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A Review of Recent Developments in Optimizing and Reducing Energy Consumption in Steel Industry Arc Furnaces

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Abstract

The steel industry consumes the most energy in the world compared to other industries. The declining trend of natural resources and fossil energy and gas storage has forced students and researchers in this field to design and be exploited to reduce energy consumption in this industry by forming specialized teams and scientific studies and considering the historical and experimental course. From steel mills in different parts of the world, offers practical methods in the field of energy consumption. Attempts to use items that have removed the effective and beneficial effects in this regard and some other indicators of good performance in places are allowed. In this research, a brief look at the appropriate location discussions for the construction of steel plants, the energy required in the steel industry and the measure of thermal and electrical energy consumption of the electric arc furnace process and the environmental impacts and their problems and challenges and waste heat recovery assessment of the furnace in electric arc has been presented.

Keywords: Energy consumption; Steel industry; Energy optimization; Arc furnace

Abbreviations: ORC: Organic Rankin Cycle; EPI: Environmental Performance Index; EAF: Electric Arc Furnace; IISI: Iron and Steel Association

Introduction

The course of economic developments in recent centuries has been associated with the diverse use of energy. But energy crises in recent decades, accompanied by recessions in many countries, have given energy a special place in the economic literature. Limited energy resources in the world and high investment costs in new and renewable energy, which has made the energy produced very expensive and uneconomical, as well as the negative view of human societies in the industrialized countries that have the highest energy consumption in the world. Concentrated, sometimes to the point of shutting down nuclear power plants or preventing new ones from being built, has led these countries to invest heavily in reducing energy consumption per unit of production. Since the steel industry, especially steel, which has very high-power consumption through the electric arc, in-depth study on how to consume energy, ways to reduce it and reach the desired point, which is competition in the global market, from it is of special importance. In the industrial sector, especially in the energy industry, such as the steel industry, finding appropriate solutions to update technology, produce and reduce energy consumption is very important. Therefore, the topic of my seminar is dedicated to "reviewing recent developments in optimizing and reducing energy consumption in the electric arc furnace of the steel industry." In the following, the electric arc furnace is introduced and then the statistics of electricity production and consumption are discussed.

Arc furnaces work according to the original design of the Herold furnace by melting the furnace charge created by the electric arc, between the graphite electrodes and the metal charge. This furnace can be seen in figure 1. In this arc furnace, an electric arc is transferred from the electrodes to the metal inside the furnace. Due to this transfer, an electric current pass through the metal inside the furnace and because of the metal's electrical resistance against this current, heat is generated. This heat uses the passage of electric current with heat to encourage the completion of the electric arc and provides the necessary conditions for melting the metal charge inside the furnace. In fact, in this type of furnace, by creating an electric arc between the electrodes and the phase of the melt or scrap iron and direct reduced iron, the electrical energy is converted into heat and transferred to the melt through radiation and heat resistance [1].

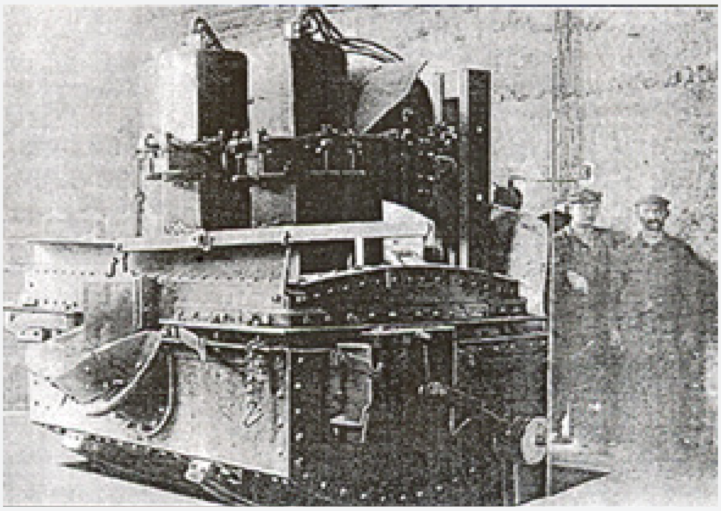

Figure 1: Preliminary design of the herold arc furnace [1].

The development of single-phase and two-phase arc furnaces has led to the construction of three-phase electric arc furnaces. In the past, electric arc furnaces were used only to produce ordinary steel, while today these types of furnaces are widely used and even to produce alloy steels. One of the reasons for the rapid growth of steel production in electric arc furnaces is that in these furnaces, electrical energy can be converted into heat with good efficiency [2]. In this way, a high melting capacity can be achieved in a small furnace. Increased production of electrical energy and expansion of electricity networks, installation of water-cooled units in the body and roof of furnaces, continuous feeding, automatic control of smelting and refining and new smelting and refining methods, in the last decade, to make the use of electric arc furnaces on a large scale possible. Figure 2 shows an example of an electric arc furnace [3].

Figure 2: An example of an electric arc furnace [3].

According to the standard of the World Steel Association, the world's steel production by 2020 is about 1800 million tons [4]. The amount of steel produced by electric arc furnaces, like that seen in figure 3, is expected to exceed 650 million tons by 2020, and the amount of steel produced by electric arc furnaces is about 30% of world steel production [5]. Electricity consumption

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in electric arc furnaces is so high that it sometimes equals the electricity consumption of a city [6]. Today, the issue of energy is one of the serious crises in the steel industry that must be paid special attention to both electricity and water consumption. In the field of consumption of gas and fossil fuels, optimal consumption methods should be applied so that steel companies can save on their consumption and reduce it. According to the strategic plan of the Ministry of Industry, Mines, and Trade, Iran has set a plan to produce 55 million tons of steel for 2025 [7]. Based on the general calculations based on the data of the comprehensive steel plan, to achieve this goal, Iran needs about 295 million cubic meters of water consumption and increase the capacity of the country's power plant by 5630MW and 18 million cubic meters of gas per year. This is even though power plants also use about 8.2 cubic meters of water per cooling cycle per generation of megawatt-hours [8]. Using energy efficiency methods, electricity consumption in the arc furnace has risen from "630"kwh / ton in 1965 to "280"kwh / ton in 2015 as shown in figure 4 [9]. Also, reducing the TTT time from 180 minutes to 40 minutes indicates an improvement in the use of technology and a reduction in energy consumption and increased production.

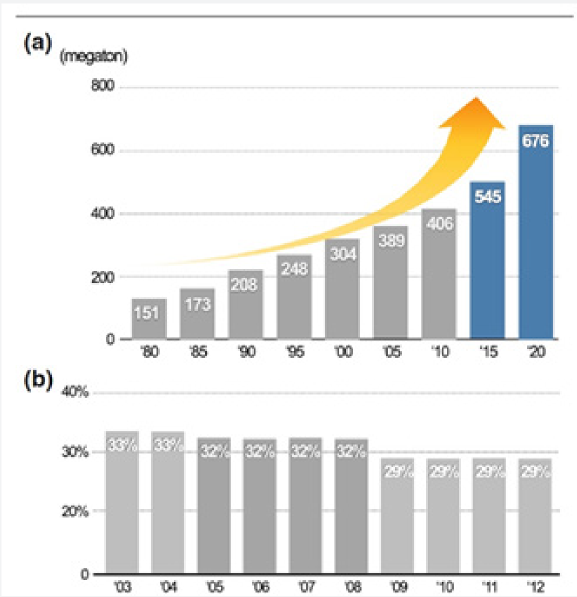

Figure 3: (a) Prediction of steel production by electric arc furnace method (b) Percentage of steel production by an electric arc furnace method.

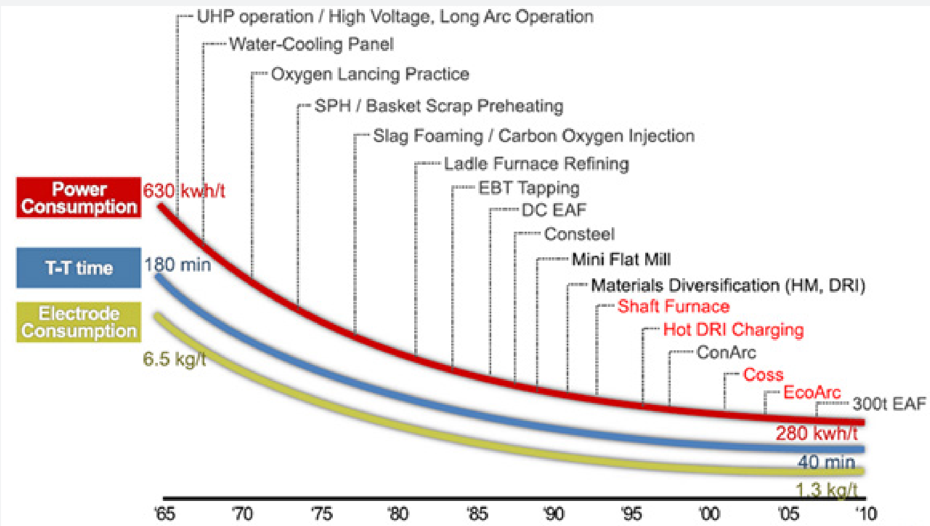

Figure 4: Technology development in steel arc furnace by time (year) [9].

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Figure 5 shows the input and output energy status of a common electric arc furnace in the steel industry [10]. To produce one ton of steel in an electric arc furnace at a temperature of 1600°C requires an average of about 694kWh of energy. Most of this input energy is transferred to steel, but a significant amount of it is lost through exhaust gases and slag, which is about 196.5kWh/ton (28.3%). Depending on the energy of the exhaust gases from the electric arc furnace, the Organic Rankin Cycle (ORC) the cycle can be used for thermal recovery of the electric arc furnace. The first use of this system was in an electric arc furnace in Germany [11]. According to the existing records, for the hot gases emitted from the electric arc furnace from each ton of molten steel product, the possibility of heat recovery and electricity generation in the range of 15 to 25kWh is provided [12]. It is also important to predict the required amount of each raw material in the furnace charge to investigate ways to reduce energy consumption in electric arc furnaces [13].

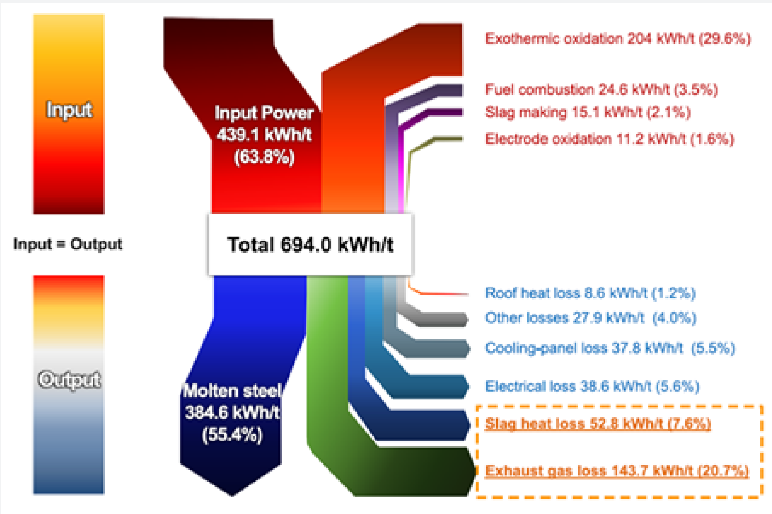

Figure 5: Balance of input and output energies in the arc furnace process [10].

Literature Review

According to the International Energy Agency, the iron and steel industry with high fossil energy consumption accounts for about 6.7% of world CO_2 production [14]. The standard of energy consumption in the Iranian steel industry is 594kWh / ton. Also, about 2.8 cubic meters of water is consumed per ton of steel produced in electric arc furnaces Kanani et al. [15,16] presented a numerical-experimental model for calculating heat transfer in electric arc furnaces. To better understand the ironmaking process in electric arc furnaces, they developed a radiation model to study how this energy is distributed inside the furnace [17]. Using experimental information obtained from the Khuzestan Steel Company about the actual voltage, current, and power of the furnace, they obtained the radiant energy emitted from the arc. Then, using appropriate boundary conditions, they used the surface-to-surface model to solve the discretized equations of radiation.

By measuring the data related to the mass flow rate and water temperature at the inlet and outlet of the panels, the share of energy on the cooling water panels of the wall and the furnace lid, and after modeling the temperature of these surfaces they got it. Amir Kavi et al. [18] by researching the steelmaking unit of Mobarakeh Steel Company to identify energy-saving factors and reduce Feo slag in electric arc furnaces, including optimal control of oxygen and lime injection, control of material charge rate, stopped working with high carbon smelting. Chen et al. [19] used a dynamic model and the TIMES model (EFOM-Markal Integrated Model) to analyze the emissions of China's steel sector.

This model, which is one of the major models of energy analysis in the industrial sector, has been used to analyze the demand for steel, energy supply, and greenhouse gas emissions (CO_2 emissions) of this sector from 2010 to 2050. This model shows that China's steel production will peak from 627 million tons in 2010 to 772 million tons in 2020 and then to 527 million tons in 2050. The share of arc steel production (EAF) will also increase significantly from 9.8% in 2010 to 45.6% in 2050. In this model, using dry coking technologies and exhaust heat recovery equipment, carbon emissions and water and energy consumption have been reduced in the modeling period. The results of this research show that the evolution of technology structure will have a great impact on reducing resource consumption and reducing emissions. Among the cases that increase energy consumption in electric arc furnaces - stopping the furnace for various reasons, including repair problems that lead to a sharp drop in melt

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temperature, and repair problems can be leakage from the panel Pointed arc furnace. For this purpose, Hajidavalloo et al. [20] have simulated heat transfer in the elbow of an electric arc furnace using ANSYS FLUENT software. The results of this simulation show that the highest temperature is in the entrance area of the bends in the elbow section.

Henning et al. [21] evaluated and simulated the cooling water system of an electric arc furnace using computational fluid dynamics. They obtained the temperature and fluid flow distributions in the various cooling water systems of an electric arc furnace using the STAR-CCM + computational fluid dynamics software. In this simulation, by applying a constant heat flux to each panel, they identified points that had high temperatures. They attributed the high temperature of these specific points to the stagnation or reversal of fluid flow in them. Tavares et al. [22] investigated the failure of steel pipes due to creep and wear. The studied pipes are related to the panels of the smoke suction system. The results of this study, which were performed by scanning electron microscopy and light microscopy, show that the decrease in local wall thickness of the pipes is due to wear and tear due to the wear of oxide particles out of the furnace. They suggested that chrome-molybdenum steel be used because of its higher resistance to creep, oxidation, and wear because the first-row pipes of the flue system are exposed to more intense heat and are in a more critical condition.

Vazdirvanidis et al. [23] investigated overheating failures in steel pipes of arc furnace cooling systems. Visual inspection, use of light microscopy, and hardness testing are the main methods of examination in this article. In this study, it has been shown that decarburization and weakening of the surface of the pipes of the furnace cooling system can be considered because of prolonged exposure to heat and oxidation conditions inside the pipes, as well as the most probable cause. Fractures, tensile stresses, and thermal fatigue were detected. The use of a more heat-resistant alloy and sufficient water to transfer heat to the pipe wall, as well as lowering the graphite electrodes in the slag for better heat transfer into the molten bath and reducing the heat reaching the furnace wall were suggested as a solution.

Khodabandeh et al. [24] investigated heat transfer in electric arc furnaces and their cooling system. After modeling the electric arc furnace using ANSYS FLUENT software, they obtained the temperature distribution in the furnace cooling system. As mentioned earlier in the ORC cycle, many steps have been taken to reduce heat loss, including the use of the organic Rankin cycle to reuse relatively low heat dissipation heat to generate electricity. Organic Rankine Cycle is a type of Rankine cycle in which the operating fluid is modified and high molecular weight organic operating fluid is used. The organic Rankine cycle has received a lot of attention due to its high efficiency and reliability, as well as less need for maintenance compared to other cycles. Its applications include applications in power plants with the geothermal heat source, solar energy, biomass energy, and dissipative heat.

Therefore, Ramirez et al. [25] evaluated the performance of the ORC unit in the hot-rolled sheet metal plant for use in the automotive and mechanical industries in Brescia, Italy, which shows that the efficiency of the ORC plant is 21.7%. Gajik et al. [26] investigated the consumption of electricity in an electric arc furnace using an artificial neural network. By studying electric arc furnaces in Italy, they compared the effect of changes in rust steel elements to evaluate power consumption, which shows that the greatest effect on electricity consumption is the percentage of carbon. Sanjo et al. [27] By examining the changes of parameters affecting energy consumption in electric arc furnaces, oxygen injection and carbon content, and metallization of direct reduced iron, the greatest effect on energy consumption as well as increasing melting temperature and increasing time POWER ON is generated and the slag status is also affected. In the study of Kong et al. [28] the use of by-products along with the process has been mentioned, which reduces the energy consumption of the system. In this research, the optimal allocation for surplus gases has been investigated by the MILP method.

Conditions for selecting a suitable site for the construction of the steel industry

One of the effective factors in establishing companies is choosing the location of the factory [29]. The choice of factory location depends on factors such as skilled workers, facilities development, and access to materials, investment costs, climate, and proximity to the market, quality of life, social considerations, and communication. Decision-making and location of the factory play an important role in the company's performance and the company's survival in the industry. It also has an important effect on minimizing costs and maximizing the use of resources. Proximity to the market reduces shipping costs and delivery time to the customer. On the other hand, the presence of skilled labor around the factory site accelerates the production of quality products, as well as reducing the cost and time of staff training and product waste due to staff inefficiency. It has an effective role in determining the location of the factory so that with the reduction of investment costs, deprived areas also prosper. There are other factors, such as access to raw materials and climate suppliers, etc., which must be considered that determining the most important factors influencing the choice of factory location speeds up the decision. Factors influencing decision-making related to the location of a manufacturing plant can be divided into six main groups. These factors are in order of importance [30].

Manpower conditions: The most important factor for manufacturing companies such as textile factories, home appliances, and electronic equipment that are highly dependent on labor and in other words is labor-oriented is the factor of labor conditions. These conditions can include things like pre-wages Job Learning Needs Motivate Manpower Productivity Employees

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Power Unions Many executives prefer to deal with weak and less organized unions to have a direct impact on manpower. On the other hand, the issue of labor supply, both in terms of number and level of skills for local companies and international companies is one of the key issues. The need for skilled manpower for some industries is usually costly and leads to certain management problems. The relationship between manpower management and productivity is one of the factors that many studies have been done and should be considered. Also, common wage patterns in the region, the cost of living, the relationship between different industries, and the strength of trade unions are other factors influencing the location of the factory [31].

Proximity to the market: Every company tries to offer its services and goods to its customers at the right time and an acceptable and reasonable price [32]. When customers and buyers of goods are focused on terms of location, the factory is recommended. And its equipment should be located near the market, including the products of the factory are delicate and prone to breakdown and decay, products need after-sales service, shipping cost is very high, product life is short. After determining the target markets and places where there is a demand for the company's goods and services to the desired extent, management must choose the best location for the factory in a way that can meet the demands of itself and its customers in the best way. Location near the market becomes more important when the final products of the factory are bulky, heavy, and have high transportation costs. Manufacturers of plastic and steel pipes, for example, should try to stay close to the market [33].

The level of quality of life: good schools, appropriate recreational and cultural spaces, and a good lifestyle, in general, are all factors in raising the quality of life. These factors may not seem to be considered in the decision to locate the factory, but in the long run, can have an impact on the productivity of factory staff [34].

Proximity to resources and suppliers: Today, many companies and factories do not provide the bulk of the parts or services they need but supply them from other companies. The decision to have a part manufactured by the factory itself or to supply it from outside the organization depends on many factors. If it is decided to provide a part or service from outside the organization, the company should be able to maintain its communication to be more coordinated with suppliers, and this will become more difficult as the geographical distance increases [35].

General expenses of taxes and government and local expenses: Other important factors to consider when locating manufacturing companies include general costs (telephone, electricity, water, and sewage), local and regional taxes, common government and banking costs, and costs. Land acquisition costs [36].

Weather conditions: The geographical and climatic conditions of the area, such as humidity and temperature, must be assessed for location. Climatic conditions have a great impact on labor productivity and human behavior. Also, some industries need special weather conditions, for example, the textile industry should be in areas that are suitable in terms of humidity [37].

Communication infrastructure and public services: All manufacturing activities require access to the communications and public services subdivision, which provides this cost quite reasonably if they generate a source of public capital, such as roads, railways, ports, power lines, municipal services, and social capital, such as schools. Universities and hospitals [38].

Access to raw materials: Any organization needs to have access to quality raw material resources at the right time to prevent the production line from shutting down. This factor becomes even more important when the required materials and resources are perishable and their transportation costs are high, including when sensitive and delicate raw materials or concentrated source is used [39].

High-quality production and low power consumption is the goal of every steel company. One of the most important factors in creating a competitive advantage in the country's steel industry is the proper location of steel units [40]. If the location of industrial complexes, especially in the field of steel, is based on access to abundant water and energy to supply the water and energy needed for production and facilitate transportation, then naturally we should expect the growth of steel units, cost reduction, and consequently, it had an increasing competitive advantage in the long run [41].

Steel production

The first stage of steel production is the processing of its raw material, iron ore. Iron ore is a combination of iron oxides and metal impurities such as sulfur, phosphorus, silica, and... First, iron ore is crushed and metal impurities are separated from it during certain processes. Then, in the pelletizing process, iron ore (as a combination of iron oxides) turns into pellets and after cooking, produces a product called pellets. The pellet produced in the direct reduction process during the reaction with carbon produces pure iron. Because the pellet loses its oxygen in this process, the resulting compound has a porous state like a direct reduced. For this reason, it is called direct reduced iron. Foamy iron is stored and stored in special tanks to be gradually used as a raw material for steel production in later stages [42].

The second stage of steel production is the conversion of iron to molten steel. The input to this process is direct reduced iron. The type and grade of steel and its chemical properties are created at this stage. Here, direct reduced iron and scrap iron are converted to molten steel in certain proportions in electric arc furnaces. After slagging from the melt, according to the expected

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quality of the additives, the required proportions are added to the molten steel in proportions, and by blowing gas, it is evenly distributed in the melt volume and mixed with it [43].

After this stage, the molten steel is emptied into bulk pots and sent for additional operations. Finally, based on laboratory samples taken from the steel, the melt refining operation is performed and the molten steel is ready for casting. The temperature of molten steel for casting is about 1650 degrees Celsius and the minimum allowable temperature is 1580 degrees. Therefore, after the finishing operation, the melt should be sent immediately for casting. If it is not possible to cast the melt due to delay or any other problem, the temperature of the melt inside the pan will be kept within acceptable limits by ladle furnaces. However, there is a high cost for this delay in casting. At this stage, the melt produced in the steelmaking process in continuous casting machines becomes ingots or slabs. Continuous casting machines are semi-arched. The molten ladle is placed on the casting tower [44].

The casting tower can hold two ladles, one in the casting position and the other in the ready position. The melt enters the middle pan through a special passage that is installed under the pan. Tundish, as an intermediate buffer, always keeps some of the melt in storage so that the continuity and uniformity of the melt flow in the molds of the casting machine is not interrupted when the molten pan is changed. To speed up the casting operation, most casting machines have two paths for casting, and the melt must enter the machine molds through two separate passages. Tundish has two outlets that direct the melt inside the pan to the molds of the casting machine. The hardening life used in the casting process is limited, so the continuous casting operation of the melt on the casting machine cannot last longer than the life of a hardening. Therefore, the continuous casting operation will inevitably be interrupted at the end of the Tundish life and the casting will resume after the tandem replacement is changed. A production sequence takes place between the two tendon switches. This sequence consists of a limited number of melts that are cast continuously and uninterruptedly.

The maximum number of these melts varies according to the width of the casting machine and the quality of the melting. The melts in a casting sequence must be of the same quality and have the same casting width. After draining into the mold, the melt is cooled by the flow of water around the mold and takes the shape of the mold, and gradually moves in a semi-arc path and cools slowly to form a long strip with a rectangular cross-section of the machine. Remove the casting. At the end of the casting line, this strip is cut crosswise to specific lengths and finally, a steel ingot is produced [45].

The energy required for the steel industry

The steel industry is one of the most energy-intensive industries in the world, and because the main source of energy consumption in the world today is oil and petroleum products, several steel production units are being built and operated in our country. At present, the per capita energy consumption to produce one ton of steel in Iran is higher than in Germany and Japan. This is at a time when these countries are using environmental energy equipment such as blast furnace acetone acid dust, which increases per capita energy consumption. Of course, in Iran, this equipment is less used [46]. Figure 6 shows the input energy for steel production over a year for different countries of the world. Different countries have different energy distributions in the way of steel production, so that for example, 94.1% of China's steel production is through fossil fuel energy such as coal and blast furnace method, while in the United States 62.7% through electric arc furnaces and consumption 53.98% is natural gas [47].

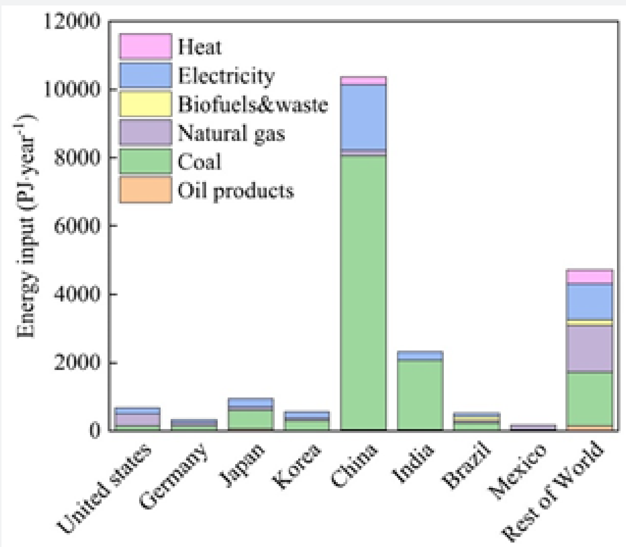

Figure 6: Energy used to produce steel in different countries [47].

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The US Energy Information Administration predicts that energy consumption in the world steel industry will grow by 11% between 2015 and 2040, due to an increase in the number of steels producing units in the world and an increase in production volume. However, due to the advancement of technology and the use of less energy-intensive equipment than current equipment and the replacement of natural gas and electricity with oil and petroleum products as fuel and energy sources for steel industry equipment, energy consumption in this industry decreased by 27% It will be accompanied by 9% more than the average reduction in energy intensity in the industrial sector. The intensity of energy consumption in the industrial sector of the world will decrease by 18% between 2015 and 2040.

Decreasing energy intensity means increasing energy efficiency in this industry or reducing energy consumption to produce each steel unit, which will be accompanied by a reduction in pollutant emissions. The US Energy Information Administration has cited technical advances and the production of energy-saving equipment as one of the reasons for the increase in energy efficiency in the steel industry, but also cited another important reason that has received less attention so far. According to this study, changing the pattern of steel production is an important reason for increasing energy efficiency in this industry. In previous years, steel was produced from raw materials such as iron ore and coke, etc., but in recent years, most steel is recycled from steel scrap, a process that requires less energy than raw steel production. On the other hand, the secondary production of steel or the production of steel from scrap steel is a process that is done with the help of electric furnaces, and energy consumption in these furnaces is less. The industry has shrunk. The steel industry is one of the most valuable and important industries for today's world economy due to its high recyclability because its products are fully recycled and this is very important for the world economy [48].

To produce each ton of steel, the product is needed to supply electricity, about 650 to 750 cubic meters of natural gas, without considering the processing of raw materials and handling, and considering the power plant coefficient. This is about 7 times the energy required to produce cement. Considering the price of steel products at about $500 per ton and the international energy cost of 20 cents (average electricity and gas consumption), currently about 30% of the selling price of steel is the cost of energy consumption. Therefore, the level of development in the steel industry and the consumption of iron and steel are made as a criterion for judging the extent of industry in countries as well as the level of development of countries. As shown in figures 7 & 8, the steel industry accounts for more than 22% of total industrial energy consumption, and Asia is the most important player in this market [49].

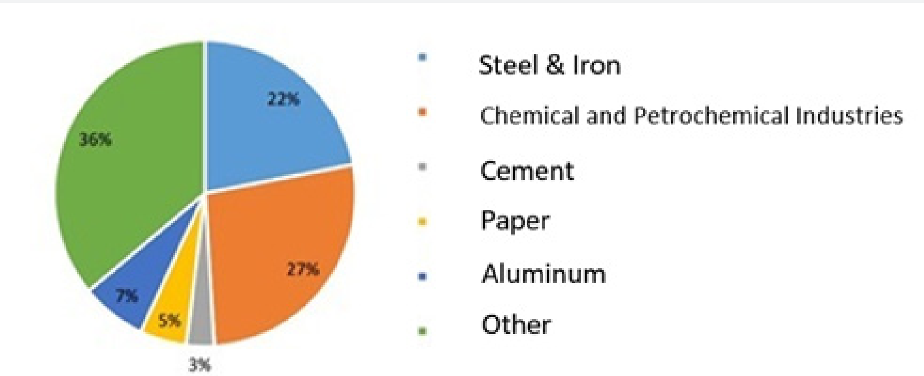

Figure 7: Share of energy consumption in the industry sector by type of industry in 2016.

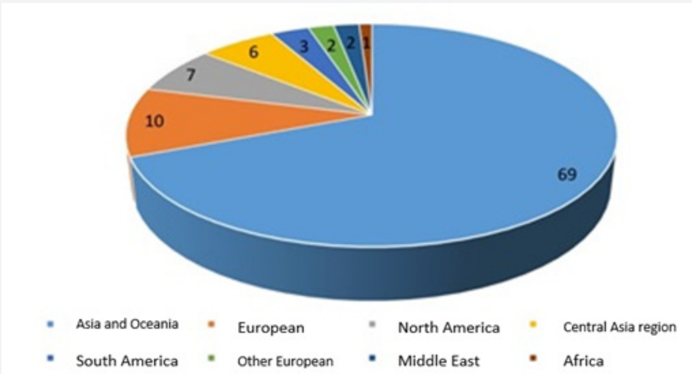

Figure 8: Asia's high share of crude steel production based in 2019 data.

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Specific energy consumption in the iron and steel production process (SEC) [50]

Specific energy consumption in the process of iron and steel production is the ratio of energy consumption to iron and steel production. The unit of specific energy consumption in the process of iron and steel production is the total specific electrical energy in terms of kilowatt-hours per ton (Ton/kwh) and thermal energy (fossil fuels) in terms of gigajoules per ton (GJ/Ton). Consumption of special electrical energy and thermal In the process of iron and steel production: Specific electrical energy consumption and specific thermal energy consumption in the iron and steel production process expresses the amount of electrical/thermal energy consumption per unit of production table 1.

Table 1: Criteria for thermal and electrical energy consumption of arc furnace process [35].

Process	The Criterion of Thermal Energy Consumption (Cubic Meters of Natural Gas Per Ton of Product)	The Criterion of Electrical Energy Consumption (Kilo-watt-Hours Per Ton of Product)
Electric arc process	$SEC_{th} \leq 15$	$SEC_e \leq [500 + 80 * (\%DRI)]$

How to calculate the specific thermal energy consumption

The specific thermal energy consumption of the production of different units of the iron and steel plant is determined by dividing the thermal energy consumption of that unit in a certain period by the amount of production of the same unit in the same period [35].

The amount of specific thermal energy consumption is expressed in terms of gigajoules per ton of product or cubic meters (natural gas) per ton of product produced [35].

How to calculate specific electrical energy consumption

Specific electrical energy consumption of iron and steel production in different units is determined by dividing the electrical energy consumption of the unit in a specific period by the amount of product produced by the same unit in the same period [35].

Introduction of new technologies in the steel industry

The complex and ever-changing nature of the environment has made innovation the most important factor in maintaining and improving the performance of companies [51]. The steel industry is one of the industries whose promotion and development directly affects the economic growth and GDP of countries as there is a direct relationship between per capita steel consumption and GDP of countries. This industry is considered a strategic commodity due to job creation, high dependence of downstream industries, application in infrastructure development, and the possibility of export and exchange rate for countries, and therefore the development of this industry is always included in the strategic goals and actions of countries [52].

Following the industrialization of countries and increasing demand for energy consumption, the optimal use of ending energy resources has become extremely important. To achieve this goal, the use of optimization methods and new technologies in the transmission and conversion of energy is essential [53]. Energy consumption is one of the main costs of steel production, which with the advancement of technology and optimization of production methods, reduces energy consumption, increases production, and reduces investment costs. The main source of energy in EAF furnaces is electrical energy, but from the beginning of the use of these furnaces, it has always been tried to use chemical energy and replace it with electrical energy, to minimize the amount of electricity consumption in these furnaces. Chemical energy through metallurgical reactions such as oxidation reactions of various elements, secondary combustion reactions, and preheating iron inlet systems using combustion of fossil fuels and other methods designed to increase the share of energy input [54]. Table 2 shows the improvement of different production conditions over ten years.

Table 2: Improvement of steel production conditions in ten years.

	The Year 2012	The Year 2002
Energy consumption (Kwh/ton)	392	450
Production (ton/hour)	94	61
Graphite electrode consumption (kg/ton)	1.9	2.9
Consumption of refractory materials (kg/ton)	3.1	6.9

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Here are Some Ways to Reduce Energy Consumption

Preheating the incoming scrap iron

One of the most important research projects in the field of reducing the power consumption of electric arc furnaces is preheating the input charging iron to the furnace. As shown in figure 5, the amount of energy associated with the exhaust gases from the arc furnace is about 20%, so using the thermal energy of the exhaust gas as a massive source of energy to preheat the iron can save Consumption of electrical energy in EAF furnaces helps to preheat scrap iron also has many environmental benefits and reduces dust entering the filtration section (Baghouse) by 30-30%. This technology has not been implemented in Iran so far, but it has been widely used, especially in Japan and Europe, where the cost of electricity generation is high. Scrap preheating is usually done by transferring hot gases to the scrap charging basket through pipes that connect the hot gases to a special hood above the scrap basket.

The source of these hot gases can be hot gases leaving the furnace or produced by natural gas burners. Scrap preheating by natural gas was first performed in 1960 by burners mounted on the roof of a scrap basket. In this method, the scrap is heated between 538°C to 650°C. heating the scrap to more than 650°C causes the scrap to oxidize. The advantage of this type of preheater in comparison with the use of hot gases from the furnace is that in this method, the preheating process is not dependent on the performance of the furnace, as a result, the process is more controllable and uniform [55]. Figure 9 shows a schematic of two scrap preheating methods for charging inside an electric arc furnace [56].

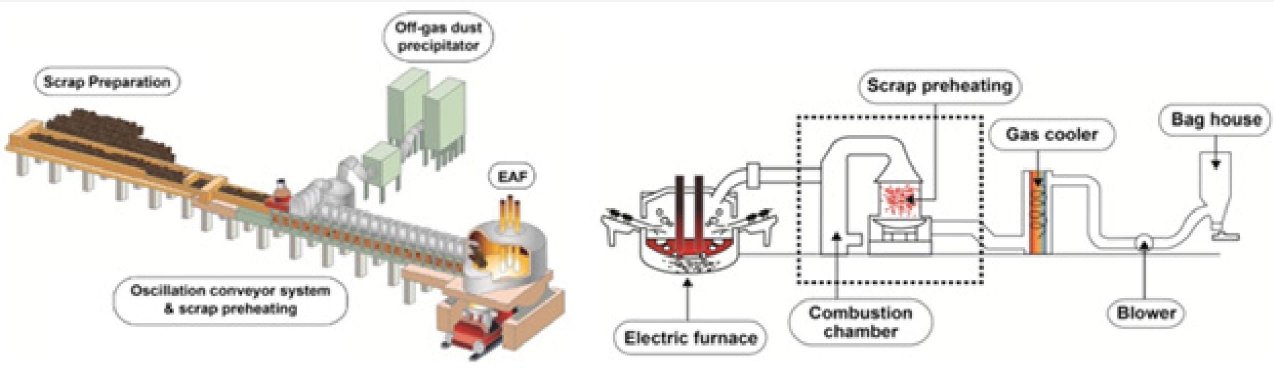

Figure 9: Two examples of scrap preheating methods by exhaust gases from an electric arc furnace [56].

Direct reduced iron preheating

The effect of iron preheating on the efficiency of electric arc furnaces has been investigated using exergy analysis. The results of energy and exergy analysis and calculation of energy and exergy terms of input and output materials of 170-ton arc furnaces of a steelmaking unit show that about 73% of the energy entering the furnace is through electrical energy and about 28% through energy. It has been chemical. Also, the output energy related to molten steel was about 42% and the share of exhaust gases was about 18%. The results show that among the materials leaving the arc furnace, the hot gases leaving the furnace after the molten steel transfer the most amounts of energy and exergy with them out of the system. It is noteworthy that the waste exergy was about 50%. The results show that the amount of energy recovered increases with increasing preheating temperature of direct reduced Iron and preheated scrap. Since, according to the Iranian steel industry, the tonnage of Direct Reduced Iron in furnaces has been higher than scrap iron, preheating of direct reduced Iron has resulted in greater electrical energy recovery. The energy and exergy efficiencies of the furnaces increased by 3.15% and 2.25%, respectively, when the direct reduced Iron was heated to a temperature of 780Kelvin. Another point that can be considered by preheating the inlet materials to electric arc furnaces; Reduction of melting time to melting. The results show a 13.5% reduction in melting time if the input material is preheated to 500℃ [57,58].

Another solution that has been recommended in this regard is the Hotlink process. Essar Steel in India and Shadeed Oman are in the lead. In the Hotlink method, charge the Hot Direct Reduced Iron it is transferred from the reduction furnace directly to the electric arc furnace using gravity by a sealing device. In this case, the regenerative furnace is installed next to the wall of the arc furnace and the Midrex outlet is transported completely hot directly to the direct reduced Iron storage tank on top of the EAF furnace [59]. Of course, for cases where hot direct reduced iron is not consumed directly, a separate system is provided in parallel to cool the hot direct reduced iron. The HDRI temperature at the outlet of the direct reduction furnace is between 700-650℃ and a temperature drop of about 50℃ occurs along the way to the EAF furnace. The results show that increasing the hot charge

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temperature leads to increased electrical energy savings in the EAF furnace and reduced electrode consumption.

This is well illustrated in figure 10. Adding molten cast iron to an electric arc furnace also reduces energy consumption in steel production. In addition to the heat generated by molten cast iron, the heat generated by the oxidation of silicon, manganese, and carbon also reduces electrical energy consumption.

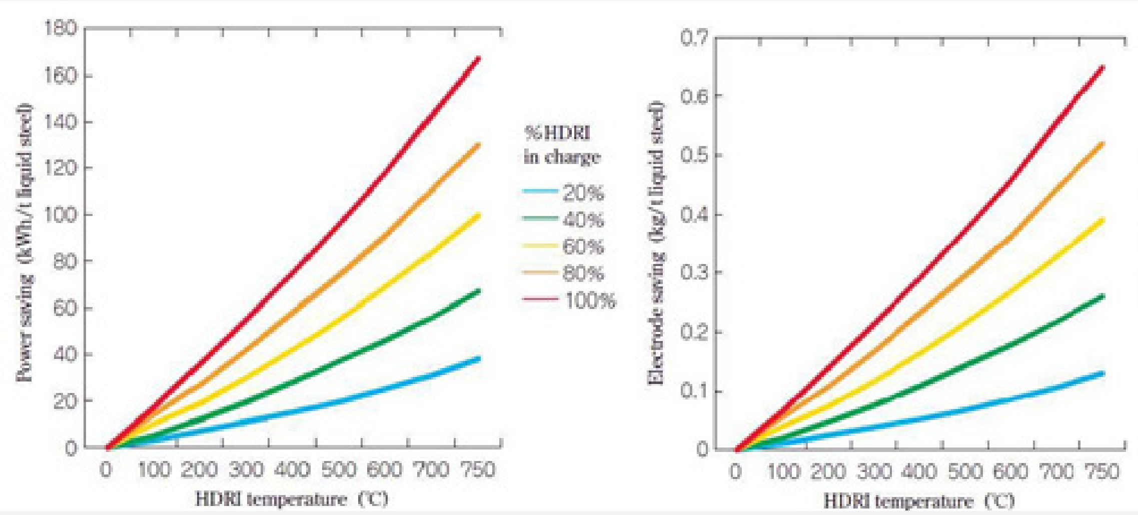

Figure 10: Saving electrical energy consumption and electrode consumption in electric arc furnaces using HDRI charging [57].

Reducing greenhouse gas emissions, reducing melting-to-melting times, and reducing production costs are other benefits of using HDRI charging to produce steel [57,58].

Oxygen-fuel burners

The oxygen injected into the furnace burns with carbon along with direct reduced iron to form chemical energy. The generated chemical energy generates heat and thus contributes to the direct reduced melting process and reduces the amount of electrical energy consumed. Oxygen burns with carbon to produce CO gas, which produces foamy slag. Foamy slag, with proper arc coverage, provides a more stable arc condition, resulting in better energy transfer from the electrode to the furnace. And will increase energy efficiency and reduce electrical energy losses. Oxygen-fuel burners have been noted for their many advantages in steelmaking. Using a second fuel source to increase the melting rate in an electric arc furnace by using cheaper fuel leads to cost savings and improved thermodynamic efficiency [60].

Oxygen-fuel burners are mainly used to replace electricity. More importantly, using a burner increases the melting speed and reduces the melting-to-melting time. The use of burners is effective in creating heat balance. For example, in power high Ultra furnaces, the presence of oxygen-fuel burners is necessary to increase the melting rate of scrap in cold parts of the furnace and as a result, uniform melting of scrap [61]. The use of the burner requires careful design, both in terms of pressure and discharge of the exhaust gas and in terms of position and angle of the burner [62]. The angle of the burner should be such that the burner does not get clogged. The position of the burners should be at the lowest possible point for maximum heat transfer [63].

Injection of carbon into the furnace

Carbon plays an important role in turbulence and metal refining in smelting and refining furnaces [64]. In addition, carbon can reduce the electricity required for smelting operations in the furnace by providing part of the energy consumption. By reducing the electrical energy, the consumption of electrodes and refractories is reduced. Find that they have some effect on reducing costs [65]. Excess carbon with the production of CO gas causes turbulence of the melt and as a result uniformity of temperature and composition [66]. It saves on electricity consumption and corrosion of the furnace refractory [67].

The use of oxygen in electric arc furnaces, which has always been on the rise over the last fifty years, is an effective factor in increasing the efficiency and process speed of these furnaces. One of the effective factors in the development of electric arc furnaces can be considered as increasing oxygen consumption in them. Increasing oxygen consumption in various ways has been effective in reducing electricity consumption. The primary use of oxygen was injected with a lance and from a slag door, but today oxygen has found more sophisticated applications in various ways, including oxygen-fuel burners and secondary combustion. Oxygen injection also reduces melting time by increasing the rate of oxidation reactions. Figure 11 shows the oxygen utilization curve in electric arc furnaces [68].

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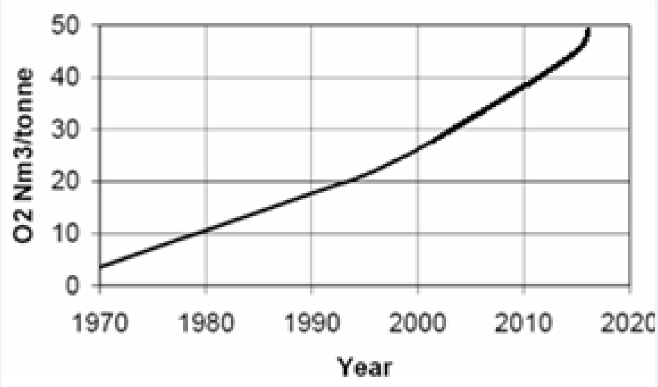

Figure 11: Oxygen consumption increase curve in EAF.

Secondary combustion

Thermodynamically, the CO_2/CO equilibrium ratio in molten steel is important even at low carbon content, and the amount of flammable carbon monoxide emitted from the chimney must be considered. If the exhaust carbon monoxide can be burned, energy is released almost three times as much as the reaction of carbon monoxide from carbon and oxygen. Combustion of carbon monoxide on the free surface of the melt is known as secondary combustion. The energy from the injection of coke in the furnace is at best 25kWh/ton, but if all the carbon monoxide in the furnace is converted to carbon dioxide, 140kWh/ton of energy will be released [69]. Thus, energy efficiency increases, and the volume of exhaust gas also decreases [70].

Preheater with oxygen-fuel burner

The preheating of the ladle furnace has been used to save energy for many years and has been done regularly. But using an oxygen-fuel burner instead of an air-fuel burner is more effective because it increases efficiency and reduces energy and material losses. The main reason for this increase in efficiency is the higher temperature of the oxygen-fuel burner flame. Another reason for the reduction in losses is that most of the heat radiation in the burner is from the radiation of carbon dioxide and water molecules, and nitrogen has less heat radiation. In the oxygen-fuel burner, the partial pressure of carbon dioxide and water is higher and the heat transfer through the gas radiation is increased. On the other hand, many times the volume of gas produced in the conditions of air use causes a sharp decrease in temperature.

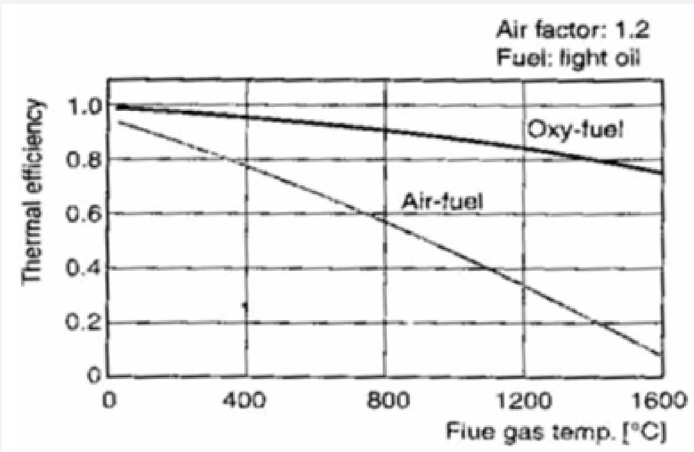

Figure 12: Comparison of thermal efficiency of the oxygen-fuel burner with air-fuel burner [72].

The presence of nitrogen also prevents the arrival and effective contact of oxygen with the fuel and is effective in reducing the flame temperature. Other advantages of oxygen-fuel burner include increased flame temperature, lower fuel consumption, improved heat transfer, and combustion more efficiently and faster, lower gas flow volume and consequently less exhaust gas, and reduced emission of harmful nitrogen compounds. By using an oxygen-fuel burner instead of an air-fuel burner, the working time

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in the pan is reduced to 20 minutes and the pouring temperature is reduced to 15℃, and 5-6kWh/ton is saved in energy [71]. One of the most important features of oxygen fuel burners is very high thermal efficiency even at high exhaust gas temperatures without preheating fuel and oxygen. The difference between the thermal efficiency of air and oxygen in combustion is shown in figure 12. It is observed that at any temperature the efficiency of oxygen-fuel combustion is higher than air-fuel. One of the main reasons for low air-fuel efficiency, even with lower exhaust gas temperature, is the larger volume of hot gas released due to the presence of nitrogen [72].

Slag foaming

Proper production of foamy slag in the furnace is one of the most effective factors in reducing energy consumption, refractory, and electrode. One of the most important results of using new blowing equipment for simultaneous injection of oxygen and carbon powder is to create foamy slag and maintain a foamy thickness to completely cover the arc. In such a case, heat transfer from the arc to the melt increases. The production of foamy slag occurs during the blowing of oxygen and carbon into the melt. In such conditions, a proper ratio of oxygen and carbon consumption is necessary. Otherwise increasing oxygen consumption will reduce efficiency.

Carbon consumption to produce foamy slag with the required thickness depends on the length of the arc and can be 4-10kg/ton [73,74] puff capacity and stability depend on the physical properties of the slag such as viscosity, density, surface tension, and concentration of undissolved solid particles. All these properties are determined by the composition of the slag and its temperature. In alkaline slags, the ability to swell increases with the increasing concentration of . By injecting lime powder and dolomite into the slag as well as charging the coke to the slag in the early stages of melting, it is possible to create foamy slag. The importance of this case in the control of FeO slag is so great that today the online control of foamy slag by analyzing the electrical or acoustic signals of the furnace is used [75-77].

Increasing the ratio of scrap to direct reduced iron

The amount of scrap production in countries to various factors such as development, population, apparent steel consumption, steel production, per capita income and welfare index, consumption culture, recycling structure of countries, production technology and productivity rate of steel products, accumulation coefficient of steel products in it depends on previous years and so on. The amount of scrap consumed in the world is about 38% of total steel production. The most important input factor affecting energy consumption in the iron and steel industry is raw materials. Since about 73% of the steel in Iran is an electric arc furnace method, since scrap does not need regenerative energy, unlike direct reduced iron, so increasing the ratio of scrap to direct reduced iron in EAF furnaces helps to reduce energy consumption.

On the other hand, increasing scrap consumption solves problems such as reducing natural resources and global warming due to increased emissions of gaseous pollutants such as CO_2. If 100% of scrap is used to produce steel, the need for pelletizing and reduction units, which are the largest consumers of energy in the steel industry, will be eliminated [56]. Figure 13 shows the cycle of return of scrap iron to steel production [4]. The general trend in the world steel industry is to increase scrap consumption and reduce raw material consumption. Changes in the proportion of iron sources for steel production by 2050 are shown in figure 14 [78].

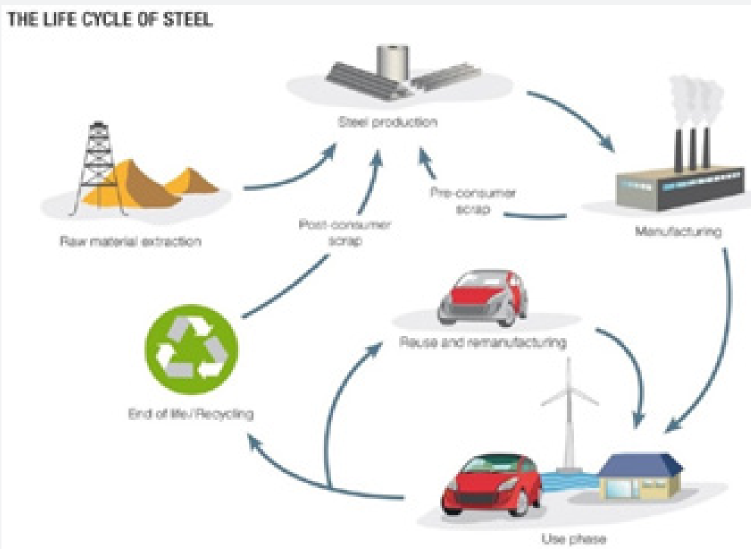

Figure 13: Return cycle of iron to scrap steel industries.

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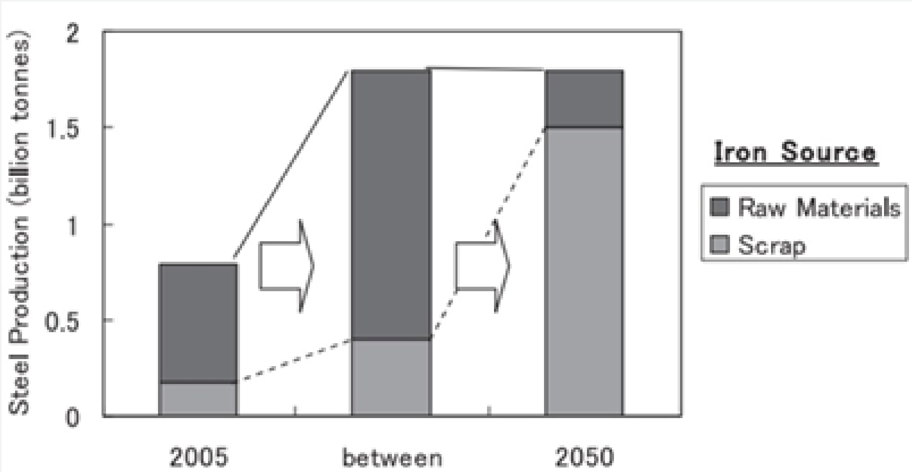

Figure 14: Changes in the ratio of raw materials and scrap as a source of iron for steel production over time.

Scrap charge

The dimensions of the scrap used in electric arc furnaces have a significant effect on energy consumption. Reducing the size of the scrap reduces the energy consumption required for melting. Also, increasing the capacity of scrap feeding baskets to electric arc furnaces leads to reducing the number of times the furnace door is opened and thus increasing the process efficiency. For this reason, the smaller size of the scrap dimensions can reduce the number of times the scrap is charged. Therefore, although the presence of scrap leads to a reduction in energy consumption in electric arc furnaces but increasing the number of times the scrap is charged due to the opening of the furnace door leads to an increase in energy consumption. It is stated that charging two scrap baskets to the EAF furnace with the maximum charge can increase the process efficiency and reduce the melting time. Due to the reasons mentioned, increasing more than two baskets is not recommended. To reduce the size of scraps and increase the density of scrap charging baskets, special designs can be made in the field of using mechanized cutting and pressing machines [79].

Investigation of environmental effects and damage to the environment by the steel industry

The Environmental Performance Index (EPI) is a tool for policymaking by countries on environmental issues. This index is based on two central environmental policies: environmental health, which measures environmental stresses on human health, and vitality. The index is estimated using 22 indicators, the most important of which are: environmental health, water (effects on human health), air pollution (effects on human health), air pollution (environmental effects), water resources (environmental effects) Biodiversity, and habitat, forestry, fisheries, agriculture, climate change, and energy. A review of the downward trend in Iran's ranking based on the EPI index shows that Iran's position has raised from 78th in 2000 to 105th in 2016. In this period, the best position was ranked 53rd in 2006 [80]. Steelmaking is a changing industry that is constantly trying to reduce the harmful effects of carbon pollutants and by using a group of innovative technologies to reduce the negative environmental impact of industrial products.

However, the industry is taking steps to upgrade its environmental certification as well as deploy a range of innovative technologies to reduce the environmental impact of steel production. Given that the steel industry is one of the largest consumers of energy in the world, it has adverse effects on the environment, so that estimates show that per ton of steel produced about 1.9 tons of CO_2 emissions, which Increases global warming [81]. Today, a suitable solution in line with the goals of energy storage and reduction of losses is the recovery of thermal energy lost in the steel production process, so attention to global research to develop thermal energy recovery technologies in various ways in the iron and steel industry has many fans [82]. Recyclable heat in this industry is generally extractable in the product sector, molten slag, and exhaust gases. Molten slag, which is a by-product of steel production furnaces, is discharged from the furnace at a very high temperature and causes a waste of energy consumption in the steel industry [83].

Some Methods of Cooling Molten Slag

Water cooling method

No element is more suitable for cooling molten slag than water, so at present in the iron and steel industry, a large amount of water is used to accelerate the cooling process, which is a method of cooling slag, problems and it has the following problems [84]:

a) A large amount of water is needed to granulate high-temperature molten slag, for example, in a blast furnace slag granulation method, 1000 cubic meters of water is used to cool 1ton of slag.

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b) Alkaline elements in slag in combination with water cause effluents which in turn cause water and environmental pollution.

c) In this method, the heat of slag is often lost. Molten slag has a large amount of heat energy that in the process of granulation of slag with water, a large volume of low-temperature steam is produced that is either wasted or rarely used for heating in winter.

d) This method of cooling slag causes air pollution so that in the reaction of water with slag, sulfur dioxide, hydrogen sulfide, and other sulfate compounds that cause air pollution are produced and released [85].

The mechanical crushing method of slag

In this process, the molten slag is converted into solid particles, then the new slag particles are collected with the recovered particles and injected into the fluidized bed in several stages, where the heat is transferred to the air by displacement. They are larger than 6mm and are sent back to the granulator to reach a size of 3mm [86,87].

Blowing air

In this method, high-velocity air not only crushes the slag fluid but also injects the granulated slag into a boiler to receive and transfer heat through the cooling walls, a commercial-scale method with a granulation capacity of 20Tons of slag per hour has been exploited on average and maximum 80tons per hour [87,88].

Eccentricity

In this method, high-temperature liquid slag is discharged directly at high speed to the rotating disk and exits radially from the outer part in the form of small particles due to centrifugal force and surface tension. The disc diameter considered in this paper is 7m with a thickness of 10mm as shown in figure 15. A layer of slag remains solid on the disc during the process and is a factor that keeps the disc temperature constant. The effective parameters in this method are inlet fluid flow, the angular velocity of the disk, rotating disk radius, dynamic viscosity of slag fluid, and slag fluid density, each of which has a significant effect on the process of granulation and heat recovery. The advantages of slag granulation design by atomizing disk method are the ability to control the diameter of granulated particles, high efficiency, and high ability to recover thermal energy [89].

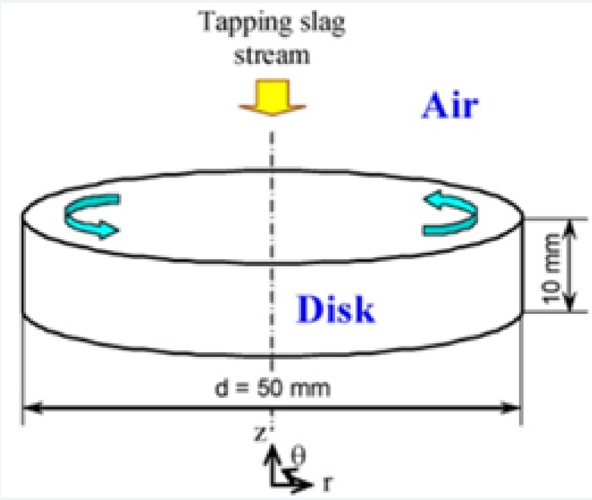

Figure 15: Three-dimensional diagram of a rotating disk.

Using worn tires instead of carbon in arc furnaces

Annually, more than one billion and three hundred million worn tires, equivalent to 12 million tons, are discarded. Approximately 84% of the total volume of worn tires consists of passenger car tires. In the United States, Japan, Russia, and Russia, 50, 116, and 300 million tires are worn out annually, respectively. Although there are about 110 applications for worn tires, the congestion and accumulation of worn tires worldwide is an environmental problem. 10 to 15% of the weight of tires is made of high carbon steel and on the other hand, chemical analysis of non-metallic parts of tires indicates that the composition of rubber is similar to coal and coke [90]. 10 to 15% of the weight of the tires is made up of high carbon steel, and on the other hand, the chemical analysis of the non-metallic part of the tires shows that the rubber composition is like coal and coke. The use of worn tires in cement kilns and thermal power plants is common. Studies in some of the world's steel industries, such as American Server Company, Ipsco, Gardavo, Timken, and Faircrest, have shown that in the steelmaking process, tires can replace auxiliary fuels such as coke, coal, natural gas, etc. And be effective in preheating 33

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metal charges and calcareous limestone. Also, the rubber steel part can be used as a first-class and clean scrap in charging the furnace.

The consumption of worn tires in the world's steel industry is increasing day by day. Due to the high volume of rubber rings in the country, this advantage can be used to reduce energy consumption in electric arc furnaces. In general, it can be said that the use of worn tires replaces auxiliary fuels, the entry of the metal part of the tire into the steel, shortening the melting time, and the penetration of carbon into the steel. Electricity consumption in EAF furnaces is significantly reduced. If worn tires are used, coke is removed from the steelmaking process, reducing the need for slag. The time of adding tires to the furnace and their location affect the efficiency and reduce energy consumption. For example, it has been reported that the addition of worn rubber rings after the furnace charge has melted and on the molten surface does not have a favorable effect on reducing energy consumption due to the rubber floating and wasting energy from burning through the chimney [91-93].

Problems and challenges in the steel industry

One of the problems and challenges of the steel industry is the supply of raw materials and energy. Due to the sharp trend of increasing energy demand in general and its demand in the industry and limited energy reserves, energy supply concerns are becoming more important. The supply of raw materials has an undeniable role in the continuation of production in the steel industry, and if for any reason there is an interruption in the supply of raw materials, production will face problems in the short term. Sustainable supply in strategic items including concentrate, iron ore, electrodes, and scrap play an effective role in production sustainability.

Water and energy supply

Water is becoming increasingly important from operational to strategic issues. Access to water is a growing risk for the electricity industry in planning investments in new power plants. Particularly in areas experiencing water stress, the dispute over water rights adds another component to the risk in the proposed new power plants. Water is also a growing concern for oil and gas companies. To the extent that the oil industry focuses on advanced and better oil recovery, Oil and gas companies need to find water resources to use in production and solve problems related to the water produced. When inventory and water consumption are combined with pressure to reduce the use of fossil fuels, the risks for energy companies increase. Although biofuels are water-repellent, especially when produced using irrigated crops, the use of water in other renewable energy sources is less. The energy industry, which is currently under pressure to reduce greenhouse gas emissions, is facing the potential challenge of having to switch to alternative fuels and reducing the need for limited freshwater resources.

The reality of limited water resources will force the energy industry to use water much more efficiently in extracting, converting, and delivering energy. Efforts to improve water efficiency can also result in significant savings in water (and energy) consumption. Transforming global water and energy concerns into effective solutions requires not only increased awareness of the challenges but also a better understanding of the energy sector's complex water-energy relationship. Decision-makers need to integrate energy issues into water policy and water issues into energy policy. Lack of a unified approach to water and energy policy will jeopardize water and energy supply [94,95] the amount of water consumption in this industry per ton of product is very high according to table 3 [96].

Table 3: Water consumption in different sectors of the steel industry (global average and Iran) [96].

Zone	Process Water Required (Gal/Tone Product)	Based on Best Performance (Gal/Tone Product)
Coking	120-900	100-120
Iron production	3200-6000	50-120
BOF method steelmaking	1000-1100	50-110
EAF method steelmaking	2200	110
Degassing (under vacuum)	1250-1400	25
Continuous casting	3600	25<

On the other hand, as can be seen in figure 16, steel production in Iran has been increasing since 1980 and has increased from less than 1000tons per year to 15,000tons per year [97]. However, according to table 4, the energy consumption of this industry in Iran is higher than the global average in all sectors [98]. Regarding the water consumption of Iranian steel units, the distance between

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the current consumption and the global average is evidence of the destruction of water resources and, of course, its recovery potential. Water networks are more important in this regard because according to what is shown in figure 17; Iran is one of the regions facing a water crisis. Therefore, the steel industry in Iran needs to extract an approach to reach the optimal point of use of water and energy resources to make the most of these limited resources. Therefore, more accurate identification of water and energy flows in this industry, especially in Iran, to find potentials to reduce resource degradation, is necessary [98].

Table 4: Energy consumption of iron-steel production units.

Production Unit	The Intensity of Energy Consumption (Gj/Ton)		
	Iran	World	Best Operating Mode
Coal concentrate	0.58	-	-
Agglomeration	2.065	2.027	-
Sintering	2.17	2.57	2
Pelletizing	1.125	0.79	0.6
Coking	1.05	1.027	0.8
EAF Steelmaking	2.25	1.7	1.4
Roll (sheet)	1.281	0.9	-
Roll (Rebar)	2.74	1.8	-

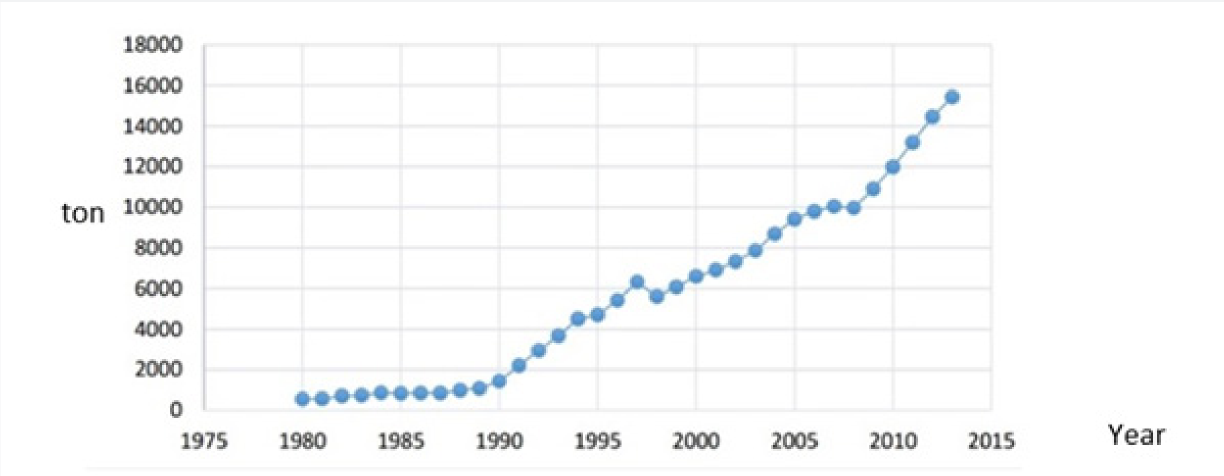

Figure 16: Crude steel production trend in Iran from 1980 to 2015 units per thousand tons [97].

Estimating the possibility of using renewable energy for the steel industry

Today, providing part of the required energy from new and renewable energy sources as a safe solution and in line with environmental considerations is considered by many industries around the world. In different industries, a lot of thermal energy is wasted in different ways, such as heat transfer from hot surfaces and losses due to produced vapors, etc. Using different technologies, this heat can be recovered and in addition to being used in preheaters and hot water, etc., it can also be used to generate electrical energy. Due to technological advances, heat loss power plants are used to improve efficiency and clean electricity generation in industries that have a high potential for continuous heat loss with a minimum temperature of 100°C.

The use of heat recycling technologies in industrial processes has many advantages, some of which include sustainable employment, industrial development, and productivity, increased research and development opportunities, as well as reducing pollution and sustainable development. Therefore, it is necessary to pay attention to heat recovery, which is one of the most important energy sources in the iron and steel industry. In the Chinese iron and steel industry, for example, 8.44GJ of heat is produced per ton of steel produced, of which only 28% is recycled [99].

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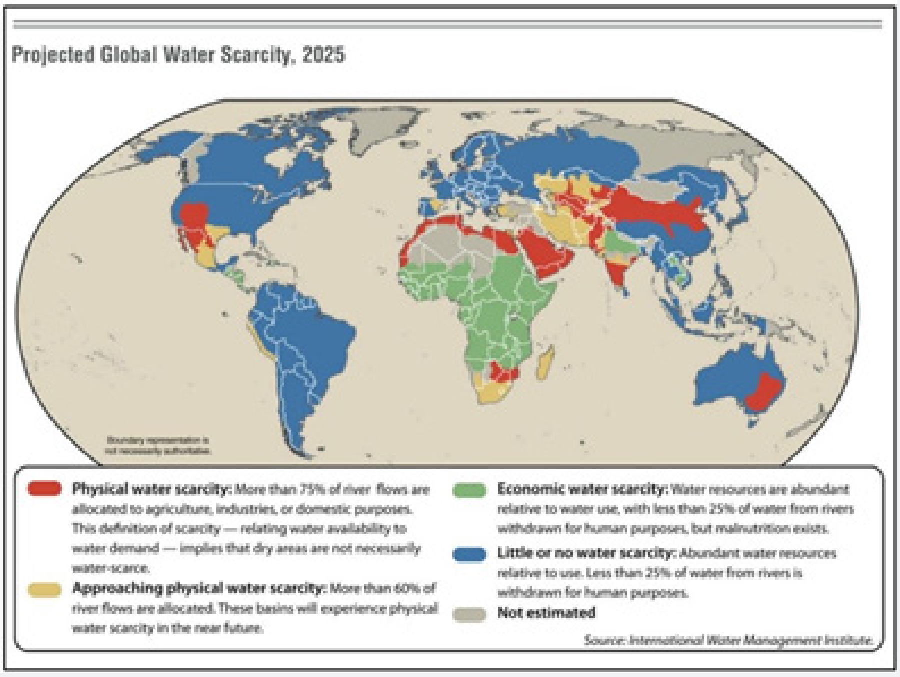

Figure 17: Water resources scarcity forecast by 2025 Iran is close to water scarcity [98].

Organic rankine cycle specifications for waste heat recovery

Due to the increasing energy consumption and the problem of electricity shortage, the use of various systems and mechanisms to increase energy efficiency have been considered. One of these technologies is the use of waste heat in factories. One of the most important ways to use heat dissipation is to use heat dissipation from factory chimneys by organic Rankin cycle. The Rankin organic cycle can be used to recover low-temperature dissipative heat. This cycle is like the steam ranking cycle, except those organic fluids are used as the working fluid. The most well-known working fluid is water vapor, and other fluids include a mixture of ammonia and water, ammonia, carbon dioxide, and organic fluids. The use of water or water vapor as a heat transfer fluid is limited in cases where an industrial waste heat source is available at low temperatures. Organic ranking cycles use organic fluids such as toluene, pentane, or silicon oil as a more suitable option. The temperature range of the Rankin organic cycle is lower than the steam Rankin cycle and therefore can be used in heat recovery [100].

The Rankin organic cycle is the steam Rankin cycle, which has been replaced by an evaporator instead of a boiler. This cycle mainly includes turbines, condensers, evaporators, and pumps. Because the operating fluids used in this cycle generally have a low boiling point, using a low-temperature heat source can produce the steam required for turbine consumption in the evaporator. To do this, the heat source can be wasted heat of industrial processes, solar, biogas, and so on. The interface used to absorb heat is also water. The sources of low-temperature energy of Rankin organic cycle energy can be wasted heat in industries such as flue gas furnaces in metal smelting, glass making, cement plant, refineries, and gas turbines [101].

ORC power plant in electric arc furnace (EAF)

The ORC system was first used in 2013 to recover waste heat from Singapore hot rolling mill furnaces, and the first use of this system in electric arc furnaces has been in Germany [101]. In the steel industry, ORC is well suited for the thermal recycling of electric arc furnaces and rolling mills. Figure 18 shows a schematic illustration of how the ORC components relate to the EAF [102]. According to the existing records, for each hot gas emitted from EAF, from each ton of molten steel product, the output of heat and power generation in the range of 15 to 25kWh is provided. Therefore, for a sample EAF, assuming the production of 1.5 million tons of product per year and assuming heat recovery up to 25kWh, the required ORC design power is about 5MW, which, assuming 7200 hours of annual operation, can produce 37,500MWh. It has electricity [102,103].

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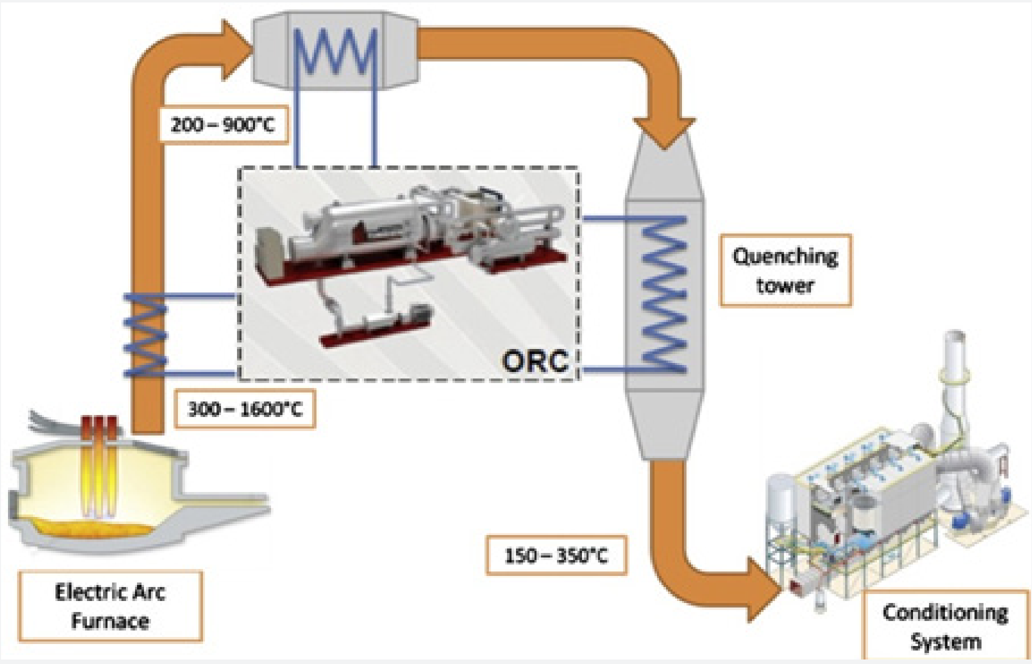

Figure 18: Thermal recycling system of arc furnace exhaust gases with ORC technology [11].

Conclusion

In this study, some energy optimization methods in the steel industry were studied. The effect of factors such as preheating scrap iron and direct reduced iron entering the electric arc furnaces using exhaust gases from the furnace, using carbon burners to inject carbon and oxygen into the melt inside the furnace and creating puff slag to reduce energy consumption and Electrodes and refractories used in the furnace and reducing melting time and increasing efficiency were mentioned. Also, secondary combustion, preheating of the molten pot, increasing the ratio of scrap iron to direct reduced iron, which of course depends on various factors such as development and welfare index and consumption culture, etc., as well as modifying the scrap load for charging inside the furnace can be mentioned. All the mentioned factors are to reduce energy consumption and increase efficiency. One of the methods to prevent the environmental damage effects of the steel industry can be the use of high heat slag produced in electric arc furnaces and the use of waste gases. The process of producing molten steel for preheating materials (direct reduced iron and scrap) and charging inside the furnace - or the use of waste gases for use in the Rankin organic cycle due to the possibility of recovering low-temperature heat loss is all methods The above is both to reduce and optimize energy consumption and to prevent CO_2 production and environmental damage.

Using worn tires as a carbon source can also be one of the best ways to reduce energy consumption in arc furnaces and help reduce environmental impact. Regarding the location, it can be said that the construction of a factory depends on many factors. In other words, to locate a project, one must prioritize the important and desired factors in order of their importance. Of course, prioritizing needs is not an easy task, but with proper timing and consistent considerations, the best place to build a project can be considered. For sustainable development, in the long run, it is necessary to pay attention to the limitations of the environment and natural resources. One way to achieve sustainable development is to evaluate the environmental impact of the project. This is not to prevent the project from being implemented, but to minimize its adverse effects and significantly improve the status and ranking of environmental performance. Due to the infrastructure, access to energy resources, water, mines and the consumer market, the southern region of the country is the first-place priority for the sustainable development of this industry.

A noteworthy point in this region is the supply of water from the seawater desalination process, which will have negative environmental effects on the coastal and marine ecosystem of the Persian Gulf. Therefore, in using this technology for water supply, a wide technical and economic study should be done to minimize the harmful environmental effects about the necessary arrangements and proper selection of the desalination plant installation site, water extraction site from the sea, and especially the return water discharge to the sea. Reach and ensure the stability of the industry. One of the indicators of industrial growth in any country is the amount of steel production and consumption.

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The steel industry plays a key role in the national economy and the welfare of communities, so the development of this industry is an effective factor in the development of other economic, industrial, scientific, and social sectors of the country. Iran with 3.3 billion tons of iron ore geological reserves and 17.93% of the world's natural gas reserves, long borders with international waters, the existence of skilled and cheap labor, the possibility of cheap transportation and knowledge and experience gained from the implementation of numerous projects and factories Steel has a clear advantage in the approval of the International Iron and Steel Association (IISI) in the production of this product. One of the ways to achieve the goals of sustainable development is to locate and study the environmental impacts that can be made available to managers and decision-makers as a planning tool based on which they can prevent the development of pollution and degradation of nature.

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