AN OUTLOOK TO IRANIANIRON ORE AND IRONMAKING INDUSTRIES*

Elham Kordzadeh[1]
Jose Murilo Mourão[2]
Thomas Schwalm[3]

Abstract

Iran has abundant reserves of iron ore and is the 10th biggest producer of iron ore in the world.With its world-wide second biggest natural gas resources, it has an excellent basis for an efficient iron and steel industry. Besides the currently operating capacity, which is mostly based on the direct reduction/electric arc furnace route, Iran'siron and steel master plan, defines a target for steel production of 55 million tons in 2025. Therefore, beneficiation, pelletizing and direct reduction capacity need expanding accordingly.

The gap between the current and desired state of steel production will lead to the installation of new capacity along the necessary power plants, transmission lines, gas pipelines, ports, roads, railways, water supply and mining. With the increase in steel capacity, iron ore needs to be extracted and reduction of iron ore reserves requires new exploration or supply shortages through imports.

Keywords: Iron Ore; Pelletizing;Ironmaking; Direct Reduction.

[1] *Metallurgist Engineer/M. Sc.,graduated from Bahonar University,Independent Researcher, Karaj, Alborz, Iran.*
[2] *MetallurgistEngineer, graduated from Escola de Minas de Ouro Preto, Brazil, Independent Consultant on iron ore and ironmaking.*
[3] *Minerals Processing Engineer/Dipl.-Ing., graduated from Mining Academy Freiberg, Germany.*

** Technical contribution to the 48º Seminário de Redução de Minério de Ferro e Matérias-Primas e 6º Simpósio Brasileiro de Aglomeração de Minério de Ferro, part of the ABM Week, October 2nd-4th, 2018, São Paulo, SP, Brazil*

1.INTRODUCTION

Iran is rich, not only in oil and gas, but in mineral deposits, as well. Iran is among the first 10 countries in the world and the first country in the Middle East in terms of having mineral resources. Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO) is the major state-owned holding company and about 90% of the country's mines and related large industries are in state hands.

One of the minerals, which is of most importance is iron ore.

Chadormalu mine, Gol-e-Gohar mine and Sangan mine are the largest iron ore mines in Iran. Iran has other specific advantages in:energy, human resources,consumer market,andis well-positioned regarding capital investments and technology development. Infrastructures is still an area to be developed further.

Iranian policies aim at attracting foreign investment in the iron ore value chain, including exploration, concentrate production and pelletizing. [1]Iran with its 4.3 billion tons of iron ore reserves, ranks at number 10 in the world. Most of the iron ore requires *beneficiation* and subsequent *pelletizing*.

With its rich natural gas resources and low energy prices, Iran has adopted the direct reduction route for most of its iron and steel production.In2017, Iran ranked 2nd in producing direct reduced iron (and first in gas based DRI) in the world after India, which predominantly produced coal based DRI. [2]

This paper gives an overview on the status of the iron ore and ironmaking industries in Iran and a perspective of this sector within the horizon of 2025.

2. IRON ORE DEPOSITS, MINING AND BENEFICIATION.

2.1 Iron Ore Regions

Iron ore deposits has been explored in different regions with different type of iron ore.
In the Sangan and Khaf region, there are many placer-type magnetite mines. Iron ores in the Zanjanareaare of hematite and magnetite and have more phosphorus and sulphur compared to the Sangan and Khaf-mines.

Magnetite and hematite iron ore in Kerman and Sirjan havehigh amounts of sulphur.
While iron ore in the Yazd area are of magnetite and hematite type,in the Sistan-andBalochestanregion, most iron ore is magnetite placer-type deposits can be found. [4]

The biggest iron ore mines are Chadormalu, Iran Central Iron Ore Company, Gol-e-Gohar, Sangan, Choghart and Jalal Abad, whose production is used for local consumption and partlyare exported to countries such as India and China.

Last year, the biggerIraniancompanies, produced about 38,3 milliontonsof concentrate. Most of these concentrates is further processed in pelletizing plants. [5]

2.2 Mineralogical Aspects

Iran is located along the Tethyan suture betweenthe Eurasian and the Arabian tectonic plate. Two successive and partlycontemporaneous Tethyan oceans existed; the older northern Paleo-Tethys and the younger southern Neotethys. Since the formation and evolution of the Prototethys,the tectonic evolution of Iran has been controlled by the opening and closure of the Paleotethys in the Paleozoic,and the closure of the Neotethys in the Cenozoic era.

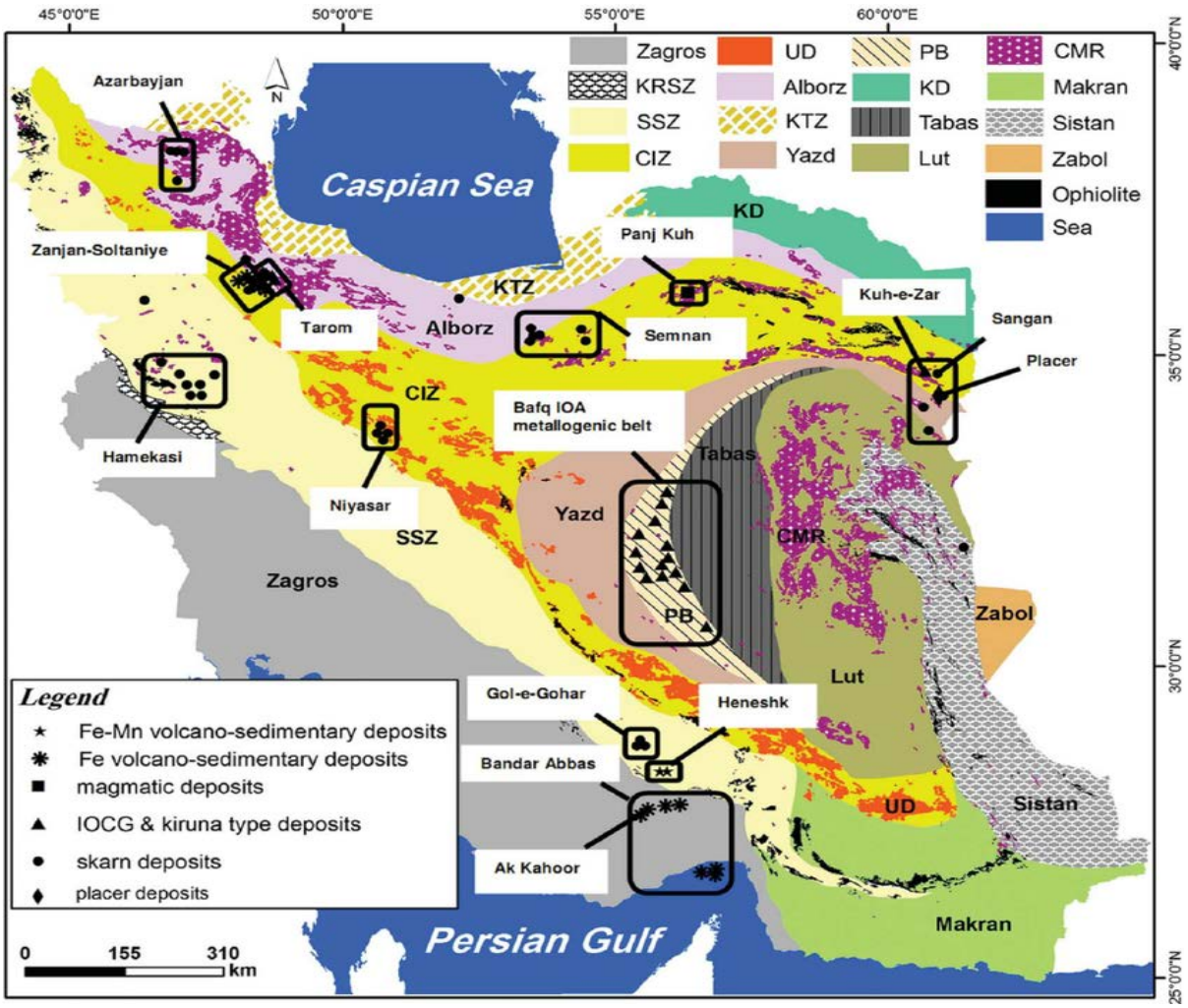

Figure 1. Iran iron ore deposits. [6]

REMARKS: (1) Zagros ranges (Zagros); (2) Kermanshah Radiolarites subzone (KRSZ); (3) Sanandaj-Sirjan magmatic-metamorphic zone (SSZ); (4) UrumiehDokhtar magmatic arc (UD); (5) Central Iranian microcontinent (CIM) (includes the Yazd, Posht-e-Badam block (PB), Tabas and Lut blocks); (6) Alborz ranges, western Alborz-Azerbaidshan (Alborz); (7) Khazar-Talesh-Ziveh structural zone (KTZ); (8) Central Iranian zone (CIZ); (9) East Iran ranges (Sistan); (10) Makran zone (Makran); (11) Kopeh-Dagh ranges (KD); (12) Zabol area (Zabol), and (13) Cenozoic magmatic rocks (CMR) [6]

The temporal spatial distribution of mineral resourcesresults from the Earth's crust orogenic movementsand occurs in tectono-magmatic periods of the Earth's history within definite tectono-magmatic zones of theEarth crust. The evolution of Tethyanrealm, which governedthe geological evolution of the entire region, caused the fragmentation of Iran into different continentalblocks. These blocks are separated from each other by complex suture zones, as shown in figure 1.

2.3.BENEFICIATION

The12 active beneficiation plants for producing concentrate are listed in table 1.

Plant Name	Capacity [tpy]	Province
Chadormalu	10,500,000	Yazd
Gol-e-Gohar	8,570,000	Kerman
Gohar Zamin	5,000,000	Kerman
Bafq	3,200,000	Yazd
Sangan-Phase 1	2,600,000	Khorasan Razavi
Iranian Zarand	2,000,000	Kerman
Iranian Sirjan	2,000,000	Kerman
SepahanIron Ore	1,000,000	Khorasan Razavi
KaniSanatKaspian	400,000	Mines from different province
Aria Jonoob Iranian Company	350,000	Yazd-Kerman
Sahand Continuous Casting	300,000	Zanjan
KaniKavanSamangan	200,000	Mines from different provinces

Table 1. Active beneficiation plants in Iran. [7]

Example 1: Gol-e-Gohar

Gol-e-Gohar iron orehas a high content onsulphur (> 0.5%) and to some extent significant phosphorus contents (0.080%). In beneficiation lines 1, 2 and 3, the iron ore with an iron head grade of about 50%, is concentrated up to 67% iron.

Beneficiation line 4with a capacity of 2mtpywas built for increasing the production of concentrate and applies HPGR/ball mill grinding.By magnetic separation, the iron content is increased to 67 to 68%.

Lines 5 to7, with a capacity of 4 mtpy, are of similar design.In addition to magnetric separation and HPGR/ball mill regrinding, a final flotation step allows the productionconcentrate with low Sulphur contents. [8]

Example 2:Chadormalu

AtChadormalu'sbeneficiationplant(see figure 2)the magnetiteportionis separated by low andmediumdensitymagnetic separation. The hematite and tailingsportion go to

high intensity magnetic separation. The hematite concentrates of this step go to a flotationfor dephosphorization and further increase on iron content. The tailings of magnetic separation go to a flotation stagefor apatite recovery. [9]

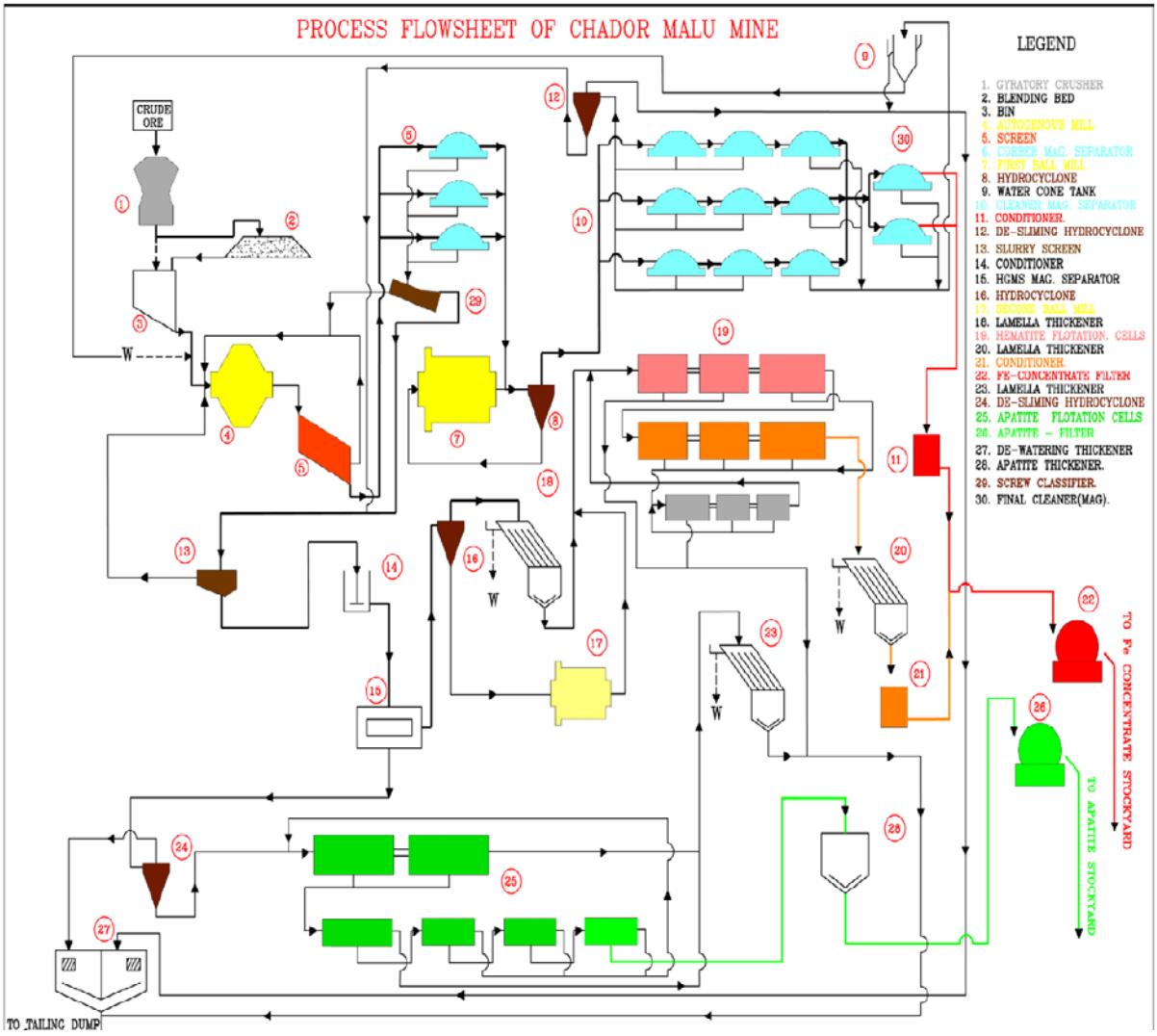

Figure2: Process flowdiagram of Chadormalu Iron ore concentrator plant source. [9]

3. PELLETIZING OF IRON ORE

Currently Iran produces about 25.6 million tons per year pellets, which are all used for local consumption.About 82% of pellets are produced ontravelling grates (TG) and 18% ongrate-kiln (GK) systems [3].

The currently operating pelletizing plants in Iran are listed in table 2. According to the government's master plan, Iran should produce 80 mtpy pellets by 2025.

Witha nominal capacity of the existing plants of 37.9 mtpy in 2016-17,the capacity utilization was only 68%. This indicates the need for plants' optimization (figure 3). On the other hand, in the mid-term, the requirement for installation of new plants.

Plant Name	Plant Type	Nominal Capacity [mtpy]	Technology provider	Local Partner	Start up
Khouzestan	Travelling Grate	2 x 2.5	Lurgi		2001
Mobarakeh	Travelling Grate	4.5	Lurgi/Italimpianti	IRITEC	2001
Ardakan	Grate Kiln	3.4	Kobelco	KanroodSaze, MSPI Co.	2007
Gol GoharI	Travelling Grate	5.0	Outotec	Copper Investment Consortium	2009
Gol GoharII	Travelling Grate	5.0	Outotec	Keyson-SBR	2015
ZISCO	Grate Kiln	2.5	Sinosteel	Mana	2015
SISCO	Travelling grate	2.5	Sinosteel	Mana	2016
Mobarakeh (Sangan)	Travelling Grate	5.0	Uralmash/ Toreks	Azaran Industrial Structure	2017
Opal Parsian/ IMIDRO	Travelling Grate	5.0	Uralmash/ Toreks	Azaran Industrial Structure	2017
Asadabad	Grate Kiln	0.55	Iran	Kian roiensara	2017

Table 2. Operating pelletizing plants in Iran. [3]

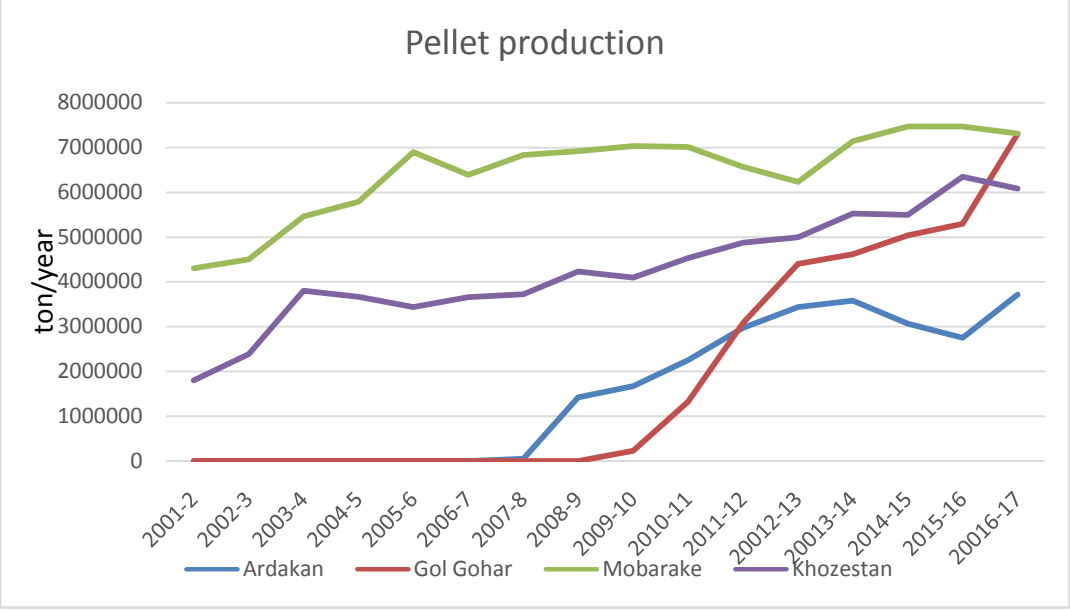

Figure 3. Production of biggest pelletizing companies between 2001-2017. [10]

4. IRONMAKING

4.1 Direct Reduction

The natural gas price in Iran is very low and the country has one of the largest natural gas sources in the world. Metallurgical coal sources for blast furnace are, however, rare. Therefore, direct reduction is the predominant ironmaking technology in Iran and only two blast furnaces exist. Table 3 shows all direct reduction plants in Iran. Midrex technology is the most important for ironmaking in Iran.

Row	Plant Name	Technology	Capacity (mtpy)
1	SirjanIranain Co. II	Midrex	0.8
2	Ardakan steel	Midrex	0.8
3	Gol-e-Gohar	Midrex	1.7
4	Chadormalu	Midrex	1.55
5	Sabzevar	Midrex	0.8
6	Qaenat	Midrex	0.8
7	SepidDasht	Midrex	0.8
8	Gol e Gohar	Midrex	1.7
9	Sirjan Jahan Steel	Midrex	0.96
10	SirjanIranain Company	Midrex	0.8
11	Arfa Steel	Midrex	0.8
12	South Kaveh steel	Midrex	1.8
13	IGISCO	Midrex	0.8
14	Khorasan Steel I	Midrex	0.8
15	Khorasan steel II	Midrex	0.8
16	HOSCO I & II	Midrex	1.6
17	Mobarakeh (Kharazi A & B)	Midrex	3.0
18	Mobarakeh (Saba)	Midrex	1.5
19	Mobarakeh (A-E)	Midrex	3.2
20	Mobarakeh (F)	Midrex	0.8
21	Khouzestan steel (I-III)	Midrex	1.2
22	Khouzestan steel (IV) Zam zam	ZamZam	0.6
23	Khouzestan steel (V)	Midrex	0.8
24	Khouzestan steel (ASCO)	HYL	1.03
25	Esfahan Steel	Ghaem	0.6
26	Shadegan	Pered	0.8
27	Neyriz	Pered	0.8
28	Myaneh	Pered	0.8
Total			**32.44**

Table 3. Iran direct reduction plants. [11, 16]

Based on internationally available direct reduction technology, Iranian companies have developed local options, as follows:

- **PERED**

The first PERED (“Persian Reduction”) DRI plant started inJune 2017 in Shadegan, Khouzestan. It is a direct reduction technology patented by ‘Mines and Metals Engineering GmbH’ in 2007. As for MIDREX, PERED converts iron oxides, in the form of pellets or lump ore, to highly reduced product suitable for steel making. The reduction of iron oxide takes place without its melting with the help of reducing gases in solid state in a vertical shaft furnace. In PERED, the reduction process takes place at a lower temperature due to the improved cooling methods and at reduced pollutant gas emissions. With less heat, more homogeneous reducing gas, more controllable pellet feed and use of centrifugal compressors, PERED requires less water, electricity and gas to operate, which shall requireless operational and maintenance expenditures.Output from PERED can also be in the form of cold direct reduced iron (CDRI), hot briquetted iron (HBI), combination of CDRI/HBI, HBI/hot direct reduced iron (HDRI), and CDRI/HDRI. [12]

- **GHAEM**

The process was developed by Esfahan steel company. Unlike in most shaft furnace-based processes, the pellets, fed to this process,are preheated at the top of the furnace using natural gas plus top gas. GHAEM I began operation in 1995 in Esfahan. It features a recovery system for preheating mixed natural gas/top gas, a combustion chamber in which the mixed pre heated gas together with gas and oxygen is reformed into the reducing gas and a shaft furnace. [13]

- **ZAMZAM**

Khouzestan Steel Company, the largest supplier of steel ingots in Iran,installedMIDREX-technology in 2001/2002.At the time of start-up, the ZAMZAM furnace was the biggest direct reduction furnace in the country with an annual capacity of 0.8mtpy of DRI.In 2008/2009, the second ZAMZAM-module was built with a capacity of 1.0mtpy. [14]

4.2 Blast Furnace

The two integrated steel plants in Iran are Esfahan Steel (ESCO)and Zarand Iron and Steel (ZISCOMIDHCO). [15]Esfahan Steel had been established between 1965 and 1972, based on technology provided by Russian Tyazhpromexport. Then, expanded capacity in early 2000, supported by POSEC, South Korea.

Table 4. Iranian Blast Furnaces plants.

Row	Plant Name	Technology Provider	Capacity (MT)
1	Esfahan Steel	Tyazhpromexport (TPE)	3.6

2	Zarand Iron and Steel	Sinosteel	1.5

Current production capacity stands at approximately 2 mtpy of finished products, including rebars, beams, pipes and sheets.A new blast furnace is currently installed atZarandIron and Steel by Sinosteel from China, with capacity of 1.5 mtpy (table 4).

5. OUTLOOK TO 2025

Iran's steel master plan, which was published in 2014, defines the strategic targets for the country's iron and steel industry, until 2025. The master plan targets at 55 million tons per year crude steel production, which will require 86 mtpy of iron ore concentrate, 80 mtpy of pellets and 52 mtpy of DRI. As shown in figure 4, in 2016-17 only about 18.5 mt of crude steel, 17.3 mt of DRI, 25.6 mt of pellets and 31.3 mt of concentrate were produced. [3]

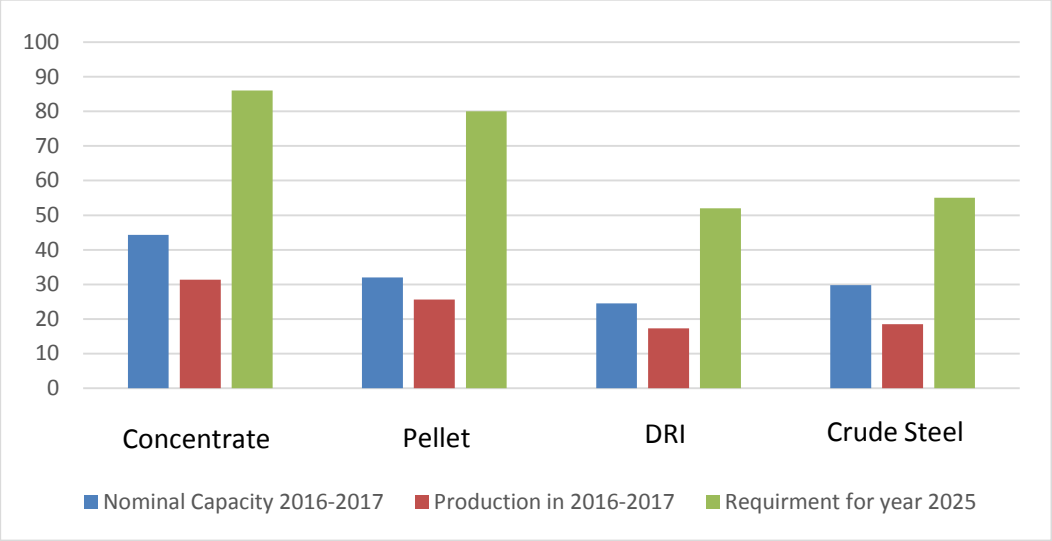

Figure 4. Nominal capacity, production in 2016-2017 and requirements for 2025. [1]

To comply with this huge growth plan in iron and steel production, the Iranian government has been planning and investing in different fields, as follows:

- Research and development on iron ore and DR technology;
- Exploration of existing and new iron ore resources;
- Expansion of mining and beneficiation capacity;
- Installation of new pelletizing plants;
- Installation of new DR plants.
- Expansion of steelmaking capacity (DR-EAF route).

In terms of pelletizing, several new plants are under tendering stage or construction, such as listed in Table 5.

Plant Name	Plant Type	Nominal Capacity [mtpy]	Technology provider	Local Partner
Gohar Zamin	Travelling grate	5.0	Outotec	TIV Energy- Asphalt Toos
Khorasan	Travelling Grate	2.5	NHI	Pamidco
NIMIDCO	Grate kiln	2.5	NETC	FakoorSanat-AsfaltToos
Shahrak	Grate kiln	0.92	MECP	Kian roeinsara
MIDHCO Butia	Grate kiln	2.5	SDM	MEMSECO-Mana-GMI
Sechahun	Grate kiln	5.0	Kobe steel	FakoorSanat
MaadKoush	Grate kiln	2.5	BSIET	
Bahabad	Travelling grate	2.5	NHI	Pamidco
South Kaveh	Not defined	5.0	Not decided	Not decided
Kharameh	Travelling grate	2.5	Not decided	Not decided

Table 5. Pelletizing plants in Iran already decided or under construction.[3]

Iran pelletizing plants are distributed mostly in the central and east parts of the country, in most cases neariron ore mines (Gol-e-Gohar, Sangan, ZISCO) or steel plants (Mobarakeh, Khouzestan Steel), as shown in Figure 5.

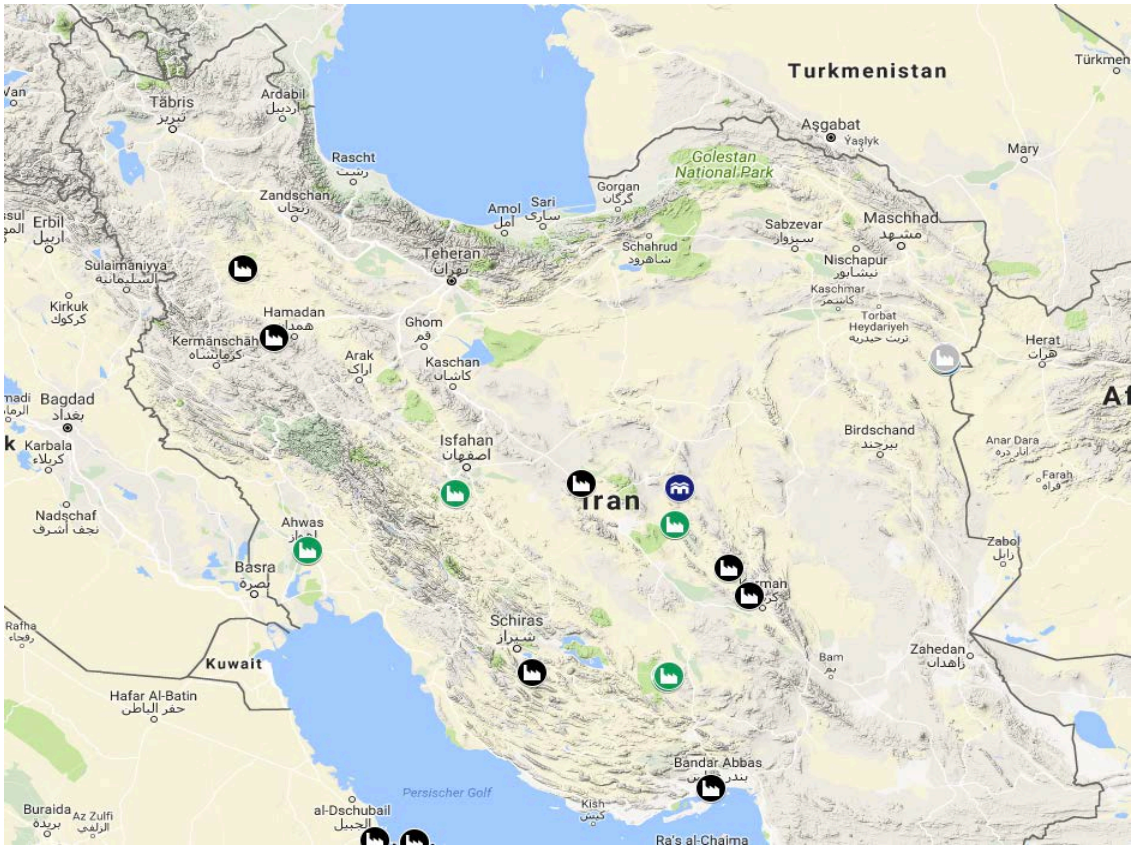

Figure 5. Pelletizing plants in operation and under construction/planning (2017).

6. CONCLUSION

Iranian Government has been doing huge investments in developing mining, iron and steel industries. It's impressive the growth of these sectors in the last years and the companies make use of the state-of-the-art technologies.

The availability of great resources on iron ore and natural gas has pushed the route Direct Reduction-Electric Arc Furnace as the main one in steel production.

There are in course important expansion plans in mining and steel sectors. It is expected that in 2025 the steel production will reach the level of 55 mtpy, what will demand around 80 mtpy of iron ore pellets.

REFERENCES

1. Ali Kherad, "How to invest in Iran", Iran iron ore, December 2015.
2. World Steel Association:"Iron Production", March 2018.
3. Foolad Technic International Engineering Company (FIECO):"Iran steel master plan study", volume 1,2014.
4. Iran Mineral Processing Research Center: "Investigation of beneficiation technologies and extraction of iron ore from steel industries point of view",2014.
5. IMIDRO site. News. https://imidro.gov.ir/news/18431--رشد-18-درصدی-تولید-کنسانتره-سنگ-آهن-معادن-بزرگ.html, 2018.
6. G. Nabatian, E. Rastad, F. Neubauer, M. Honarmand& M. Ghaderi: "Fe and Fe-Mn mineralization in Iran: Implication from Tethyan Metallogeny", Australian Journal of Earth Sciences, 2015.
7. Iran Ministry of Industry, Mines and Trade.
8. Gol-E-Goharwebsite, https://www.geg.ir/index.aspx?siteid=1&fkeyid=&siteid=1&pageid=175.
9. M.Pezeshkan:"An Investigation of the Optimization of Chadormalu Iron Ore Processing Plant in order to produce qualitative steel", 2007.
10. Securities and Exchange Organization (http://www.codal.ir), companies' annual reports.

11. M.R.Taheri, MMTE:“DRI Production in Iran“,2nd World DRI and Pellet Congress, Abu Dhabi, April 2014.

12. Mines &Metals Engineering GmbH:“PERED-Technology”.

13. A. Chatterjee: “Sponge iron reduction by direct reduction of iron oxide”, 2012.

14. KhouzestanSteel Co. 2nd World DRI & Pellet Congress. 2014.

15. Esfahan Steel Company website:https://www.esfahansteel.com/en-news?id=337

16. World DRI Statistics 2017, MIDREX Technologies, Charlotte, USA.