NON-PEER-REVIEWED PAPER

Potentials of energy conservation in the industry sector of Iran

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Abstract

Iran has one of the greatest resources of fossil energy in the world. Statistics show that Iran with having 157 billion crude oil barrels, is in 4th place and with 222 bBOE Natural gas is of 1st place and by having 52 bBOE coal is in 10th place and totally by having 605.5 bBOE, Iran is the 3rd country in terms of possessing fossil fuels (oil, gas and coal) in the world. On the other hand, this country is the 3rd consumer of natural gas (156.1 bcm or 1,036 MBOE) and 12th consumer of crude oil (1,971 bbl/day) in the world. So by consumption of 1,973 MBOE, Iran is in 11th place of consumers of primary energy in the world and by having GDP of 482 b USD is in 26th place. This shows high energy intensity of this country. By comparing energy intensity of Iran between years 1999 to 2009 for supply of primary energy to GDP, it would be seen that energy intensity (without considering production losses) from 1.90 TPES/GDP in 1999 has reached to 1.97 TPES/GDP in year 2009 with a slight slope, which shows economic growth and development from one hand and failure in energy conservation on the other hand.

Based on Iran's policies for "Rectification of Energy Consumption", till 2016, energy intensity should reduce 33 % and till 2021 it should reduce 50 % compared to the energy intensity of the year 2011. In this way the cumulative energy saving in the country is estimated to reach around 6,600 MBOE which is approximately 4 times of the primary energy supplied to the country in 2009. As a result, Iran could avoid the threats of the energy consumption trends for the country. The end users of energy in order of magnitude are: industries, buildings, transportation, and agriculture. With focus on the industry sector Iran has the potential of energy saving of 159 MBOE/year.

In fact, this potential could be an opportunity for development of Energy Service companies especially in the industry sector. At the moment, UNIDO is trying to utilize this potential through its UN-GEF program for implementing energy conservation programs in most energy intensive industries in Iran (Steel, Petrochemical plants, oil refineries, cement and brick industries). This paper will review potentials of energy conservation in different industry sectors of Iran.

Introduction

According to BP Statistical Review of World Energy 2013, Iran with 4,358 kbbl/day crude oil production is in the 4th place of crude oil producers and with 151.8 bcm per year (2,744 kBOE/day) natural gas production is in 4th place of main gas producers in 2011. Also final energy consumption is about 1,192.8 MBOE[1] from primary energy production where share of consumption in industry sector is around 293.6 MBOE (3rd place among the other sectors: Residential, Commercial, Transportation and Agriculture). Comparison with other countries shows that Iran was in 11th place for primary energy consumption in 2011 (Figure 1).

The trend of energy consumption in Iran is shown in Figure 2.

1. Islamic Republic of Iran's Energy Balance, 2011.

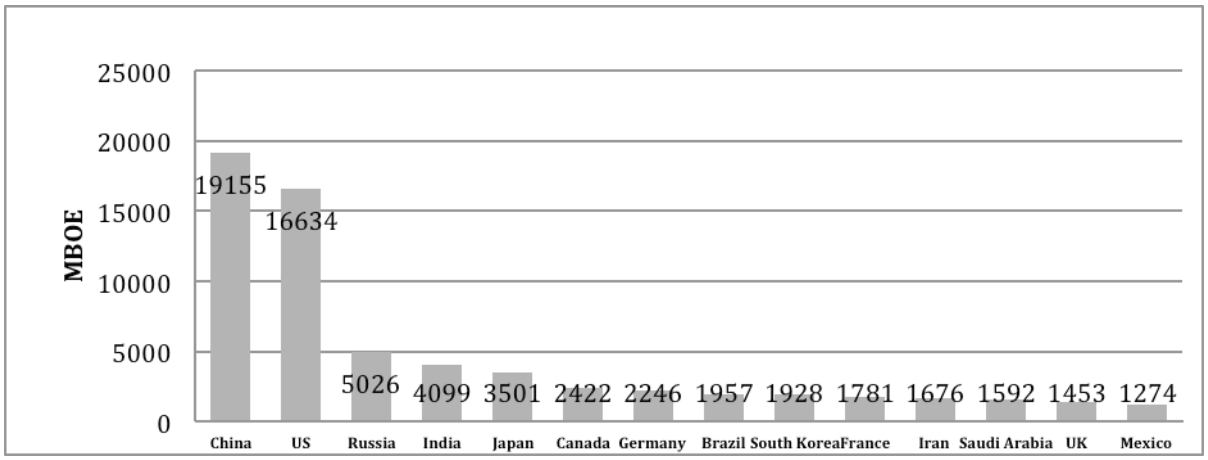

Figure 1. World energy consumption 2013. Source: BP Statistical Review of World Energy, June 2013.

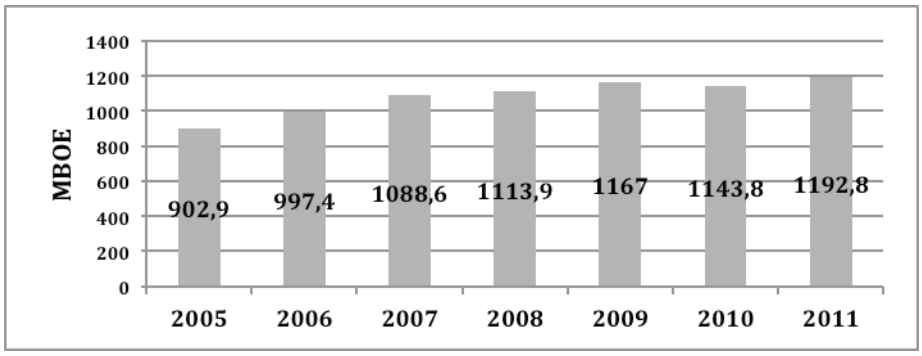

Figure 2. Trend of final energy consumption in Iran. Source: Islamic Republic of Iran's Energy Balance, 2011.

Energy Consumption in Industry Section

Between the years 1970 and 2000, energy consumption in Iran became almost eight-fold, from 90 million barrels oil equivalent (MBOE) in 1971 to over 700 MBOE in 2001. In the same period, the annual energy consumption growth rate was estimated to be 7.8 %. This trend has continued since 2001. The major contributory factors are:

- High growth rate in consumption of electrical energy in the domestic and commercial sectors causing gas fired power plant expansion.
- Increase in energy consumption of transport sector due to expansion of cities causing more need for transportation.
- Unexpectedly increases in industrial energy intensity due to reconstruction of the damages of 8 years of imposed war against Iran, especially in "Big 5"energy intensive industries (Refineries, Petrochemical plants, Iron & Steel, Cement and Brick). An overview of production plans are as follows:
  - **Steel**: In 2007 output was 9–10 Mt/y and in 2009/10 was 11 Mt/y. With numerous expansions and new constructions already under development, there are plans to increase output to approximately 40 Mt/y by 2015. The long term vision is 55 Mt/y.
  - **Cement**: Output of cement was 67 Mt/y in 2008. There are already numerous expansions and new-builds. Output was projected to increase to 74 Mt/y (2010/11) then 95–100 Mt/y (2012/13). After that, the plans are not known.
  - **Refineries**: In addition to the existing 9 refineries, 7 new (private) refineries are at various stages of construction. In total, these will double Iran's capacity from 1.6 to 3.2 billion barrels oil per day. Although Iran has one of the largest oil reserves in the world, it lacks capacity to refine high quality gasoline for transportation sector, and relies on importation. Due to sanctions large investment in this sector has problems. Consequently, large portion of the planned investments are involved in upgrading existing plants to increase gasoline production.
  - **Petrochemical plants**: Several new petrochemical plants are planned or are under construction. Output is projected to grow from 24 Mt (2007) to 48 Mt (2015).
  - **Bricks**: Currently, there are 2,200 brick/heavy clay sites in Iran that produced 33.5 Mt in 2007/8. Long term output is projected to rise to approximately 50 Mt/y. To address this, Iran has announced that the state-owned industries are planned to be mostly privatized to bring

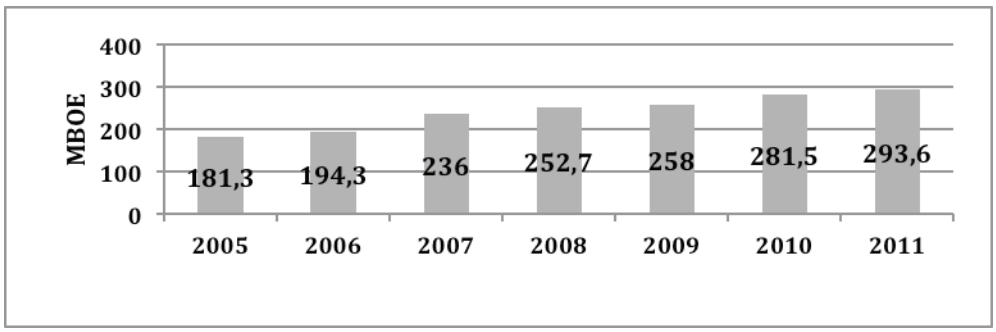

Figure 3. Trend of energy consumption in Iran industry sector. Source: Islamic Republic of Iran's Energy Balance, 2011.

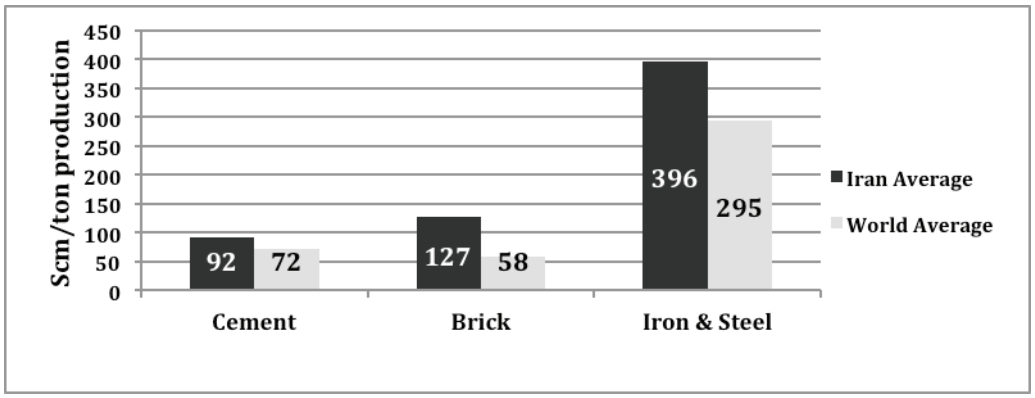

Figure 4. Comparison between Iran and world average energy intensities. Source: Islamic Republic of Iran's Hydrocarbon Balance, 2007.

in vital international technology and financing in order to fund the expansion and modernization plans. Iran needs to develop energy efficiency and at the same time retain sector growth.

- Age of the facilities: Sanctions are the major problem to retrofit the existing industries, especially the "Big 5", as the old facilities are less energy efficient.

As it is seen, for the cement industries of Iran energy intensity is about 1.28 times of the average of the world, and for brick it is 2.19 times and finally for iron and steel section it is about 1.34 times. Generally, energy intensity is very high due to following reasons:

- Energy subsidies: One the most important causes of increase in energy consumption is governmental subsidies that make the price of energy very low and leave no interest for industry sector for improving energy efficiency. Currently, energy prices in Iran are as low as following: Natural gas ($1.5/MWh in 2010), liquid oil products ($1.5/MWh in 2010) and electricity ($20.0/MWh in 2010)[2]. Solid fuels: coal and coke are not subsidized. Anecdotal data suggests that the energy subsidies make energy prices 4 to 14 times lower than they would be at "International" levels.
- Lack of active R&D and new technologies in most of industrial sectors.
- Role of government as owner: As many important industries are owned by government and it is the main supplier of energy, there is no interest for reduction of energy consumption in these industries.
- Long time rate of return for energy efficiency projects: energy efficient facilities are more expensive than existing facilities and their replacement will take very long time for rate of return.

To prevent the domestic primary energy demand from depleting Iran's oil exporting capacity, the production of natural gas has developed and industry sector was instructed to switch from liquid fuel to gas for power generation. All of the "Big 5" and many of existing factories are obliged to have their own (subsidized) gas fired power generation plants. Replacing oil with natural gas wherever possible in the "Big 5" and all other sectors is environmentally beneficial by the fact that gas is less pollutant than liquid fuels. However, increase in fossil-fuel energy consumption cannot be sustainable. On the other hand, energy consumption in Iran is disproportion to the development of economic productivity and there are plans for substantial growth across most sectors over next 5 to10 years. Iran's Government has set an ambitious target of 6 % annual growth for all key industrial sectors. This projection seems quite modest when consider it in an annual basis but this

2. Based on weighted average of day, eve and night rates per MWh.

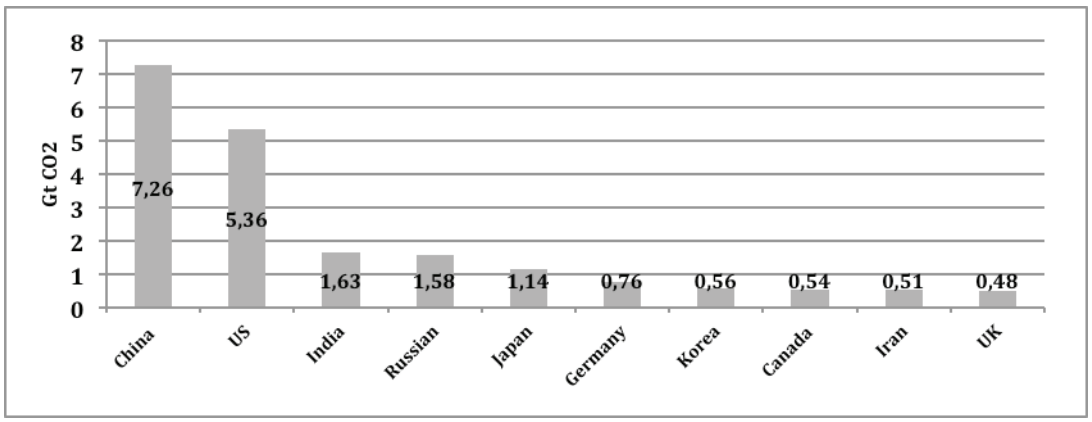

Figure 5. Status of Iran for carbon emission in comparison with other countries. Source: Key world energy 2012.

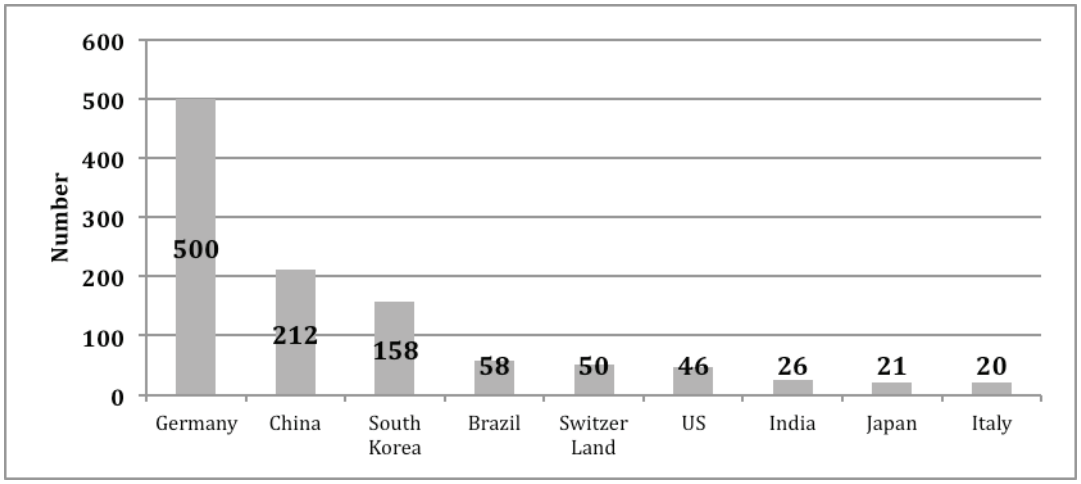

Figure 6. Comparison between number of ESCO companies in countries.

represents a cumulative increase in overall output of 270 % compared to 2007/8 production by 2025. Besides, according to Iran's commitments in "Rectification of Energy Consumption law", till 2016 energy intensity should be reduced 33 % and till 2021 it should be reduced 50 % compared to the energy intensity of the year 2011. Therefore, Energy Conservation is a necessity.

Inefficiency of energy consumption in Iran has caused high emissions and according to IEA report of 2012, Iran is in the 9th place in terms of CO_2 emission.

Considering these issues, Iranian decision-makers have tried to find new way for energy supply and one of the best ways is energy efficiency especially through Energy Service Companies (ESCOs) who implement energy efficiency measures through energy performance contracts (EPCs) in the client's premises without imposing upfront costs to client.

The ESCO companies were initially established in Sweden in 1978 and after that in UK, Italy and Canada. According to 2007 statistics in Figure 6, Germany with more than 500 companies is in the first place in terms of number of ESCO companies[3].

ESCOs operate in different fields. For example:

- Installation and operation of heating systems for buildings.
- Installation and operation of CHP for factories or building complexes.
- Installation and operation of energy efficient systems for industries.
- Retrofit and operating of lighting systems in public routes.
- Energy management in industrial and non-industrial buildings.
- Retrofitting in industrial equipment for energy saving purposes.

Despite registration of first ESCOs around 1990 in Iran, this concept has still remained insufficiently known and it has still a challenge to introduce its mechanism to the stakeholders. According to Iran Energy Efficiency Organization (IEEO) (SABA) data, over 110 companies have announced their preparedness to provide energy services but we believe less than 5 of them can support most important tasks expected from ESCO in a project. The main weakness of these companies is lack of credit ability for financing the projects.

Taking the technical and financial risks of energy efficiency projects by ESCOs has made it an attractive option for projects.

3. World Energy Resource Institute, 2007.

Table 1. Potential energy saving based on industrial standard development.

Industry	Potential energy saving (MBOE/Year)	CO_2 Reduction mT/ Year
Cement (existing plants)	2.2	0.8
Cement (new plants)	2.25	0.8
Brick	3.24	1.1
Glass	0.29	0.1
Gypsum	0.34	0.1
Lime	0.08	0.03
Tire	0.22	0.08
Iron & Steel (existing plants)	6.77	2.3
Iron & Steel (new plants)	6.33	2.2
Zinc & Plumb	0.224	0.08
Sugar	1.93	0.7
Vegetable oil	0.47	0.2
Tile	0.3	0.1
Oil refineries (9 existing plants)	10.92	3.8
Oil refineries (new plants)	9.12	3.2
Gas refineries (12 existing plants)	6.16	2.1
Non-polymeric petrochemical complexes	9.02	3.12
Polymeric petrochemical complexes	0.89	0.31
Petrochemical complexes (new plants)	33.22	11.5
Oil distribution line	0.16	0.06
Gas distribution line	6.16	2.1
Power plants (new plants)	49.13	17
Pilot projects	1.71	0.603
CCHP	6.42	2.23
Financing and grant projects	2.23	0.8
Total	**158.92**	**55.07**

For estimating the required budget and potential for engagement of ESCOs, Iran has undertaken the following steps in industries (especially "Big 5"):

- Identification of inefficient energy intensive industries: These surveys have done through energy audits.
- Development of energy consumption standards: After energy audits and comparing the current status with design data, an immense gap has been identified compared to international status, so it was decided that development of energy consumption criteria for industry is a necessity. Based on this necessity, more than 30 standards were developed. These standards range from Iron & Steel to petrochemical plants and refineries. During energy audits and identification of the current status of industries, different solutions were suggested for energy saving in each industry in order to comply with the standards. The feasibility studies during standard development showed the potentials of energy saving in industries as follows in Table 1.
- Establishing relevant organizations: Two important organizations, IFCO (Iranian Fuel Conservation Co.) and SABA (responsible for electrical conservation), with responsibility of energy efficiency exist in Iran. These organizations are prepared to support and supervise ESCO contracts.
- Energy saving materials and equipment: Efficient material and equipment have been implemented and produced with governmental support.

A number of enhancement methods regarding energy saving for "Big 5" industries are identified as follow.

ENHANCEMENTS METHODS FOR OIL REFINERY PROCESSES[4]

Five of the most significant processes in petroleum refineries are:

- Atmospheric and vacuum crude distillation
- Fluid catalytic cracking (FCC)
- Catalytic hydrotreating
- Catalytic reforming
- Alkylation

These processes account for approximately 70 % of the energy consumed by the refining industry and offer significant opportunities to increase energy efficiency. Most important technologies for EE in refineries are as follows:

- Improvement of fired heater efficiency in atmospheric distillation unit
- Enhancement of heat integration between atmospheric and vacuum process atmospheric distillation unit
- Improvement of separation efficiency for distillation process atmospheric distillation unit

4. http://business.edf.org/sites/business.edf.org/files/11209_LCMI-Refineries.pdf

- Enhancement of heat integration between atmospheric and vacuum processes
- Improvement of separation efficiency for distillation process in vacuum distillation unit
- Installation of a power recovery turbine in catalytic cracking unit
- Conversion of condensing turbine drive to electric motor drive catalytic cracking unit
- Improvement of preheater efficiency hydrotreating process
- Improvement of heat integration hydrotreating process
- Improvement of catalyst efficiency hydrotreating process
- Enhancement of heat integration between atmospheric and vacuum processes catalytic reforming process
- Improvement of separation efficiency for distillation process catalytic reforming process
- Improvement of compressor efficiency alkylation unit
- Utilisation of advanced separation technology alkylation unit
- Upgrade of control system alkylation unit

According to estimates, by utilizing the mentioned technologies in 9 existing refineries[5], Iran can reach the total energy saving of about 1.5 MBOE per year.

ENHANCEMENTS METHODS FOR CEMENT PROCESSES[6]

- Raw materials production
  a. Efficient Transport System
  b. Raw Meal Blending
  c. Process Control Vertical Mill
  d. High-Efficiency Roller Mill
  e. High-Efficiency Classifiers
  f. Roller Mills for Fuel Preparation
- Clinker Making (Applicable to Rotary Kilns)
  a. Energy Management & Control Systems
  b. Seal Replacement
  c. Combustion System Improvement
  d. Indirect Firing
  e. Shell Heat Loss Reduction
  f. Optimize Grate Cooler
  g. Conversion to Grate Cooler
  h. Heat Recovery for Power Generation
  i. Low-pressure Drop Suspension preheaters
  j. Addition of pre-calciner or Upgrade
  k. Conversion of Long Dry Kiln to preheater
  l. Conversion of Long Dry Kiln to pre-calciner
  m. Efficient Mill Drives
  n. Use of Secondary Fuels
- Product Change
  a. Blended cements
  b. Reduced fineness of cement for selected uses
  c. Limestone cement
  d. Low alkali cement (rotary only)
  e. Use of steel slag in kiln
- Finish Grinding
  a. Energy Management & Process Control
  b. High Pressure Roller Press
  c. High-Efficiency Classifiers
  d. Improved Grinding Media in Ball Mills
- Plant general Measures
  a. Preventative Maintenance
  b. High Efficiency Motors
  c. Adjustable Speed Drives
  d. Optimization of Compressed Air Systems
  e. Efficient Lighting

According to estimates, by utilising the mentioned technologies in 68 existing cement plants, Iran can gain total energy savings of about 2.68 MBOE per year.

ENHANCEMENTS METHODS FOR BRICK PROCESSES[7]

- Use of high efficiency carburettor in Hoffman furnaces
- Furnace heat recovery
- Furnace with furnace tunnel which consumes energy three times less
- Utilisation of modern packaging systems to reduce waste

According to estimates, by utilising the mentioned technologies in 2,200 existing brick plants, total energy savings of about 3.24 MBOE per year is achievable for Iran.

5. Imam Khomeini Oil Refinery Company of Shazand, Tehran Oil Refinery Company (ShahidTondGouyan), Bandar Abbas Oil Refinery Company, Isfahan Oil Refinery Company, Abadan Oil Refinery Company, Tabriz Oil Refinery Company, Lavan Oil Refinery Company, Shiraz Oil Refinery Company, Kermanshah Oil Refinery Company.

6. Worrell, E. and Galitsky, C., Energy Efficiency Improvement and Cost Saving Opportunities for Cement Making, An ENERGY STAR® Guide for Energy and Plant Managers, U.S. Environmental Protection Agency, 2008.

7. Iran Fuel Conservation Organization (IFCO). Available at: http://ifco.ir/industry/industryParts/mine/brick.asp

ENHANCEMENTS METHODS FOR IRON & STEEL PROCESSES[8]

- Steel-making – Electric Arc Furnace
  a. Improved process control (neural network)
  b. Adjustable speed drives
  c. Transformer efficiency – ultra-high power transformers
  d. Bottom stirring/stirring gas injection
  e. Foamy slag practice
  f. Oxy-fuel burners
  g. DC arc furnace
  h. Scrap preheating – tunnel furnace (Consteel)
  i. Scrap preheating, post-combustion – shaft furnace (Fuchs)
  j. Flue gas monitoring and control
  k. Eccentric bottom tapping on existing furnace
  l. DC twin-shell with scrap preheating
- Casting
  a. Efficient caster ladle/tundish heating
  b. Near net shape casting – thin slab
  c. Near net shape casting – strip
- Hot Rolling
  a. Energy efficient drives in the rolling mill
  b. Process control in hot strip mill
  c. Recuperative and regenerative burners
  d. Insulation of furnaces
  e. Controlling oxygen levels and/or variable speed drives on combustion air fans
  f. Heat recovery to the product
  g. Waste heat recovery (cooling water)
- General
  a. Preventive maintenance
  b. Energy monitoring and management systems

According to estimates, by utilising the mentioned technologies in 6 most important existing Iron & Steel plants[9] in Iran, total energy savings of about 2.68 MBOE per year is achievable.

Discussion

Although Iran, with its abundant fossil and renewable energy resources like oil, gas, coal, solar, wind and geothermal, does not have much limitations to access energy resources, its long-term plans for economic growth, increase of population and enhancement of welfare has led to growth in energy demand in the country. Meeting the energy demand will require technology and substantial investments in Iran's energy sector, while increasing production capacity has led to higher emissions of pollutants and environmental impacts.

Appropriate device to control the energy demand is removing the energy subsidies, this price mechanism results in reducing energy demand and increase of demand for energy efficiency in various energy intensive sectors. After implementing this price policy, owners of energy intensive industries have more interest towards energy saving measures.

Iran's industrial sector has a potential of annual savings of about 159 million barrels of crude oil equivalent (about 0.44 MBOE per day) which is one of the most important sectors for energy efficiency projects. Due to age and lack of access to new technologies, the industrial sector is extremely inefficient and energy efficiency projects will have a high rate of return for investment after removing the subsidies of energy.At the moment, UNIDO is trying to utilize this potential through its UN-GEF program for implementing energy conservation programs in most energy intensive industries in Iran(Steel, Petrochemical plants, oil refineries, cement and brick industries). This $20 M project was started in 2012 and will be accomplished in 2017. The project objective is to promote energy efficiency in five high energy consuming industrial sectors by adopting a national framework for Energy Management Standards (EnMS).

Medium term targets for this project is as follows till March 2016: no saving in the first year (2012/3) and 7.5 % reduction in the Relative Energy Consumption (REC) of the "Big 5" sectors over the next 3 years. For long term targets by March 2025: 20 % reductions in Specific Energy Consumption (SEC) of the "Big 5" sectors between 2010 and 2025.

Three main barriers exist for EE in Iran:

- First, low energy prices result in infeasible payback for EE investments.
- Second, financial constraints: Industrial facilities do not have sufficient financial capacity available to invest in EE enhancements, bank loans are hardly available and interest rates are prohibitively high.
- Third, no domestic suppliers of the required EE technologies are available.

The first barrier will be solved through new legislations for removal of subsidies, in which price of oil products will reach to 90 % of their international FOB price at Persian Gulf, natural gas price will reach to 75 % of average price of Iran's exported natural gas and electricity price will reach to its actual production cost at power plants. This removal commenced since 2011 and must be finalized till 2017. 30 % of revenues of this law must be spent for EE enhancements in industrial sector. So there will be a good financial source for EE implementation in Iran.

8. Worrell, E., et al, Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Sector, Energy Analysis Department, 1999; Worrell, E., et al., Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel Industry, An ENERGY STAR® Guide for Energy and Plant Managers, U.S. Environmental Protection Agency, 2010.

9. Esfahan Steel Company, National Iranian Steel Co., Khuzestan Steel Company, Oxin Steel, Mobarakeh Steel Company, ChaharMahal & Bakhtiari Automotive Co.

Second and third barriers still exist and this will be an emerging market for international ESCOs and suppliers of EE technologies and equipment and financers of EE solutions.

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