Feasibility Study of Carbon Dioxide Capture from Power Plants and other Major Stationary Sources and Storage in Iranian Oil Fields for Enhanced Oil Recovery (EOR)

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Conclusion/Summary

Conclusions

This study shows that carbon dioxide capture and storage is feasible for Iran for several reasons:

1. There are large stationary sources of carbon dioxide emission at reasonable distances from Iranian oil fields.
2. The production of many oil reservoirs has been depleted, which require enhanced oil recover (EOR) for both domestic use and export.
3. There are suitable reservoirs with respect to the type and capacity for CO2 injection and storage in the area.
4. Of the total CO2 emission of 4.8 million tons in Ramin power plant near the city of Ahwaz in south-western Iran, about 3.92 million tons (81%) can be captured and stored in Ahwaz oil fields.
5. Our estimate shows that EOR can significantly improve the economy of the project with additional benefit if the avoided CO2 emission can be traded or sold as a Clean Development Mechanism (CDM) certified emission reduction (CER).

Introduction

The Iranian on-shore oil fields have experienced an annual depletion in productivity between 9 to 11 percent which can be enhanced by secondary or tertiary recovery. Considering that most of the reservoirs are of the carbonated fractured type containing heavy crude, the selection of the optimum secondary or tertiary recovery method is of great importance. In 2004 the total recoverable oil reserve of Iran was 136.99 billion barrels out of the total reserve of 580 billion barrels. The reducing trend of production of some of the southern oil fields of Iran is shown in Figure 1.

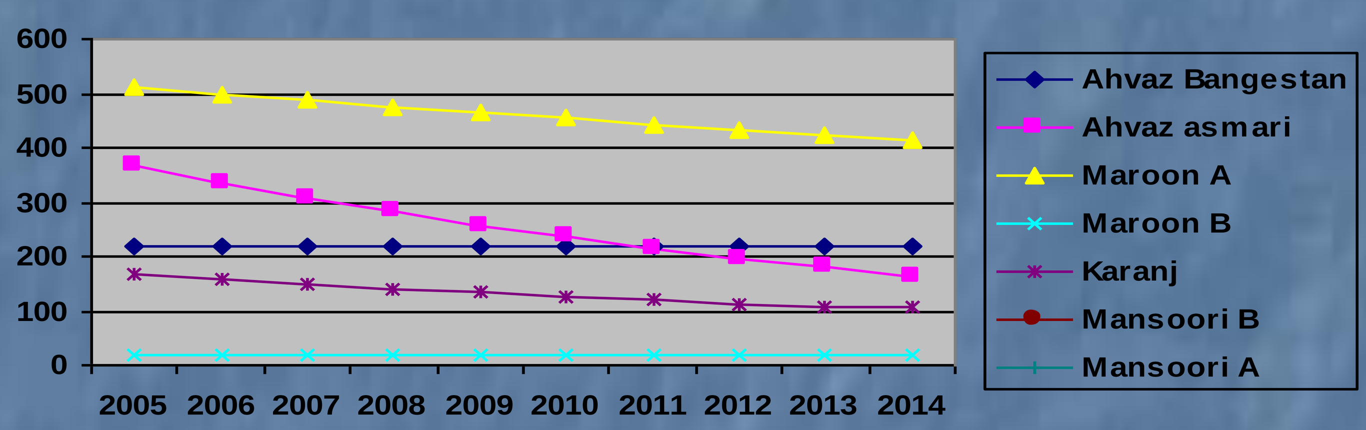

Fig1-The reducing trend of production of southern oil fields of Iran(1000 bbl per day)

Trend of CO2 emission from stationary sources in Iran

The emission of CO2 from the energy sector of Iran has had a sharp increasing trend in recent years. The emission of CO2 has increased from 240.36 million tons per year in 1994 to about 381.9 million tons per year in 2005, showing a growth of 58.8 percent in a decade. In 2005 the power generation and industrial sectors alone have contributed to more than 40.5 percent of the total CO2 emission. In this year emission from power plants was about 95.793 million tons and emission from steel, cement and chemical industries was about58.937 million tons. Figure 2 shows the emission trend of CO2 in power plants from 1994 to 2005.

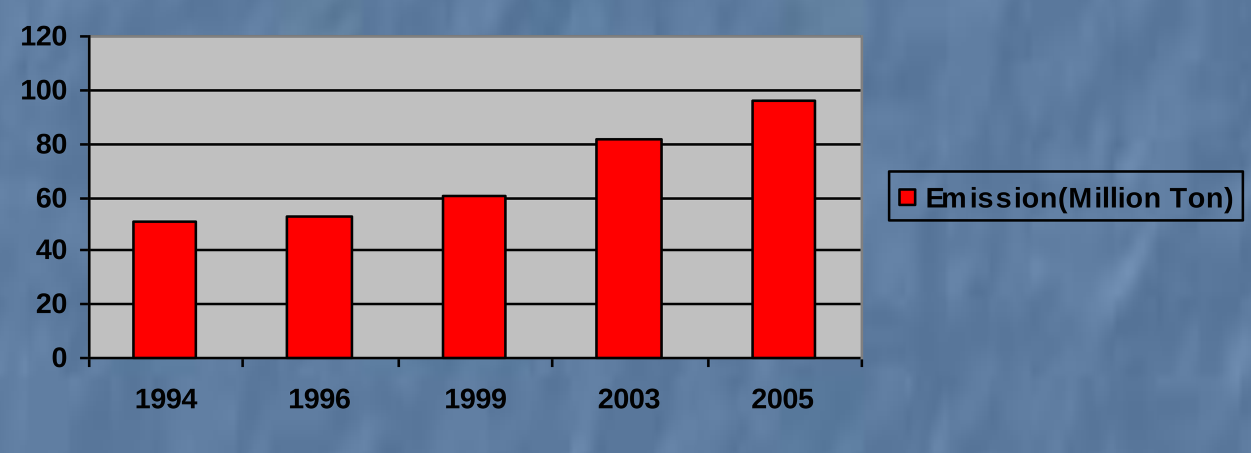

Fig2- CO2 Emission trend from Iran power plants 1995-2005

It can be seen from Fig. 2 that the average annual growth rate of CO2 emission has been 7.9 percent compared with the overall growth rate of 7.2 percent in all sectors. It is anticipated that with this level of growth rate the emission of CO2 from power plants in 2025 will reach 247 million tons per year and the overall emission of all sectors will reach 930 million tons annually, which are alarming figures.

Geographical distribution of sources and sinks

Thermal power plants and large stationary sources such as steel, cement and chemical industries which have hydrogen plants are the major sources of emission that are considered in this study. Since the information on power plants were readily available and these sources have major contribution to CO2 emission, in this feasibility study quantitative analysis was focused on this sector; other sectors were discussed qualitatively only.

Figure 3 shows the geographical distribution of major stationary sources with emission of more than one million ton per year in Iran. From this figure it can be seen that in south-west of Iran and near the Persian Gulf there is favorable proximity between sources of CO2 and sinks for injection of CO2 for the purpose of Enhanced Oil Recovery (EOR).

Fig 3. Geographical distribution of major stationary sources in Iran. Red squares indicate the power plants and the purple areas indicate the oil fields.

Suitability and selection of reservoirs for CO2 injection

In the site selection for injection of CO2 the miscibility of the gas with oil is of great importance. Compared with the miscible case, in the immiscible case the amount of C7+ , well depth, well pressure and temperature are of less importance. The immiscible ones are also more suitable for heavy oils whereas for oils with API gravity of more than 25, the miscible ones are advantageous.

In order to assess the suitability of reservoirs of the Khuzestan Province in south-west Iran where most On-shore reservoirs are located, information of 11 reservoirs were collected and it was found that 5 of them are suitable reservoirs for CO2 injection with respect to the type of reservoir and the distance to major sources of CO2 emission.

Other information such as the in-situ amount of oil, production capacity, reservoir's porosity, thickness of the core, area of the reservoir, oil viscosity and density, reservoir pressure, saturation water, the amount of carbon dioxide and hydrogen sulfide and the heavy hydrocarbons were also investigated.

The efficiency of oil displacement increases as the initial saturation of oil increases. It is therefore recommended that the saturation of oil should be more than 30% for CO2 EOR to be effective. Among different reservoirs that were under study, Ahwaz reservoir has higher saturation and thus a good candidate for CO2 injection. Viscosity of oil in most of the reservoirs under investigation was suitable for CO2 injection except three of them which have too small viscosities for this purpose. Based on this screening step, the volumes of all suitable reservoirs were estimated, and from the information on the reservoir porosity and oil saturation the maximum amount of carbon dioxide that can be stored in these fields was calculated. The effective volume of the reservoir, UPV, was calculated from:

$$UPV = QV. (Si - So)$$

Where QV is the total volume of the porous medium, Si is the initial saturation index and So is the final saturation index. Among the reservoirs under the study, Ahwaz reservoir has the highest free (effective) volume. Our estimate shows that, this reservoir with porosity of 0.14, initial pressure of 5700 psi and initial saturation of 0.4 can store up to 1,400 million tons of carbon dioxide. Ahwaz area's major Bangestan reservoirs are located in the vicinity of the city of Ahwaz in south-west of Iran. These reservoirs have been explored in the period from 1958 to 1968. Production from these fields started in 1971 and since then about 100 wells were drilled in that area. These reservoirs consist of Ilam and Sarvak formations which are mainly of carbonated type with very limited fractures. Thus most of the produced oil comes from the reservoir matrix. Initial pressure of this reservoir was more than 5500 psig. At this high pressure, miscibility condition would be achieved even by injection of relatively dry gases which indicates that in further development of these fields miscible gas injection should be considered. In 2005 the amount of natural gas for injection in this field was 11.173 million cubic meters per day, whereas only 2.653 million cubic meters of associated gas was available in the nearby fields. Considering the expansion project planned until 2020, the associated gas available for re-injection will be approximately 5.44 million cubic meters per day; which is far below the amount needed for EOR as mentioned above.

Case Study

Ramin power plant near Ahwaz was selected as the source of CO2 and the Ahwaz oil fields were selected as the storage site to study the feasibility of CO2 storage for EOR. Ramin power plant which is located at 25 kilometers north-east of Ahwaz, contains 6 units of 350 MW steam turbines with the total nominal capacity of 1890 MW and the actual capacity of 1748 MW. The thermal efficiency of the power plant is about 37.2%. The plant consumes 70,000 cubic meters of natural gas per hour which produces about 4,8 million tons of CO2 per year. Two pictures of this power plant is given in Figure 4.

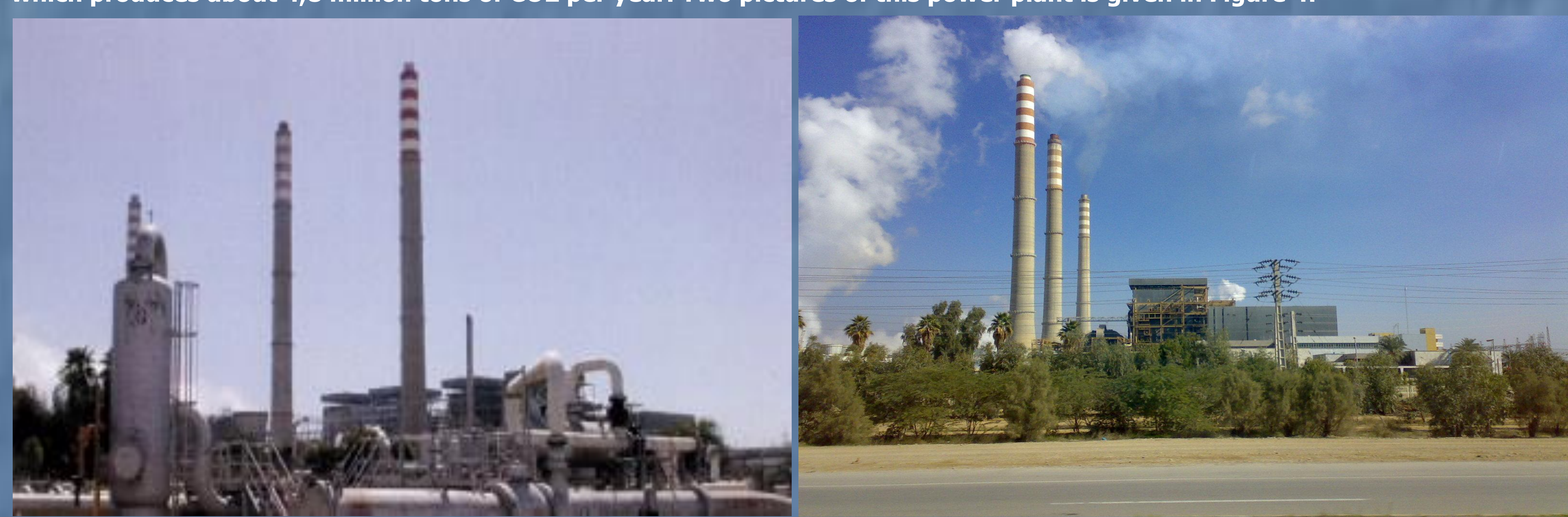

Figure 4. picture of Ramin power plant near Ahwaz

The amine absorption plant using MEA solvent with the feed supplied by the power plant was simulated by a suitable software. This plant ~~was designed for a capacity of 149.6 million cubic meters~~ per day. A ~~compression~~ station to supply the pressure needed for transport of CO2 and to provide the necessary pressure for re-injection was also designed for this feasibility study . Figure 5 compares the capacity of capturing plant for Ramin Power Plant with the capacity of other natural gas refineries of Iran.

CO2 flow rate :178.6 Ton/hour
CO2 purity :more than 98%
Plant capacity:149.6 MM cubic meter day

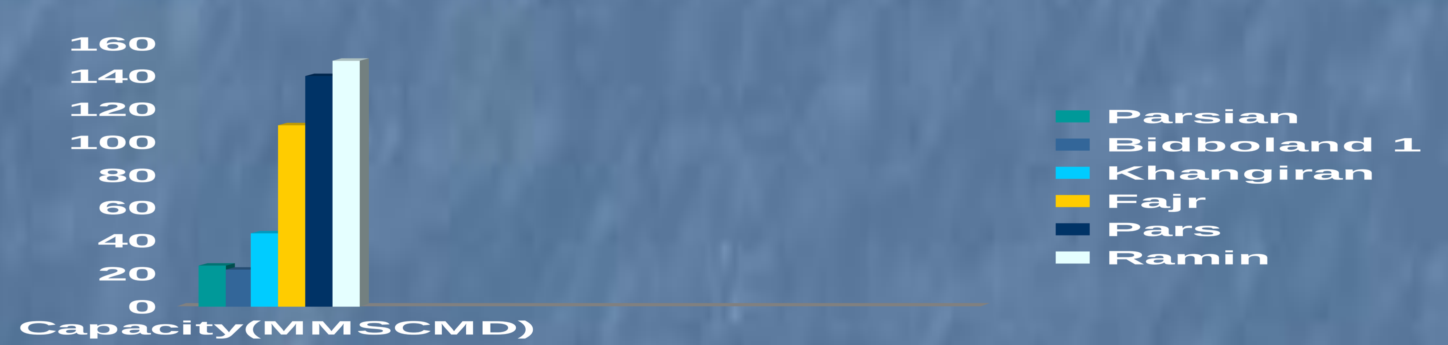

Figure 5. Comparison of the capacity of Ahvaz capturing power plant with the total natural gas refining capacity of Iran.

Economic Evaluation of the Project

It is estimated that the cost of separation, transport and injection of CO2 will be around millions US$1,071.7. This cost does not take into account the benefit gained from EOR nor does it take into account the environmental benefits as a result of CO2 emission avoided. Several scenarios for the price of oil per barrel were considered including: $ 28, $ 35, $ 45, $55 (IEA price model for September 2008), $77 and $85 (the average 2008 price). For the two scenarios of EOR of 20,000 barrels per day and 33,600 barrels per day which are based on the current practice of EOR with natural gas injection, the seven scenarios assumed for the price of oil as mentioned above and with two options of "with" and "without" carbon trading or CDM, our estimate shows that the rate of return of the investment varies from 1 to 6.5 years. At the current price of oil ($85) and without carbon trading, the rate of return is only 1.06 years.