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# Drivers and Barriers for Efficient Energy Management Practices in Energy-Intensive Industries: A Case-Study of Iron and Steel Sector

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**Abstract:** The two major reasons behind the world's energy crisis are losses in energy transmission and less efficient energy use at sinks. The former flaw can be catered by changing the entire energy transmission system which requires investment and planning on a large scale, whereas the later deficiency can be overcome through proper management of energy utilizing systems. Energy-intensive industries have a substantial share in energy consumption and equally high energy saving potentials if they adopt some integrated and improved energy efficiency. This study investigates the energy management systems in the iron and steel sector of Pakistan, and compare it with findings of similar work in Sweden, Bangladesh, and Ghana. A systematic questionnaire was circulated in the iron and steel sector across the country and afterward the collected data was analyzed to find major barriers and drivers for efficient energy management practices. In addition, questions on non-energy benefits and information sources relevant to the energy efficiency were also part of the questionnaire. Cost reduction resulting from lowered energy use was rated as the most important driver for applying energy-efficient operation. On the other hand, the cost of production disruption was considered among high-level barriers to the implementation of improved energy efficiency. An increase in the life-time of equipment was labeled as the top non-energy benefits. Company peers and seminars/conferences were referred as the best information sources related to energy efficiency. The outcome of the study will be helpful to the decision-maker in the industry, as well as the government levels.

**Keywords:** energy management system; energy efficiency; integrated management; energy-intensive industry; iron and steel making

## 1. Introduction

Pakistan has been facing severe energy crisis for the last one and a half decades that have badly affected every walk of life particularly the economic growth [1,2]. The fundamental reasons behind the energy crisis are lesser growth in exploration of energy sources, a flawed estimate of the

mounting energy demand, and energy losses during transmission and end-use [3]. Energy-intensive industries get a large share as an energy-using sector in Pakistan [4]. Energy conservation opportunities in Pakistan are estimated to be 5 billion USD per year with a share of 25% for industry, 20% for agriculture, 20% for transport, and 30% for buildings [5]. Energy saving in the industrial sector can be realized if some integrated energy management and improved energy efficiency are adopted [6–8]. However, like the other developing countries, the energy management practices in energy-intensive industries in Pakistan are mostly based on manual calculations and therefore are not fully robust and integrated. Hence, a substantial amount of energy is lost which causes damage to the national economy, wastage of national resources, and adversely affects the environment.

Energy-efficient operation in industries through vibrant energy management practices has been the subject of interest worldwide. In this context, numerous studies have been reported across the globe, such as United States of America [9–11], Japan [12], China [13,14], India [15–17], Bangladesh [18–20], Indonesia [21], Ghana [22], Germany [23,24], United Kingdom [25], Sweden [26,27], Russia [28], Finland, Poland, and Italy [29], and Turkey [30]. It has been inferred that a substantial amount of energy, utility bill, and emissions can be cut by using efficient energy management systems and updated technologies within rational payback periods [31,32]. The energy efficiency also has numerous non-energy benefits, such as improved productivity, improved air quality, the extended lifetime of equipment, and reduced product waste [33]. The energy efficiency of process industries has substantially risen in the last few decades, efficient utilization of energy is still considered the most important and cost-effective means for minimizing the greenhouse gas emissions [34]. The energy conservation through effective management can also help in realizing the circular economy of a country [35]. With the emergence of the Internet of Things (IoT), energy management is entering into the phase of automation in the paradigm shift from Industry 3.0 to 4.0 [36].

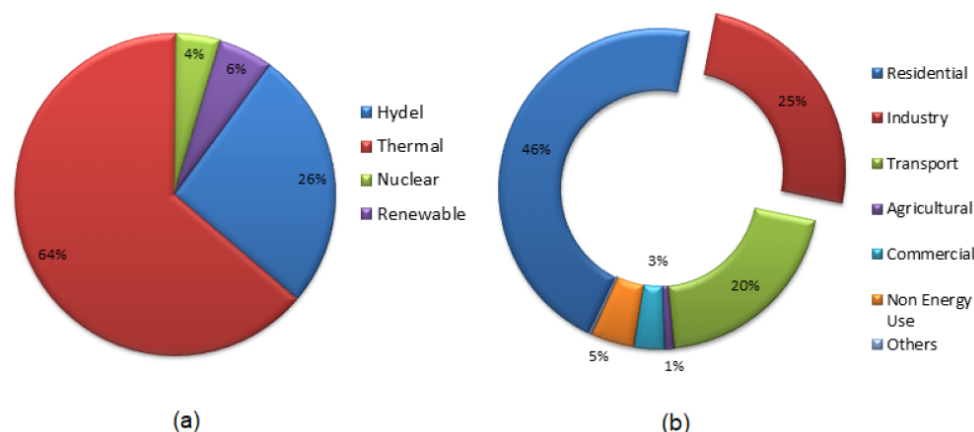
Energy policies and energy management practices have also been the subject of interest in Pakistan [6–8,37–46]. Mirjat et al. [37] argued that government policies since independence varied over time and had been less integrated without the use of energy modeling tools e.g., LEAP, MARKAL/TIMES, etc. Hence, they emphasized the need for energy modeling for realizing sustainable energy policies to cope with the energy crisis. Latif et al. [38] used the MARKAL approach from 2014 to 2035 for renewable and non-renewable energy scenarios, and showed that for Pakistan renewable sources are the best option in reducing energy-related risks and fossil fuel import bills, and at the same time enhances economic and environmental sustainability. In studies by Rafique et al. [39,40], the need and prospects of new sources, such as renewable energy have been emphasized to have a sustainable power development and its implementation in the country. Solangi et al. [41] compare various renewable resources: solar, wind, hydro, geothermal, and biomass with regard to environmental, technical, economic, and socio-political aspects by using an integrated Delphi (analytical hierarchy process) and Fuzzy (a technique for order of preference by similarity to ideal solution). In this study, Solangi et al. revealed that among renewable resources, wind energy is the most feasible for Pakistan, followed by hydro, solar, biomass, and geothermal energy. A study by Ali et al. [42] elaborated on the impact of energy projects launched in the context of China Pakistan Economic Corridor (CPEC) and their affect on industrial, services, and agriculture sectors.

The energy management practices also got the attention of researchers for the manufacturing sector. Junaid et al. [43] and Sabir et al. [6] discussed the potential barriers to the incorporation of green technology and energy management systems in the textile industry. A study by Akhtar et al. [7] discussed the optimal frameworks for adopting energy management systems in Combined Cycle Power Plant (CCPP). In a study by Zeb et al. [8], the potential applications of Thermoelectric Generator (TEG) and Waste Heat Recovery System (WHRS) in the cement industry were elaborated. Aslam et al. [44] reviewed smart meter technology and its implementation across various sectors, i.e., industrial, commercial, residential. Masood et al. [45] conducted a survey and in conclusion, highlighted a need for the introduction of green infrastructure within air conditioning units of spinning mills of the textile industry. Nadeem et al. [46] also conducted a survey in selected government organizations,

industries, and academic institutes of Pakistan to identify barriers and highlights stakeholders' opinions for encouraging energy efficiency. Hassan et al. [47] conducted a survey across small and medium-size industries in Pakistan to find barriers to energy-efficient practices. A correlation between the size of the firms, the qualification of an energy manager, and the barriers were investigated.

### 1.1. Energy Management System Programs for Industrial Sector in Pakistan

According to the State of Industry Report 2018 [48] published by National Energy and Power Regulatory Authority (NEPRA) Pakistan, around 64% of the total energy in the country is produced through thermal resources (e.g., natural gas, coal, and furnace oil), 26% of total energy by hydel, 6% of total energy by renewable and remaining 4% of total energy by nuclear, see Figure 1a. On the energy end-use, around 46% of the total produced energy is used for residential purposes followed by the industrial sector at 25% and the transport sector at 20%, etc., see Figure 1b. Overall energy end-use in Pakistan from 2008 to 2018 is depicted in Figure 2 [49,50]. In five years duration from 2013 to 2018, over 30% increase is observed in overall energy end-use. From the fiscal year, 2013 to 2014 with payment of circulation dept of PKR 480 billion to independent power producers (IPPs) initiated the electricity production [51], and so it affected overall energy consumption. Furthermore, in these five years from 2013 to 2018, nearly 7000 MW electricity was added in the national grid to overcome energy shortfall in Pakistan. In the energy mix, as already shown in Figure 1a, Pakistan is largely dependent on fossil fuel-based thermal energy, and among these fossil fuels share, more than 50% is fulfilled by natural gas. Certainly, with depletion of natural gas reserves, Pakistan has to rely on liquefied natural gas (LNG) import, and so from 0.7% to 8.7% overall share of LNG in energy end-use from 2015 to 2018 [52]. Moreover, economic growth and population growth link with an increase in overall energy end-use of a country, and for Pakistan, from 2013 to 2018 GDP growth was around 30% and annual population growth stated greater than 2% [53].



**Figure 1.** (a) Breakdown of energy production in Pakistan for 2018, and (b) Sector-wise energy usage in Pakistan for 2018.

Pakistan Energy Efficiency and Conservation Board (PEECB) is the governing body that looks after energy efficiency related policies and programs. The government policies mostly remained focused on water resources management than energy concerns for several decades, in fact since the independence of Pakistan (1947). The first attempt on energy and power planning was carried out in the late 1960s followed by several studies based on five-yearly medium-terms [37]. The energy efficiency and conservation got first formal recognition by the Government of Pakistan (GoP) through the establishment of the National Energy Conservation Centre (ENERCON) back in 1986. Recently, the National Energy Efficiency and Conservation Act 2016 (2016 National EE&C Act), established a new institute namely National Energy Efficiency and Conservation Authority (NEECA) to replace the existing National Energy Conservation Center (ENERCON). According to

the 2016 National EE&C Act, PEECB consists of members from Federal Ministries and Divisions, designated departments of four provincial governments, the Chairman of Oil and Gas Regulatory Authority (OGRA), the Chairman of NEPRA, one nominee from the Chambers of Commerce and Industry, one person from the agriculture sector, five persons from the private sector, and the Managing Director of NEECA.

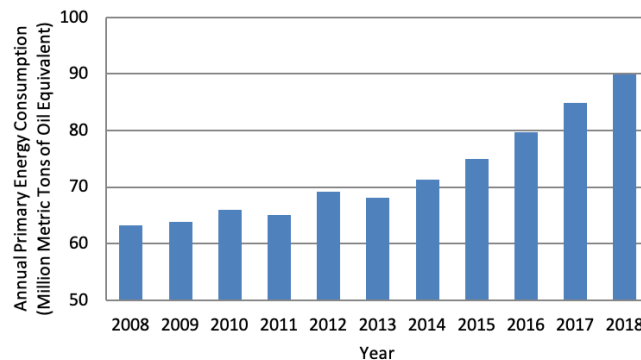


Figure 2. Primary overall energy end-use in Pakistan from 2008 to 2018.

The energy efficiency-related efforts have been mostly driven by donors' fundings. The formation of ENERCON was funded by USAID and motivated by the desire for a reduction in energy waste and improvement in the efficiency of energy use [5,54]. In 2005, the Royal Netherlands Embassy (RNE) funded a project for reducing energy wastage through the incorporation of energy efficiency (EE) strategies in tanneries [55]. From 2005 to 2012, several programs by two other donors, i.e., GIZ and a SWITCH-Asia program of the European Unions, were launched focusing on Renewable Energy and Energy Efficiency (RE&EE) for selected units in the textile sector, foundry sector, steel re-rolling sector, the edible oil sector, dairy sector, hospitals, food, metal processing, sugar, pulp and paper, and tannery sectors [5,56]. Similarly, in 2009, USAID funded Energy Efficiency and Capacity Project (EECP) to conduct training and capacity building in the energy sector through the development of industrial energy conservation plans and equipment up-gradation. Another project from 2009 to 2018 was financed by Asian Development Facility (ADF), Agence Française de Développement (AFD), and Government of Pakistan (GoP) on the pattern of a Multi-tranche Financing Facility (MFF) to promote Sustainable Energy Efficiency Investment. In 2014, UNIDO launched a four-year project in the industrial sector entitled "Sustainable Energy Initiative for industries in Pakistan" to (i) Develop the policy and regulatory framework on the use of RE&EE in Industry, (ii) Create an investment platform for promoting investments in RE&EE and scaling up the market, and (iii) Establishing an accreditation center for energy experts on energy management system and RE applications in the industry [5]. In 2015, JICA-funded a project "Energy Efficiency Management Project (EEMP) for the industrial sector in Pakistan" to provide direct benefits to the casting industry and auto parts manufacturing industry of Pakistan under Japanese energy experts [5].

### 1.2. Steel Sector in Pakistan

The first state-owned steel complex in Pakistan was established in Karachi, back in 1973. Over time, several private sectors' investments lead to the installation of new steel production units all over Pakistan which caused a substantial increase in steel production in the country. According to the State Bank of Pakistan, the second quarterly report for the fiscal year 2016 [57], in Pakistan there are around 600 smaller and bigger mills. Furthermore, in 2016 Pakistan was also listed among the countries with positive production dynamics in steel making [58].

The trend of crude steel production in Pakistan from 2008 to 2018 is shown in Figure 3a, along with import and export trends of finished and semi-finished steel products in Figure 3b,c, respectively [59,60]. From Figure 3a it can be seen that the domestic production of steel has substantially increased, but the

import of steel (see Figure 3b) has also increased due to enormous domestic demand. Astonishingly, in 2017 the steel production increased more than 1400 thousand tonnes from the previous year, and this increase is more than two folds from 2015 to 2016, from Figure 3a it can be observed that the steel production increase of a single year (2016 to 2017) is equivalent to the steel production increase for six years, i.e., from 2008 to 2014. Due to this drastic increase in steel production from 2016 to 2017, a decrease in steel imports by 450 thousand tonnes (see Figure 3b) and increase in steel export ca. 50 thousand tonnes (see Figure 3c) can be observed. The major reasons behind the increase in steel production is due to the increase in demand from (i) dynamic customer base for steel commodities in transportation, defense, automotive, and appliances sectors, (ii) speed in industrialization and expansions, (iii) increase in population causing the increase in housing projects that consume steel, (iv) infrastructure projects under CPEC [61]. However, from 2017 to 2018 ca. 250 thousand tonnes decrease in steel production (Figure 3a) and ca. 450 thousand tonnes decrease in steel imports (see Figure 3b) can be observed. Interestingly, despite the decrease in steel production and import for the year 2017 to 2018, steel export increases by 3.5 folds, see Figure 3c. The probable reasons behind this are the suspension of mega projects by the Government of Pakistan (GoP) and private sector developers, which includes CPEC related construction work and ban on high-rise buildings construction by the Supreme Court of Pakistan. Furthermore, due to the USA. led sanctions on Iran, and illegal smuggling of steel bars from the Iranian border to Pakistan further reduced steel demand in the local market [62].

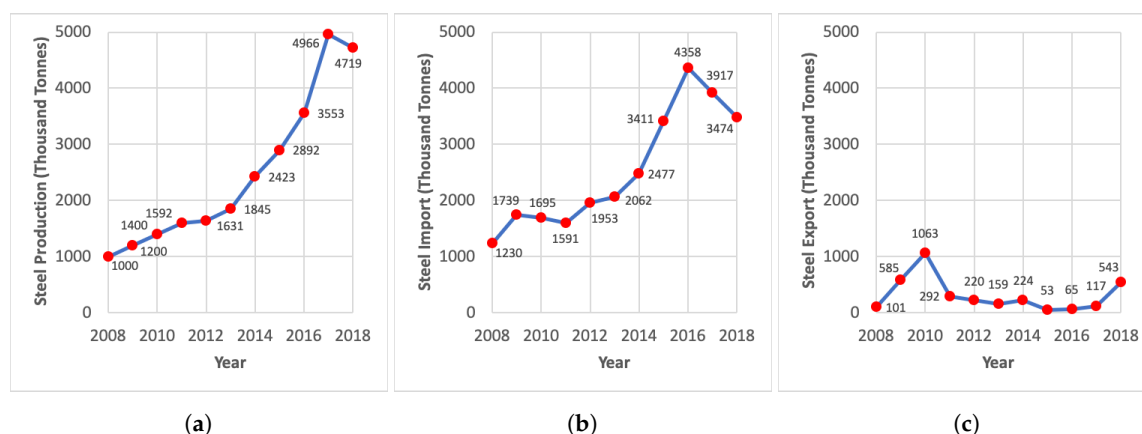


Figure 3. Steel: (a) Production, (b) Import, and (c) Export in Pakistan from 2008 to 2018.

Most of the iron and steel mills in Pakistan consist of small-size plants and most of them rely on obsolete and energy inefficient steel making technology. Therefore, the quality of the steel from such mills is substandard, as well as costly in comparison to big manufacturers in Pakistan. According to an economy-related annual report of the State Bank of Pakistan from 2017 to 2018 [61], and the Pakistan Stock Exchange (formerly known as Karachi Stock Exchange) [63], fifteen major private sector steel manufacturers dominate in terms of share in the production. To capitalize on the demand, the local steel manufacturers are facing competition from international giants in steel making. The competition comes both in quality and process, where domestic small players cannot compete due to high production cost and double taxation. Recently, the industry has felt relief due to the imposition of anti-dumping duty (ADD) on regulatory duties on finished steel products [61]. This favorable development has motivated the local industry to invest in capacity expansions, innovation, and diversification. In this context, a reduction in utilities consumption can give further space to the local industry to increase production and keep low prices.

The energy management system of the iron and steel mills is a subject of great interest worldwide [20,27,64,65]. Swedish iron and steel sector reported 9.7% energy saving potential by adopting energy management practices [27]. They also investigated the environmental impact of the iron and steel sector in the country. According to a report of the US energy department, 9 to

18% energy saving opportunity exists in the iron and steel sector if best management practices and technology options are adopted [64]. Similarly, a study on the iron and steel sector of Bangladesh revealed that 6 to 8% energy saving opportunity can be achieved through best energy management practices [20]. The main obstacles to energy efficiency were uncertainty towards the company's future, poor information quality, and cost in-effective technical measures. The Indonesian steel sector is reported to use about 38% of the total industrial sector energy usage. The barrier to energy efficiency was less influencing to energy manager, more inclination towards production activity, less intend to change, lack in a management capacity, and conflicts of interest [65].

This study systematically reviews energy management practices in the iron and steel sector of Pakistan. The aim was to find barriers, drivers, and non-energy benefits related to energy efficiency by adopting more robust energy management systems in the local mills. The findings were compared with similar studies conducted in other countries to identify the pro and cons of the existing practices. Considering the fact that energy efficiency is the most effective mean for reducing the emissions of greenhouse gases from industry, this study will help in realizing the importance of effective energy management in achieving energy efficiency and step forward to the circular economy of the country. We believe that this study will help the policymakers at the company, as well as at the country level to strive for realizing energy efficiency by overcoming the deficiencies of the existing practices.

Section 2 describes the methodology adopted in this study followed by results and discussions in Section 3. Conclusions of this work are shown in Section 4.

## 2. Methodology

In this work, the data used is collected with the help of a questionnaire. The same questionnaire was used in studies carried out for Ghana [22], Sweden [27], and Bangladesh [20] in 2013, 2014, and 2018, respectively. The questionnaire was initiated in 2006 during the workshop organized by the Swedish Foundry Association to discuss major barriers to and driving forces for energy efficiency within the iron and steel sector [66]. Initially, the questionnaire included only barriers and drivers related to energy efficiency, and later non-energy benefits and information sources relevant to the energy efficiency of the iron and steel sector were also added. The questionnaire includes simple and mostly closed-ended questions aiming the following objectives:

- Major barriers to energy efficiency
- Major driving forces for energy efficiency
- Major non-energy benefits with energy efficiency

The developed questionnaire mainly consists of four sections, which include barriers for energy efficiency, driving forces for energy efficiency, extra potential in energy management policy, and information sources regarding energy-efficient operation of iron and steel sector. In barriers for the energy efficiency section, the respondent is required to grade twenty-three barriers, see Figure 4. In driving for the energy efficiency section, the respondent is required to grade thirty-five drivers, see Figure 5. In the third section of the questionnaire, the respondent is required to grade twenty-three extra potentials related to energy management policy, see Figure 6. In the information sources section, the respondent is required to grade fourteen modes, see Figure 7. The questionnaires were shared with all iron and steel mills registered in the Pakistan Stock Exchange, and 68% of these mills responded to us. In general, most of these mills lack in any sort of energy management and optimization, even in few of these mills there is not any separate department for energy efficiency. Hence, the questionnaire was filled out by staff from the production and quality departments of the understudy mills. The provided closed-end questions were required to grade between "1" and "5" by the mills' employees, where "1" shows the evaluating criteria is of least importance and "5" shows the evaluating criteria is of significant importance and effective. The collected results from the participated mills were rated by taking the average score of each criterion. The most effective criteria were the one with the highest average score and presumably reflect overall iron and steel mills' barriers to drivers for added values of

energy efficiency. Moreover, results were normalized for range 0 to 1 and presented graphically for comparison. Furthermore, normalize scale is divided into five levels: very low (0 to 0.2), low (0.2 to 0.4), moderate (0.4 to 0.6), high (0.6 to 0.8) and very high (0.8 to 1).

### 3. Results and Discussions

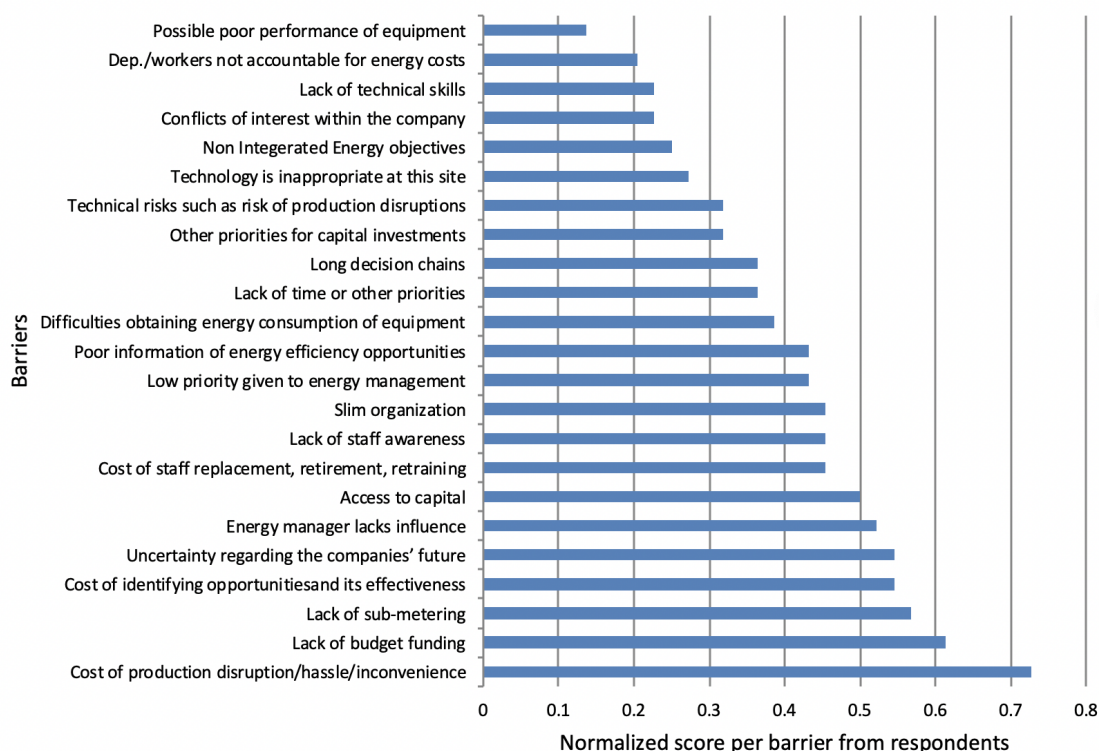
In this section, the results of circulated questionnaires in iron and steel mills of Pakistan are presented, discussed, and compared with previous questionnaire studies of Bangladesh [20], Ghana [22], and Sweden [27].

#### 3.1. Barriers to Energy Efficiency

From the Figure 4 it can be observed that highly effecting barriers towards energy-efficient operations and implementation of measures were “cost of production disruption” and “lack of budget funding”. Following barriers “lack of sub-metering”, “cost of identifying opportunities for effective usage”, “uncertain regarding the company future”, “energy manager lacks in influence”, “access to capital”, “cost of staff replacement, retirement, retraining”, “lack of staff awareness”, “slim organization”, “low priority given to energy management” and “poor information of energy management” towards effective usage of energy were considered of moderate level. Among these moderate level barriers; “lack of sub-metering”, “uncertain regarding the company future” and “cost of staff replacement, retirement, retraining” correlate with “access to capital”. As with the non-availability of funds, the future of the company becomes uncertain, so purchasing new devices for monitoring energy usage and hiring new staff becomes out of question. Additionally, “uncertain regarding the company future” link up with “energy manager lack influence”, “lack of staff awareness”, “low priority given to energy management” and “poor information of energy efficiency opportunities”. As employees of a company with uncertain future lost their interest in a job, they are more interested in switching job, so ultimately managers lost influence and seem less interested in new investments, e.g., on training programs of employees who are about to leave a company. The barriers which have low influence toward effective usage of energy are “difficulties in obtaining energy consumption of equipment”, “lack of time or other priorities”, “long decision chains”, “other priorities for capital investments”, “technical risks related to production disruptions”, “inappropriate technology at this site”, “non-integrated energy objectives”, “conflicts of interest within the company”, “lack of technical skills” and “departments/workers are not accountable for energy cost”. It seems companies do have appropriate tools and technical skills for measuring individual equipment energy usage. Additionally, from a low rating of “lack of time other priorities” and “long decision chains”, it seems that employees do not themselves seem overburden in terms of assigned tasks and management hierarchy. Last not the least, equipment within the mills seems well maintained as “possible poor performance of equipment” has been given the least weightage.

Like Bangladeshi [20] and Swedish [27], Pakistani respondents considered “cost of production disruption/hassle/inconvenience” among high-level barriers for implementation of improved energy efficiency in iron and steel sector. However, respondents from Ghana [22] considered “cost of production disruption/hassle/inconvenience” of a moderate level barrier. “Access to capital” is rated by Pakistani respondents as of a moderate level, whereas in Ghana [22] and Sweden [27] it seems more difficult and so rated at a high level, but unlikely in Bangladesh [20] it is rated for a very low level. So one can conclude that in Pakistan access to capital is possible with little effort, which may be evident from the rating of “other priorities for capital investment”. Unlike the other three countries’ high-level rating of “other priorities for capital investment”, respondents in Pakistan considered it among low-level barriers. In comparison to Ghana [22] and Sweden [27] instead of moderate level rating, “lack of time” is rated for low level in Pakistan and Bangladesh [20], it seems employees are not overburdened with their day to day performance tasks. Furthermore, despite the fact, among underdeveloped countries, Pakistani companies employees considered them self-sufficient in implementing improved energy efficiency, as they rated “lack of technical skills” slightly lower

than Sweden, but in similar normalized score range limits. However, Bangladesh [20] and Ghana [22] considered “lack of technical skills” as a high-level barrier for implementing.



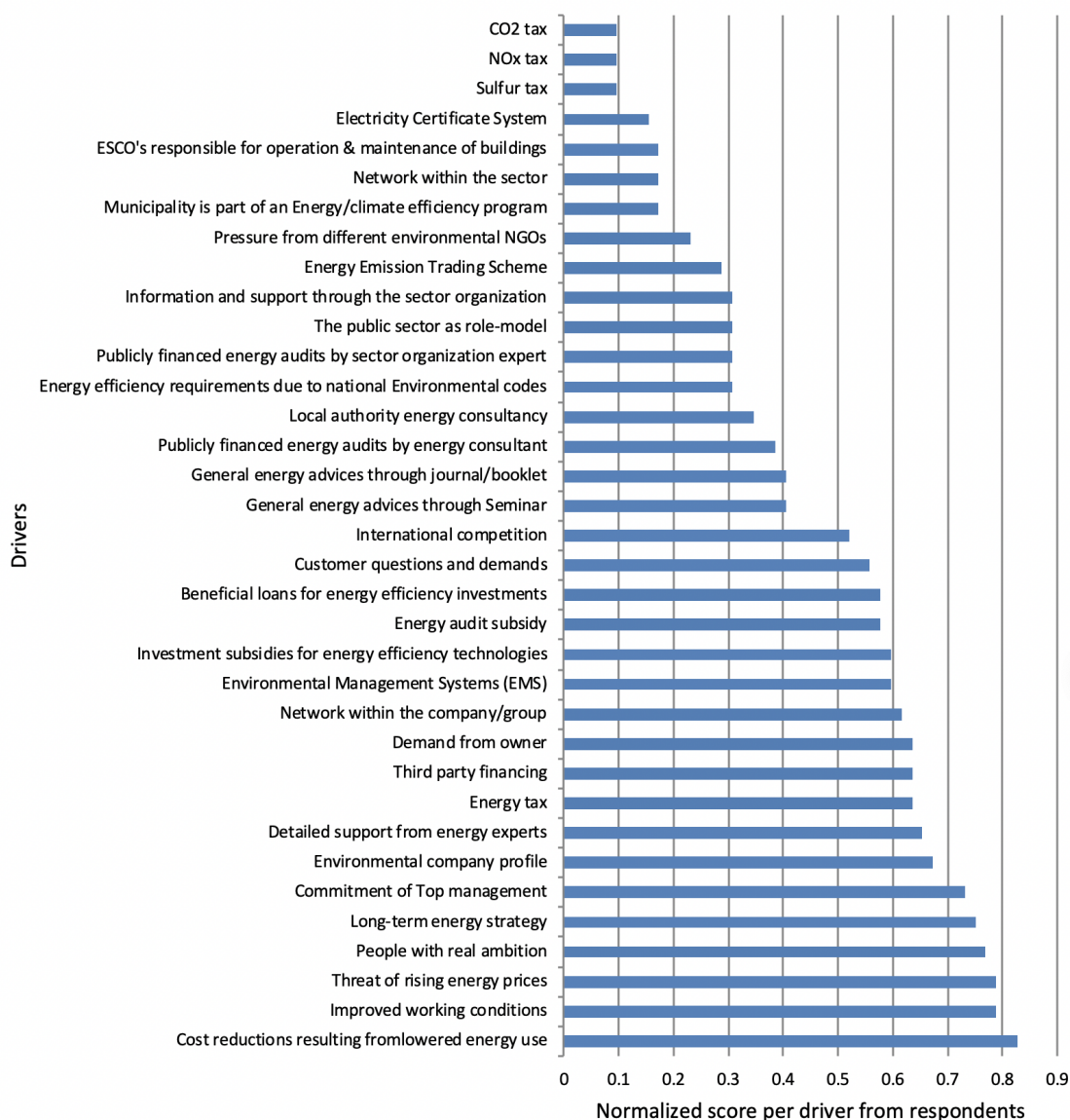
**Figure 4.** Barriers towards energy efficiency of iron and steel sector of Pakistan.

### 3.2. Driving Forces to Work for Energy Efficiency

The same questionnaire was utilized to highlight the important factors which can act as drivers and helpful in implementing the energy-efficient practices and effectively adopting energy-efficient technologies. According to the gathered data from respondents, see Figure 5, it can be concluded that all respondents are very much interesting in overall cost reduction by lowering energy use. After “cost reductions resulting from lowered energy use”, respondents considered “improved working conditions”, “threat of rising energy prices”, “people with real ambition”, “long-term energy strategy”, “commitment of top management”, “environmental company profile”, “energy tax”, “third party financing”, “demand from owner”, and “network within the company/group” as high-level drivers for energy-efficient operations in iron and steel mills. Among these drivers, “people with real ambition”, “commitment of top management”, “demand from owner” and “network within the company/group” are very much interlinked, as none of them can function align and therefore they all must be on the same page. “Demand from owner” slightly rated down than “people with real ambition” and “commitment of top management” as the driver for energy-efficient operation, the possible reason could be that initially the owner has to invest some money and later rely on the payback period for increasing profit margins, though the good thing is that rating difference isn’t that much. Following factors “Environmental management systems”, “investment subsidies for energy efficiency technologies”, “energy audit subsidy”, “beneficial loans for energy efficiency investments”, “customer questions and demands”, “international competition”, “general energy advices through seminar”, and “general energy advices through journal/booklet” were rated for moderate level by respondents. Astonishingly, respondents gave a low-level rating to governmental or third party practices, such as “publicly financed energy audits by energy consultant”, “local authority energy consultancy”, “energy efficiency requirements due to national environmental codes”, “publicly



financed energy audits by sector organization expert”, “the public sector as role-model”, “information and support through the sector organization”, “energy emission trading scheme”, and “pressure from different environmental NGOs”. Such low-level ranking for government-oriented practices shows concern about how much government is serious in taking actions toward the implementation of energy-efficient operation.



**Figure 5.** Drivers for energy efficient operation of iron and steel sector in Pakistan.

Moreover, from Figure 5 it can also be concluded that in Pakistan the mills’ employees seem more interested towards directly minimizing energy use rather than via adopting environment-friendly practices, e.g., emissions (CO<sub>2</sub>, NO<sub>x</sub>, sulfur) related taxes implementation, “municipality is part of climate efficiency program”, “pressure from different environmental NGOs”, “energy emission trading scheme”, and “energy efficiency requirements due to national environmental codes” were rated much lower than “cost reductions resulting from lowered energy use”, “long-term energy strategy”, “detailed support from energy experts”, “energy tax”, “energy audit subsidy”, and “local authority energy consultancy”. Astonishingly, despite low ratings related to environment-friendly practices than energy-efficient operations, respondents considered “environmental company profile”, and “environmental management system” almost four times more important than “electricity certificate

system" as a driving force towards efficient energy operation. Additionally, it is found that companies are more interested in getting third party financing than financial loans and government subsidies for improving energy management. May be the difference between these three drives is due to the liability and expectation differences, as government regulations are usually strict and as well as banking loan conditions. Moreover, general perception can also be drawn that for implementation of policies in companies rely more on the national government, and internal group levels rather than local government, and senatorial network levels.

It is quite interesting that similar to Bangladesh [20], Ghana [22], and Sweden [27] studies, in Pakistan employees of steel and iron sector also consider "cost reduction resulting from lowered energy use" as a most important driver for applying energy-efficient operation. Afterward, "Threat of rising energy prices" is considered among the top three driving forces by Pakistan, Bangladesh [20], and Ghana [22], however in the case of Sweden [27], it still seems important but ranked at fifth place. It seems individual actions are more important in Pakistan and Sweden [27], as "people with real ambition" were ranked at number 4 with similar normalized weightage by both countries, whereas in Bangladesh [20] and Ghana [22] it seems of moderate level and low-level driving forces, respectively. Additionally, all four countries respondents considered "long-term energy strategy", and "commitment of top management" among high importance drivers. In Pakistan, mills seem very much owner oriented, as "demand from owner" is rated higher than Bangladesh [20] and Sweden [27]. In Pakistan, it seems "general energy advices through seminar", and "general energy advices through journal/booklet" are capable to play a better role than Bangladesh [20], Ghana [22], and Sweden [27], as Ghana respondents gave them a low-level rating, whereas Bangladesh and Sweden respondents never considered them for improved energy efficiency purpose. Furthermore, it is observed that respondents from all four countries: Pakistan, Bangladesh [20], Ghana [22], and Sweden [27] weigh moderately to "Environment Management System (EMS)" as a driver towards energy management and improved energy efficiency. In Pakistan and Bangladesh [20], very much likely respondents gave least weigh to emissions oriented taxes, however Ghana [22] and Sweden [27] gave slightly higher importance, but still lesser than moderate level.

### 3.3. Non-Energy Benefits with Energy Efficiency Energy Management Potential

Apart from the usual cost advantages by applying improved energy efficiency in the iron and steel mills of Pakistan, the respondents also rated non-energy benefits, see Figure 6. None of the non-energy benefits were considered of higher-level potential from respondents. Following non-energy benefits: "increased lifetime of equipment", "improved temperature control", "improved company image", "reduced maintenance costs", "reduced cooling demand", "increased productivity/increased production", "safer working environment", "increased working ethic", "more reliable production (e.g., reduced production stops)", "reduced labor demand", "improved quality of light", "shorter cycle times for processes", "increases sales", "improved air quality", "reduced emissions of CO, CO<sub>2</sub>, NO<sub>x</sub> & SO<sub>x</sub>", "reduced emissions of ash or dust", "reduced noise", and "improved quality of product" were rated for moderate level. Among them "increased lifetime of equipment", "reduce maintenance cost", "increased productivity/increased production", "safer working environment", "more reliable production (e.g., reduced production stops)", and "reduced noise" directly interlink with each other. Due to adopted energy management and improved energy efficiency, electricity can be also maintained with any fluctuation and so "improved quality of light", furthermore due to well-maintained equipment and adopting energy management policy, fuel consumption also get lower, and correlate with "improved air quality", "reduced CO, CO<sub>2</sub>, NO<sub>x</sub> & SO<sub>x</sub>", and "improved temperature control". "Utilization of waste heat, waste fuel, waste gas", "reduced amount of wastewater", "reduced amount of hazardous materials", "reduced amount of waste from other wastes", and "lower material costs" were considered as of low level non-energy benefits.

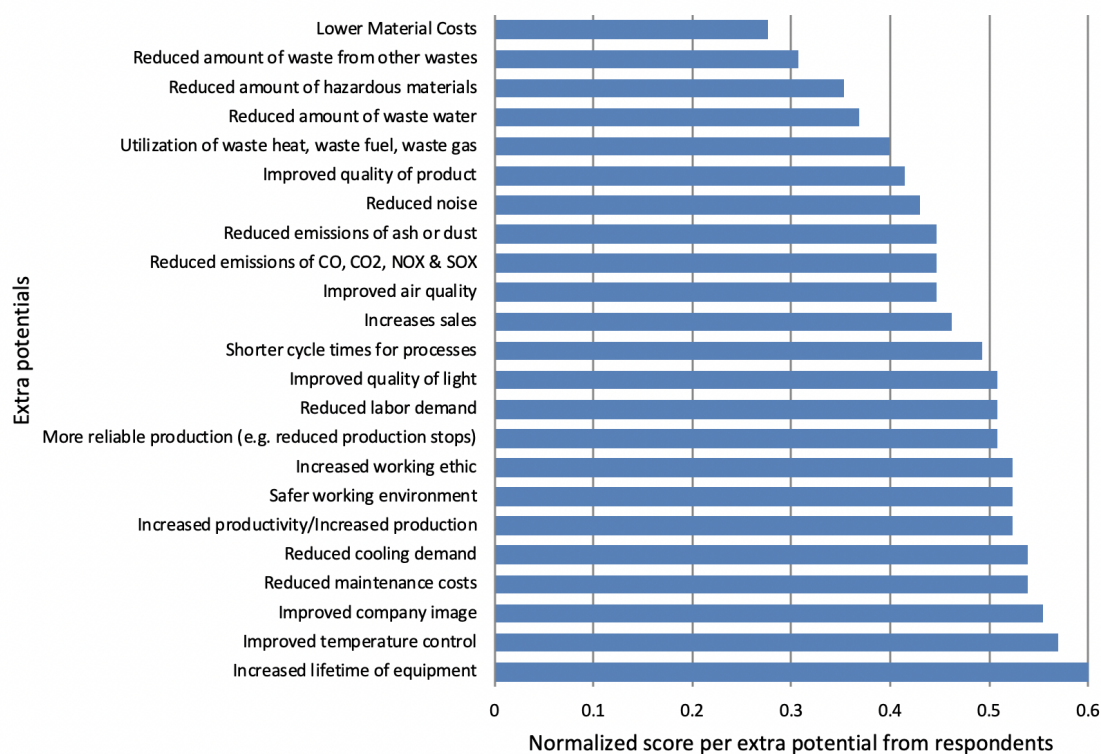


Figure 6. Non-energy benefits with improved energy efficiency.

### 3.4. Useful Energy Efficiency Information Sources

Like non-energy benefits, respondents graded useful efficient information sources between moderate level and low-level. The companies mostly get information regarding energy efficiency through “colleagues within company/group”, “conferences & seminars”, “consultants performing audits”, “colleagues within sector”, “written sources of information like journals”, “information by power companies” and “sector organization” at a moderate level. Furthermore, companies considered “product information from supplier”, “government sponsored energy audits”, “country administrative board”, “regional energy agency”, “university research project”, and “national energy agency” low-level sources of circulating information. Moreover, companies have a very low chance to get information regarding energy-efficient operation via “municipality”. The low-level rating reflects the gap between government and administrative structures towards energy management strategies. Figure 7 shows the data obtained from regarding the sufficiency of energy-efficient operation related information provided to the iron and steel sector.

During our discussions with mills’ questionnaire respondents and input of the UNIDO’s representatives in Pakistan, working with iron and steel sector on potential energy efficiency improvement, it was inferred that the potential for improvement in energy efficiency with existing technology is minimum around 7 to 8%, and with up-gradation of equipment, it could be up to 25% [5]. In a recent report published by UNIDO Pakistan on Sectoral Analysis on Renewable Energy and Energy Efficiency, energy saving opportunity in four sample Iron and steel companies were 12%, 29%, 30%, and 8%, respectively [67]. Similar results of energy efficiency improvement were mentioned for steel sectors in Sweden [27] and Bangladesh [20], i.e., 7 to 8%, and 4 to 6%, respectively.

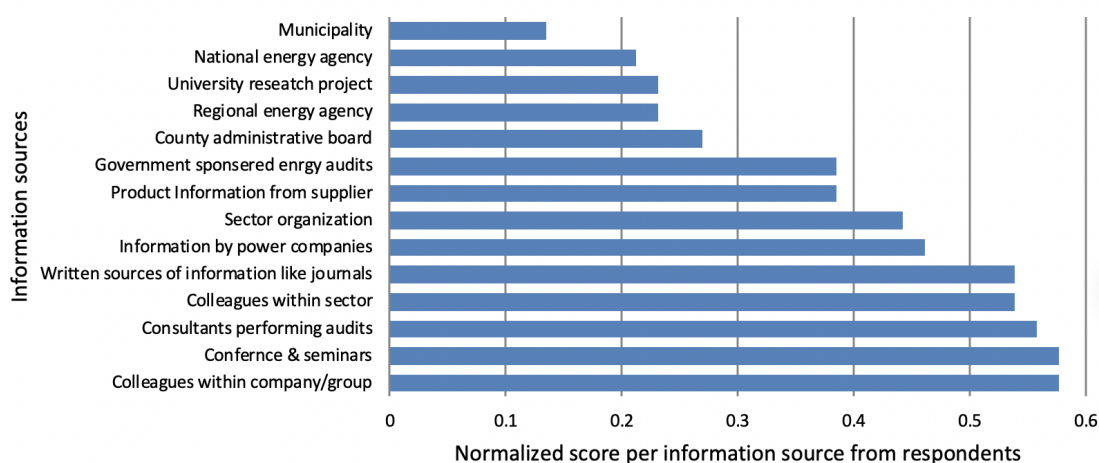


Figure 7. Useful information sources regarding energy-efficient operation of iron and steel sector.

#### 4. Conclusions and Outlook

From this study, it can be concluded that the most notable barriers are cost of production disruption/hassle/inconvenience, and lack of budget funding. Most of the drivers revolve around the finances of the company. Like other similar studies on Bangladesh [20], Ghana [22], and Sweden [27] iron and steel sectors, cost reductions resulting from lowered energy use was found to be the most effective driving force for implementing energy management and improved energy efficiency in the companies. Other notable drivers were threat of rising energy prices, long-term energy strategy, commitment of top management, and environmental company profile. Apart from the usual cost advantages, some additional benefits, so-called non-energy benefits were also reported. These include increased lifetime of equipment, increased productivity/increased production, and safer working environment. It was reported that energy managing policy has also helped them to reduce emissions of carbon-containing gases, as well as  $\text{NO}_x$  and  $\text{SO}_x$ . Regarding communication of energy policies, awareness of energy efficiency practice, a reflection of a gap within government and administrative structures towards energy management strategies was noticed.

To the authors' knowledge, the unique part of this study is that it is the first kind of systematic study on investigation of barriers, drivers, and non-energy benefits of adopting energy efficient practices in Pakistan energy-intensive industries, in particular the iron and steel sector. General findings include that both barriers and drivers seem to differ between a developed country and developing countries, a finding that may be of great interest when developing countries like Pakistan aim to develop their energy system and industrial sectors. During this maturity process, barriers and drivers may vary and customized according to the need of the specific sector. In future work, the classification of barriers, drivers, and non-energy benefits can be performed on the basis of their interlinks and similar impact on energy efficient operation of a plant. Additionally, weights can be specified to each query of the questionnaire to find more rational assessment. Finding of energy management practices of iron and steel sectors can be compared with other highly energy intensive sectors, such as pulp and paper, food, basic chemicals, cement, and refinery.

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## Abbreviations

The following abbreviations are used in this manuscript:

ADD	Anti-Dumping Duty
ADF	Asian Development Bank
AFD	Agence Française de Développement (French Development Agency)
CCPP	Combined Cycle Power Plant
CPEC	China Pakistan Economic Corridor
EE	Energy Efficiency
EECP	Energy Efficiency and Capacity Project
EEMP	Energy Efficiency Management Project
ENERCON	National Energy Conservation Centre
EMS	Environmental Management System
IoT	Internet of Things
IPPs	Independent Power Producers
JICA	Japan International Cooperation Agency
GIZ	Gesellschaft für Internationale Zusammenarbeit (Society of International Cooperation)
GoP	Government of Pakistan
LEAP	Long-range Energy Alternatives Planning System
LNG	Liquefied Natural Gas
MFF	Multi-tranche Financing Facility
NEECA	National Energy Efficiency and Conservation Authority
NEPRA	National Energy and Power Regulatory Authority
NGO	Non-Governmental Organization
OGRA	Oil & Gas Regulatory Authority
PEECB	Pakistan Energy Efficiency and Conservation Board
RE&EE	Renewable Energy and Energy Efficiency
RNE	Royal Netherlands Embassy
TEG	Thermoelectric Generator
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
WHRS	Waste Heat Recovery System

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