Analysis of Ultimate Energy Consumption by Sector in Islamic Republic of Iran

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Abstract: Total ultimate energy consumption in Iran was 1033.32 MBOE in 2006, and increased at an average annual rate of 6% in 1996-2006. Household and commercial sector has been the main consumer sector (418.47 MBOE) and the fastest-growing sector (7.2%) that followed by transport (264.65 MBOE; 7%), industry (238.86 MBOE; 5.3%) and Agriculture (37.39 MBOE; 2.1%). Iran's ultimate energy consumption pattern over the last decades is inefficient and contributes towards the excessive consumption of fossil fuels which produces several quantities of pollutants and green house gases. Low price of energy and high subsidies represent an effective incentive for inefficient energy consumption pattern and accelerate energy consumption and environmental pollutions. The present paper provides a detailed analysis of the ultimate energy consumption in Iran by sectors during the last 10 years. We conclude that energy conservation policies by sectors are necessary in Iran and also the paper includes several suggestions for each sector to reduce energy consumption.

Key-Words: Iran, Energy Consumption, Transportation Sector, Residential and Commercial Sector, Industrial Sector, Agricultural Sector, Energy Audits.

1 Introduction

The process of economic development in the developing countries has involved a strong growth of energy demand over the last 50 years. As in most of the industrial countries, these countries had to reduce energy requirements due to rising energy prices following the energy crisis in the 1970s [1].

Jobert and Karanfi [1] studied a detailed analysis of the energy consumption in Turkey over the last 40 years. Their study investigates the causal relationships between income and energy consumption. Their findings suggest that in the long run, income and energy consumption appear to be neutral with respect to each other both at the aggregate and at the industrial level. They found contemporaneous values of energy consumption and income are correlated. Furthermore, a descriptive analysis is conducted in order to reveal the differences in the use of energy resources. They conclude that energy conservation policies are necessary for environmental concerns and their empirical results imply that such policies would not impede economic growth in the long term.

Ghisi, Gosch and Lamberts [2] surveyed electricity end-uses in the residential sector of Brazil. They assess the actual scenario of electricity consumption and estimate electricity end-uses in the residential sector of Brazil for different bioclimatic zones. Their research's results indicate that the largest end-uses are for refrigerator and freezer together, which account for about 38–49% of the electricity consumption in dwellings in Brazil. Air-conditioning and electrical shower are the end-uses that are more dependent on the climatic conditions.

Wing [3] studies conflicting explanations for the decline in U.S. energy intensity over the last 40 years of the 20th century. Decomposing changes in the energy–GDP ratio into shifts in the structure of sectoral composition and adjustments in the efficiency of energy use within individual industries reveals that while inter-industry structural change was the principal driver of the observed decline in

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aggregate energy intensity, intra-industry efficiency improvements played a more important role in the post-1980 period. Econometric results attribute this phenomenon to adjustments in quasi-fixed inputs particularly vehicle stocks, and disembodied autonomous technological progress, and show that price-induced substitution of variable inputs generated transitory energy savings, while innovation induced by energy prices had only a minor impact.

Pela et. al [4] describe the current energy sector in Ecuador, its present structure, the oil industry, subsidies, and renewable energy, focusing on the evolution and reform of the electricity sector. They proposed increasing the utilization of NG and renewable energies to meet Ecuador commitments to the Kyoto Protocol.

Along with the above studies, we feel that the survey of energy consumption by end use sectors and its variation during the last 10 years in Iran can be more efficiently analyzed. The main objective of this paper is to present an overview of the Iranian energy end-uses, in order to identify the potentials of improvement. These elements are needed for a better understanding of Iranian's energy problem and its current energy policies.

In Iran, Office of Energy Planning in Ministry of Power establishes an energy balance for Iran annually and recently Ministry of Petroleum decides to establish an annual hydrocarbon's energy balance for Iran. The data in the present paper are developed from an energy management group in International Institute of Energy Studies (IIES) that is establishing a hydrocarbon's energy balance for Iran in 2006.

The paper is organized as follows. At first we describe end-users sectors in Iran. Then we review historical consumption by sectors during last 10 years and analyze historical trends in each sector by fuel. Finally we present the conclusions of our study and discuss policy implications.

2 End-users by Sector

The residential and commercial sector has the most share of energy consumption in Iran. In year 2006, about 40 percent of total energy consumption in the country has been used by this sector. The basic energy carrier in this sector is natural gas, and other carriers, such as electricity, kerosene, gas oil, LPG and fuel oil are being used by this sector.

The transportation sector by about 26 percent of ultimate energy consumption has the second place, but from the economics point of view and value of total energy consumed in this sector, it stands in the

first place. Therefore, consideration on fuel conservation policies is of vital importance in this sector. The basic energy carriers in this sector are gasoline and gas oil, and other carriers, such as aviation fuels (ATK, JP4), fuel oil (for ships), LPG and natural gas (CNG) are being used by this sector. The industrial sector by about 23 percent of ultimate energy consumption has the third place. The basic energy carriers in this sector are natural gas, electricity and fuel oil, and other carriers such as gas oil, coal, LPG, kerosene and gasoline are being used by this sector.

The agricultural sector consists of some major subsets containing aviculture, husbandry, farming, floriculture, apiculture and culture of mushrooms, which greatly use gas oil as main fuel in this sector. Aviculture has the most important share of energy consumption in the agriculture sector. At last, this sector, with total consumption of 37.4 MBOE in year 2006 (about 4% of total), has the lowest share of energy consumption among other consumer sectors.

Figure 1 illustrates the trends of energy consumption by end-use sector in Iran from 1996-2006, and figure 2 illustrates share of energy consumption by end-use sector in Iran in 2006.
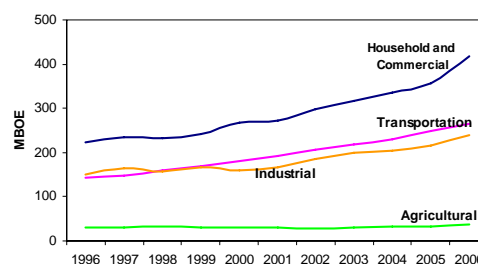

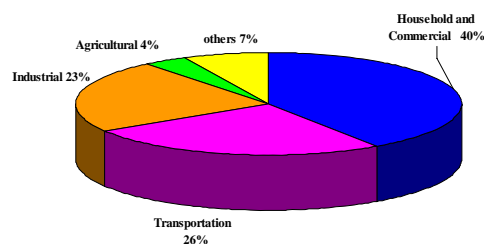Figure 1: Total consumption by end-use sector, 1996-2006 [5]

Figure 2: End-use sector share of total consumption, 2006 [5]

3 Residential and Commercial

3.1 Historical Review of Residential and Commercial Sector

Total energy consumption in this sector is 418.47 MBOE which has increased about 17 percent within last year. The most used energy carrier in this sector

is natural gas with total consumption of 287.41 MBOE which is almost 69 percent of total energy consumption. Consumption of natural gas is 25 percent more than the same amount in the last year. The next two important carriers in this sector are electricity with near 45.7 MBOE (11 percent of total) and kerosene with 41.7 MBOE (10 percent of total) of energy consumption, but the major difference between these two is the 13 percent increase for the first one and the 3.65 percent decrease for the next one in comparison with last year in the same sector. The other energy carriers which consist the remaining 10 percent of total consumption of this sector are gas oil (16.77 MBOE, 4.01%), LPG (13.86 MBOE, 3.3%), fuel oil (12.2 MBOE, 2.92%), gasoline (0.59 MBOE, 0.14%) and coal and traditional fuels (0.17 MBOE, 0.04%) [5].

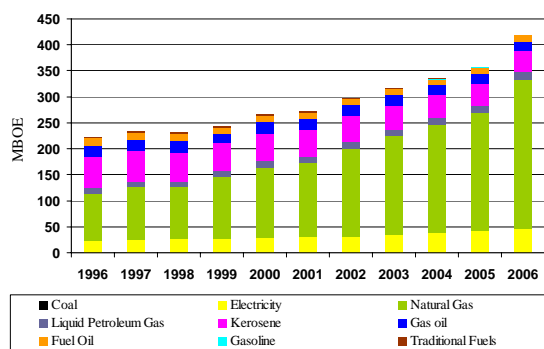Figure 3 illustrates the trends of residential and commercial energy consumption in Iran from 1996 -2006.

Figure 3: Residential and Commercial Energy Consumption by Fuel, 1996-2006, [5]

3.2 Analysis of Historical Trends of Residential and Commercial Sector

Great amount of energy loss in this sector is mainly related to the techniques of building construction and production methods of highly energy consuming devices, used in this sector. So, considering strict policies and strategies toward optimal use of energy in construction sector, such as using heat insulators and double layer glasses, sealing doors and windows and etc., is an essential need in the country.

Old production technologies for most energy consuming devices used in residential and commercial buildings and using heating devices in general, consuming a great share of energy consumption in this sector, has led to considerable low energy efficiency in this sector.

Although Iranian Fuel Conservation Organization (IFCO) has done several energy saving projects in this sector, residential and commercial energy

consumption per head in Iran is considerably greater than world standard.

Residential natural gas consumption has been increasing with average annual rate of 13.9 percent in last 10 years. It has increased from 12587 million cm[1] in 1996 to 40592 million cm in 2006. In the same period, the total number of houses under coverage has increased from about 4.5 million houses to some 12.5 million houses, with average annual rate of 12.1 percent. It shows that the consumption incremental rate has been relatively equal to increase of houses utilizing natural gas.

Natural gas is the cheapest available fuel for residential consumers. Historical review shows that the price of natural gas has always been at least 14 times lower than electricity price, regarding their heat values. Although the equipments which use natural gas as fuel are much less efficient than electrical home appliances, however, due to the ease of use and maintenance and also because of the low price of natural gas and such appliances themselves, they are more favored by consumers.

Commercial natural gas consumption has been 1881 million cm in 1996 which has increased to 6065 million cm in 2006, with the same average annual rate for residential sector. In 1996 natural gas has been 24.1 percent of total energy consumption in this sector, but it has risen to more than 45.5 percent in 2006.

Natural gas is mainly using for building heating and cooling systems, provision of warm water and cooking in both commercial and residential sectors. High efficiency and low price of natural gas has made it as the main fuel in this sector. Expansion of natural gas network all over the country in recent years has led to considerable decrease in LPG consumption, especially in cities and large counts and villages, and in case of a whole management, LPG market could be diverted to villages and small cities and counts which has no natural gas coverage. This wide presence of natural gas network has also led to decreasing trend of kerosene and gas oil consumption in this sector (replacement of instruments which use oil, gas oil or LPG with the same devices using natural gas).

Residential and commercial energy consumption has been increasing all over the 10 year under study period. The average annual incremental rate for first 9 years (1996-2005) has been some 5.5 percent, but 25 percent increase in natural gas consumption in this sector in year 2006 has led to a 17.2 percent increase of total energy consumption in the last year.

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[1] Cubic Meter

4 Transportation

4.1 Historical Review of Transportation Sector

Total energy consumption in transportation sector in 2006 year, reached to 264.95 MBOE which has increased about 6.05 percent within last year. The most used energy carriers in this sector are gasoline and gas oil with total consumptions of 146.45 and 104.27 MBOE which is almost 95 percent of total energy consumption in Iran's light and heavy duty fleets. Light duty vehicles (LDV) fleet constitutes 99% of gasoline consumption in transportation sector. The next two carriers in this sector are aviation fuels with near 7.36 MBOE (2.37 percent of total) and fuel oil with 3.5 MBOE (1.32 percent of total) of energy consumption. The other energy carriers which consist the remaining 1.28 percent of total consumption of this sector are CNG (3.22 MBOE, 1.22%) and LPG (0.15 MBOE, 0.06%). Consumption of natural gas was 77 percent more than the same amount in the last year due to current policies in conversion of public vehicle to CNG-fueled. The number of natural gas vehicles in Iran is 367000 (ranked 6th in the world) and we have 264 in-operation CNG refueling stations up to Oct. 2007. In the recent years, CNG implemented and developed as a major alternative fuel in Iran [5].

Figure 4 illustrates the trends of transportation energy consumption in Iran from 1996 -2006.
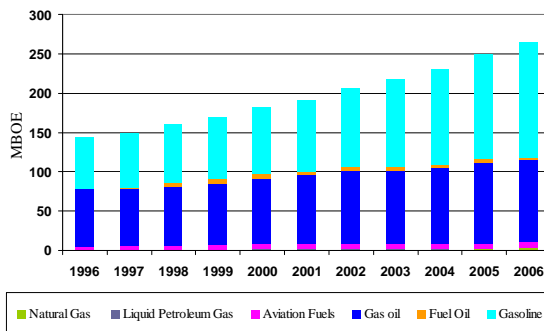

Figure 4: Transportation Energy Consumption by Fuel, 1996-2006 [5]

4.2 Analysis of Historical Trends of Transportation Sector

During the under-studying period (last 10 years), petroleum products consumption has experienced an average annual growth rate of 2.5% in Iran. Gasoline has maximum annual growth rate of 10%.

According to the performed researches [8], and based on the historical trends of gasoline, main causes of high gasoline consumption in Iran are as follows:

A. in Iran, price of gasoline is too low.

B. there is no policy for setting goals on fuel prices.

C. incompatible growth rate of sale prices with growth rate of international prices (imports), caused subsidies to increase sharply.

D. Iran's economy has intensive dependency on fuel prices which caused fear to higher price setting.

E. Automobile manufacturing has had large growth rates in the recent years and number of vehicles has increased.

F. the technologies of manufactured vehicles and motorcycles are too old, thus the average fuel consumption of most of the new-manufactured vehicles is too higher than same classes in other countries of the world (state-of-the-art vehicles).

G. new products can not pass the existing standards.

H. average age of Iran's LDVs is more than developed countries, whereas it has decreased in the recent years.

Some other effective factors that are not directly derived from historical trends analysis, whereas they are important, are as follows:

A. Undeveloped and weak public transportation.

B. Departure of rural inhabitants and increasing population of big cities that has resulted in increasingly transportation demand.

C. Lack of appropriate rules and regulations in order to decrease the number of single-passenger vehicles.

After gasoline, gas oil has a large amount of consumption with annual growth rate of 3%. For analysis of high gas oil consumption in Iran, it must be considered that this product is consuming in several various sectors like industrial, agricultural, power plants and transportation. Therefore we must consider all this sectors to extract main causes of tremendous consumption of gas oil.

Gas oil consumption in this sector is related to the diesel vehicles or heavy duty vehicles. Iran's HDV fleet is so old. Up to the end of 2006, there were 653648 diesel vehicles (122802 minibuses, 75602 buses, 455240 trucks) which more than 5% of them were over 35 years oil, 29% between 30-35 years old and 45% between 25-30. Average age of HDV fleet in Iran is 22.5 years, while this factor in European countries is 8 [5].

Cited statistics highlights the necessity of conservation policies to converting the old fleet to new and also fuel consumption criteria for HDV's and standard legislation in this context.

Increasing growth rate of gasoline consumption in the last decade, as it is mentioned before, has lead to need to a long-term planning in order to using an appropriate alternative fuel. Especially, regarding to current situation of average fuel consumption of light vehicles that is very higher than world norms

and standards, moreover, with respect to the fact that this gap is increasing, cited requirement becomes more appear and sensible.

Iran, by having more than 14.9% of the world gas reserves (27.5 Trillion m3) and widespread gas pipeline networks, has a very proper infrastructure for offering CNG as a clean alternative fuel for Iran's transportation system [5]. However because of low number of CNG vehicles in comparison with total number of vehicles, this conservation measure has not reduced gasoline consumption effectively yet. But the number of CNG vehicles in Iran is increasing and caused the consumption of natural gas in 2006 year be 77 percent more than the same amount in the last year in this sector.

5 Industrial

5.1 Historical Review of Industrial Sector

Total energy consumption in this sector is 238.86 MBOE which has increased about 11.08 percent within last year. About 23 percent of total energy consumption in Iran is contributed to industrial sector, which involves 26.11 percent of petroleum products, 59.23 percent of natural gas, 11.25 percent of electricity and 3.41 percent of coal.

The most used energy carrier in this sector is natural gas with total consumption of 141.47 MBOE which has increased about 18.81 percent within last year. The next important carrier in this sector is fuel oil with near 41.3 MBOE (17.29 percent of total). The other energy carriers which consist the remaining 23.48 percent of total consumption of this sector are electricity (26.87 MBOE, 11.25%), gas oil (18.68 MBOE, 7.82%), coal (8.15 MBOE, 3.41%), LPG (1.82 MBOE, 0.76%), Kerosene (0.36 MBOE, 0.15%) and gasoline (0.21 MBOE, 0.09%).

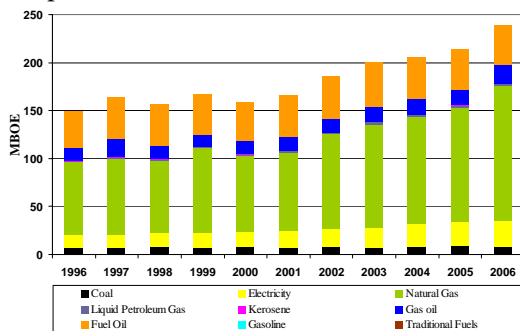Figure 5 illustrates the trends of industrial energy consumption in Iran from 1996 -2006.

Figure 5: Industrial Energy Consumption by Fuel, 1996-2006, [5]

5.2   Analysis of Historical Trends of Industrial Sector

The industrial sector plays a significant role in global energy consumption. Energy saving has been a crucial issue for sustainable development. The majority of processing industries still employ 1960's and 1970's technologies, thus making it somewhat difficult to procure and furnish corresponding infrastructural investment for productivity gains [9].

Currently the average yearly growth in industrial energy consumption is above 5%. In Recent years, there are different energy carriers used by different industries, mostly toward the fossil fuels. Portion of coal, oil products including kerosene, gas oil, fuel oil, and natural gas are changing due to governmental policies. The leading policy of government in order to replace natural gas instead of other energy carriers emerge great increase in natural gas demand in 2006, so that we had 30 percent gasoline, 7.7 percent coal and some 3 percent fuel oil decrease in comparison with last year in the same sector. Although consumption of kerosene had 24 percent increase in comparison with last year, the yearly consumption has been decreasing with average rate of 8.36 percent, along last 10 years.

As shown in figure 6 the group of refinery and petrochemical has the main energy consumption in industrial sector. Iron and steel is the second main consumer in this sector. The other main industrial consumers are brick, cement and food industry respectively.
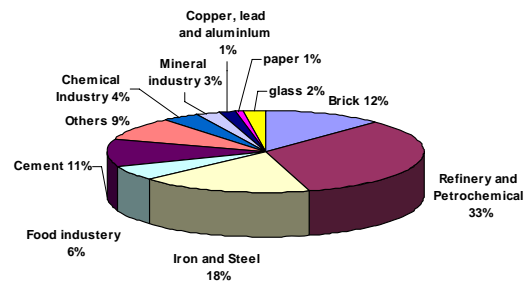

Figure 6: share of different industrial groups in total industrial consumption, 2006

SEC^2 is an important factor which determines the energy situation in a typical industry. The total amount of energy consumption and also the deviation of the SEC for each section from the world average provide adequate information for policy makers how to determine the priorities in industrial section.

As shown in Figure 7, the SEC of Iran has a great distance with the international standards. So, special attention is paid to the production of energy

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[2] SEC stands for Specific Energy Consumption

intensive materials, such as steel and cement. Brick and sugar factories have old technologies and need to special policies in order to upgrade their technological aspects. [9]
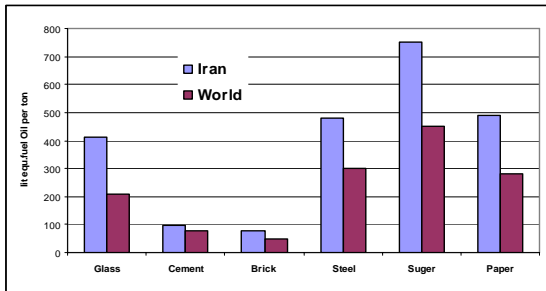

Figure 7: SEC of Iran in comparison with the world average [9]

6 Agricultural

6.1 Historical Review of Agricultural Sector

Total energy consumption in this sector is 37.39 MBOE which has increased about 20 percent within last year. The most used energy carrier in this sector is gas oil with total consumption of 25.64 MBOE which is almost 69 percent of total energy consumption. Consumption of natural gas is about 11.3 percent more than the same amount in the last year. The second important carrier in this sector is electricity with near 11.45 MBOE (30.6 percent of total) of energy consumption, which has increased about 18.3 percent in comparison with last year. The other energy carriers which consist less than one percent of total consumption of this sector are kerosene and (0.23 MBOE, 0.62%) and gasoline (0.07 MBOE, 0.2%) [5].

Figure 8 illustrates the trends of agricultural energy consumption in Iran from 1996-2006. As shown in this figure, the total energy consumption in this sector has been almost constant, except a light growth rate in last 5 years.
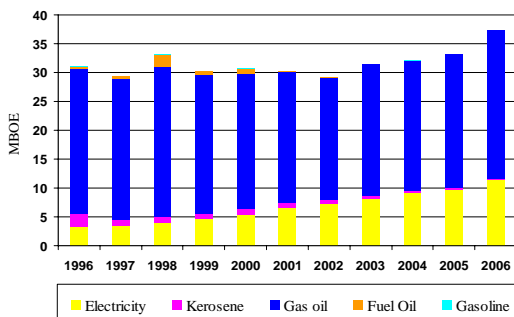

Figure 8: Agricultural Energy Consumption by Fuel, 1996-2006 [5]

6.2 Analysis of Historical Trends of Agricultural Sector

The main fuel in this sector has always been gas oil with almost 81.5 percent of total energy consumption in 1996 which is reduced to 68.5 percent of total in 2006. Gas oil is mainly using for aviculture, floriculture, animal husbandry and especially well pumps, but in recent years it has been replacing with electricity.

Share of electricity consumption in this sector has increased from 10.8 percent in 1996 to 30.6 percent of total energy consumption in 2006. It is because of the government strategy to replace agricultural gas oil consumption with electricity. With provision of fuel change conditions for farmers, they has also shown tendency toward this strategy. Growth of electricity consumption in this sector approves this idea. Kerosene has had a tiny share of energy supply for this sector but as consumption of kerosene has been decreasing in country and consequently in every sub sectors, it has decreased constantly all over the last years in the agricultural sector. Share of kerosene consumption has been less than 1 percent of total energy consumption in 2006. The average annual growth rate for the under-study period has been about 2 percent, but in the last year, 2006, the total energy consumption of agricultural sector had a considerable increase of about 12.5 percent which is unique and has not happened for at least 10 years before.

7 Conclusion

Total ultimate energy consumption in Iran was 1033.32 MBOE in 2006, and increased at an average annual rate of 6.02% in 1996-2006. Significant opportunities to control the rapid growth of ultimate energy consumption are removing energy subsidies and improving in generating efficiency and increasing productivity.

In 2006, energy subsidies amounted to IR 406787 milliards ($44.216 milliards).

Although the removal of energy subsidies would have a major impact on energy demand, without a comprehensive compensation package, the removal of energy subsidies would have a regressive effect, especially damaging the poorest part of the population.

The transport and residential sectors are the most heavily subsidized, accounting respectively for 37.31 percent and 20.47 percent of total subsidies and also they consume about 66 percent of total ultimate energy.

Household and commercial sector has been the fastest-growing sector since 1996 (7.2%) (followed by transport (7%), industry (5.3%) and Agriculture (2.1%)).

There are significant opportunities to reduce final energy consumption in the household and service

sectors via a reduction in energy consumption for heating, electrical appliances and lighting. In this sector, the use of minimum standards for new buildings and appliances, more wide-spread uptake of existing cost-effective measures (such as insulation and combined heat and power) and the provision of energy services and demand side management may be important to ensure that this potential reduction is realized.

Growth in transport sector accelerated over the last decade. Vehicle ownership has been increasing rapidly, but the efficiency of the vehicle fleet is very low by international standards. About two-thirds of vehicles in Iran are more than 15 years old. Pollution from vehicles in large cities is a serious problem. To reduce demand for refined products and lower air pollution, the government is seeking to introduce CNG-fueled vehicles. The price of CNG will be set at 40 percent of the price of gasoline, on a calorific-value basis to expanding the use of CNG-fueled vehicles.

The third ultimate energy consumer is industry. Refinery, petrochemical, iron, steel, brick and cement account 85 percent of total industrial energy consumption. The energy efficiency of industrial processes is well below the international average. The refining industry in Iran is generally old and inefficient and lacks conversion capacity. Most of the country's nine refineries are in need of modernization, which will require foreign investment and modern technologies. Advanced energy conservation technologies should primarily be applied to industries with large energy consumption and great energy conservation potential. Other major solutions for the industries include standardization, training educational programs as a long term program, tax, financial mechanisms for energy management, incentive programs.

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