Difference in SMEs and LEs**
CostReduction	0,54
OwnerDemand	0,36
TechnicalConsultancy	0,33
TrainingPrograms	0,28
ProfessionalsAssistance	0,26
EquipmentSubsidy	0,25
PrioritiesToEEI	0,23
EnergySavingCulture	0,23
SectorSupport	-0,21
FinancingLoans	-0,28

2.3.3.2. Drivers By Energy Intensity Level Of The Sector

Figure 11 represents the perceived drivers according to the ranking made by the respondents based on their energy intensity levels along with their respective average scores. We observed some significant differences between the perceived drivers of EIS and NEIS. In particular, the average scores of the perceived drivers in NEIS are mostly higher than those in energy intensive sectors. This finding might suggest that the enterprises from NEIS tend to perceive a factor as a driver stronger than the enterprises from energy intensive sectors.

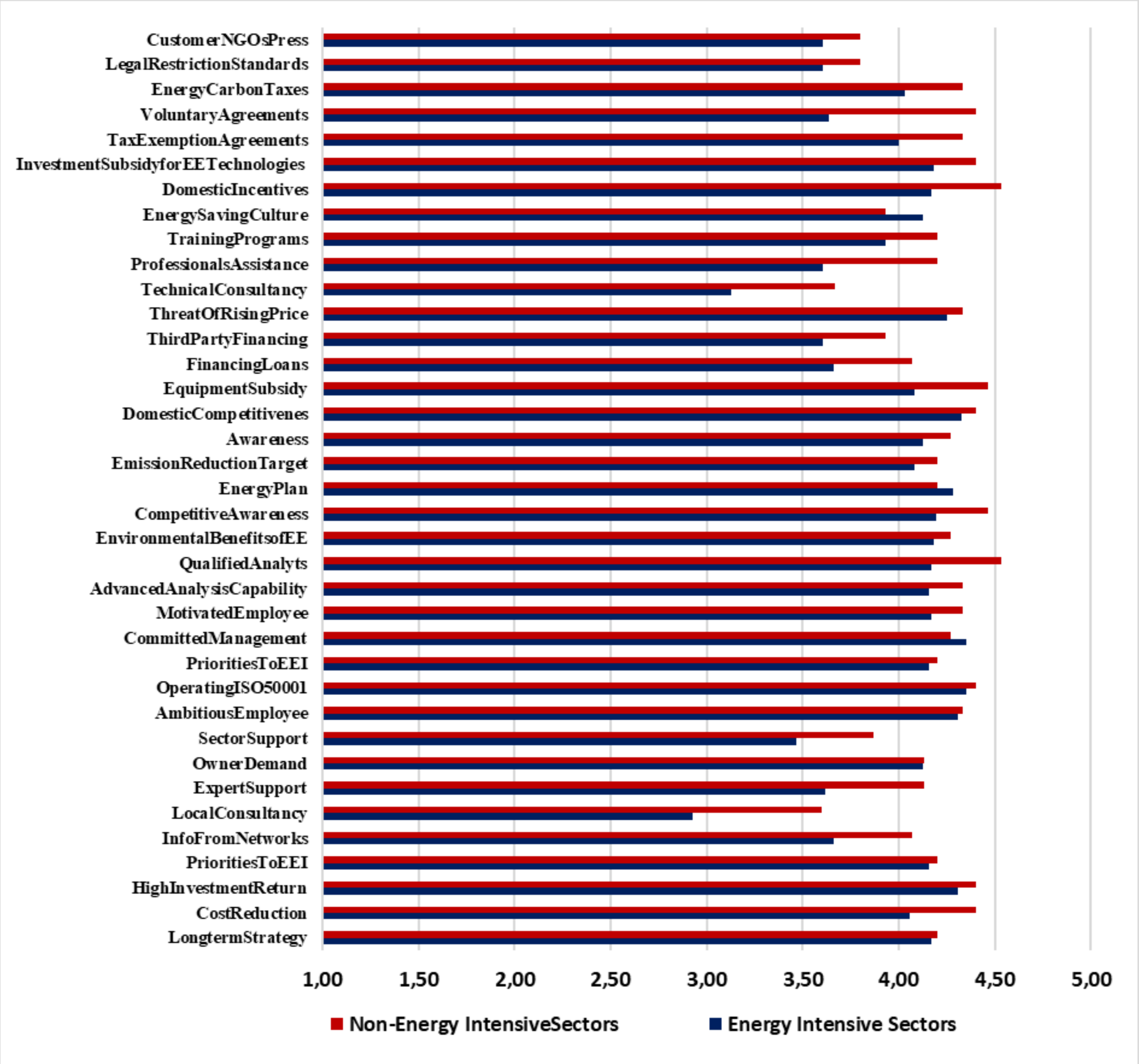

Figure 11: Drivers based on EIS versus NEIS.

The results reveal that all the drivers, except for *"Local Consultancy"*, were considered as important drivers since their average scores are higher than 3 for both EIS and NEIS. *"Local Consultancy*" refers offering energy consultancy to the enterprises by local authorities and administrations and it had an average score of 2.93 in energy intensive sectors. More importantly, 30 out of 37 perceived drivers have an average score of over 4 among non-energy intensive sectors, which shows a significant perception of drivers for industrial EE adoption.

The results for NEIS reveal that *“Advanced Analysis Capability”*, that refers to advanced capability in identifying opportunities and inefficiencies in the process, and *“Domestic Incentives”,* that refers beneficial national and domestic incentives for EEI, were considered as the most important drivers with an average score of 4.53. *“Competitive Awareness”,* that refers to having a long-term and international competition awareness for EE opportunities and gains, and *“Equipment Subsidy”,* that refers to subsidies for energy-efficient equipment, were ranked as the second major perceived drivers with 4.47 mean rating and followed by the drivers *“Cost Reduction”* referring to the cost reduction resulting from lower energy consumption, *“High Investment Return”,* referring to high rate of return on the investment, *“Operating ISO50001”,* referring to operating a energy management system of ISO 50001, *“Domestic Competitivenes”,* referring to competing with other domestic enterprises in the sector, *“Investment Subsidy for EE Technologies”,* referring to the investment subsidies for EE technologies and schemes, and *“Voluntary Agreements”,* referring to having voluntary agreements for efficiency energy usage.

The results for EIS are slightly different from NEIS. The majority of the respondents from EIS considered *“Operating ISO50001”* and *“Committed Management”* as the most important drivers with an average score of 4.35. Note that these two most important drivers for the EIS showed no variations in the average score of the responses. *“Domestic Competitivenes”* was considered as the second major perceived driver with an average score of 4.32. *“High Investment Return”* and *“Ambitious Employee”* were ranked as the third most significant drivers with an average score of 4.31. Besides, the driver *“Ambitious Employee”* has one of the closest differences of average scores (-0,02) between EIS and NEIS. The other closest difference is (-0,03) between EIS and NEIS for the driver *“Longterm Strategy”.* The closest difference of average scores (-0,01) is for the driver called *“Owner Demand”*. These findings highlight that owner's requirement and demand for EEI (*Owner Demand),* people with real ambition within a (*Ambitious Employee)* and existence of long-term energy consumption and management strategy of an enterprise (*Longterm Strategy*) were ranked very close on average as significant drivers by the respondents from both NEISand energy intensive sectors.

Table 16: Differences based on average perceived barriers against energy intensive level of enterprises.

Drivers	**Difference in EIS and NEIS**
VoluntaryAgreements	-0,77
LocalConsultancy	-0,67
ProfessionalsAssistance	-0,59
TechicalConsultancy	-0,54
ExpertSupport	-0,51
InformationFromNetworks	-0,40
FinancingLoans	-0,40
SectorSupport	-0,40

As shown in Table 16, the highest difference of average scores (-0,77) belongs to the driver called *"Voluntary Agreements"*. The other top-ranked differences of drivers between EIS and NEISpertain to offering energy consultancy to the enterprises by local authorities and administrations (*Local Consultancy)*, assistance from energy professionals (*Professionals Assistance*), locally available energy consultancy /technical support (*Technical Consultancy*), support from energy experts (*Expert Support*), acquaintances and networks within the energy sector (*Info From Networks*), beneficial and favorable international loans for financing EE investment (*Financing Loans*), and support from the sector organization and association on EEI *(Sector Support)* , which are related to informative and policy- based drivers. The reason why these drivers were chosen less important by the enterprises in energy-intensive sectors might be due to the fact that these enterprises are already more conscious and informed about the EEI and therefore they became technically more professional than enterprises operating in non-energy-intensive sectors.

2.4. CONCLUSION

In this study, we investigated barriers to and drivers for the implementation of energy efficiency measures/tools/investments (EEI) and the perceptional importance of them from the perspective of the energy experts. To this end, we focused on the Turkish industry. We, firstly, developed a questionnaire survey (QS), which consists of many questions that collect information about experiences, perspectives, and perceptions of the enterprises from 14 sub-industrial sectors, scales, and technical expertise levels about the EEI. We formed the questions by using as many factors for barriers and drivers as the literature has put forward so far. We, then, surveyed all Turkish industrial enterprises that have received state support at least once for Efficiency Improvement Project (EIP) since 2009. 86 of 135 industrial enterprises responded to the QS. Particularly, 53 of the QS was filled by energy managers who were mostly in charge of EIPs completion in their enterprises. The rest of the QS were also filled by the staff from either managerial or technical positions. Besides, 84% of the respondent enterprises are large-sized scale whereas 14 % of them are medium-sized scale and only 2 % of the respondents are small-sized enterprises. Therefore, the rate of response, 63.7%, is high, which might indicate the representativity of the population and the reliability of the outcomes of this study.

The results of this study ensure several outstanding findings for both researchers and policy-makers. The most important finding of this study is that all drivers in the QS were found as important by the respondents on average. Additionally, 26 out of 37 drivers were ranked over 4 out of 5 on average, which indicates a strong perception of these drivers for EEI. As the top-five-ranked drivers for EE investments, organizational, market, economic, and information/awareness factors were found major categorical factors for promoting EEI. That are specifically operating ISO50001, committed management, domestic competitiveness of an enterprise, high investment returns, ambitious employee, the existence of an energy plan, and the threat of rising energy prices. As another result regarding the drivers, the average scores of the perceived drivers in SMEs are mostly higher than those in LEs. This finding suggests that the likelihood of ranking the drivers with a higher score increases as the enterprises’ scale firm size becomes smaller. Furthermore, the average scores of the perceived drivers in NEISare mostly higher than those in energy-intensive sectors. In particular, the enterprises from NEIS tended to perceive a factor as a driver stronger than the enterprises from energy-intensive sectors.

In contrast, surprisingly only 4 barriers to EE investment are perceived as important since they were ranked over 3 among 51 barriers on average. The rest 47 barriers were not considered as hindering factors by the respondents for EEI. Economic, policy, and informational factors were found major theoretical factors to inhibit EEI. These factors include long payback, long bureaucratic procedures due to lots of paperwork demanded by government incentives, absence of economic incentive regulation for implementing EEI, and failure to reach sectoral experiences and good practices for EE improvements. Policy/regulatory factors (e.g. long bureaucratic procedures, lack of incentive mechanisms) were listed as the most hindering factors for EEI as well as economic and informational factors. Organizational, competence, awareness, and technical barrier-related factors were not perceived as hampering factors for EE investments. Another result regarding the barriers is that the respondents from SMEs and LEs had different opinions about the barriers. Specifically, the average scores of the perceived barriers in SMEs are mostly higher than those in LEs. This finding suggests that the tendency of perceiving the factors as barriers diminishes as the enterprises' scale becomes larger. In addition, the respondents from NEIS are more prone to consider a factor as a barrier compared to those from energy-intensive sectors.

This study reveals several policy implications that can be used to promote EE investment and overcome the barriers to them. One of them is associated with the paperwork and bureaucratic procedures for financial subsidies. This study shows that easing them will promote EE investment. Moreover, this study confirms that increasing the number of incentives might convince enterprises to invest in EE. Another policy implication is related to communication among enterprises. If they share sectoral experiences and good practices for EE improvements, the amount of EE investments might increase. We also observed that long payback periods were seen as the most important economic barrier by the respondent enterprises. Therefore, not only regulating the credit facilities and banks' lending policies for EIPs but also reinforcing supporting mechanisms might shorten the payback periods of EIPs, which might, in turn, promote EE investments.

For enterprises and practitioners, this study also provides some insights into improving their work and experience with EE improvements. This study identifies the most highly prioritized tools and measures among a variety of them to enhance the EE. For instance, operating ISO50001 offers continuous energy performance improvement; therefore, it is very useful to be adopted by the enterprises for sustainable efficiency improvements. Investment decisions in new EE tools for enterprises might bring an ambiguity in terms of economic (payback periods and profits) and production (interruption and disruption) levels. Therefore, exploring profoundly the sectoral experiences and good practices for EE equipment and technologies in cooperation with suppliers and Energy Service Companies (ESCOs), and making a decision based on what is best for them would help to reduce the risks and uncertainty due to EE technology change.

There are a few limitations to this study. We specifically focused on industrial enterprises that have received partial governmental financial support during the implementation of EIPs since 2009. Therefore, the population targeted in this study was only 135 enterprises. As a result of this, the sample enterprises are limited (86 enterprises), and 84% of the respondents to the QS are from large-scale enterprises. This might be an issue for generalizing the findings of this study to the industrial level irrespective of whether or not an enterprise completed an EIP. Hence, a survey with a large sample including the responses from all SMEs as well as different sub-industrial sectors would provide comprehensive evidence. Moreover, researchers could use larger industry-sector surveys in order to add to this study's and its conclusions' validity.

CHAPTER 3

BARRIERS TO AND MOTIVATIONS FOR INDUSTRIAL ENERGY EFFICIENCY IMPLEMENTATIONS: EVIDENCE FROM A DEVELOPING COUNTRY

ABSTRACT

This paper investigates barriers to and motivations for energy efficiency implementations (EEI) in the industry. We developed a questionnaire based on a broad approach to modeling the determinants of EEI by taking into account all possible barriers and drivers proposed by the literature so far. By using it, we surveyed all Turkish industrial enterprises which have received state support at least once for Efficiency Improvement Project since 2009 and applied the PLS-SEM methodology to the primary data. The results of this study might be used by a party of the Paris Agreement to achieve its net-zero emissions target and in fighting against climate change. In particular, this study reveals that increasing awareness, improving techno-economic capability, reinforcing subsidies and incentives, mitigating economy, information, and competence-related issues would result in improving energy efficiency. Alleviating high market risks and energy price uncertainties and coping with less profit perception might create a good climate for energy efficiency investments. If the performances of energy efficiency projects, sectoral experiences, and good practices about them, energy conservation opportunities through them are shared among the firms, energy efficiency improves. Training technical personnel and subsidizing the education costs of employees also remove several barriers to EEI.

Keywords: Industrial energy efficiency, Barriers, Motivations, Drivers, SMLEs, PLS-SEM

Jel Codes: A13, C52, C83, Q55, Q48.

3.1. INTRODUCTION

Global warming and its impacts on Earth, namely, global climate change, has become the major challenge of our time that every country regardless of their development level confronts because it poses a threat to humankind. It has been occurring due to the increasing amount of greenhouse gases (GHG) in the atmosphere since the end of the nineteenth century. GHG trap heat inside the atmosphere, resulting in global warming. GHG is released into the atmosphere mainly by humans. For instance, carbon dioxide (CO_2) emissions are increased because of fossil fuel burning, i.e. energy consumption. Nowadays, more than 70 countries account for more than 80 percent of carbon dioxide (CO_2) emissions (McKinsey, 2022). Taking over responsibility for global climate change, many countries determine common targets and road maps to achieve them in order to mitigate global warming. One of the major milestones on this struggle is the Paris Agreement, which is an international treaty adopted by 196 Parties in 2015. Its ultimate aim is to keep mean global temperature increase below 2, preferable 1.5, degrees Celsius by 2100 compared to pre-industrial levels. The Parties, then, adopted the Glasgow Climate Pact in 2021, which has a specific reference to energy efficiency (EE) in the process of the Conference of the Parties (COP). This was the first time EE has been explicitly cited. Article 36 calls on Parties to “accelerate the development, deployment and dissemination” of actions including “rapidly scaling up” EE measures.

The industry sector accounts for a large share of the world's final energy consumption that cause global warming. Improving industrial EE is, therefore, one of the most efficient (also cost-effective) approaches to diminishing global energy use, fossil fuel consumption and CO_2 emissions (Trianni et al. 2016). Sorrell et al. (2004), Sardinanou (2008), and Thollander and Dotzauer (2010) claim that energy efficient applications in industry have a bigger impact on global energy use and CO_2 emissions than in other sectors. According to Intergovermental Panel on Climate Change, if the industrial enterprises use energy more efficiently, they can reduce CO_2 emissions by 61% in 2050 compared to 2018 (IPCC, 2022).

However, there is a gap between potential EE measures and the actual implemented measures (Sorrell et al., 2004; Sardinanou, 2008; Thollander and Dotzauer, 2010). This is referred to as 'the energy-efficiency gap' or 'the energy paradox' (Jaffe and Stavins, 1994). Backlund et al. (2012) estimate it as approximately 11%. According to Reddy (2013), energy-efficiency gap occurs due to a set of barriers, consisting of economic, financial, regulatory, organizational, informational or knowledge-related barriers. The barriers could either prevent or decrease investments in energy efficient technologies. Nevertheless, there are economic, financial, organizational, competence-related, awareness-related, and policy-related factors that promote the adoption of energy efficient technologies and decrease the energy-efficiency gap. They are called motivations or drivers by the literature. While many studies have investigated the barriers to EE (Soepardi et al.,2018; Cagno et al., 2013; Trianni and Cagno, 2012; Kostka et al., 2011; Okazaki and Yamaguchi, 2011; Palm and Thollander, 2010), several others have explored the drivers or motivations for EE in industry (Thollander, et. al, 2008; Ren, 2009; Cagno et. al., 2013; Reddy, 2013; Trianni et al, 2016; Lawrence et al., 2019). We observe that the literature mainly focuses on barriers to and drivers for energy-efficiency investments for the developed countries (Haraldsson and Johansson, 2019; Lawrence et al., 2019; König et al., 2020). Since energy efficiency implementations (EEI) are used to address a global phenomenon, namely global climate change, analyzing barriers and motivations for mainly developed countries might not reveal the potentials of EEI in fighting against it. Furthermore, as a legally binding global climate change agreement, Paris Agreement leads all parties, i.e. not only developed countries but also developing countries, to strengthen and implement appropriate energy and climate policies to achieve net-zero CO_2 emissions target by 2050 (IEA, 2021).

This study aims to investigate the barriers to and motivations for industrial EEI in a developing country. To this end, we used primary data retrieved from the enterprises in the Turkish industry. The sample covers all industrial enterprises that has completed at least one state-funded Efficiency Improvement Project (EIP) since 2009. We surveyed them by using the questionnaire survey (QS) that we developed based on the literature. The QS covers 9 categorical barriers with 51 indicators and 8 categorical motivations with 37 indicators, which makes it have the most comprehensive content comparing to similar studies (Cagno et al., 2013; Kalangos, 2017). However, our model is very complex with many constructs, indicator variables and structural paths. Therefore, we preferred PLS-SEM method to test the research hypotheses since it can be used to estimate such complex models without imposing distributional assumptions on the data.

This study focuses on the case of the Turkish industry since Turkey takes actions to promote EEI and the success of these actions depends on the barriers and motivations to EEI. Even though Turkey ratified Paris Agreement in 2021 and declared a net-zero emissions target by 2053, it does not have a medium- and long-term roadmap in line with it (IPC, 2022). Nevertheless, Turkey has a short-term plan related to improving EE, namely The National Energy Efficiency Action Plan, the implementation period of which is between 2017 and 2023. It aims to reduce Turkey's primary energy consumption by 14% in 2023. For this aim, 55 actions in 6 categories are defined. The categories cover industry and technology along with buildings and services, energy, transportation, agriculture, and horizontal issues. Financial support for the EIPs are one of the actions in the Turkish industry. Approximately 175 EIPs have been completed and financed up to 30% of their cost by the Turkish government since 2009. They have helped about 50 thousand tonnes of oil equivalent (toe) be saved so far. However, this suggests that EIPs as a whole do not make a sufficient contribution to the cumulative savings if we take into account the fact that The National Energy Efficiency Action Plan is projected to achieve cumulatively 23.9 mtoe savings by 2023. On the other hand, Trianni et al. (2013) pointed out the high level of the energy savings potential of the industry. It is determined as 20% in the Turkish industry by TMMOB (2012). This reveals the energy efficiency gap in the Turkish industry. Our study explores the existence of barriers to and the lack of motivations for the EEI that might cause the energy efficiency gap in the Turkish industry. Therefore, we aim to shed light on the sources of the energy efficiency gap in a developing country by using the Turkish case.

A few studies have focused on a couple of developing countries (Bergh and Cohen, 2011; Kostka et al., 2013; Kalangos, 2017; Hasan et al., 2019). There is only one study considering Turkey as a case for simultaneously investigating barriers to and drivers for

EE. However, in this study Kalangos (2017) investigated barriers to and drivers for EE adoption in only Turkish automotive, chemicals and textile sectors, including 30 industrial enterprises. Moreover, he only explored the policy drivers. Different from it, our study not only investigates the Turkish industry as a whole but also explores all possible drivers for EE along with policy drivers. Moreover, we utilize the experiences of the energy managers and experts who work at the industrial enterprises that implemented at least one EIP. This approach to analyzing the barriers to and motivations for EEI provides useful insights directly from the field.

This study contributes to the related literature in several ways. Firstly, we utilized primary data from a developing country, which is a contribution to the literature, the majority of which has concentrated on developed countries. Secondly, the recent literature mostly reviews barriers to and drivers/motivations for EE separately (Kostka et al., 2013; Du et al., 2016; Backman, 2017). On the other hand, the studies that investigate both barriers to and drivers for EE (Hasan et al., 2019; Lawrence et al., 2019) have a limited scope in terms of the sub-industrial sectors and/or the sizes of the enterprises (Trianni et al., 2014; Hrovatin et al., 2021). This study is comprehensive so that it uses enterprises of any size from all sub-industrial sectors. Moreover, this study investigates key constructs based on the potential and perceived barriers to and drivers for EEI in an industry sector. Using the theoretical frameworks that have been introduced and the empirical findings that have been revealed in the literature so far, our study uses more broad and detailed classifications. This approach is not only necessary for better understanding of the empirical factors but also required to build a sound and viable policy recommendation. Thirdly, we explored the reasons of unwillingness of EE implementation in terms of barriers, and the motivations that might not exist in a country that offers financial incentives and operational support. Revealing them might help not only industrial enterprises implement cost-efficient technologies but also the policy makers create appropriate incentives. Finally, we applied the Partial Least Square Structural Equation Modeling (PLS-SEM) technique using SmartPLS 3.0 since it is a well-substantiated method for estimating complex cause-effect-relationship models (Gudergan et al., 2008). Zafar et al. (2021) investigate only a couple of barriers (i.e. technical, technological and informational barriers) to EEI by using PLS SEM technique to the data collected from 6 manufacturing organizations of Pakistan. Soepardi et al. (2018) also explores only 6 categorical barrier related constructs with small data size (38 practitioners from 12 steel firms). To the best of our knowledge, there is no study existed to consider simultaneously barriers and drivers for EEI, therefore we also fill this gap by applying PLS-SEM to investigate both barriers and drivers. The novelty of our study is that we applied it in a very comprehensive approach.

This paper is structured as follows. In Section 2, we review the literature on barriers and drivers for EEI by focusing on the key constructs creating them. In Section 4, we give the details about how we develop and test our model. In Section 4, we discuss conclusion and insights obtained from the study and accordingly, we mention the limitations of the study and make some suggestions for future research in this area in section 5 and conclude the paper.

3.2. LITERATURE REVIEW ON BARRIERS TO AND MOTIVATIONS FOR INDUSTRIAL ENERGY EFFICIENCY

Barriers to EE are not particularly a new issue. It could be dated as back to the years when EE started to become significant in addressing energy security after the 1973 energy crisis. Several disciplines namely engineering, economics and behavioural and organizational studies have made contributions to EE literature by investigating barriers (Soepardi et al.,2018; Cagno et al., 2013; Trianni and Cagno, 2012; Kostka et al., 2011; Okazaki and Yamaguchi, 2011; Palm and Thollander, 2010; Oikonomou et al., 2009; Schleich and Gruber, 2008; Shi et al., 2008; Sardianou, 2008; Anderson and Newell,2004; De Groot et al., 2001; Harris et al., 2000). A large body of literature has concentrated on the barriers and failures due to the large potential in that sector for further EEI.

In this study, barriers to EE can be defined as "any pull factors or mechanisms, that inhibit investment in technologies that are both energy-efficient and economically efficient, and may cause or help the existence of the energy efficiency gap" (Sorrell et al. 2000; Jaffe and Stavins, 1994). The availability of information or capacity within enterprises, dealing with risk and how it is viewed, internal processes of enterprises, or the availability of financial resources are some examples of barriers (Fleiter et al. 2011). Therefore, it should be noted that a barrier may be resulted from several factors such as economic, financial, organizational, behavioral, technical, information, knowledge, material, market and regulation aspects. We listed the common barriers introduced by the literature in Table 17. They include 9 categorical differentiations such as "Economic", "Behavioural", "Organizational", "Competence", "Information", "Awareness", "Market", "Policy", "Technical", and 51 barrier-related indicators.

Table 17: Taxonomies of operational and empirical barriers for investigation

Category	Variable Abbreviation	Statement for Variable	Source
Economic	Low Capital	Low capital availability	(Thollander and Ottosson, 2008), (Trianni et al., 2013), (Rohdin et al., 2007),
	Costs of Interrupted Production	Hidden cost of production interruption/disruption/inconvenience	Cagno et al., 2013
	Low Energy Cost in Total	Low share of energy costs	Trianni et al. (2013)
	Long Payback	Long payback periods	(Soepardi et al.,2018), (Schleich and Gruber, 2008), (Shi et al., 2008), (Cagno et al., 2013), (Harris et al., 2000),(De Groot et al., 2001), (Anderson and Newell,2004),(Sardianou, 2008),(Oikonomou et al., 2009), (Kostka et al., 2011)
	High Education Cost of EE Tech	Unwillingness of employers to bear the cost of educating their employees about new energy efficient technology	(Thollander and Ottosson, 2008), (Trianni et al., 2013), (Rohdin et al., 2007)
	Less Profit Perception	EE projects are not seen profitable enough /not considered worth the costs	Lawrence et al., 2019
Behavioral	Other Priorities	Other Priorities (Other investments are more important)	Cagno et al., 2013
	Inertia	Inertia	Cagno et al., 2013
	Focus Daily Problems	Managers and employees focus their attention to daily manufacturing problems	(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou, 2008), (Fleiter et al., 2012), (Meath et al., 2016)
	Long Decision Making	Long decision-making process	(Soepardi et al.,2018), (Shi et al., 2008), (Cagno et al., 2013), (Olsthoorn et al., 2015), (Sorrell et al., 2000),
	Firm Imperfect Evaluation	Imperfect evaulation criteria	Cagno et al., 2013
	Having Different Objectives	Lack of sharing the objectives	Cagno et al., 2013
	No Benefit Perception	Perception or thought of EE is not beneficial	Trianni et al. (2013)
	Lack of Measure Awereness	Lack of interest and awareness	Cagno et al., 2013
Organizational	Low Efficiency Status	Low status of EE	Cagno et al., 2013
	Complex Decision Chain	Complex decision chain	Cagno et al., 2013; Thollander et al. (2013)
	Poor Physical Conditions	Lack of industrial space or unsuitable physical conditions for EEI	Own contribution

	Lack of Time	Lack of time	Cagno et al., 2013; Thollander and Ottosson, 2008), (Rohdin et al., 2007)
	Resistance to change	Resistance to change in managerial levels	Lawrence et al., 2019
	Limited Authority	Limited authority of the energy management department and its personnel within the enterprise for EEI is not strong enough and its authority is limited	(Thollander and Ottosson, 2008), (Rohdin et al., 2007)
	No Inspection	Industrial establishment is characterised as energy-efficient	Own contribution
Competences	Poor Equipment	Difficulties in identifying opportunities and inefficiencies	Lee, K. H,. 2015
	Poor Technical Characteristics	Current technical characteristics of process is not adequate to implement EEI	Cagno et al., 2013
	Lack of Qualified Staff	Lack of staff/skilled technical personnel	(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou, 2008), (Fleiter et al., 2012), (Meath et al., 2016)
	Need for Consultancy	Lack of staff for implementation interventions and analysis	(Rohdin et al., 2007);(Soepardi et al.,2018), (Olsthoorn et al., 2015), (Harris et al., 2000), (Reddy, 2001), (Sardianou, 2008), (Fleiter et al., 2012), (Meath et al., 2016)
Awereness	Lack of EEAwareness	Lack of information with regard to energy conservation opportunities	Lawrence et al., 2019
	Lack of Knowhow	Lack of	Lawrence et al., 2019; Rohdin et al., 2007
	Lack of Profitability Awareness	Lack of information with regard to the profitability of energy saving measures	Lawrence et al., 2019
	No Trust on Info Source	Lack of reliance on the information source for EEI Lack of awerness/ignorence to EEI	Cagno et al., 2013
Market	Cost of Finding Capital	High cost for investing capital availability for the operating sector	(Soepardi et al.,2018), (Schleich and Gruber, 2008), (Shi et al., 2008), (Cagno et al., 2013), (Harris et al., 2000),(De Groot et al., 2001),
	Low Technology Diffusion	Low diffiusion of technology/Inadequate energy-efficient technologies	(Soepardi et al.,2018), (Shi et al., 2008), (Cagno et al., 2013), (Olsthoorn et al., 2015),(Oikonomou et al., 2009), (Fleiter et al., 2012)
	High Market Risk	High market risks	Rohdin et al. (2007); Cagno et al., 2013
	Limited Access to Capital	Limited access to capital	Thollander and Ottosson, 2008), (Trianni et al., 2013), (Rohdin et al., 2007),
	Uncertain Future Prices	The uncertainty about future energy prices	Rohdin et al. (2007)

	High Transaction Cost	High transaction costs	Lawrence et al., 2019
	Difficulty of Determining Parameters	Difficulty in identification quality parameters of investment/Uncertainty of how energy management improves EE	Lawrence et al., 2019
Policy	Lack of Government Audit	Lack of audit for EE by Government	Cagno et al., 2013
	Incorrect Auditor Assessments	Inaccurate assessment for EEI by auditors	Cagno et al., 2013
	Lack Incentive Mechanisms	Absence of economic incentive regulation for implementing the EEI.	(Soepardi et al.,2018), (Oikonomou et al., 2009), (Okazaki and Yamaguchi, 2011), (Shi et al., 2008),(Olsthoorn et al., 2015),(Reddy, 2001)
	Long Bureaucratic Procedures	Lots of paper work and bureaucratic procedure for getting incentive and Complex bureaucratic procedures	Wang et al., 2018
	Time Limits of Completing Projects	Strict time limitation for EEI supported by state	Own contribution
	Limited Incentivized Sectors	Lack of incentive or less amount of incentive	(Soepardi et al.,2018), (Oikonomou et al., 2009), (Okazaki and Yamaguchi, 2011), (Shi et al., 2008),(Olsthoorn et al., 2015),(Reddy, 2001)
	Energy Tax on Equipments	Taxes on energy efficient technology and equipment	(Apeaning and Thollander, 2013), (Brunke et al., 2014),
Information	No Technology Performance Informing	ESCOs and their suppliers not sufficiently informing the market about the performance of energy efficient technologies	Thollander et al., 2013
	No Sectoral Information Sharing	Failure to share sectoral experiences and good practices for EE improvements	Wang et al., 2018
	No External Communication	Lack of external corporate communications	Cagno et al., 2013
Technical	No Current Techno Information	Inadequate energy-efficient technologies	Cagno et al., 2013
	OnlyMarketingAvailableTech	Marketing of existing technologies by suppliers instead of the most efficient and up-to-date technologies	Cagno et al., 2013
	Difficulty of Finding Appropriate Technology	difficulty in identification of efficient and appropriate technology for the business process	Cagno et al., 2013
	Unavailability of Advance Technology	Unavailability of more advanced technologies related to the operating sector of activity	Own contribution
	Lack of Technology Experts	Difficulty in gatering external technical skills in the market	Cagno et al., 2013

In this study, the motivations are defined as “factors that positively affect an enterprise’s intentions, awareness for innovation and energy-efficient culture, adoption of energy-efficient technologies; the removal, reduction, or avoidance of barriers and therefore assist innovation activities” (Trianni et al, 2017; Thollander, et. al, 2008; Ren, 2009; Cagno et. al., 2013; Reddy, 2013). Briefly, motivations for EEI are the factors that work in the opposite direction with barriers. Note that the literature also uses the term “drivers” to refer to these factors.

The related literature suggests many motivations and drivers that enhance and increase the EE of enterprises. Their taxonomy provides enlightening information on the extent and complexities of drivers and motivations (Solnørdal and Foss, 2018). Hence, we, firstly, focused on reviewing literature for drivers and/or motivations. Along with them, we also took into account the perspective of enterprises while constituting taxonomies used for them. In this regard, we listed the common drivers and/or motivations put forwarded by the literature in Table 18. They consist of 8 categorical differentiations such as “Economic”, “Behavioural”, “Organizational”, “Competence”, “Informative”, “Awareness”, “Market”, “Policy”, and 37 motivation-related indicators.

Table 18: Taxonomies of operational and empirical motivations for investigation

Category	Variable Abbreviation	Statement for Variable	Source
Economic	Longterm Strategy	Long-term energy consumption and management strategy of firm	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014) , (Wang et al., 2018)
	Cost Reduction	Cost reduction resulting from lower energy consumption	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013) ,(Wang et al., 2018)
	High Investment Return	High rate of return on the investment	Own Contribution
Informational	Priorities To EEI	Priorities given to EEI	Sorrell et al., 2000
	Info From Networks	Acquaintances and networks within the energy sector	(Thollander and Ottosson, 2008), (Brunke et al., 2014)
	Local Consultancy	Local authority energy consultancy	Lee, K. H., (2015)
	Expert Support	Support from energy experts	Lee, K. H., (2015)
	Owner Demand	Demand from owner, Owner's requirement	Brunke et al. (2014)
	Sector Support	Support from the sector organisation	Lee, K. H., (2015)
	Ambitious Employee	People with real ambition/highly motivated employee	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014);
Organizational	Operating ISO50001	Operating a Energy management system ISO 50001	Lawrence et al., 2019
	Priorities To EEI	Priorities of EEI projects	Own Contribution
	Committed Management	Management with ambition/Assurance from preeminent management	(Brunke et al., 2014), (Thollander et al., 2013), (Wang et al., 2018)
Competences	High Motivated Employees	Highly motivated employee	Thollander and Ottosson, 2008), (Trianni et al., 2013), (Rohdin et al., 2007),
	Advanced Analysis Capability	Advanced capabilitiy in identifying opportunities and inefficiencies in the process	Lawrence et al., 2019
	Qualified Analyts	Advanced technical capabilitiy in analysis and implementation of EE projects	Thollander et al. (2013)

	Environmental Benefits of EE	Environmental benefits (other than CO_2…	Lee, K. H., (2015)
	Competitive Awareness	Competitive awareness	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013),
Awereness	Energy Plan	Energy Plan	(Rohdin et al., 2007), (Brunke et al., 2014)
	Emission Reduction Target	Viable reduction in carbon emissions	Lee, K. H., (2015)
	Awareness on Gains	Awerness on EEI Gains	Trianni et al., (2013)
	Domestic Competitivenes	Competing with other domestic firms in the sector	Wang et al., (2018)
	Equipment Subsidy	Energy-efficient equipment subsidies	Wang et al., (2018)
Economic	Financing Loans	Beneficial international loans for EE investment / Favorable loans for efficient energy financing	Lee, K. H., (2015)
	Third Party Financing	Third-party financing	Thollander et al. (2013) ; Lee, K. H., (2015)
	Threat Of Rising Price	Menace of rising energy prices	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013)
	Technical Consultancy	Locally available energy consultancy /Technical support	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013)
Informative	Professionals Assistance	Assistance from energy professionals	Own Contribution
	Training Programs	Programs of education and training	(Lawrence et al., 2019); (Wang et al., 2018)
	Energy Saving Culture	Energy-saving culture	Wang et al., (2018)
	Domestic Incentives	Beneficial national/domestic incentives for EEI (Enerji Bakanlığı)	Lee, K. H., (2015)
	Techno Invest Substitution	Subsidies for EE investments, technologies and schemes	Wang et al., (2018)
Policy	Tax Exemption Agreements	Long-term agreements with tax exemption	Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Rohdin et al., 2007), (Brunke et al., 2014) , (Wang et al., 2018)
	VoluntaryAgreements	Voluntary agreements	(Thollander and Ottosson, 2008), (Apeaning and Thollander, 2013), (Brunke et al., 2014), (Wang et al., 2018)
	Energy Carbon Taxes	Taxes (e.g. energy, CO_2)	(Apeaning and Thollander, 2013), (Brunke et al., 2014), (Thollander et al., 2013)

	Legal Restr Standards	Legal restrictions/standards	Wang et al., (2018)
	Customer NGOs Press	Pressure from customers and NGOs	Brunke et al. (2014)

3.3. RESEARCH MODEL, HYPOTHESIS DEVELOPMENT, AND EMPIRICAL RESULTS

3.3.1. Research Model and Hypothesis Development

In this study, we applied a higher order construct model (hierarchical latent variable model / hierarchical component model), which is a good fit for exploring the effects of different categorical barriers and motivations on EEI. According to this model, if the indicators that belong to some dimension or sub-dimension of the dependent variable has individually significant effect on the dependent variable, they are utilized to create higher-order latent variable constructs. In conceptual models, hierarchical latent variable models allow for matching the level of abstraction for predictor and criterion variables (Becker at al., 2012). These models can be used for reducing the number of path model relationships which leads to support model parsimony and reduce model complexity (Edwards, 2001; Johnson et al., 2011; Polites et al., 2012). Additionally, higher order construct (HOC)s deals with multicollienarty problem among formative indicators by offering tools to rearrange the indicators across different concrete sub-dimensions of the more abstract construct (Hair et al., 2017). There are many different hierarchical component model approaches, such as Repeated Indicators Approach (Wold, 1982), Extended Repeated Indicators Approach (Becker at al., 2012), Improved Extended Repeated Indicators Approach (Cheah et al., 2019), Joint Two-Stage Approach (Ringle et al., 2012), Dis-joint Two-Stage Approach (Becker at al., 2012), Hybrid Approach and Three-Stage Approach (Van Riel, 2017). In this study, we used Dis-joint Two-Stage Approach to modelling and the Repeated Indicator Approach for the higher order constructs.

Several studies in the literature rely on the perspectives, context and expectations by different sub-industries and firm size levels while determining the factors affecting perceived EEI (Trianni et al., 2014; Kostka et al., 2013; Rodhin et al. 2007; Rodhin et al., 2006). The literature recommends that multi-dimensional constructs be derived from the consolidated theories, which indicate the number of sub dimensions and their relationships to the higher order constructs (Johnson at al. 2012; Becker at al., 2012).

This study uses a two-order construct model with “Energy Efficiency” as the dependent variable. “Barriers” and “Motivations” are modelled as the second order HOCs while their categorical constructs as the first order HOCs. We derived the latent variable scores to form the second order constructs from the first order categorical constructs since they use the same indicators. As an endogenous construct, EE has relationships with second order constructs.

Based on the literature review, we used 9 and 8 categorical constructs for Barriers and Motivations, respectively. While naming these categorical constructs, we inspired by Cagno et al.’s (2013) taxonomy for determining the origins of each barrier and motivations. Therefore “IB” and “EB” stands for internal and external barriers, respectively whereas “IM” and “EM” respesent internal and external motivations to enterprise. They are “Market (EB)”, “Economic (IB)”, “Organizational (IB)”, “Behavioural (IB)”, “Competences (IB)”, “Awareness (IB)”, “Information (EB)”, “Policy (EB)”, “Technical (EB)” for Barriers while “Economic (IM)”, “Informational (IM)”, “Organizational (IM)”, “Competence (IM)”, “Awareness (IM)”, “Market (EM)”, “Informative (EM)”, “Policy (EM)” for Motivations. There are 51 barrier-related and 37 motivation-related indicators. Thus, to test all experienced and perceptional barriers and motivations which might have a significant impact for enhancing EEI in Turkish industry sector, we gathered all the related barriers and motivations from previous researches and include them in our initial theoretical model. Figure 12 shows it.

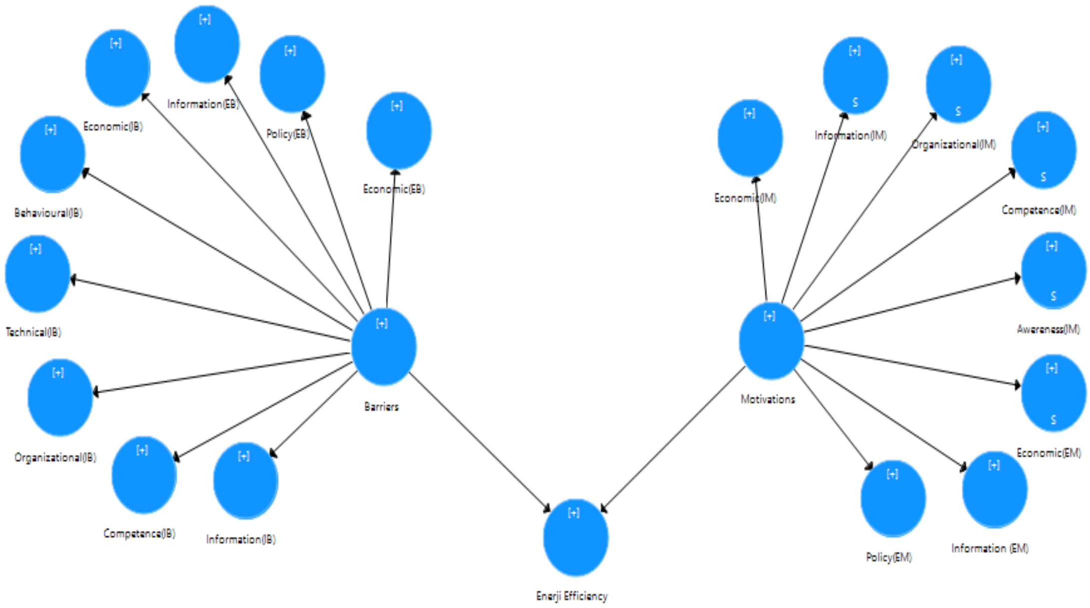

Figure 12: Initial Theoretical Model

As can be seen Figure 12, the initial model was very complex in a sense that it had numerous hypotheses. However, we had a sample with a small size. To circumvent this issue, we modified the initial theoretical model (Figure 12) after the validation of the measurement model so we obtained a functioning model. Then, instead of testing each “characteristic” of barriers and motivations on the EE, we only tested the barriers and motivations on the EE by using the modified model. This approach allowed us to deal with a slightly less number of hypotheses but with a better insight. Consequently, our claim is that motivations have a positive effect on accelerating EE and barriers do vice versa. Hypothesis 1 and 2 summarizes these arguments:

H1: There is a significant impact of Motivations on EEI

H2: There is a significant impact of Barriers on EEI

To test the research hypotheses of the study, we used the data that we collected via a survey. The survey was conducted with all Turkish industrial enterprises which have received state support at least once for EIP since 2009. They were asked if they consider the indicators, which are stated in Table 17 and 18, as a barrier to and a motivation and driver for EEI. We also asked about their willingness to implement a new EIP in the next 5 years (the indicator of Percieved EE) and their plans to apply for any government or international incentives for the financing of new EIP (the indicator of Fund EE) to use it as indicators for Energy Efficiency. Indicators were measured with 5-point Likert scales where 1 meant strong disagreement and 5 meant strong agreement. Thus, enterprises' perceptions of barriers to EEI were measured with 51 indicators whereas their perception of motivations were measured with 37 indicators.

There are only 135 industrial enterprises completed EIPs since 2009. Therefore, we sent the QS to all of them, which constitute the total population. 86 enterprises responded to the QS. Since the data was gathered from such a specific target group of industrial enterprises, we, firstly, checked the appropriateness of the data by exploring the common method bias for further analysis. To this end, we used Harman's single factor test, which shows how much of the total variance can be explained when a single factor solution is used by means of gathering all the primary constructs under one component factor. The result of Harman's single factor test revealed that 27.874% of the total variance could be explained by a single factor. This figure is quite below the threshold value of 50%. This finding suggests that in this study, common technique bias is not a significant issue; therefore, the data is appropriate for further analysis.

3.3.2. Validating the Measurement Model

Then, we examined the measurement model for validity and reliability analysis and the structural model assessments in order to test the relationship among latent variables. When evaluating higher-order models, in addition to the application of the regular model evaluation criteria for PLS-SEM analysis (Chin, 2010), the measurement model of the higher order constructs as a whole is considered as a second step in order to validate higher order constructs. Hence, we split up the procedure for validation of the measurement model analysis into two parts. Firstly, we conducted the validation process of the lower-order components. Then, we carried out it for the higher-order measurement model representing the relationships between the higher and the lower order components.

Latif (2021) emphasizes the quality of the constructs of the model based on the measurement model evaluation. Based on this, we began with the evaluation of the factor loadings of lower order constructs (LOCs). Then, we examined the convergent validity and discriminant validity to evaluate the measurement model (Hair et al., 2016).

3.3.2.1. Factor Loadings, Reliability and Validity Analysis

Center loading refers to “the extent to which each of the indicators in the correlation Matrix correlates with the given principal components factor loadings can range from -1.0 to + 1.0 with higher absolute values indicating a higher correlation of the indicator with the underlying factor” (Pett et al., 2003). According to Hair et al. (2010; 2017) factor loadings of all constructs should be greater than 0.708.

The consistency levels between multiple measurements of a variable can be checked by reliability assessment (Hair et al., 2010). Reliability is defined as “the extent to which a measuring instrument is stable and consistent” and it is checked by the repeatability of the instrument (Mark, 1996). The internal consistency and reliability of the model is provided by checking the Cronbach’s Alpha (CA) and composite reliability (CR) values. The reliability can also be checked by assessing outer loading’ results.

In order to start the measurement model assessment, the factor loadings of the indicators of LOCs are initially obtained. Then, the indicators with factor loadings below 0.400 are removed from the measurement model one by one since they are reflectively measured indicators so that they are interchangeable and can be removed from the model (Hair et al., 2017). Each time we removed such indicator, we obtained new factor loadings, and checked if there were any other indicator with a factor loading less than 0.40. When there was more than one indicator with factor loadings of less than 0.40 in LOCs, we first removed the indicator with the lowest factor loading, and repeated the same procedure. Table 19 demonstrates the results of factor loadings of all indicators included in the final measurement model.

Table 19: Results of outer loadings

Construct	Indicator	Loading
Awareness (IM)	InternCompetitiveAwareness	0.841
	AwarenessonGains	0.802
	EmissReductTarget	0.798
	PlansonEnergyMeasuring	0.781
	EnvBenefitsofEE	0.713
Behavioural (IB)	Inertia	0.927
	FocusDailyProblems	0.786
	HavingDifferentObjectives	0.686
	LongDecisionMaking	0.557
Techno-Economic Capability (EM)	OperatingISO50001	0.815
	QualifiedAnalyts	0.659
	InternFinancingLoans	0.657
Market (EB)	CostofFindingCapital	0.831
	HighMarketRisk	0.825
	HighTransactionCost	0.795
	LowTechnologyDiffusion	0.643
	DifficultyofDeterminingParameters	0.625
	UncertainFuturePrices	0.601
	LimitedAccesstoCapital	0.566
Economic(IB)	HighEducationCost	0.875
	LessProfitPerception	0.778
Informational Competence (IB)	LackofMeasureAwereness	0.845
	NeedforConsultancy	0.816
	LackofQualifiedStaff	0.778
	LackofEEAwareness	0.695
	NoTechPerformanceInforming	0.924
	NoExternalCommunication	0.816
	NoSectoralInformatıonSharing	0.795
Information(EB)	LocalConsultancy	0.861
	ExpertSupport	0.819
	SectorAssocationSupport	0.693
	InfoFromSectoralNetworks	0.634
	HighPrioritiesToEEI	0.572
Organizational (IB)	Resisttochange	0.742

	PoorPhysConditions	0.736
	ComplexDecisionChain	0.669
Policy (EM)	TechoInvestSubstitution	0.915
	DomesticIncentives	0.818
	TaxExemptAgreements	0.657
	CustomerNGOsPress	0.596
	LegalRestrStandards	0.459
Policy(EB)	EnergyTaxonEquipments	0.904
	LackIncentiveMechanisms	0.808
	IncorrectAuditorAssessments	0.663
Technical (EB)	UnavailabilityofAdvanceTech	0.849
	DifficultyofFindingAppropTech	0.736
	OnlyMarketingAvailableTech	0.683

As Table 19 shows, most of the outer loadings are greater than 0.700, which indicates that all indicators shown in Table 19 are reliable. On the other hand, we used not only them but also the indicators with the factor loadings between 0.400 to 0.700 to examine if the construct reliability and validity conditions are achieved. During validity and reliability assessments of LOCs, we both removed 41 indicators and consequently merged some of the LOCs under the same construct. Therefore, our model evolved as shown in Figure 13.

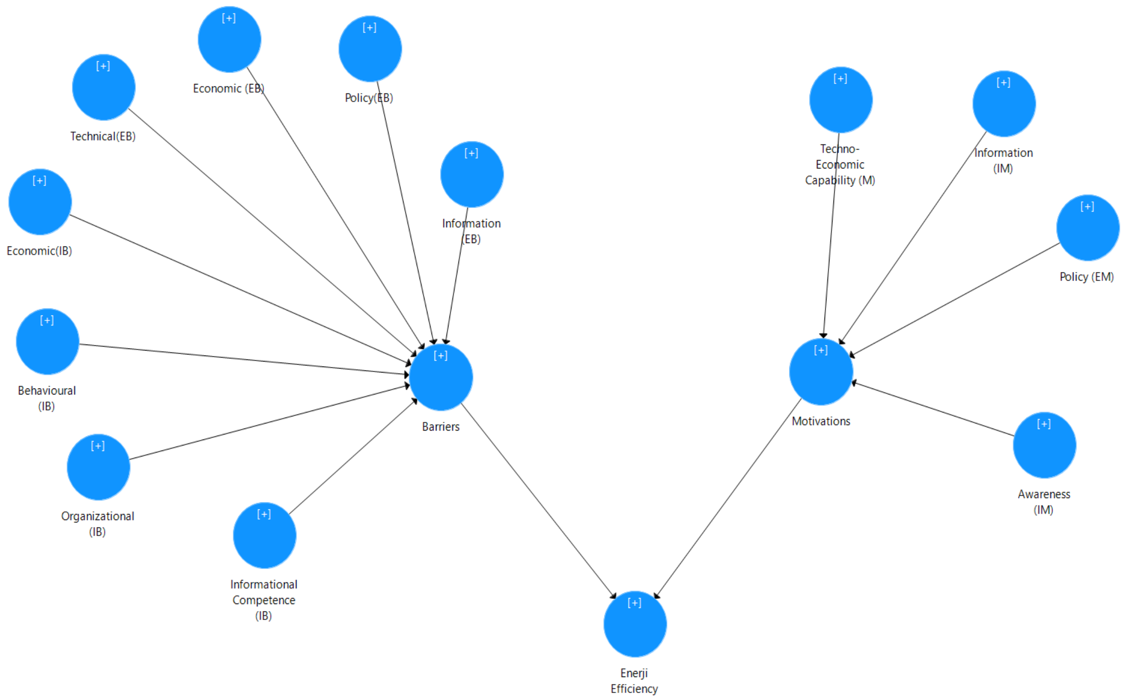

Figure 13: Hypothized model after the measurement model assessment

When both convergent and discriminant validity are present, construct validity is established in PLS-SEM methodology. Convergent validity is the degree of multiple attempts to measure the same concept, which means that two or more indicators of the same construct should highly covary with each other if they represent the same concept (Bagozzi et al., 1991).

The outer loadings of the indicators and the Average Variance Extracted (AVE) were used to assess the convergent validity of reflective constructs. The AVE established by Fornell & Larcker (1981) is a widely used criterion for convergent validity. A convergent validity score of at least 0.5 indicates that a latent variable can explain at least half of the variance of its indicators on average, and indicators merge to measure the same construct, indicating that convergent validity has been established (Fornell and Larcker, 1981). Besides the composite reliability (CR) can be also used with AVE value assessment in order to establish convergent validity. It should be noted that CR ranges from 0 to 1, with higher numbers suggesting higher degrees of reliability. In exploratory research, CR values of 0.60 to 0.70 are acceptable, whereas values of 0.70 to 0.90 might be considered satisfactory in more advanced stages of research (Kline et al., 2011).

Values greater than 0.90 (and especially greater than 0.95) are unfavorable because they indicate that all of the indicator variables are measuring the same phenomenon and hence are unlikely to be a valid measure of the concept.

We calculated AVE, CA, and CR values of LOCs', which are given in Table 20 and Table 21. All AVE values of LOCs, except "Market (EB)" construct, were higher than the recommended threshold of 0.500. Since CR statistics of "Market (EB)" is 0.872 and higher than the recommended threshold of 0.700, "Market (EB)" construct was kept in the model even though AVE value (0.499) was slightly lower than 0.500. Hence, no indicators were further removed as convergent validity is satisfied.

Table 20: Construct Convergent Validity (AVE)

Construct	**Average Variance Extracted (AVE)**
Awareness (IM)	0.621
Behavioural (IB)	0.564
Techno-Economic Capability (EM)	0.510
Market (EB)	0.499
Economic (IB)	0.685
Informational Competence (IB)	0.617
Information (EB)	0.717
Information (IM)	0.524
Organizational (IB)	0.513
Policy (EM)	0.501
Policy (EB)	0.636
Technical (EB)	0.577

Table 21: Internal Consistency of Constructs

Construct	**Cronbach's Alpha**	**Composite Reliability**
Awareness (IM)	0.852	0.891
Behavioural (IB)	0.793	0.834
Techno-Economic Capability (EM)	0.523	0.756
Market (EB)	0.849	0.872
Economic (IB)	0.547	0.813
Informational Competence (IB)	0.826	0.865
Information (EB)	0.822	0.883

Information (IM)	0.793	0.843
Organizational (IB)	0.542	0.759
Policy (EM)	0.784	0.826
Policy (EB)	0.715	0.838
Technical (EB)	0.657	0.802

Variance Inflation Factor (VIF) statistics is utilized to assess multicollinearity (Fornell and Bookstein, 1982). Rejecting the hypothesis due to multicollinearity in the measurement model requires the value of each indicator's VIF to be less than 5 (Hair et al., 2016). Table 3.4 reveals that the VIF values of each indicator that we obtained. They are all smaller than 3.3 threshold (Kock, 2015). Hence, multicollinearity is not an issue among the indicators of the measurement model.

Table 22: Multicollinearity Statistics for Indicators (Outer VIF Values of Indicators)

Indicators	**VIF**
LongDecisionMaking	1.472
HavingDifferentObjectives	1.527
ComplexDecisionChain	1.235
PoorPhysConditions	1.084
Resisttochange	1.197
LackofQualifiedStaff	2.013
NeedforConsultancy	1.344
LackofEEAwareness	2.106
LackofMeasureAwereness	2.582
CostofFindingCapital	2.864
LowTechnologyDiffusion	1.841
HighMarketRisk	2.388
LimitedAccesstoCapital	1.921
UncertainFuturePrices	1.501
HighTransactionCost	1.734
DifficultyofDeterminingParameters	1.344
IncorrectAuditorAssessments	1.244
LackIncentiveMechanisms	1.572
EnergyTaxonEquipments	1.710
NoTechPerformanceInforming	1.711
NoSectoralInformatıonSharing	1.956
NoExternalCommunication	1.931

OnlyMarketingAvailableTech	1.328
DifficultyofFindingAppropTech	1.403
UnavailabilityofAdvanceTech	1.201
HighPrioritiesToEEI	1.545
InfoFromSectoralNetworks	1.808
LocalConsultancy	2.221
ExpertSupport	1.531
HighEducationCost	1.165
SectorAssocationSupport	1.911
OperatingISO50001	1.173
QualifiedAnalyts	1.131
EnvBenefitsofEE	1.842
InternCompetitiveAwareness	2.208
LessProfitPerception	1.165
PlansonEnergyMeasuring	1.941
EmissReductTarget	1.782
AwarenessonGains	2.114
InternFinancingLoans	1.104
DomesticIncentives	2.349
TechoInvestSubstitution	2.489
TaxExemptAgreements	1.743
LegalRestrStandards	1.394
CustomerNGOsPress	1.338
Inertia	1.582
FocusDailyProblems	1.791

3.3.2.2. Discriminant Validity

According to Farrell (2010), discriminant validity is a measure for discriminating the extent to which a latent variable in the model discriminates from other latent variables. If a latent variable is unique then it should not correlate too highly with other latent variables (Bagozzi et al., 1991). The establishment of discriminant validity is crucial for conducting latent variable analysis (Bollen, 1989; Fornell and Larcker, 1981). If researchers want to be certain about that the test results of hypotheses that structural model is based on, reflect reality rather than statistical discrepancies, they have to establish the discriminant validity (Farrell 2010).

To assess the discriminant validity, we calculated cross factor loadings, "Fornell and Larcker Criterion", and Heterotrait-Monotrait Ratio (HTMT). Table 23 reports the cross-factor loadings of the observed indicators included in the model. The factor loadings highlighted in grey cells demonstrate the correlations between indicators at the same level and belong to the underlying construct for each column. It should be noted that the indicators which have cross-factor loadings less than 0.10 were discarded from the measurement model to establish discriminant validity. As a result of the removal of the items one by one based on the lowest crossfactor loadings, all the factor loadings of the LOCs become greater than their cross-loadings, which implies discriminant validity.

Table 23: Cross Loadings of Indicators among the First-order Factors LOCs

Indicators/Construct	**Awareness (IM)**	**Behavioural (IB)**	**Techno-Economic Capability (EM)**	**Market (EB)**	**Economic (IB)**	**Informational Competence (IB)**	**Information (EB)**	**Information (IM)**	**Organizational (IB)**	**Policy (EM)**	**Policy (EB)**	**Technical (EB)**
InternCompetitiveAwareness	0.841	-0.122	0.353	-0.067	-0.188	-0.297	-0.245	0.411	-0.101	0.499	-0.100	-0.045
AwarenessonGains	0.802	-0.072	0.340	-0.193	-0.323	-0.352	-0.279	0.385	-0.161	0.497	-0.135	-0.144
EmissReductTarget	0.798	-0.231	0.464	-0.151	-0.107	-0.426	-0.290	0.255	-0.234	0.338	-0.034	0.020
PlansonEnergyMeasuring	0.781	-0.097	0.315	-0.001	-0.247	-0.436	-0.121	0.229	-0.031	0.485	0.116	-0.040
EnvBenefitsofEE	0.713	-0.290	0.520	-0.083	-0.207	-0.316	-0.266	0.253	0.015	0.297	0.029	-0.103
HighPrioritiesToEEI	0.536	0.033	0.313	-0.037	-0.205	-0.033	-0.170	0.572	-0.037	0.341	-0.079	0.027
CustomerNGOsPress	0.494	-0.148	0.374	0.123	-0.017	-0.177	-0.168	0.459	0.026	0.596	0.036	0.162
DomesticIncentives	0.440	0.178	0.347	0.023	-0.318	-0.113	0.075	0.435	-0.046	0.818	-0.072	0.086
QualifiedAnalyts	0.428	-0.028	0.659	-0.100	-0.157	-0.065	-0.024	0.035	-0.161	0.286	0.032	-0.053
OperatingISO50001	0.428	-0.192	0.815	0.040	-0.052	-0.369	-0.072	0.070	0.011	0.255	0.223	0.060
TechoInvestSubstitution	0.407	0.152	0.378	0.035	-0.326	-0.165	0.063	0.420	0.060	0.915	-0.042	0.030
InfoFromSectoralNetworks	0.396	0.047	0.262	0.025	-0.036	-0.027	-0.143	0.634	0.019	0.497	-0.052	0.013
LocalConsultancy	0.260	-0.023	0.103	0.100	0.048	0.100	-0.084	0.861	0.113	0.479	-0.185	0.079
SectorAssocationSupport	0.241	-0.144	0.423	0.130	0.016	-0.029	-0.007	0.693	0.157	0.486	-0.196	0.023
TaxExemptAgreements	0.229	-0.011	0.319	0.172	-0.051	-0.055	0.154	0.475	0.135	0.657	-0.013	0.127
ExpertSupport	0.214	-0.006	0.051	0.009	0.003	0.112	-0.001	0.819	0.131	0.372	-0.271	-0.080
LegalRestrStandards	0.193	-0.163	0.276	0.080	0.025	-0.034	0.061	0.330	0.096	0.459	-0.052	0.139

InternFinancingLoans	0.183	-0.064	0.657	0.194	-0.034	-0.072	0.110	0.328	0.150	0.489	0.043	0.148
IncorrectAuditorAssessments	0.059	0.261	0.184	0.427	0.125	0.190	0.227	-0.092	0.296	-0.020	0.663	0.436
ComplexDecisionChain	0.016	0.512	0.062	0.438	0.092	0.289	0.328	0.099	0.669	0.227	0.358	0.511
DifficultyofFindingAppropTech	0.015	0.433	-0.163	0.466	0.180	0.392	0.389	0.066	0.422	0.116	0.297	0.736
LackIncentiveMechanisms	0.002	0.395	0.146	0.380	0.215	0.110	0.345	-0.179	0.274	0.028	0.808	0.200
Resisttochange	-0.039	0.307	-0.003	0.430	0.132	0.419	0.290	0.158	0.742	0.088	0.330	0.342
UnavailabilityofAdvanceTech	-0.047	0.243	0.132	0.455	0.201	0.339	0.250	0.030	0.430	0.061	0.347	0.849
UncertainFuturePrices	-0.047	0.114	0.052	0.601	0.211	0.234	0.359	-0.025	0.166	0.082	0.399	0.332
CostofFindingCapital	-0.054	0.246	0.170	0.831	0.212	0.364	0.469	0.104	0.429	0.143	0.518	0.447
LowTechnologyDiffusion	-0.063	0.167	0.152	0.643	0.118	0.290	0.412	0.019	0.527	0.071	0.370	0.436
HighMarketRisk	-0.083	0.098	0.064	0.825	0.238	0.228	0.473	0.124	0.246	0.077	0.425	0.399
HighTransactionCost	-0.098	0.271	0.039	0.795	0.196	0.309	0.432	0.056	0.450	0.074	0.481	0.475
EnergyTaxonEquipments	-0.103	0.257	0.089	0.551	0.265	0.151	0.317	-0.265	0.406	-0.062	0.904	0.421
OnlyMarketingAvailableTech	-0.113	0.181	0.154	0.382	0.291	0.286	0.581	-0.084	0.225	0.066	0.370	0.683
FocusDailyProblems	-0.127	0.786	-0.145	0.127	0.079	0.343	0.243	0.113	0.271	0.191	0.214	0.232
LimitedAccesstoCapital	-0.157	0.276	0.184	0.566	0.225	0.213	0.496	-0.021	0.197	0.111	0.381	0.387
HavingDifferentObjectives	-0.169	0.686	-0.019	0.352	0.235	0.389	0.248	0.079	0.470	-0.032	0.325	0.363
Inertia	-0.174	0.927	-0.153	0.250	-0.014	0.439	0.438	-0.091	0.371	0.048	0.349	0.310
NoTechPerformanceInforming	-0.189	0.275	0.068	0.527	0.205	0.428	0.924	0.010	0.225	0.084	0.324	0.400
DifficultyofDeterminingParameters	-0.189	0.313	-0.077	0.625	0.311	0.361	0.374	-0.122	0.420	-0.065	0.338	0.443
HighEducationCost	-0.212	0.006	-0.084	0.308	0.875	0.224	0.197	-0.029	0.185	-0.273	0.280	0.266
LessProfitPerception	-0.212	0.122	-0.092	0.191	0.778	0.221	0.139	-0.002	0.090	-0.192	0.143	0.192
PoorPhysConditions	-0.262	0.200	-0.022	0.223	0.136	0.252	0.144	0.006	0.736	-0.135	0.237	0.262
LongDecisionMaking	-0.267	0.557	-0.034	0.302	0.133	0.327	0.410	-0.143	0.417	0.060	0.337	0.391
LackofMeasureAwereness	-0.296	0.482	-0.202	0.451	0.140	0.845	0.505	0.030	0.453	-0.072	0.160	0.458
NoSectoralInformatıonSharing	-0.301	0.458	-0.039	0.557	0.120	0.470	0.795	-0.155	0.457	-0.058	0.497	0.474
LackofQualifiedStaff	-0.317	0.408	-0.266	0.221	0.120	0.778	0.317	0.132	0.429	-0.163	0.124	0.288
LackofEEAwareness	-0.349	0.510	-0.14	0.426	0.204	0.695	0.430	-0.018	0.549	0.022	0.294	0.325

			5									
NoExternalCommunication	-0.374	0.470	-0.118	0.372	0.175	0.483	0.816	-0.197	0.286	-0.107	0.190	0.397
NeedforConsultancy	-0.500	0.307	-0.215	0.272	0.335	0.816	0.405	0.078	0.258	-0.237	0.150	0.302

We also checked if Fornell and Larcker (1981) criterion was satisfied for discriminant validity. Accordingly, the square root of the AVE should be more than any correlation with another factor. These values are shown in Table 24. As observed from Table, all of the first-order factors achieve this criterion.

Table 24: Fornell and Larcker Criterion of LOCs

	1	2	3	4	5	6	7	8	9	10	11	12
1 Awareness (IM)	0.788											
2 Behavioural (IB)	-0.194	0.751										
3 Techno-Economic Capability (EM)	0.49	-0.148	0.714									
4 Market (EB)	-0.129	0.283	0.065	0.706								
5 Economic (IB)	-0.254	0.068	-0.105	0.309	0.828							
6 Informational Competence (IB)	-0.472	0.479	-0.268	0.403	0.268	0.786						
7 Information (EB)	-0.302	0.421	-0.005	0.566	0.206	0.52	0.847					
8 Information (IM)	0.387	-0.011	0.19	0.055	-0.021	0.086	-0.092	0.724				
9 Organizational (IB)	-0.159	0.433	0.006	0.483	0.172	0.445	0.333	0.115	0.716			
10 Policy (EM)	0.54	0.084	0.462	0.079	-0.285	-0.195	0.004	0.545	0.044	0.708		
11 Policy (EB)	-0.038	0.369	0.159	0.574	0.265	0.181	0.373	-0.241	0.415	-0.029	0.798	
12 Technical (EB)	-0.061	0.358	0.075	0.566	0.281	0.438	0.478	0.014	0.484	0.099	0.437	0.759

Henseler et al., (2015) states that Fornell and Larcker Criterion and cross loadings have some limitations on revealing the discriminant validity so that they recommend to use HTMT statistics. We tested discriminant validity by also using the HTMT, the results of which are given in Table 25. The HTMT ratio should be less than 0.90 if there are conceptually similar constructs (Henseler et al., 2015). As shown in Table 25, all HTMT ratios are below the 0.90 threshold. Hence, the convergent validity and reliability of the measurement model with LOCs is established.

Table 25: HTMT statistics- Lower Order Discriminant Validity

	1	2	3	4	5	6	7	8	9	10	11	12
1 Awareness (IM)												
2 Behavioural (IB)	0.295											
3 Techno-Economic Capability (EM)	0.747	0.243										
4 Market (EB)	0.19	0.42	0.317									
5 Economic (IB)	0.398	0.255	0.211	0.429								
6 Informational Competence (IB)	0.521	0.644	0.358	0.508	0.37							
7 Information (EB)	0.4	0.575	0.206	0.713	0.282	0.65						
8 Information (IM)	0.546	0.197	0.561	0.172	0.16	0.152	0.232					
9 Organizational (IB)	0.252	0.808	0.314	0.734	0.296	0.779	0.589	0.297				
10 Policy (EM)	0.58	0.258	0.744	0.204	0.317	0.213	0.178	0.778	0.323			
11 Policy (EB)	0.145	0.542	0.297	0.736	0.39	0.295	0.509	0.302	0.674	0.119		
12 Technical (EB)	0.197	0.595	0.349	0.755	0.475	0.585	0.733	0.14	0.839	0.221	0.642	

3.3.3. Validating Higher Order (2nd Order) Constructs (Barriers and Motivations)

As a second step, we checked the higher order constructs (HOCs) for the validation of the measurement model. Sarstedt et al. (2019) recommend that the HOCs be tested for discriminant validity by considering the other LOCs in the model. As the second order constructs, Barriers and Motivations latent variables are assessed for construct reliability and convergent validity. To do so, we used the latent variable scores of the LOCs that we derived from the first stage of the measurement model assessment. Thus, the latent variable scores of the measurement model of the first step were used as items of the second order latent variable constructs. We discarded 4 items with factor loadings smaller than 0.500 one by one based on the lowest cross loading from the model if they also had lower AVE values than 0.500. Consequently, both HOCs Reliability and Validity conditions are fulfilled for the final measurement model. Figure 14 shows the results of the final measurement model. The statistics in the circles of the latent constructs are the value of their AVEs and the figures on the arrows are the factor loadings.

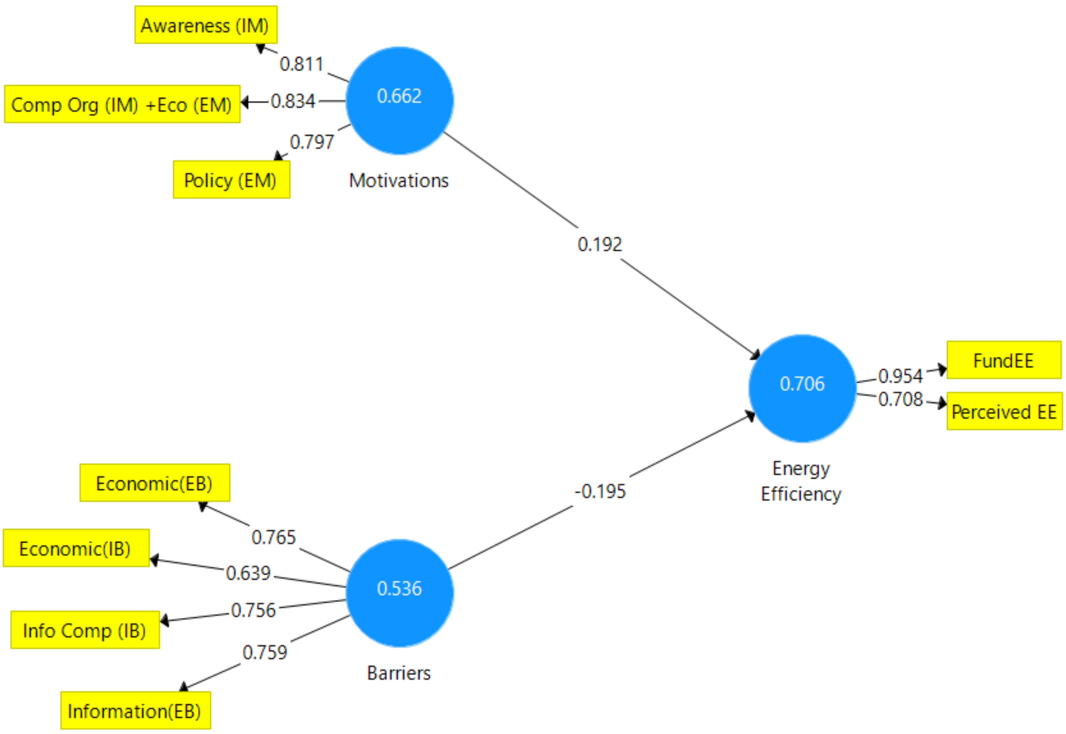

Figure 14: Final Measurement Model Results with AVE and Factor Loadings

Cronbach's Alpha and Composite Reliability statistics are above 0.500 and 0.700, respectively as shown in Table 26. Thus, constract reliability and convergent validity are established for HOCs.

Table 26: Higher Order Constructs Reliability and Convergent Validity

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Barriers	0.709	0.821	0.536
Energy Efficiency	0.635	0.825	0.706
Motivations	0.748	0.855	0.662

We also checked the correlations among the HOCs if they exceed the square root of their AVE for Fornell and Larcker (1981) criteria to be satisfied. Table 27 shows the results. Hence, the discriminant validity of higher order measurement model is met.

Table 27: Fornell and Larcker (1981) Criterion- Higher Order Discriminant Validity

	Barriers	Energy Efficiency	Motivations
Barriers	0.732		
Energy Efficiency	-0.245	0.840	
Motivations	-0.263	0.244	0.814

Table 28: Cross Loadings of Items Among the Second-order Factors HOCs

	Barriers	Energy Efficiency	Motivations
Awareness (IM)	-0.402	0.180	0.811
Techno-Economic Capability (EM)	-0.117	0.229	0.834
Economic(EB)	0.765	-0.170	0.012
Economic(IB)	0.639	-0.194	-0.252
FundEE	-0.256	0.954	0.264
Informational Competence (IB)	0.756	-0.187	-0.378
Information(EB)	0.759	-0.158	-0.114
Perceived EE	-0.123	0.708	0.097
Policy (EM)	-0.151	0.179	0.797

Table 29: HTMT - Higher Order Discriminant Validity

	Barriers	Energy Efficiency	Motivations
Barriers			
Energy Efficiency	0.323		
Motivations	0.415	0.302	

3.3.4. Assesment of the Structural Model

We tested the hypotheses connecting the constructs (path relationships) by creating a structural equation model after establishing a reliable and validated measurement model. The coefficient of determination (R^2) for endogenous variable, estimation of path coefficient (β), effect size (f^2), predictive relevance (Q^2) for endogenous construct and effect size (q^2) which is for exogenous construct's contribution to an endogenous latent variable's Q^2 value were all widely accepted criteria for evaluating the structural model (e.g. Henseler et al., 2009; Chin, 2010; Götz et al., 2010; Hair, 2017).

Since barriers and motivations cannot directly be measured by exogeneous indicators, we used latent factors "Barriers" and "Motivations" as reflective endogenous second-order latent factors. Therefore, we used the Repeated Indicator Approach for the higher order constructs and a causal model that used latent variable scores. This disjoint two-stage approach enables LOCs to predict HOCs without the "flooding out" effect of repeated indicators (Gaskin, 2017).

In PLS-SEM methodology, path coefficients which are standardized beta coefficients are utilized to define the strength and significance of the hypothesized relationships between the latent construct (Aghili and Amirkhani, 2021; Götz et. al, 2010). In the structural model, the predicted values for path relationships should be evaluated in terms of sign, magnitude, and significance using bootstrapping (Henseler et al., 2009). Similarly, in order to assess the significance of hypotheses, the bootstrapping technique is used to analyse the t-value for the path coefficients (Hair et. al., 2014; Efron, B., 1992; Yung and Bentler, 1994). Specifically, estimated path coefficients can range from -1.0 to + 1.0. Strong positive linear relationships (and vice versa for negative values) are represented by values closer to +1, with greater absolute values suggesting a higher correlation. (Hair et. al., 2016). However, the path coefficients closer to 0 show weaker relationship (Chin, 1998; Urbach and Ahleman, 2010; Hair et al., 2017).

The p-value which is theoretically a constant measure of evidence, is usually evaluated as highly important, marginally important, and not statistically important at the levels where $p \leq 0.01$, $p \leq 0.05$, and $p > 0.10$ respectively (Rice, 1989). The path coefficient is concluded as statistically significant when the t value is larger than the critical value which are commonly used for two-tailed tests are 1.65 (significance level = 10%), 1.96 (significance level = 5%), and 2.57 (significance level = 1%). When assuming a significance level of 5%, the *p* value must be smaller than 0.05 to conclude that the relationship under consideration is significant at a 5% level (Hair et al, 2017).

In this study, we considered standard beta, t-statistics, p-values and the R^2 value by applying a complete bootstrapping process with a subsample of 5000 with 0.05 and 0.10 significance levels to test and evaluate the structural model (Hair et al., 2014). We also checked the predictive applicability (Q^2) of the structural model to make a better insight into the model assessment.

3.3.5. Hypotheses Testing

H1 is established whether Barriers has a significant impact on the EEI. The results show that Barriers has an insignificant effect on EEI. (β=-0.195, t stat= 1.750, p= 0.080). Therefore, H1 is not supported and hence "*Barriers has a significant impact on the EEI*" rejected as a hypothesis.

Table 30: Bootstrapping Results / Summary of Findings

	Estimated β for Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
H1: Barriers -> Energy Efficiency	-0.195	0.111	1.747	0.081
H2: Motivations -> Energy Efficiency	0.193	0.095	2.019	0.044

Source: Authors' analysis

H2 evaluates whether Motivations has a significant impact on the Energy Efficiency. The results show that Motivations has a significant effect on Energy Efficiency. (β=0.193, t stat= 2.019 p= 0.044 < 0.05). Therefore, we found an evidence supporting H2. Hence, "*Motivations has a significant impact on the EEI*" cannot be rejected.

The findings presented in Table 30 show that, Barriers → Energy Efficiency (β=-0.195, t stat= 1.747, p= 0.081) hypothesis is negative and insignificant whereas Motivations → Energy Efficiency (β=0.193, t stat= 2.019 p= 0.044) hypothesis is positive and significant. Therefore, hypothesis H2 is failed to reject while hypothesis H1 rejected.

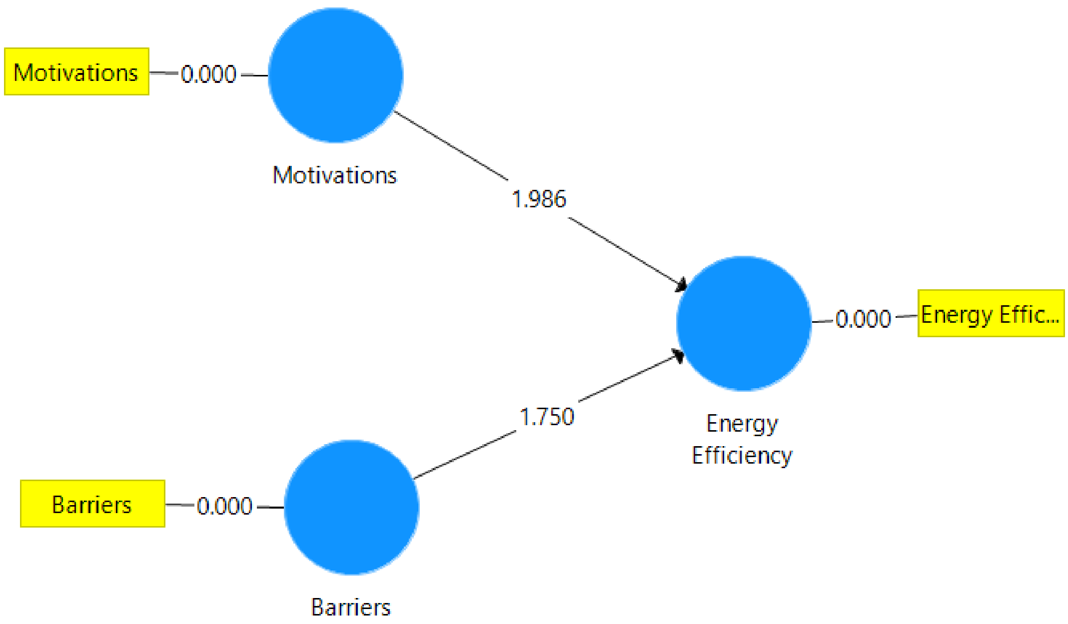

Figure 15: Structural Model with t-statistics

It should be noted that predictive power of the structural model is assessed by the R squares (R^2) values of the Energy Efficiency as an endogenous construct. The variance explained R^2 values for the dependent latent constructs are used to calculate structural model predictability.

R^2 index is used to show how much amount of variance explained by the exogenous variables which are Barriers and Motivations in this model. Satisfactory R^2 values may vary depending on the research area. R^2 values of 0.67, 0.33, and 0.19 are regarded substantial, moderate, and weak, respectively (Chin, 1998; Henseler et al., 2009; Hair et al., 2017). Whereas according to Falk and Miller's (1992), the model is called good when the R^2 value is greater than 0.10. In this study R^2 value of the "Energy Efficiency" as the only endogenous construct of the model is 0.095, which is close to the 0.10 threshold recommended by Falk and Miller's (1992). Therefore, we can consider the structural model as satisfactory.

We also checked the predictive applicability (Q^2) of the structural model to make a better insight into the accuracy of our model. Therefore, in addition to analyzing the magnitude of the R^2 values as a measure of predictive accuracy, we looked at Stone-Geisser's Q^2 value (Hair et al., 2017; Stone, 1974). A tested model has more predictive relevance when Q^2 is higher and the proposed threshold value for Q^2 is greater than 0. We used blindfolding method to obtain Q^2 value in Smart PLS. We obtained 0.056 which is greater than 0 indicates that the Barriers and Motivations constructs have predictive relevance for the endogenous construct in the structural model (Hair et al., 2017).

In addition to above discussions, it should be noted that if a study is exploratory in nature, significance level of 0.10 is usually assumed based on the objective and field of the study (Hair et al., 2017). In this regard, it should be noted that both hypotheses are failed to reject when the significance level is 0.10 in this study. Therefore, "Motivations has a significant impact on the EEI" hypothesis is statistically significant and supported since its t statistic is 2.019 which is larger than both critical values commonly used for two-tailed tests of 1.65 (significance level = 10%) and 1.96 (significance level = 5%). Whereas "Barriers has a significant impact on the EEI" hypothesis is weakly supported since its t statistic is 1.747 which is in between 1.65 (significance level = 10%) and 1.96 (significance level = 5%).

3.4. CONCLUSION AND DISCUSSION

In this study, we investigated barriers to and motivations for energy efficiency implementations (EEI) in industry. Different from the previous research, we adopted a broad approach to modelling the determinants of EEI by taking into account all possible barriers and drivers proposed by the literature so far. We developed a questionnaire based on this broad approach. By using it, we surveyed all Turkish industrial enterprises which have received state support at least once for Efficiency Improvement Project (EIP)s since 2009. The questionnaire survey (QS) consists of questions that collect information about experiences, perspectives and perceptions of the enterprises from different industrial sub sectors, scales and technical expertise levels about EEI. The dependent variable in our model, “Energy Efficiency”, is measured by the answers to the questions of the respondents’ willingness to implement a new EIP in the next 5 years and plans to apply for any government or international incentives for the financing of a new EIP. We found that the motivations as a whole positively and significantly have an impact on EEI whereas the effect of barriers as a whole is negatively significant. The results related to motivations are in line with some of the findings of Groot et al. (2001), Rodhin et al. (2007) and Hasanbeigi et al. (2010). The results on the barriers are consistent with Cagno et al. (2013), Trianni and Cagno (2012), and Kostka et al. (2011).

The results of this study reveal that the valid model for the Turkish industry has 12 motivation related indicators out of 37 and that the motivations for industrial EE are reflectively determined by three latent variables: Awareness (IM), Techno-Economic Capability and Policy (EM). First, this study uses “Awareness” to refer to five variables: (1) international competitive awareness on EEI (2) actionable awareness of EE opportunities and gains (3) viable reduction targets in carbon emissions (4) concrete energy plans on energy consumption (5) environmental benefits for increasing their awareness for promoting the implementation of EE the most. The result of this study related to awareness implies that if industrial enterprises raise the awareness for EEI, they increase the number of EEI. A way to do this is to train employee about the importance of EE technologies and adoption. Second, we used “Techno-Economic Capability” to refer to the ability that the enterprises have to assess, implement and fund EIP. For instance, we found that operating ISO 50001 improves EE. Moreover, providing techno-economical capability, beneficial international loans for EE investment also reflect motivations. Namely, if the enterprises are informed more and take related actions about these determinants, they might use energy more efficiently. Third, we found several significant policy related motivations, which are investment subsidies for EE technologies and schemes, national/domestic incentives for EEI, long-term agreements with tax exemption, pressure from customers and non-governmental organizations (NGOs), and obligatory legal restrictions/standards. This finding suggests that subsidies and incentives enhance EE. Moreover, establishing obligations and restrictions on efficient usage of energy have a positive impact on EEI.

Regarding barriers to industrial EEI, the results show that the valid model for the Turkish industry has 19 barrier related indicators among 51. The barriers are reflectively constructed by four latent variables: Economic (IB), Market (EB), Information (EB) and Informational-Competence (IB). We gathered high education cost of employees and less profit perception due to the EEI under the Economic (IB) construct since they occur within the enterprise rather than outside or market. We constructed "Market" to refer to seven finance and economic related variables including limited access and cost of finding capital, as well as high market risks and uncertain future energy prices. Besides, we created "Informational Competence" construct, which was formed by the indicators such as insufficient information about the performance of EEI for operating market, failure to share sectoral experiences and good practices for EEI, lack of skilled technical personnel for implementation interventions of EE, lack of information with regard to energy conservation opportunities. Lastly, we constructed 3 variables under the "Information (EB)" construct, namely, ESCOs and their suppliers not sufficiently informing the market about the performance of energy efficient technologies, failure to share sectoral experiences and good practices for EEI, and lack of external corporate communications.

Surprisingly, we found that the construct "Barriers" had a weak effect on "Energy Efficiency". This result may have occurred for several reasons. Firstly, our study uses a sample population, the major of which are large-scale enterprises. The previous studies mainly retrieved data from the small and medium size enterprises. The energy managers or experts from the large-scale enterprises might perceive barriers differently than those from the small and medium size enterprises. For instance, the experts from the small enterprises, which are tend to be more structured organizations, might suffer from the lack of time or lack of internal skills more than those from the large scale enterprises. Whereas small and medium enterprises might face fewer difficulties in adopting both management and technical EEI (Trianni and Cagno, 2012). Therefore, the weak effect of barriers on EEI may be a result of the heterogeneity of the sample population. Secondly, even though the QS consists of the questions based on a broad classification of barriers developed in the literature so far, it may even not include all the elements identified as barriers for the Turkish case. Belonging to different sub-sectors and operating different regions, the enterprises in the Turkish industry may have different business cultures and environments, in turn, different perceptions of barriers. The next reason might be that the respondents have insufficient knowledge about an enquired element of a barrier even though the QS was replied mostly by energy managers or energy experts. A lack of knowledge might cause a bias in the selection of importance level of that barrier. Lastly, the respondents may react and reflect less justification or degree of intervention regarding the evaluation of barriers in order to hide their drawbacks. For instance, large scale enterprises mostly have a well-established program for adopting EEI; therefore, the energy experts or managers might underestimate the given element of barriers since they thought their enterprises as quite energy efficient. It should be noted that the data came from only industrial enterprises that completed EIPs at least one, so that this may cause bias and prejudice for evaluating the barriers and motivations.

In order to decrease global energy use, fossil fuel consumption, and CO_2 emissions, the parties of the Paris Agreement have to take actions. These actions are compulsory for them to fulfill their obligations that the Paris Agreement brought about. As one of them, improving industrial EE are considered as cost-effective, even costless. That is why they are viable for especially developing countries with limited sources to fight against global climate change. However, for them (as well as for developed countries) to promote EEI, the success of their EE actions rely on the barriers to and motivations for EEI. The results of this study might be used for a party of the Paris Agreement to achieve its net-zero emissions target and in fighting against the climate change. Specifically, this study suggests that increasing awareness, improving techno-economic capability, reinforcing subsidies and incentives, mitigating economy related, information related, and competence related issues would result in improving EE. Alleviating high market risks and energy price uncertainties and coping with less profit perception might create a good climate for EE investments. If the performances of EE projects, sectoral experiences and good practices about them, energy conservation opportunities through them are shared among the firms, EE improves. Training technical personnel and subsidizing education cost of employees also remove several barriers to EEI.

On the other hand, it should be noted that the barriers and motivations have been identified in various forms depending upon sectors, sub-sectors, and scale of the enterprises. The complexity of the EE process might also change the perceptions of barriers and motivations. More importantly, the identifications might differ according to its origin, i.e. region and country. Therefore, the future research using data from other developing countries with different features than the Turkish economy and data including small and medium scale enterprises might provide a deeper insight.

3.5. LIMITATIONS OF THE STUDY

This study has several limitations. One of its main limitations is related to the prevalence of the developed country coverage in the existing literature examining barriers to and drivers for EE (Cantore, 2017). Since we reviewed most of the related literature while composing the indicators for barriers and motivations for EE in our questionaire survey we observed that studies usually examined the developed countries (Schleich and Gruber, 2008; Fleiter et al., 2012). In this regard, the findings derived from these studies may not reflect the common barriers to an adaptation of EE for a developing country such as Turkey. Moreover, most of these studies focus on the barriers and motivations for EEI in small and medium manufacturing enterprises (Trianni and Cagno, 2013; Backman, 2017; Hrovatin et al., 2021). We used primary data retrieved from the industrial enterprises that completed at least one EIP, which is partially funded by the state. They happened to mostly be large-scale enterprises. In particular, 84% of the respondents to our questionnaire are the energy managers or experts from the large-scale firms. Therefore, they might not consider some of the barriers, such as financial and economic ones, as barriers. As another result, the perception of factors affecting EEI by small and medium size enterprises are not represented well in this study.

Another limitation of this study might stem from the design of the questionnaire and the respondents' limited knowledge and/or perception toward barriers and motivations. We used a questionnaire the 5-Point Likert scale without “no idea” or “not known” type of scale options under each indicator. In addition, our questionnaire forced the respondents to answer every question in order to go further with another one. We preferred such questionnaire since our sample was very small and we needed to obtain as many observations as we can. We relied on the know-how of respondents who were either energy manager or energy experts. However, if the respondents do not know or hear anything about the surveyed indicators if they might be barrier or motivations and/or they do not see themselves eligible to give even a perceptional response, the answers to this kind of questions might be deceptive.

Lastly, as we accept the fact that enterprises are managed by human and all the decisions are made by them working for these enterprises regarding the implementation of EE measures. Therefore, we did not focus on the psychological barriers and motivations from the view of an individual worker under the scope of this study. The justification and degree of intervention of psychological barriers and motivations are a matter of a debate of another literature. In order to be more precise, we solely concentrated on the EE literature for industry while investigating barriers to and drivers for implementation of EE measures.

CONCLUSION

In this thesis, we focused on the reasons and the size of energy efficiency gap in the Turkish industry sector. In this regard, we, firstly, calculated the direct rebound effects (REs) for the Turkish industry for the first time by using the completed 175 energy improvement projects (EIPs), partially financed by the Turkish government between the period 2009-2019. We found counter-intuitive results because all EIPs caused energy conservation. The calculated REs ranged from a very high negative backfire effect to partial RE. Moreover, the energy savings in the 49% of the EIPs not only achieved but also exceeded the energy savings level proposed in the beginning. Specifically, REs were found negative in 86 out of the 175 EIPs with observation of negative backfire effect in the 14 EIPs and prebound effect in the 72 EIP. These results indicate the super-conservative response to energy efficiency measures/tools/investments (EEI) in most of the EIPs; as a result of this super conservation attitude, most of the enterprises saved more energy than they initially expected via EIPs.

Secondly, we categorized and assessed the magnitude of REs based on fuel type and the sub-sectors since the amount of energy-savings potentials due to EIPs were strongly subjective to the fuel type and the sub-sectors. Regarding the fuel type, 93.33 percent of the completed EIPs aiming to save heat exhibited negative RE exhibit negative RE; whereas, only 40 percent of the completed EIPs aiming to save electricity exhibited negative RE. Regarding the sub-sectors of completed EIPs, 92 percent of the EIPs displayed negative REs in the manufacture of coke and refined petroleum products sub-sector which had the most extra energy saving EIPs; whereas, only 8 percent of them exhibited partial RE. The highest level of average actual energy savings via EIPs observed in three sub-sectors: the manufacture of coke and refined petroleum products, the manufacture of paper and paper products, and the manufacture of computer, electronic and optical product sub-sectors. Actual energy savings per EIP in these three sub-sectors are calculated ninety, twenty-nine and fifteen times greater than the average energy savings of per EIP completed in the manufacture of motor vehicles, trailers and semi-trailers sub-sector, respectively. On the other hand, 36 percent of the EIPs exhibited partial RE in the manufacture of food products sub-sector which caused 280.32 toe less than what initially planned in this sub-sector.

As a result of calculating the REs to find out the size of energy efficiency gap in the Turkish industry sector through supported EIPs by the government, we proved that supporting EIPs by government was an effective policy and tool to increase the overall energy savings, and to diminish industrial energy intensity and CO_2 emissions. In line with this deduction, we offer some concrete and clear policy implications to the policy-makers to enhance the effectiveness of EIPs' supporting mechanism. Since we revealed the energy-saving potentials of the industrial sub-sectors through the completed EIPs, policy-makers might prefer to allocate the funds among the industrial sub-sectors by taking into account their energy-savings potential. As a result of this, they can benefit from the EIPs by means of increased overall energy savings, reducing energy intensity and emissions of greenhouse gases.

The reasons causing the energy efficiency gap in the Turkish industry sector has become more important after the discovery of the existence of super-conservation response in the industry sector of a developing country. Therefore, we concentrated on the determinants of the super-conservation response through the EIPs. To this end, we investigated barriers to and drivers for the implementation of energy EEI and the perceptional importance of them from the perspective of the energy experts. We, firstly, developed a questionnaire survey (QS), which consists of many questions including as many factors for barriers and drivers as from the related literature in order to collect information about experiences, perspectives, and perceptions of the enterprises from 14 sub-industrial sectors, scales, and technical expertise levels about the EEI. We, then, surveyed all Turkish industrial enterprises that have received state support at least once for EIP since 2009. 86 of 135 industrial enterprises responded to the QS. Thus, the rate of response, 63.7%, is high. Besides, 53 of the QS was filled by energy managers who were mostly in charge of EIPs completion in their enterprises. The rest of the QS were also filled by the staff from either managerial or technical positions. Moreover, 84% of the respondent enterprises are large-sized firms whereas 14 % of them are medium-sized firms and only 2 % of the respondents are small-sized firms. In the light of high response rate, experienced respondent profile and variety of firm-size representation, we deduced the results derived the QS showed reliable and compelling outcomes.

Overall, the most important finding of this study is that all drivers in the QS were found as important by the respondents on average. In fact, 26 out of 37 drivers were ranked over 4 out of 5 on average, which indicates a strong perception of these drivers for EEI since we used 5 point Likert scale ranking in our survey. As the top-five-ranked drivers for energy efficiency investments, organizational, market, economic, and information/awareness factors were found major categorical factors for promoting EEI. In contrast, surprisingly only 4 barriers to EEI were perceived as important since they were ranked over 3 among 52 barriers on average. The rest 48 barriers were not considered as hindering factors by the respondents for EEI. Economic, policy, and informational factors were found major theoretical factors to inhibit EEI.

Based on firm-size and energy intensity levels of the respondent enterprises, we found some perceptional variations in the opinions of the respondents regarding the barriers to and drivers for EEI. First of all, regarding the drivers for EEI, the average scores of the perceived drivers in SMEs are mostly higher than those in LEs. This finding suggests that the likelihood of ranking the drivers with a higher score increases as the firm size becomes smaller. Besides, the average scores of the perceived drivers in NEIS were mostly higher than those in energy-intensive sectors. In particular, the enterprises from NEIS tended to perceive a factors a driver stronger than the enterprises from energy-intensive sectors. Regarding the barriers to EEI, we observed that respondents from SMEs and LEs had different opinions about the barriers since the average scores of the perceived barriers in SMEs were mostly higher than those in LEs. As a result of this finding, we conclude that the tendency of perceiving the factors as barriers diminishes as the firm-size becomes larger. Additionally, the respondents from NEIS are more prone to consider a factor as a barrier compared to those from energy-intensive sectors.

In line with the above findings, we offer some recommendations and policy implications for promoting EEI. The first one is easing the paperwork and bureaucratic procedures for financial subsidies. The second one is increasing the number of incentives in order to help to convince enterprises to invest in energy efficiency. The third one is sharing sectoral experiences and good practices for EEI among enterprises in order to increase the number of EIPs. The last one is reinforcing supporting mechanisms to reduce payback periods of EIPs.

After the completion of the field research for investigating common barriers to and drivers for EEI in Turkish industry sector via a comprehensive QS, we determined the most important perceived barriers to and drivers for EEI by only considering the pure rankings of the factors. Different from it, we expanded the evaluation approach to figure out the determinants of EEI and therefore, we employed a broad approach to modelling while simultaneously analyzing all possible barriers and drivers from the QS. The QS has a comprehensive content such that they include 9 categorical barriers with 51 indicators and 8 categorical motivations with 37 indicators. To deal with this comprehensive content, we applied a higher order construct model: specifically Disjoint Two-Stage Approach to modelling and the Repeated Indicator Approach for the higher order constructs. We preferred PLS-SEM method to test whether barriers and/or motivations have significant effects on EEI as it can be used to estimate higher order and complex models without imposing distributional assumptions on the data. The dependent variable in our structural model, “Energy Efficiency”, is measured by the answers to the questions of the respondents’ willingness to implement a new EIP in the next 5 years and plans to apply for any government or international incentives for the financing of a new EIP.

Consequently, we found that the motivations as a whole positively and significantly have an impact on EEI whereas the effect of barriers as a whole is negatively significant. The results related to motivations are in line with some of the findings of Groot et al. (2001), Rodhin et al. (2007) and Hasanbeigi et al. (2010). The results on the barriers are also consistent with Cagno et al. (2013), Trianni and Cagno (2012), and Kostka et al. (2011). To be more specific, the results of this study revealed that the valid model for the Turkish industry has 12 motivation related indicators out of 37 and that the motivations for industrial EE were reflectively determined by three latent variables: Awareness (IM), Techno-Economic Capability and Policy (EM). On the other hand, the results showed that the valid model for the Turkish industry includeded 19 barrier related indicators among 51. The barriers were reflectively constructed by four latent variables: Economic (IB), Market (EB), Information (EB) and Informational-Competence (IB). Surprisingly, we found that the construct “Barriers” had a weak effect on “Energy Efficiency”. This result may have occurred due to heterogeneity of the sample population, possibility of limitations of the questions asked in the QS and less justification or degree of the respondents about the EEI evaluation.

Promoting industrial EE is considered as one of the cost-effective or even costless approaches for the parties of the Paris Agreement have to take actions in order to decrease global energy use, fossil fuel consumption, and CO_2 emissions. Therefore, taking actions for improving industrial EE are compulsory for especially developing countries (as well as for developed countries) with limited sources not only to fight against global climate change but also to fulfill their obligations that the Paris Agreement brought about. That is why the success of their EE actions somehow rely on the barriers to and motivations for EEI. In this context, the results of derived from this study such as increasing awareness, improving techno-economic capability, reinforcing subsidies and incentives, mitigating economy related, information related, and competence related issues might be regarded for parties of the Paris Agreement to achieve its net-zero emissions target and in fighting against the climate change while improving EE. Alleviating high market risks and energy price uncertainties and coping with less profit perception might also provide a better environment for EE investments. If the performances of EE projects, sectoral experiences and good practices about them, energy conservation opportunities through them are shared among the firms, EE improves. Training technical personnel and subsidizing education cost of employees also might remove several barriers to EEI.

Finally, it should be noted that the barriers and motivations have been identified in various forms depending upon sectors, sub-sectors, and scale of the enterprises. The complexity of the EE process might also change the perceptions of barriers and motivations. More importantly, the identifications might differ according to its origin, i.e. region and country. Therefore, the future research using data from other developing countries with different features than the Turkish economy and data including higher number of small and medium scale enterprises might provide a deeper insight.

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APPENDIX

APPENDIX 1: ORIGINALITY REPORT

HACETTEPE UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
Ph.D. DISSERTATION ORIGINALITY REPORT

HACETTEPE UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
ECONOMICS DEPARTMENT

Date: 15/06/2022

Thesis Title: Essays on The Rebound Effects of The Energy Efficiency

According to the originality report obtained by my thesis advisor by using the Turnitin plagiarism detection software and by applying the filtering options checked below on 15/06/2022 for the total of 122 pages including the a) Title Page, b) Introduction, c) Main Chapters, and d) Conclusion sections of my thesis entitled as above, the similarity index of my thesis is 17 %.

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I respectfully submit this for approval.

15/06/2022

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Program:	Economics
Status:	☒ Ph.D. ☐ Combined MA/ Ph.D.

ADVISOR APPROVAL

APPROVED.

Prof. Dr. Ayşen SİVRİKAYA

APPENDIX 2: COMMISSION OF ETHICS PERMISSION

Tarih: 04/03/2021
Sayı: E-35853172-300-00001478861

T.C.
HACETTEPE ÜNİVERSİTESİ REKTÖRLÜĞÜ
Rektörlük

Sayı : E-35853172-300-00001478861 4.03.2021
Konu : Doç. Dr. Ayşen SİVRİKAYA Hk. (Etik Komisyon İzni)

İKTİSADİ VE İDARİ BİLİMLER FAKÜLTESİ DEKANLIĞINA

İlgi : 05.02.2021 tarihli ve E-90955707-300-00001436523 sayılı yazınız.

Fakülteniz Sosyal Hizmet Bölümü doktora programı öğrencilerinden **Songül TEKELİ**'nin **Doç. Dr. Ayşen SİVRİKAYA** yardımcılığında yürüttüğü "**Türkiye Sanayi Sektöründe Verimlilik Artırıcı Projelerin Doğrudan Rebound Etkisi ve Enerji Verimliliğini Etkileyen Bariyer ve Motivasyonlar**" başlıklı araştırma projesi Üniversitemiz Senatosu Etik Komisyonunun **23 Şubat 2021** tarihinde yapmış olduğu toplantıda incelenmiş olup, etik açıdan uygun bulunmuştur.

Bilgilerinizi ve gereğini saygılarımla rica ederim.

Prof. Dr. Vural GÖKMEN
Rektör Yardımcısı

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