Analysis of environmental emissions and greenhouse gases in Islamic Republic of Iran

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Abstract:- Concerns about energy consumption and consequential environmental impact in Iran has been raised in recent years. Iran's total emissions in 2006 includes 413.23 million tons of carbon dioxide, 2.18 million tons of carbon monoxide, 2.5 million tons of NOx, 0.75 million tons of SO_2, 2.26 million tons of residual hydrocarbons, 0.59 million tons of aldehydes and 0.32 million tons of dusts.
The present paper will study the energy consumption and various types of emissions in consumption sectors in Iran. Through analyzing the trends, it will identify technological bottlenecks and improvement opportunities in order to decrease environmental impacts associated with energy consumption. Introducing natural gas is the leading opportunity of Iranian energy infrastructure. In contrast, the following problems were identified and some solutions are proposed in this study. These challenges include transportation sector from technological point of view; low standard of different fuels such as gasoline, fuel oil and gas oil; Low price of fuels; lack of logical pattern to guide the consumption sectors and low efficiency of conversion equipment.

Keywords: - Environment, energy, household, transportation, industry, Iran

1 Introduction

Since energy production is extensively based on using fossil fuels, the environmental issues will become of great importance. The economical and environmental issues and obligations cause the industry to move toward better design conditions. On the other side, environmental aspects, energy intensity and economical viewpoints are integrated to each other which must be thoroughly considered in order to increase efficiency and decrease costs.
There have been several studies in different countries in order to assess the environmental impacts in various sectors.
Li has studied the economic and energy and environmental relationships of china up to the year 2030 [1]. An integrated econometric model consisting of macroeconomic sub-model, energy sub-model and environment sub-model was developed and used to perform a long-term simulation study for China. He concluded that for the sustainable development, more comprehensive measures should be adopted, including improvements in energy efficiency, more rapid energy switching from coal to natural gas and renewable energy sources, imposing carbon tax, development of clean coal technology, establishment of strategic petroleum stockpiling, enforcement of air protection, etc.
Shuichi and Toshihiko have been focused on emissions of residential sector released in Japan [2]. They examine the economics of energy-efficiency strategies, for reducing CO2 emissions in a residential sector in Japan, from the perspective of regional characteristics. The results show that, if half of the households use energy-efficient appliances, then CO2 emissions in the residential sector in the year 2020 will decreases from the BAU scenario of 0.726 Mt-C to 0.674 Mt-C.
A similar study, by applying the Long-range Energy Alternatives Planning (LEAP) system for modeling the total energy consumption and associated emissions from the household sector of Delhi, has been done too [3].
Cai et. al employed three scenarios based on the long-range energy alternative planning system (LEAP) model to simulate the different development paths in electricity sector in order to assess the CO2 emissions reduction potential of this sector [4]. They found that setting the year 2000 as the base year, the intensity reduction target could possibly range from 4.2% to 19.4%, dependent on the implementation effectiveness of various mitigation options.

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Junichiro et al. [5] evaluate CO2 emission reduction potentials and the minimum cost of technological options in the iron and steel sector by regions across the world. They modified a global energy systems model and two types of targets are studied; the top-down and the bottom-up type. Their cost-effective technological responses are obtained, and the emissions reduction effects are evaluated for the bottom-up targets.

Energy consumption has environmental impact on each system in which fossil fuels, the most consuming fuel in Iran's energy system, will release different emissions. The present study has been analyzed environmental perspective of energy consumption in Iran. Its analytical approach consists of different emissions, sectors, energy carries and leading factors affecting the above mentioned matters of interest.

The required data were identified and obtained from energy balance and annual reports relevant institutions.

The emissions is calculated for each section by multiplying the amount of fuel consumed in each section by the emission factor for that fuel to obtain the equivalent tons of emissions produced among different sections. The emission factors for each fuel was acquired and compiled from the department of Energy Information Administration (EIA) database and Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model [6]. Another project has been also done for estimation the emission factors which the results of that research are in good agreement with the available information in above databases. Experiments are done in cars, power plants and different industries, and agriculture information is estimated by comparing with the transportation sector, and residential and commercial by calculations using the type of fuel and efficiency of equipments.

2 Energy demand and environmental assessment

Total ultimate energy consumption in Iran was 1034.82 MBOE in 2006, and it has been increased with an average annual rate of 5.4% during the last decade (1996-2006). As shown in Fig. 1, Household and commercial sector has been the main consumer sector. The amount of energy consumption is 411.85MBOE while in the same period, the annual average growing rate is 6.3%. This trend is followed by transportation which the above indexes are 266.44 MBOE, and 6.3% respectively. Industry (212.23 MBOE; 3.6%) and Agriculture (36.32 MBOE; 1.6%) are the later groups in the total pattern of energy demand. [7]

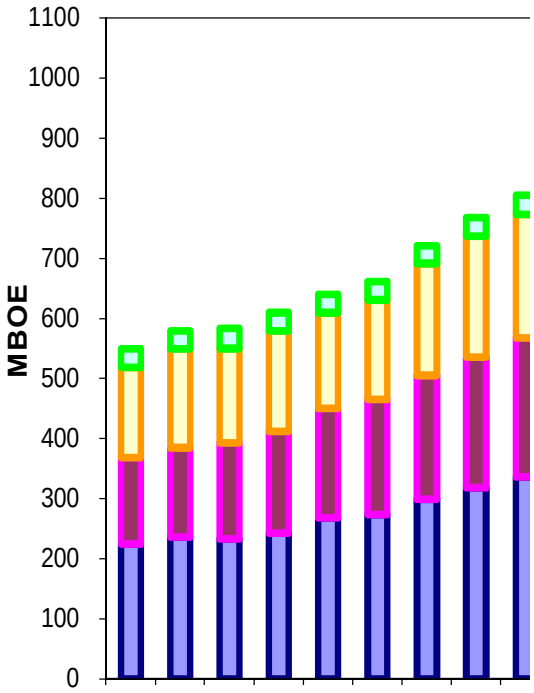

Fig. 1 Comparison of energy consumption in demand sector during the last decade [7]

During the last decade, energy consumption patterns show increasing behavior in all sectors. Due to the increase in population and development in urban and rural areas, and improve in the welfare level of the society, household and commercial section has been allocated the most amount of change to itself.

In the transportation system, the second energy consumer group, the number of cars, high consumption of produced cars and weak structure of transportation system such as roads, highways, and traffic control are the main contributors to its high consumption trend. The increase rate in industry and agriculture is more smooth and do not show much fluctuation. In these two latter ones the development is slower and the structure is very old and need to be considered seriously.

Several types of energy carriers are now available for internal market which approximately belongs to fossil fuels family and renewable energy is not considered seriously (Fig. 2).

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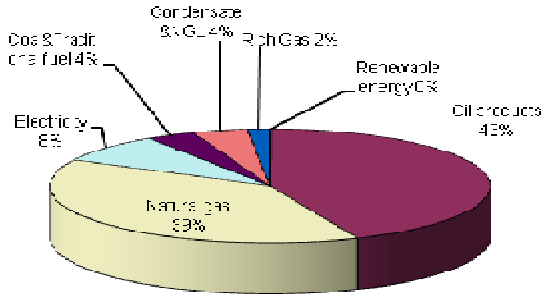

Fig. 2 Energy carriers contribution to each section, 2006 [7]

The most used energy carrier in Iran is oil product with total consumption of 449.79 MBOE which is almost 43 percent of total energy consumption in 2006. The next important energy carrier is natural gas with the total amount of consumption of 403.74 MBOE (39 percent of total consumption).
Because of high subsidies of government on internal fuels, the price of all hydrocarbon fuels are very low and easy accessible.
Another important change in energy structure as it is implied in Figure 3, has been started by introducing natural gas and development of distribution network and replacing it in the household and commercial sectors, and in industrial factories as a second fuel. The most advantage of this fuel underlies in its environmental characteristics which has less carbon oxides and other residual emissions than the traditional oil-based fuels.
Although some individual activities have been done in wind turbines and solar water heaters recently, but these technologies are not still economical in Iran.
Competition for land, forest and water resources and depletion of oil reservoirs and international sensitivity on environmental matters has increased as economic development has proceeded in Iran. Thus concerns about the environmental impacts from development have been given high consideration during planning especially with regard to the development of energy generation schemes.

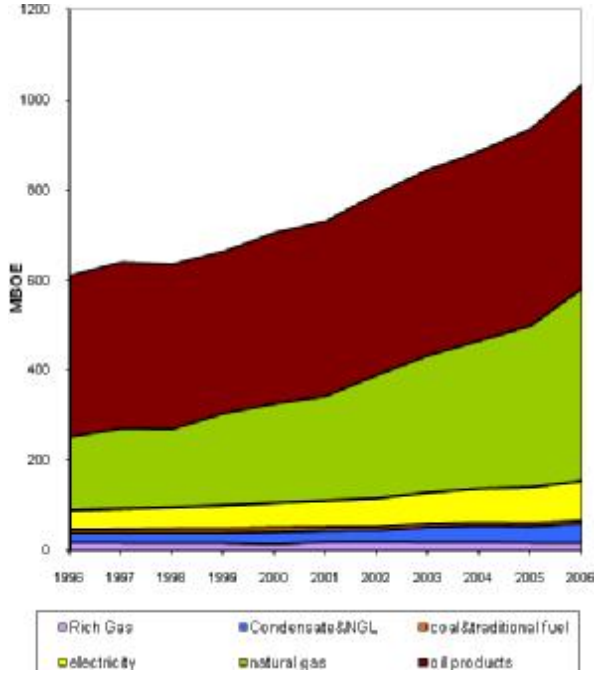

Fig. 3 The historical consumption trends of different energy carriers [7]

2.1 The carbon monoxide emission

Carbon monoxide (CO) is produced due to the incomplete oxidation of carbon during the process of combustion when any fuel is burned. Carbon Monoxide can poison slowly over a period of several hours, even in low concentrations. Sensitive organs such as the brain, heart, and lungs suffer the most from a lack of oxygen. High concentrations of carbon monoxide kill in less than five minutes. At low concentrations it will require a longer period of time to affect the body. Health impacts of carbon monoxide poisoning are fatigue, headache, dizziness, nausea, vomiting, disorientation and loss of consciousness.
Iran's total carbon monoxide pollutant in the year of 2006 was 2.18 million ton. As shown in Fig. 4, more than 90 percent of the carbon monoxide emissions come from transportation sector due to poor efficiency of transportation system. It consists of especially the technological aspect of cars and old standard of fuels (gasoline and gas oil specs). According to fuel demand increase in transportation sector, carbon monoxide emission has been ascending with average annual rate of 7.55 percent in last 10 years. It has increased from the total amount of 993867 ton in 1996 to 2057953 ton in 2006. Other sources of CO emissions are industrial boilers and incinerators, defective gas heaters and heating appliances.

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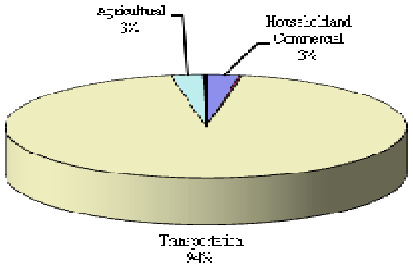

Fig. 4 End-use share of carbon monoxide emission, 2006 [7]

Fig. 5 illustrates trends of CO emissions by ultimate sectors in Iran during 1980-2006. Transportation sector has the fastest annual average rate in emitting CO (%7.6) while this rate for household and commercial sector has decreased (%-9.4) because of replacement of natural gas.

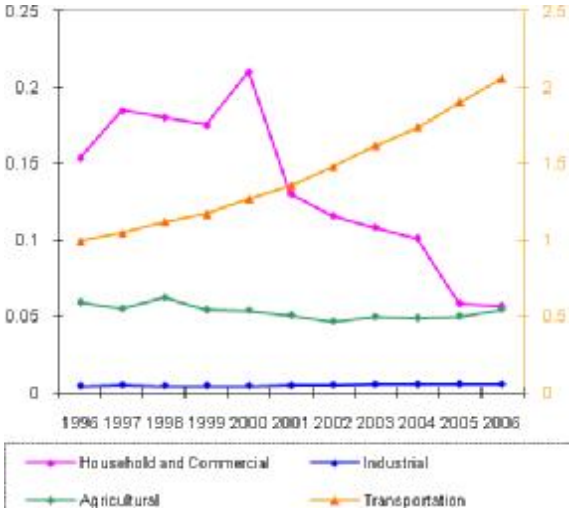

Fig. 5 CO emissions by ultimate sectors [7]

2.2 The carbon dioxide emission

Carbon dioxide is generated as a byproduct of the combustion process of fossil fuels. Carbon dioxide content in fresh air varies between 300 ppm and 600 ppm, depending on the location. It is dangerous when inhaled in high concentrations (50,000 ppm). Carbon dioxide ppm levels (CDPL) are a surrogate for measuring indoor pollutants that may cause occupants to grow drowsy, get headaches, or function at lower activity levels.

Iran's total carbon dioxide pollutant in the year of 2006 was 413.23 million ton which has been increasing with average annual rate of 4.8 percent in last 10 years. Fig. 6 illustrates share of carbon dioxide emission by end-use sector in Iran in 2006. All sectors except agriculture play a significant role in carbon dioxide pollutant.

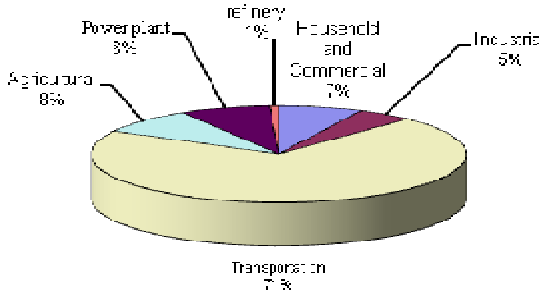

Fig. 6 End-use sectors share of carbon dioxide emission, 2006 [7]

Fig. 7 presents trends of CO_2 emission by ultimate sectors in Iran during 1980-2006. CO_2 emission has ascended with average annual rate 6.1, 4.3 and 2.7 percent in transportation, household and commercial and industrial sectors (especially power plants) respectively and has reduced about 0.7 percent in agriculture sector between last ten years.

The analysis of trend is similar to what has explained in section 2.1.

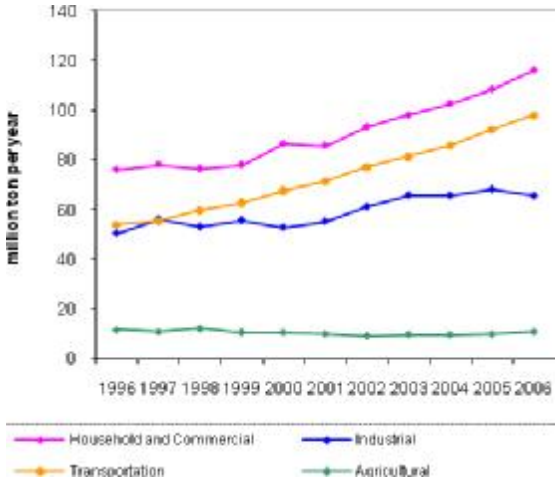

Fig. 7 CO2 emissions by ultimate sectors [7]

2.3 The Nitrogen oxides emission

Nitrogen oxides (NOx) are formed when nitrogen (N2) and oxygen (O2) are combined at high temperatures and pressure during the combustion of fuel. All fuels, such as gasoline, diesel, biodiesel, propane, coal, and ethanol, emit NOx when burned. Due to the many compounds that are a part of NOx (predominantly nitrogen dioxide and nitric oxide), the pollutant contributes to a wide variety of health and environmental problems. NOx is also a main component of

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ground-level ozone and contributes to global warming. NOx causes respiratory problems such as asthma, emphysema and bronchitis, aggravates existing heart disease and the other health impact are damage to lung tissue and premature death [8]. Iran's total NOx pollutant in the year of 2006 was 2.5 million ton which has been increasing with average annual rate of 4.6 percent in last 10 years. As shown in Fig. 8, about 70 percent of NOx emissions come from transportation sector, 8% from power generation (electric utilities) and the remaining 22% from industrial, residential, commercial and agriculture sectors.

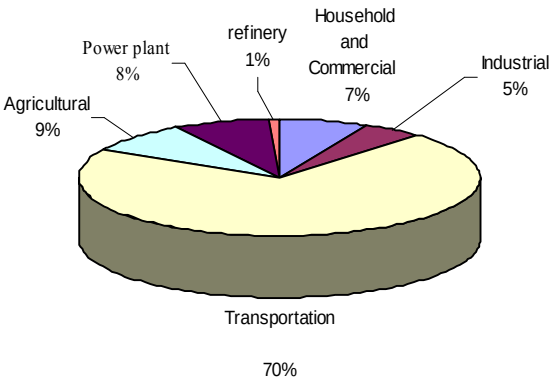

Fig. 8 End-use contribution of NOx emission by each section, 2006 [7]

Fig. 9 represents trends of NOx emission by ultimate sectors in Iran during 1980-2006. Transportation sector has the fastest annual average rate in emitting NOx (%5.8) while this rate for agriculture sector has reduced (% -0.76). This descending trend results from replacement of Gas oil with electricity.
The average annual rate in household and commercial and industry in NOx emission has increased 2.6 and 2.5 percent respectively during the period. [7]

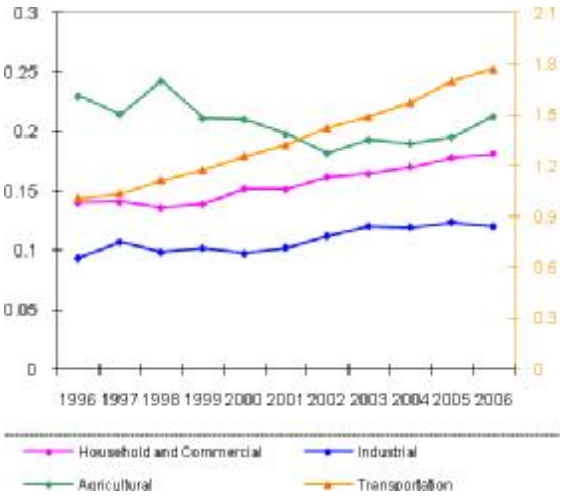

Fig. 9 NOx emissions by ultimate sectors [7]

2.4 The sulphur oxides emission

Sulfur oxides (SOX), mainly sulfur dioxide (SO2), is formed from the sulphur contained in raw materials such as coal, oil and metal-containing ores during combustion and refining processes. Sulfur oxides severely affect human health by affecting the upper respiratory system and the eyes. The effect is compounded when combined with particulates, which enter the respiratory system through the nose and mouth. Sox, which is toxic as well as soluble in water, is also deposited back to the soil in the form of acid rain when combined with water. Acid rain has destroyed lakes, forests, and has corroded buildings.

This emission has been released 0.75 million ton in 2006 with average annual rate of 0.3 percent in last 10 years. As shown in Fig. 10, because of high sulfur content of produced gas oil and fuel oil due to old structure of Iranian refineries, the factories and power plants are the major source of SO_x emission. There are some programs for reform in internal refineries in ten years.

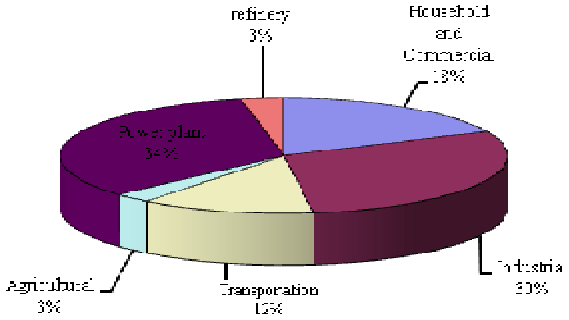

Fig. 10 End-use share of SOx emission, 2006 [7]

Fig. 11 implies trends of SOx emission by ultimate sectors in Iran during 1980-2006. Transportation sector has the fastest annual average rate in emitting SOx (%4.3), followed by industrial sector (the second group, %0.96) while this rate for household and commercial and agriculture sectors has descended with % -1.76 and % -0.76 respectively. [7]

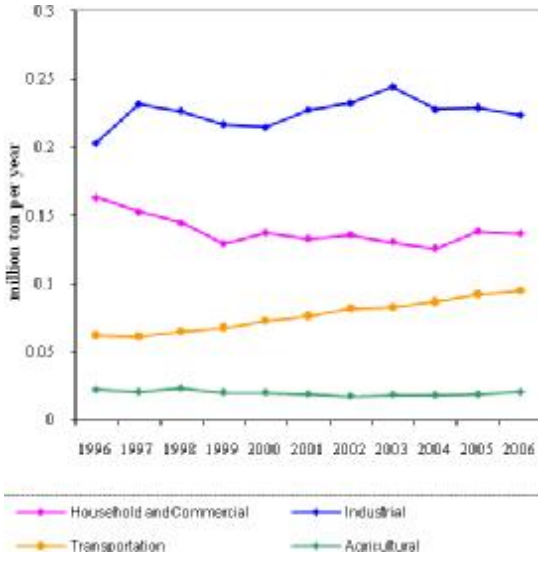

Fig. 11 SOx emissions by ultimate sectors [7]

2.5 The residual hydrocarbons emission

Most of the emission of hydrocarbon residuals is due to gasoline and diesel-powered automobiles as well as petroleum operations. They may cause respiratory problems as well as cause irritation of the eyes and nose. Furthermore, they are carcinogenic as well. By replacing gasoline and diesel vehicles with natural gas vehicles, hydrocarbon emissions can be gained reduction.

Total residual hydrocarbons pollutant released by energy sector in 2006 was 2.26 million ton which has been increasing with average annual rate of 6.7 percent in last 10 years. As shown in Fig. 12, more than 90 percent of the residual hydrocarbons emissions come from transportation sector. the combustion process in the car engines is not efficient, some hydrocarbon can not be converted to the products and will be released to the atmosphere.

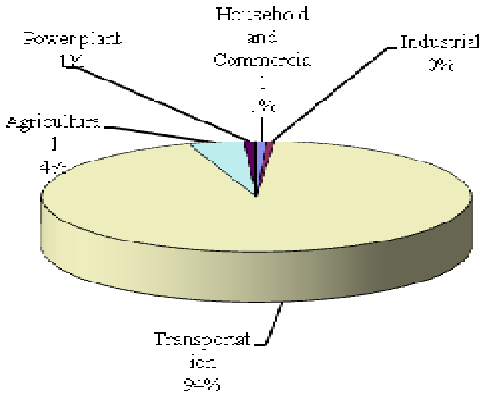

Fig. 12 End-use share of residual hydrocarbons emission, 2006 [7]

Also one can observe in Fig. 13 that transportation sector has the fastest annual average rate in emitting residual hydrocarbons (%7.3) that followed by household and commercial sector (%3.43) while this rate for agriculture sector has reduced (%-0.76). [7]

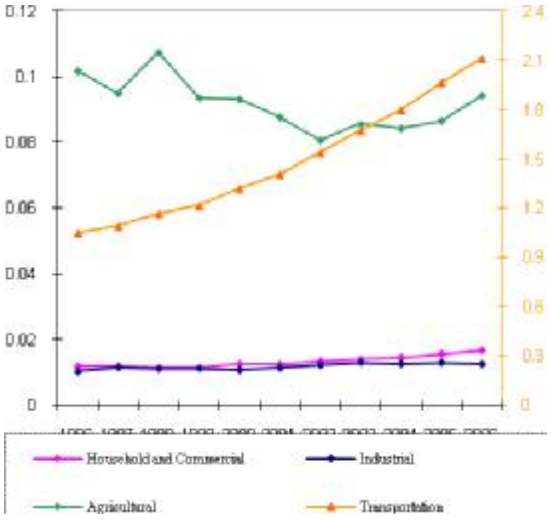

Fig. 13 hydrocarbon emissions by ultimate sectors [7]

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2.6 The aldehydes emission

Aldehyde is a secondary emission in which it is produced from the other pollutants such as CO and MTBE under specific conditions.

Aldehydes pollutant in the year of 2006 was 0.59 million ton. Average annual rate was 5.2 percent in last 10 years. As explicitly presented in Fig. 14, residential and transportation sectors are the main contributors in releasing this emission.

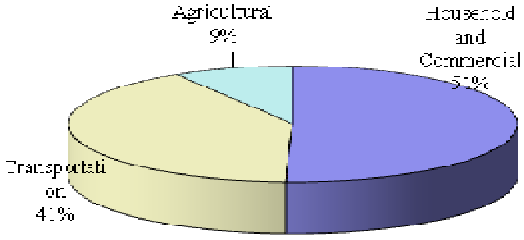

Fig. 14 End-use sectors share of aldehydes emission, 2006 [7]

Fig. 15 implies that household and commercial sector has the fastest annual average rate in emitting aldehydes (%8.2). It is followed by transportation and industrial (%3.95 and %3.46 respectively). This rate for agriculture sector has descended (%-0.76). [7]

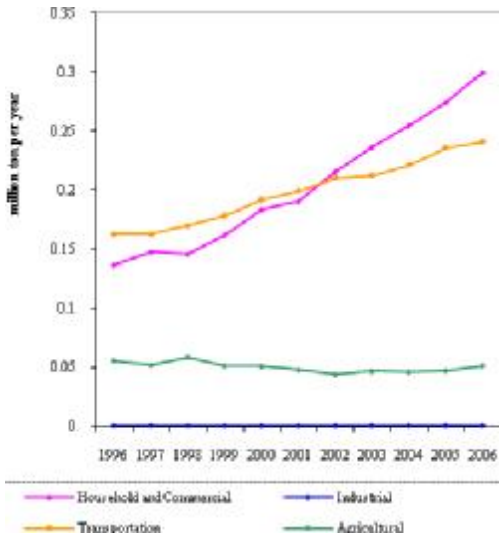

Fig. 15 aldehydes emissions by ultimate sectors [7]

2.7 The Particulates emission

Particulates are any dispersed matter, liquid or solid, in which the individual aggregates are larger than single gaseous molecules (0.0002 mm) but smaller than 500 mm. Examples of particulates include dust, resulting from agriculture and construction, and soot resulting from rich fossil fuel combustion Ash is also a particulate, resulting from naturally occurring metals in coal and oil that is released during combustion. Particulates are carcinogenic and may have synergistic effects when combined with SOx by entering the respiratory system. They may also be involved in the change of our global climate by reflecting solar radiation back into space, reducing the overall temperature of the earth, an effect which is not yet documented. One of the main anthropogenic sources of particulates is the combustion of fossil fuels, especially coal and oil.

Particulates pollutant in the year of 2006 was 0.32 million ton which has been increasing with average annual rate of 3.1 percent in last 10 years. It is implied in Fig. 16 that more than 80 percent of particulates emissions come from transportation sector.

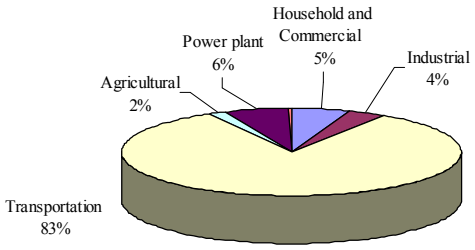

Fig. 16 End-use sectors share of Particulates emission, 2006 [7]

Fig. 17 illustrates trends of particular emissions by ultimate sectors during 1980-2006. Transportation sector has the fastest annual average rate in emitting particulars (%4.25) and followed by industrial sector (%2.36). This rate for household and commercial and agriculture sectors has reduced (% -5.53 and % -0.78 respectively). [7]

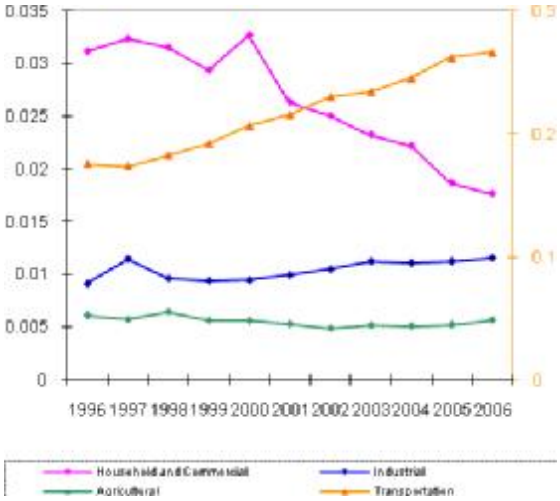

Fig. 17 Particulates emissions by ultimate sectors [7]

2.8 Macroeconomic index of emissions

During the last decades, all types of emissions has been increased as the fuel demand has ascended. Lack of comprehensive strategy in the environmental organizations, the slope of trend in recent years has being more and more.

Fig. 18 represents trends of various emissions per capita during 1980-2006. The residual hydrocarbon and carbon monoxide emission has had the fastest-growing emission trend slope as follow: 5.02% and 4.36% respectively. Also, CO_2 as the main pollutant has been increased a lot and the rate of change is rather high (3.11%).

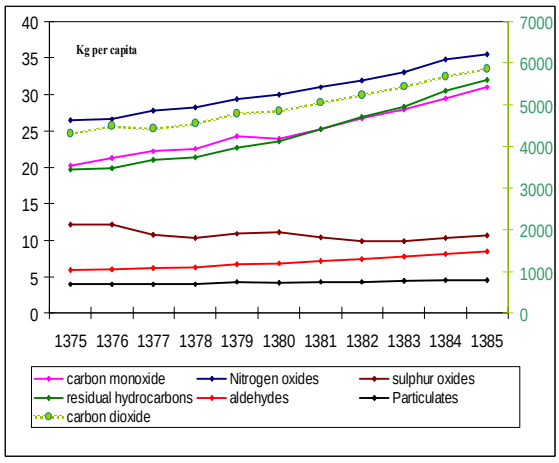

Fig. 18 Historical trends of various emissions per capita [7]

Another important factor affect the amount of pollutant is the degree of industrialization. As illustrated in Fig. 19, North America is the main contributor of CO_2 emission in 2005, and the Africa is the least contributor. Middle East is the fourth most pollutant among different regions.

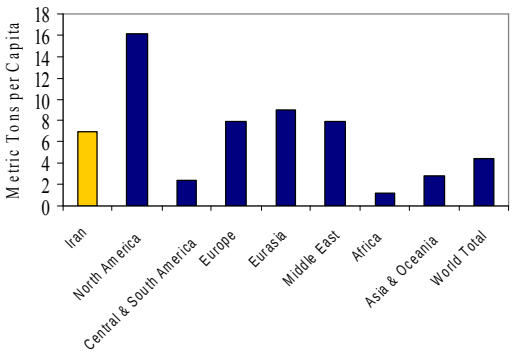

Fig. 19 Comparison of CO_2 released to the atmosphere in different regions [8]

As discussed above, degree of industrialization is one the important reason of increasing the environmental effects. The amount of produced CO_2 per capita has the greatest value for North America and least for Africa. Iran's CO_2 per capita is relatively high in comparison with other regions and this originates for the irrational use of fuels in energy structure while Iran belongs to developing countries and the structure needs to promote much.

The ratio of CO_2 emission per GDP corresponds to changes in energy intensity (energy per unit of GDP), and CO_2 intensity of the fuel mix (CO_2 per unit of energy). The following figure shows that 13.8% of change is observed in this index during 1990 to 2004.

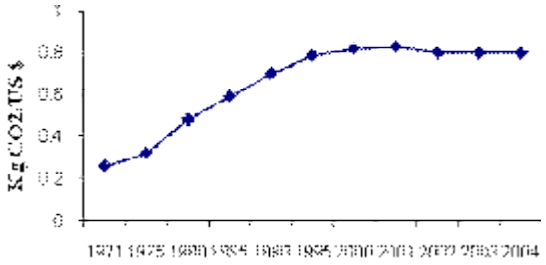

Fig. 20 CO_2 emissions per GDP using Purchasing Power Parities (based on 2000 prices and PPP), IRAN [9]

3 Remaining challenges and future strategies

Besides being more industrialized, the irrational consumption of hydrocarbon fuels has strong relationship with environmental impacts. Low efficiency of demand and conversion sectors is also considerable in Iran. In recent decades, debate on the environmental impact caused by international societies provides enough incentives

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for the agencies to consider environmental effects more.

As a result, greater importance has been ascribed to socio-environmental aspects in the planning of energy sector projects in terms of ensuring that Iranian environmental policy guidelines conform to national and sectional standards.

Therefore, environmental problems resulting caused by energy production, conversion and utilization take a great attention from public, industry and government.

In addition, there must be economic and social decisions need to be taken in order to incorporate the environmental issues adequately.

By considering all above mentioned points, the following results are inevitable:

a) Transportation sector has dominant effect in pollution. So the efficiency of cars from technological point of view as well as the structure of the system should be promoted.

b) Low standard of different fuels such as gasoline, fuel oil and gas oil is another important reason especially for the sulfur content and complete combustion.

c) Thermal power plants use fuel oil with high content of sulfur which has negative impact.

d) These non–standard fuels are produced in internal refineries which do not operate in optimal condition and their products do not have high quality. But by doing the development programs in future. It will be estimated that the products of refineries will be modified in order to reach the international standards.

e) Low price of internal fuels such as gasoline and fuel oil will encourage consumers to use more and more. So no logical pattern exists to guide the consumption sectors.

f) Energy improvement programs in industry, household, and power plant will result in significant effects in environment.

4 Conclusion

The present study emphasizes that energy consumption and environmental problems are integrated thoroughly. So, low efficiency of energy consumption sectors has negative effects in the other section.

Car factories in Iran require a technological revolution in which their efficiency must be increased and their environmental pollutants will reduced.

Energy policies must assure normal expansion of Iran economic system while, at the same time, reducing emissions and protecting the environment. This is no simple task since one comes at the expense of the other.

Energy conservation to increase energy efficiency is a major part of an effective energy policy. Efforts to conserve energy must be made by management regulations, incentives, technological transfer, technological service and education, and promotion by all sectors. Adjustment of fuel prices can also promote energy conversation by making people less reluctant to waste fuel. By reducing the amount of fuel burned to accommodate energy demand, emissions will be reduced. Fuel conversion from fuels with high carbon, sulfur, and metal content to fuels with low content is essential to cleaning up the environment. Power plants running on coal and oil are being converted to natural gas.

Technology advancement and research and development on new low emission techniques must also be part of a viable energy policy. Research has consistently brought outstanding results in lowering emissions.

New, innovative energy development should be the focus of energy policies. Solar energy, geothermal energy, and wind energy are some kind of renewable energy that the potential in Iran is available which they need to be cultivated to eliminate further damage to the environment.

It has been discussed that by economical development, increasing in the energy demand is associated and as a result the amount of pollutions will increase. The necessity of comprehensive environmental strategy with regard to energy sector and infrastructure of the country is obvious.

References

[1] Li ZhiDong, An econometric study on China's economy, energy and environment to the year 2030, Energy Policy 31 (2003) 1137–1150.

[2] Shuichi Ashina, Toshihiko Nakata, Energy - efficiency strategy for CO2 emissions in a residential sector in Japan, Applied Energy 85 (2008) 101–114.

[3] Rashmi Kadian, R.P. Dahiya, H.P. Garg, Energy-related emissions and mitigation opportunities from the household sector in Delhi Energy Policy 35 (2007) 6195–6211.

[4] Wenjia Cai, Can Wang, Ke Wang, Ying Zhang, Jining Chen, Scenario analysis on CO2 emissions reduction potential in China's

Manuscript received Sep. 7, 2007; revised Mar. 7, 2008

electricity sector, Energy Policy 35 (2007) 6445–6456.
[5] Junichiro Oda, Keigo Akimoto, Fuminori Sano, Toshimasa Tomoda, "Diffusion of energy efficient technologies and CO2 emission reductions in iron and steel sector", Energy Economics 29 (2007) 868–888
[6] http://www.eia.doe.gov/oiaf/1605/ coefficients .html
[7] Hydrocarbon's energy balance for Iran in 2006, energy management group, International Institute of Energy Studies (IIES).
[8] http://www.eia.doe.gov/emeu/international .html
[9] IEA statistics: CO2 emissions from fuel combustion 1971-2004, 2006 edition