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Opportunity of Natural Gas Resources for Countries to Reduce Carbon Emission: A Case study of Iran's South Pars Zone

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ABSTRACT

The intentional agreements against the climate change recommend the countries to utilize natural gas instead of other fossil fuels in order to reduce carbon emission and this is a good opportunity for the countries with large resources of natural gas to develop the industries in relation to natural gas products. Regarding the existence of the largest gas field in the vicinity of the Iran's South Pars Zone (SPZ), large gas refineries and ethane-based petrochemical complexes have been established in this region. In this paper, the appropriate strategies comprised of optimizing the energy consumption, recycling of waste plastics to manufacture second grade plastic by the aid of petrochemical facilities, conversion of the fuel system in the vehicles and investment on the renewable energies were investigated. Regarding the high demand for natural gas in the world, development of the industries, related to natural gas such as construction of LNG (liquefied natural gas) plants can increase the incomes by export and also aid the other countries to contribute in the carbon reduction plans.

1. Introduction

Climate change has concerned people in many countries and the authorities know that it is necessary to take fast and serious decisions against climate change. Regarding the fact on the dependence of climate change in the world to emission of greenhouse gases (GHG), the member countries of United Nations decided to devise action plans for reduction of GHG emission, so ratified international treaties against climate change such as Kyoto and Paris and decided to implement various strategies to reduce GHG emission. According to the findings of the researchers, urbanization and industrialization in the counties are two main factors for production of the GHG, knowing that carbon dioxide (CO_2) and methane (CH_4) have major influences, emitted by fossil fuel power plant, cement factories, steel and fertilizers industries [1]. Knowing that all industrial, agricultural and transportation sectors require energy,

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energy uses have been taken into account for 73% of the GHG emission in 2016 [1]. For the same reason, various international environment-concerned organizations investigate into the methods of production and consumption of the energy carriers by the countries, as well as the IEA (International Energy Agency) who monitor, control and report the amount of carbon emission by the countries. The international treaties for reduction of the carbon emission have defined some dates as the stations to evaluate the reactions by various countries, for example at 2030 and 2050, where the second one is known as the date for net zero emission, at which the amount of emission has been targeted to be equal to the amount of carbon consumption. To achieve net zero emission by 2050, the countries agreed to implement useful strategies, for example by less consumption of fossil fuels and investment on generation of renewable energies. The reports show more sever influence of climate change in the Middle East countries, for example in Iran, 97% of the country experiences drought condition and significant loss of agricultural products due to climate change [2]. Tabari et al. [3] reviewed annual range of temperature for some regions of Iran between 1966 and 2005, and demonstrated significant increase of temperature in last decades. A main defect by increase of GHG emission is reduction of precipitation, however these problems are more concerned when the climatic models show that the influence of climate change may last for decades and centuries [4]. On the other hand, the mismanagement for consumption of the freshwater resources has intensified the influence of deserting. For reduction of the emission in the country, Iran has ratified Paris agreement and the government targeted to increase the share of renewable energies by 5% of the total energy capacity, cut gas flaring by 90%, decrease energy consumption in the building sector by 5% and enhance the standards for manufacturing of the vehicles according to Euro IV [5]. Although these actions are seemed useful, the damages by the climate change seem larger than the influences of these plans. In such conditions, mitigation of more CO_2 emission, by considering the opportunities related to natural gas resources seems a vital option.

Regarding less emission of carbon-dioxide by natural gas when burning, equal to 70-75% of oil and 55-60% of coal [6], one of the main strategies to reduce carbon emission is related to replacement of oil and coal by natural gas to generate energy and for feedstock. The strategies of IEA for future of petrochemical industry named Clean Technology Scenario (CTS) to achieve net zero emission by 2050 [7], indicates this significance. These strategies are CCUS (carbon capture, utilize and storage) by share of 35%, conversion of feedstock from coal to natural gas by share of 25%, more efficient utilization of energy by share of 25%, plastic recycling by share of 9% and use of alternative feedstock by share of 6% [7]. So, it seems there is significant opportunities for the countries with large resources of natural gas. Fig. 1 shows the relation between these strategies to the opportunities for the countries with large resource of natural gas and related facilities. For the most significant factor as CCUS, by equipment of the natural gas plants with CCS (carbon capture and storage) facilities, the emitted carbon will be captured to be utilized for other purposes. Production of primary chemicals based on natural gas requires far less carbon capture. By ethane recovery from the natural gas, the required feedstock for the petrochemical plants can shift from oil and coal to ethane, so that in addition to less emission, more efficient energy is used for production of petrochemicals [8-12]. The recent studies [13, 14] show that the existing liquid steam cracking ethylene units are appropriate for recycling of the polyalkenes obtained by waste plastics, via the co-pyrolysis. According to CTS, it is necessary to find alternative feedstock to obtain carbon, displaced fossil fuels for production of products, for example production of carbon using bioenergy and electrolysis. The countries with large resources of natural gas can determine incentives for the

companies that invest on the R&D (research and development) to develop the industrial methods for production of alternative feedstock.

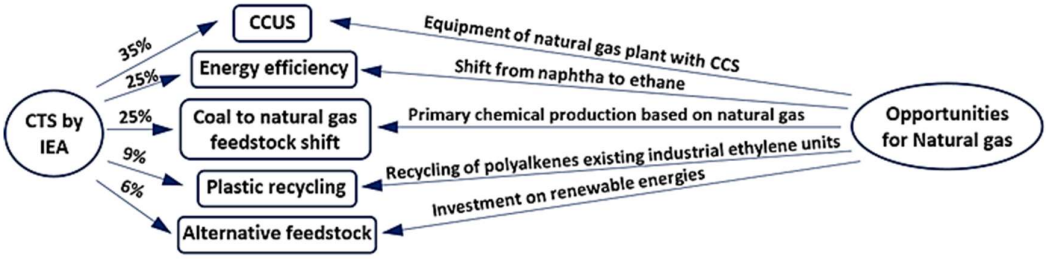


Fig. 1. The strategies determined by IEA and the related opportunities for the countries with natural gas resources

To explain the significance of R&D, it is enough to consider the change in the cost for production of renewable energies between years 2008-2020, according to Fig. 2 [15]. By the aid of new technologies, the cost of energy, generated by solar panels and wind turbines decreased even from that generated by fossil fuels. According to Fig. 2, the cost of energy, generated by solar panel and wind turbine decreased by 90% and 69%, respectively, between 2008-2020 [15]. Also Fig. 2 shows that the cost related to nuclear energy is the highest one. Although the Middle East countries own large resources of oil and natural gas and Iran stands in second place after Russia as the countries with largest resources of natural gas in the world, nowadays it is necessary to invest on generation of renewable energies regarding the high potential of the country in this sector, however a large problem for this plan is related to large subsidies paid by the government for the fossil fuels. Due to existence of cheap energy carriers and large subsidies by the government for the fossil fuels, there is not a serious plan to develop generation of renewable energies.

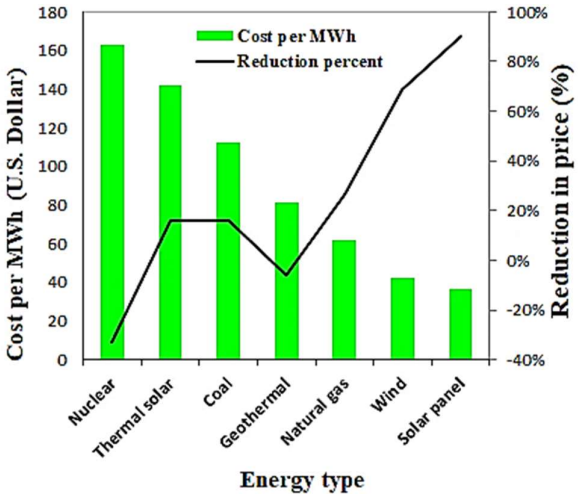


Fig. 2. A comparison for cost of energy, generated by various fossil and renewable fuels, beside reduction of price for each energy between 2008-2020 [15]

In the recent decades, Iran has developed the facilities for extraction of natural gas from the largest natural gas reservoir in the world, named North Gonbad, adjacent to the Iran's South Pars Zone (SPZ), in 24 phases which produce 75% of the total natural gas required by the country [16]. Fig. 3 shows the geographical location of this region beside the oil and natural gas reservoirs around the Persian Gulf. In addition to large refining capacity for natural gas, several petrochemical plants were constructed in this region to establish a special economic and energy

zone in the country. Although due to existence of these plants, a high amount of carbon is emitted in this region, regarding the consumption of natural gas for generation of energy and supply of feedstock by these plants, it seems that there are applicable methods for involvement of the industrial complexes in this region with the carbon emission reduction plans.

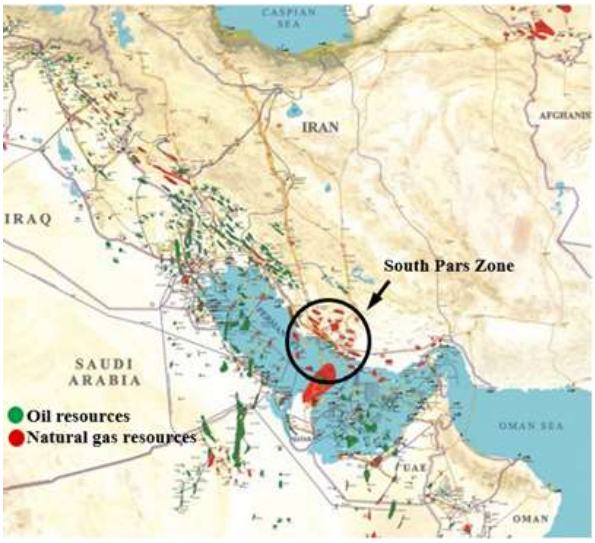


Fig. 3. Geographical location and fossil fuel resources around Persian Gulf

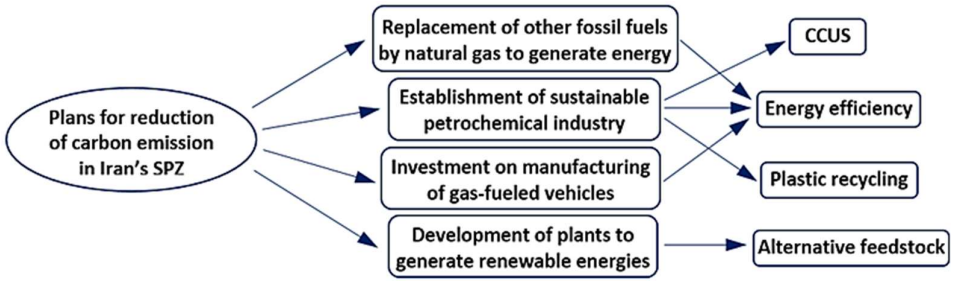


Fig. 4. The plans proposed in this study for reduction of carbon emission in Iran's SPZ using the opportunities existed for natural gas

In this paper, some of the potential plans to reduce carbon emission, suitable for the developing countries with large resources of natural gas are proposed. These plans not only can aid to reduce carbon emission by the country, but also provide appropriate conditions for expansion of products and exports related to petrochemicals. Iran's SPZ is seemed an appropriate region to be involved with these plans. Fig. 4 shows some of these plans, proposed for Iran's SPZ and relation of these plans to the main strategies by IEA, which are examined in details through this paper. After discussion on the plans, considering the available conditions in Iran's SPZ, in the last part of the paper, the geographical features of this location related to high solar irradiation and high speed of wind are examined to prove the high potential for generation of renewable energies in this region.

2. Replacement of other fossil fuels by natural gas to generate energy

Consumption of fossil fuels to generate energy accounts for more than 90% of the GHG emission in Iran [17], where 94% of electricity is generated using fossil fuels, though there is a low share for coal equal to 0.2%. There is a large share for natural gas to generate energy in the country equal to 65%, where 70% of the electricity has been generated by the same fuel in 2020. Regarding the low share for consumption of natural gas to generate electricity equal to 24%

in the world beside a large share of coal, compared to the large share of natural gas to generate electricity in Iran, there is a great advantage related to less emission of carbon in this sector for Iran, however the country is accounted for the 8th largest emitter of the carbon in 2018, due to less efficiency in consumption of energy by various sectors, which is investigated in the following.

Fig. 5 shows the amount of emissions by various sectors (with incomplete data for emission by land-use) in Iran between 1995-2016, compared to variation of GDP (gross domestic product) per capita. According to this figure, though in most part of the graph, GDP of the country increases according to the increase in amount of carbon emission, there is a larger rate for increase of emission, however in the latest part of this period, GDP decreases (partly due to sanctions against Iran) when the amount of emission is growing. According to Fig. 5, by increase of the emissions related to power, industry and building sectors, there is an inverse influence on GDP, which indicates low efficiency

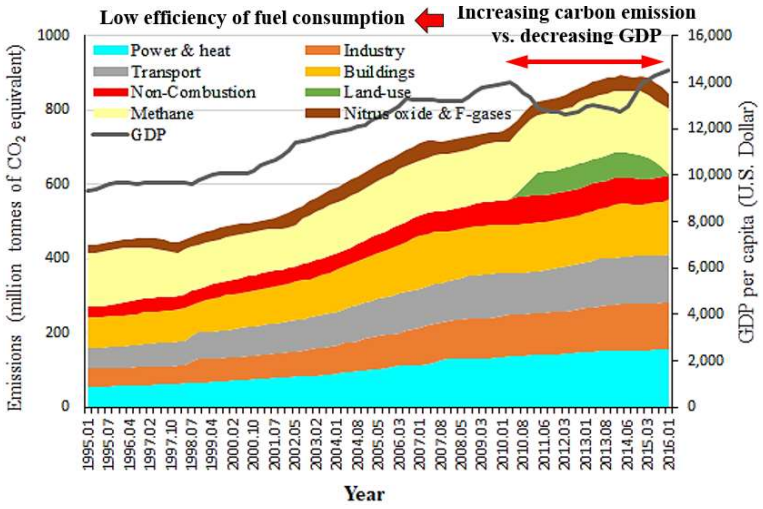


Fig. 5. Emissions by various sectors in Iran, compared to variation of GDP per capita [18-22]

of the energy consumption by these sectors. Although reduction of GDP in these years is partly attributed to reduction of exports due to Iran's sanctions, Fig. 5 indicates low efficiency of the industrial sectors and lack of long-term plans and enough finance to increase efficiency in energy consumption [23]. To understand the influence of the technology on reduction of emission, it is enough to consider the reports that indicates reduction of emission by industrial sector equals to 40%, by implementing new technologies for more efficient consumption of the fuel [24, 25].

The energy demand per capita in Iran is 100% higher than the global average [25] and 80% above the average for the Middle East [26], however there is no serious intention to decrease this consumption, considering that government pays the largest subsidies for fuel in the world [27]. The same vision has led in high consumption of energy by various sectors such as industries, construction and transportation instead of developing oil and gas products. With this regard, by the same rate for consumption of fossil fuels, it seems that there is no concern to reduce carbon emission by the industry [28]. Also, existence of old technology in the industry indicates low chance for reduction of fuel consumption by this sector [29], even though the government decides to reduce the subsidies for fuels. However, using the new technologies, the consumption in the petrochemical plants may be decreased considerably in the facilities, established in SPZ.

Due to existence of natural gas refineries and petrochemical plants in SPZ, this region causes gas flaring in the country according to Fig. 6, when some reports demonstrate that flaring accounts for 10%-19% of the total carbon emission

by Iran [30, 31]. According to Fig. 6, in spite of the large capacity in SPZ to produce sweet gas and petrochemical products, less gas flaring locations are seen in this region, compared to other flared gas around Persian Gulf. The World Bank follows a program to aid the countries for reduction of gas flaring, comprised of developing country-specific gas flaring reduction programs, however there are some barriers to follow this program in Iran. Reduction of flaring is accounted from the priorities in the federal plans to reduce emissions by the country. Regarding existence of tens of natural gas well in SPZ, the waste gas instead of flaring can be transported through pipes to the offshore facilities to be injected into gas wells to increase the amount of gas extraction, especially when due to increase of the gas extraction, the pressure of the well drops. Also there are good opportunity for the flaring gas to be used for production of methanol using modular conversion equipment [33]. With this regards, the last phase (phase 11) of the main project to develop South Pars Gas Field comprises of gas injection to reservoir to compensate pressure drop.

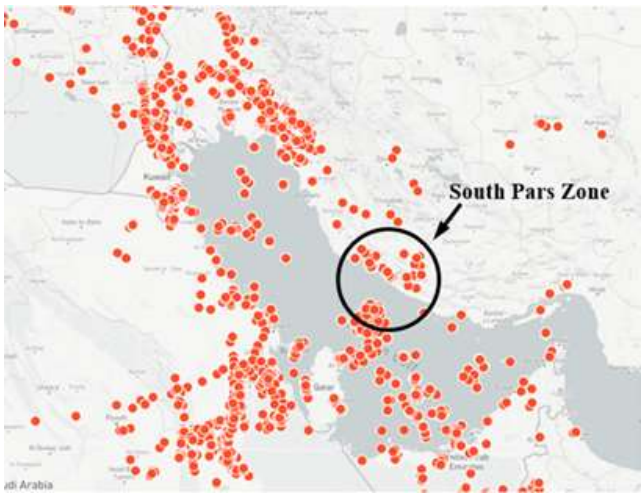


Fig. 6. Flaring locations in the regions around Persian Gulf in 2021 [32]

The above descriptions for emission sources of industry sector in Iran indicate lack of advanced technology to reduce consumption of fuels, especially when the largest part of energy is generated by natural gas, which is highly demanded in the international markets, so it is necessary for the government to apply advanced technology to increase the efficiency in consumption of natural gas and create opportunities to increase its export. Using the higher technologies, some countries with less resources of natural gas could dominate the market with related products. For example, Australia owning 1% of the natural gas resources, exports 18% of this fuel [34] and Qatar has employed the largest fleet of LNG (natural gas, liquefied) carriers in the world to export its natural gas worldwide. Fig. 7 shows the main exporter and importer countries for LNG. LNG is the world's 14th most traded product with $162B market value at 2021, by the share of 18.2% for Qatar with value of $29.6B and share of 23.1% for Australia with value of $37.5B. According to this figure, the Asian countries are the main customer for this strategic product however there is a growing demand for LNG by the world. Although there are some projects in SPZ for production of LNG, these is no capacity yet for this product in this region.

3. Establishment of sustainable petrochemical industry

A main emitter of carbon takes place due to production of petrochemicals, knowing that it has consumed 14% of the oil and 8% of the natural gas in 2016. As was stated, a main strategy by IEA to achieve net zero emission is related to recycling of plastics. Because knowing that the demand for oil is estimated to grow 10 times between 2017 and

2030, by the current rate the production of plastics is estimated to consume 20% of the crude oil in 2050 [35], however according to CTS, production of second grade plastics should reach a third of total plastic production. Also, another main strategy by IEA for a clean petrochemical industry is related to shift from coal to natural gas feedstock, so considering that the all hydrocarbons consumed by this industry in Iran comprise of 75% gas and 25% oil, in comparison to the higher consumption of this industry in the world based on oil and coal, the petrochemical products by Iran seemed to be accompanied by less carbon emission, however the large consumption of this industry is again related to high lower efficiency and high flaring, which require to be updated according to new technologies.

A main advantage of industrial facilities related to natural gas and petrochemical plants in SPZ is inclusion of water treatment units in these plants which enables to receive water required for process and cooling from the Persian Gulf, however the other petrochemical complexes in the country (such as hub of petrochemical complexes located in Mahshahr) use fresh water resources [16]. Petrochemical industry in Iran consumes just 8.7% of the total natural gas, produced by the country, comprised of 3.7% for feedstock and 5% for energy, however the second part of consumption may be replaced by renewable energies, especially when considering that by the aid of new technologies, the cost for generation of some renewable energies is less than for natural gas.

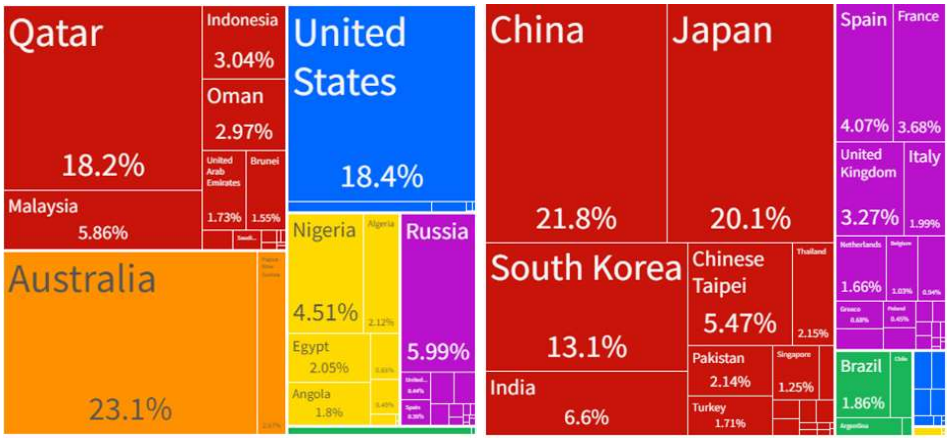


Fig. 7. (a) Main exporter countries for LNG, (b) Main importer countries for LNG [18] (data for 2021)

By equipment of the petrochemical complexes in SPZ with the CCS units, consumption of fuel can be reduced. Regarding the existence of some methanol plant in this region, the carbon dioxide, stored in the gas reservoirs may be exploited to increase production of methanol. Manufacturing of methanol by captured carbon dioxide using renewable energies obtain a net-zero fuel instead of fossil fuels for power generation achieving a carbon-neutral sustainability [26]. Also, the plastic recycling units can be added to these complexes, so by expansion of plastic recycling not only consumption of fossil fuels for production of virgin plastic decreases, but also further emission due to disposal of waste plastics is reduced. In spite of large amount of wastes emitted to oceans by Asian counties (equal to 81% of the total waste emissions to oceans), this disposal method in Iran is refrained, but instead, a large part of wastes is landfilled, which in turn, pollutes the water resources and space and occupies large lands. The rate of recycling for plastics is equal to 18%, considerably less than recycling rate for other materials such as paper and steel, because of expensive processes required for cleaning, sorting and omission of impurities. The rate of recycling can be increased by establishment of chemical units within the petrochemical complexes, to change polymeric

structure of the plastics to obtain optimum structure, required products. The government can determine tax incentives and other supports to motivate the large plants to constitute recycling units.

It is worthy to note that for production of second grade plastics, the melted waste material beside some amount of a virgin denser plastic is mixed in biaxial extruders to compose a homogenous plastic [35, 36]. For example, for recycling of HDPE, some virgin PP is added to produce the second grade HDPE. Table 1 shows the main petrochemical complexes in SPZ and Fig. 8 shows the main products by these complexes in MTY. As shown in Fig. 8, there is a minor production capacity for LDPE in the region, so production of second grade LDPE seems a good offer, applicable to produce plastic bags and second grade PE pipes. Also knowing existence of a high demand for polystyrene in the construction industry, supply of appropriate waste plastics to produce second grade polystyrene seems good.

Table 1. Main petrochemical complexes in Iran's SPZ with main products, illustrated in Fig. 8

Pardis	Zagros	Boushehr	Marjan
Noori	Mehr	Kavian	Farsa shimi
Pars	Jam	Jam-Etminan	Entekhab
Arya-Sasol	Morvarid	Takht-Jamshid	Hemmat

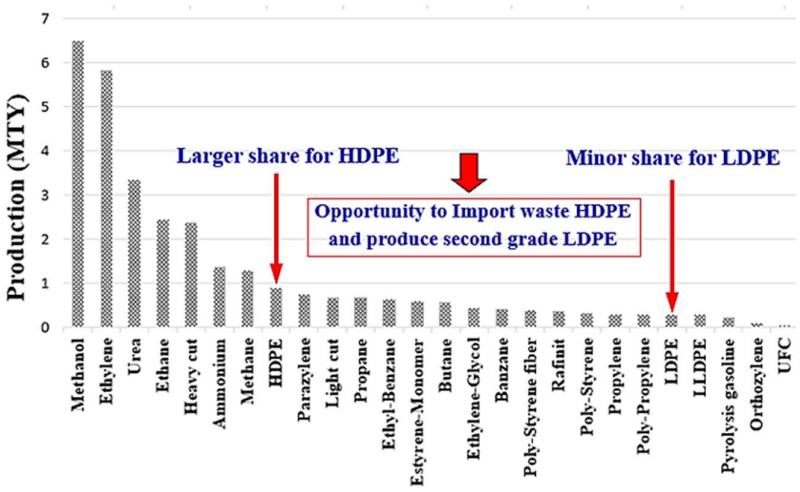


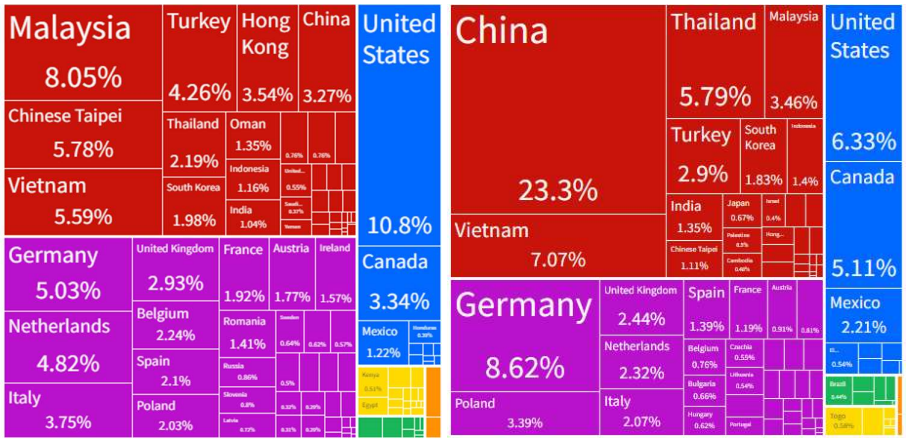
Fig. 8. Essential petrochemicals products by large complexes in SPZ, listed in Table 1 [37]

Nowadays, trade of waste plastics has a large market volume worldwide with various materials, so the countries can choose their required plastics according to the stock. Fig. 9 shows the main importer countries in the waste plastic market. The largest importers of waste plastics are Malaysia, Chinese-Taipei and Vietnam. By appropriate selection of a waste plastic stock from this market, some countries with less hydrocarbon resources like Thailand, Vietnam and Turkey, using second grade plastics produce plastic products such as bags and sacks of ethylene polymers according to Fig. 9(b).

4. Upgrading of vehicles by gas-fueled and efficient systems

Transportation sector is a main emitter of GHG emission, and it was blamed for 16.2% of the GHG emission and 56% of the oil demand in the world, in 2016. So, the vehicle manufacturers try to decrease the fuel consumption in the vehicles, by employing more efficient engines or decrease the weight. So for example the manufacturers in USA

try to decrease weight of the vehicles by 30% and 50% in 2030 and 2050, respectively [38]. Another remedy is replacement of fossil fuels by renewable ones as applied in the electric vehicles.



(a) (b)

Fig. 9. (a) Main importer countries for waste plastics, (b) main exporter countries in the market of bags and sacks of ethylene polymers [34] (data for 2020)

High emission of carbon by transportation sector in Iran, which equals to a fifth of the entire emission [39], indicates low efficiency of the vehicles in consuming fuels, however due to low price of the fuels, high consumption of the vehicles is neither concerned by customers, nor by manufacturers of the vehicle. Inefficiency in fuel consumption takes place when high amount of various pollutants emitted by the vehicles creates many problems and diseases against the health of people. So the government has some plans to reduce emission of pollutants by this sector such as manufacture of natural gas fuel vehicles, upgrading the public transport fleet, promotion of policies for urban traffic management and making mandatory regulations for manufacturers to implement European standards for fuel consumption [40]. There were around five million natural gas vehicles in Iran in 2019, which achieved second place in number of the natural gas fueled vehicles after China. Due to less price of natural gas, especially by increase of the price of oil and gasoline, many logistic fleets, shippers and public transit systems plan to convert the engine of their vehicles to be compatible with natural gas fuel.

CNG (Compressed natural gas) and LNG can also be used in aircrafts and ships to decrease both carbon emission and fuel cost for transportation. Due to its more efficiency for long distances, LNG is offered for heavier and suburban vehicles, however CNG is offered for those used for within-state transition. Due to existence of large complexes for refineries and petrochemical plants in SPZ, large road and marine transport fleets exist in this region which cause large emission, however based on supply of enough natural gas in the region, the government can make useful regulation in favor of natural gas fueled vehicles. Regarding the large consumption of tankers from fossil fuels, there is an international trend by ship building companies to manufacture LNG fueled ships and tankers. Fig. 10 shows the increase in the manufacturing of LNG fueled ships, compared to the total number of ships manufactured between 2000-2014 [41]. Iran possesses the largest tanker fleet in the world and can reduce the carbon, emitted by this sector, through conversion of the fuel system in the oil tankers to the LNG fueled systems.

5. Development plants for generation of renewable energies

Fig. 2 indicated that using higher technologies, the price for some of renewable energies decreased even less than the price of fossil fuels. The geographical location of Iran indicates its high potential to produce renewable energies, for example considering large number of sunny days beside high irradiation increases the efficiency for production of solar power [42, 43], and enough speed of wind to produce electricity by wind turbines, however the nation encounters some difficulties for development of renewable energies such as lack of expertise in related technology and enough financing, that has limited the share of non-hydro renewable energies to 0.1%. In the recent years by experiencing reduction of precipitation and less efficiency of the hydro-power facilities, the significance of other renewable energies has been better understood. Fig. 11 shows high potential of SPZ to develop renewable energies, considering high solar irradiation and high speed of wind, beside great potential to exploit from thermal solar energy.

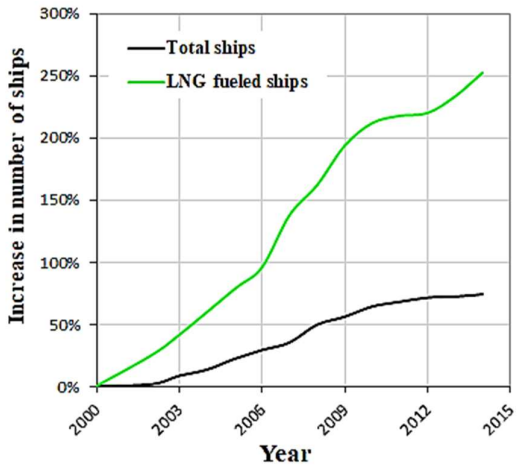


Fig. 10. Number of LNG fueled ships manufactured between 2000-2014, compared to the total number of ships [41]

A main reason for less attempt of developing countries with large fossil fuel resources, is related to high subsidies given by government for the fossil fuels and expensive price for generation of renewable energies [44], so neither industries, nor people are not motivated to replace fossil fuels by renewable ones. On the other hand, the sanctions have created barriers for the country to receive financial and technical supports from the developed countries and there is no serious attempt to decrease high consumption of energy in the domestic sector. Recent increase of international price for fossil fuels, rationalizes development of renewable energies for the countries, when recent progression of technologies has decreased the cost of renewable energies.

6. Summary and conclusion

Climate change has caused sever influences in many countries in the last decade, through increase of temperature or increase of the natural disasters such as flood and drought in the Middle East countries. Researchers demonstrated that emission of GHGs mainly influences on the climate change, by a large share due to consumption of fossil fuels. So, one of the main plans for reduction of carbon emission, recommended by international organizations concerned with climate change is replacement of other fossil fuels by natural gas to generate energy or provide feedstock for industrial plants, regarding the less emission of carbon by this material. With these regards, existence of natural gas resources for the countries provides a significant opportunity to implement carbon emission reduction plans in parallel with the main strategies by IEA.

(a)

(b)

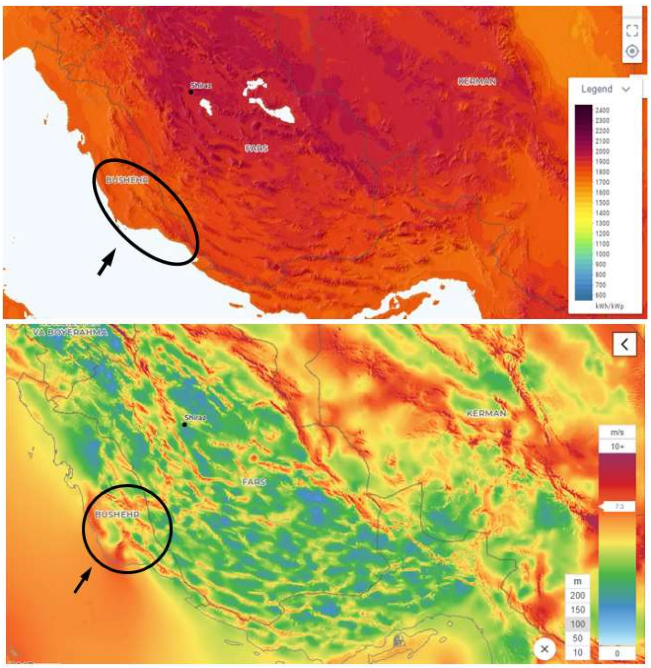


Fig. 11. Effective parameters to estimate potential of renewable energy generation in SPZ, (a) horizontal irradiation [41], (b) mean wind speed [42]

In Iran's SPZ, as the closest region of the country to the largest natural gas field in the world, large gas refineries and petrochemical complexes have been established which use natural gas as the fuel. In this paper, various plans for reduction of carbon emission in this region, related to optimization of energy consumption by the industrial facilities, recycling of waste plastics, reduction of carbon emission by transportation sector and investment on the renewable energies were proposed. The results of the study are summarized in the below.

- Lower increase of Iran's GDP, compared to escalation of carbon emission related to consumption of fossil fuels in the last decades indicates low efficiency of fuel consumption by the various sectors, especially by the industry sector. To compensate this shortcoming, it is necessary to upgrade the industries using new technologies to decrease fuel consumption.
- Regarding the Iran's position as the second country with largest resources of natural gas and particular significance of this fuel, called as the future fuel, it is necessary to develop the midstream and upstream industries related to this product. For example, regarding the low share of Iran in the market of LNG and its high international demand, the government must invest on the construction of related plants and facilities in Iran's SPZ.
- There are large petrochemical complexes in Iran's SPZ which use natural gas for generation of energy and supply of feedstock. Development of natural gas/ethane-based petrochemical complexes instead of oil/naphtha-based plants is in parallel with the main strategies by IEA to reduce carbon emission.
- Omission of the large subsidies by the government for gasoline and other diesel fuels may motivate the owners of large vehicles such as oil tankers to upgrade their vehicles with gas-fueled systems and contribute in reduction of carbon emission.
- Regarding the high potentials in Iran's SPZ for investment on generation of renewable energies, and main strategy of IEA related to replacement of the fossil fuels by renewable energy carriers, it is necessary to invest

in development of related facilities such as installation of wind turbines and solar panels. Progression of the technology in the recent years which has reduced the price for generation of renewable energies rationalizes investment by the government in this sector.

Nomenclature

SPZ	Iran's South Pars Zone	IEA	International Energy Agency
LNG	Liquefied natural gas	CTS	Clean Technology Scenario
GHG	Greenhouse gas	CCUS	Carbon capture, utilize and storage
CCS	Carbon capture and storage	GDP	Gross domestic product
R&D	Research and development	CNG	Compressed natural gas

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