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Carbon Capture & Storage Deployment in Iran

Zoya Banan[a,]*, Abbas Maleki[b]

[a] Department of Energy Engineering, Sharif University of Technology, Azadi Str., Tehran, Iran
[b] Department of Energy Engineering, Sharif University of Technology, Azadi Str., Tehran, Iran

Abstract

Based on International Energy Agency studies, achievement of 450 ppm CO2-equivalent emission target in global emission means that the CO2 emissions in 2050 must be reduced to %50 of 2005 level, and this implies that a portfolio of emission reduction policies and strategies need to be exploited through current century.
At the present time, Carbon Capture and Storage (CCS) Technology is a dominant strategy among all the long-term carbon abatement strategies in many countries. Nevertheless, its potential as a climate mitigating option will be proved, only if it is implemented in the countries which are developing at a great pace and taking advantage of fossil fuels in order to afford their energy demands. As regards Iran is ranked as the eighth great CO2 emitter country worldwide, it is quite a qualified option for CCS implementation as an emission mitigation solution.
In this essay, first of all, an analytical framework is expanded which is covering the evaluation of CCS deployment determinants in Iran. At the second step, barriers against deployment of this technology and also, the required solutions and policies are discussed. Finally, three scenarios for CCS development process in Iran are depicted on the basis of IPCC Emission Scenarios (SRES), considering the aforementioned policies. By means of these scenarios, contribution and deployment status of this technology in the oncoming Energy System of Iran will be assessed.

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Keywords: Climate Change, Greenhouse Gas Emission Abatement Policies, Carbon Capture & Storage (CCS), Iran, Scenario Processing;

1. Preface

In 1992, public concern for climate change issue resulting from emission of greenhouse gases in atmosphere, leaded to establishment of United Nations Framework Convention on Climate Change in New York, US. The main goal of this convention can be found in its Article 2 which is stabilization of greenhouse gas concentrations in the atmosphere at a level that prevents the human interactions in climate system. According to Energy International Agency studies in Energy Technology Perspectives in 2010,

* Corresponding author. Tel.: +989128024886;
E-mail address: banan@energy.sharif.ir.

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achieving this goal need the reduction in CO_2 emissions in 2050 so that it reach to half of this gas emissions in 2005, and otherwise, CO_2 emissions will be doubled by 2050 [1]. Achieving this goal requires a great revolution in energy technologies and taking advantage of low emission technologies [2].

Besides, utilization of efficient systems and substitution of current industrial equipments with efficient ones cause great costs and also, renewable technologies are still not well developed and commercialized. So, as long as it is costly to use renewable energy technologies and efficient energy system, gas turbine will be dominant systems in power generation operations and fuel oil is the main fuel in cement and steel industry. This lead to continuity of fossil fuels dependency and therefore, greenhouse gas emissions. For at least half a century abandon using the fossil fuels will not be the solution for the greenhouse gas problems and this means that methods for taking advantage of fossil fuels without releasing CO_2 must be developed.

Carbon Capture and Storage (CCS) is a mitigating approach for CO_2 emissions and has greatly been attached to fossil fuels combustion. Also, EIA studies show that CCS can afford %20 of required aforementioned emission reduction. Therefore, it is necessary to use CCS technology for supporting the emission reduction efforts.

CCS capability in mitigation of climate change will be proved only if it is implemented in developing countries which are greatly dependant to fossil fuels in affording their energy demands, along with developed ones [3], see Fig 1. So, it is important to evaluate Iran conditions and features, as a developing country in Middle East, for implementation of CCS as a GHG emission mitigating option.

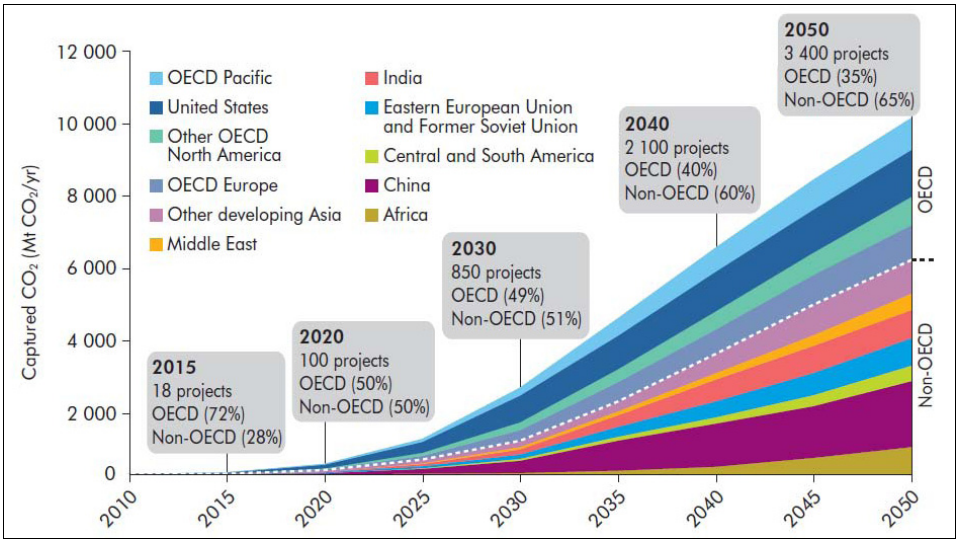

Fig. 1. CCS development roadmap [2]

2. Iran Status for Carbon Capture & Storage Technology Diffusion

Deployment of CCS technologies is highly affected by market-specific factors. These factors provide exclusive conditions which directly influence the pace and extent of diffusion and development of this technology. These factors can be classified as follow: 1) national supply and demand for energy, 2) national CO_2 emission, and 3) national potential capacity for CO_2 storage [4].

Growing carbon dioxide emission trend has been depicted in Fig 2. The related data for CO_2 emissions in Iran show relative growth rate of %64.4 in 2009 compared to emissions in 2000.

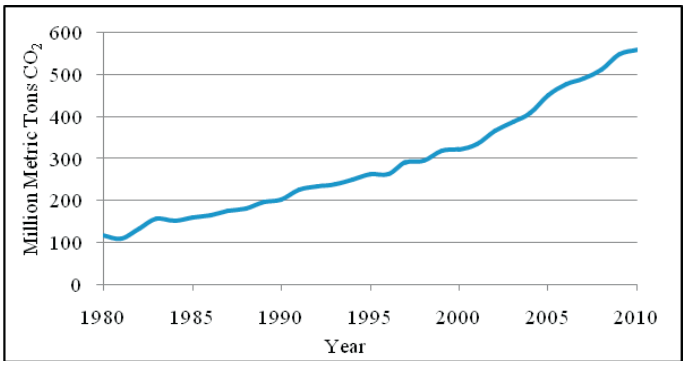

Fig. 2. CO_2 historical emission trend in Iran [5]

Thermal power plants are mostly designed to work by natural gas in Iran and fuel oil and gas oil would be used in case of emergency, gas lack, cold weather and so forth, as substitute fuels. Iran's power plants consist of 3 categories of department of energy, great industry and private sector power stations. Currently, fuel oil consumption is decreasing in these power stations. However, natural gas and gas oil have an increasing rate of consumption and considering oil and gas reservoirs status in Iran, continuity of this trend is greatly expected. Thus, easy access to gaseous reserve and tactful utilization of them, would allow Iran to keep its gas-fired power plants, although non-use of coal for power generation in this country will limit the development of Integrated Gasification Combined Cycle (IGCC) technologies.

Contribution of different types of power stations in Iran in electricity generation through 2004-2010 has been demonstrated in Table 1. According to the related contribution percents, gas power, steam power and combined cycle are the dominant power stations among the installed capacity. In general, these plants are classified as thermal power plants. Corresponding to Table 1, the historical trend for thermal plants verifies their dominant contribution in power generation operation through these years; in 2010, %95.8 of total generated electricity has been produced by thermal power plants.

Table 1. Share of different kind of power stations in electricity production in Iran [6]

Year	Steam (%)	Gas (%)	Combined Cycle (%)	Diesel (%)	Hydro (%)	Renewable (%)	Total (%)
2006	55.4	15.1	22.7	0.16	6.6	0.004	100
2007	52.3	17.0	21.1	0.12	9.4	0.04	100
2006	49.0	18.6	22.2	0.13	10.1	0.07	100
2007	47.8	14.2	28.3	0.12	9.5	0.08	100
2008	48.7	18.9	29.5	0.11	2.6	0.10	100
2009	47.2	16.2	32.8	0.06	3.7	0.12	100
2010	44.2	16.5	33.6	0.06	4.7	0.08	100

Thus, the historical and current proceedings proof the probability of thermal power plants dominance in generating electricity and therefore, cumulative CO_2 emissions will keep its increasing rate.

As Iran is ranked as the 4th greatest owner of oil reservoirs and has the second place from gas reserves point of view, multiple storage options are possible and thus, this country has a great potential capacity for CO2 storage, and particularly, remarkable pressure-drop in its oil and gas reservoirs implies that enhanced oil recovery and enhanced gas recovery by carbon dioxide are prominent options.

During the last decades, Iran has been one of the developing countries which have participated in environmental protection activities. Iran has joined the Basel Convention in 1993, the UNFCCC in 1996, the London Convention in 1997, and the Kyoto Protocol in 1998, and also, has kept its contribution in UNEP even after Islamic Revolution. It can be inferred from this pattern of proceed that this country is interested in participating in environmental protection plans and has been comrade in executive conventions.

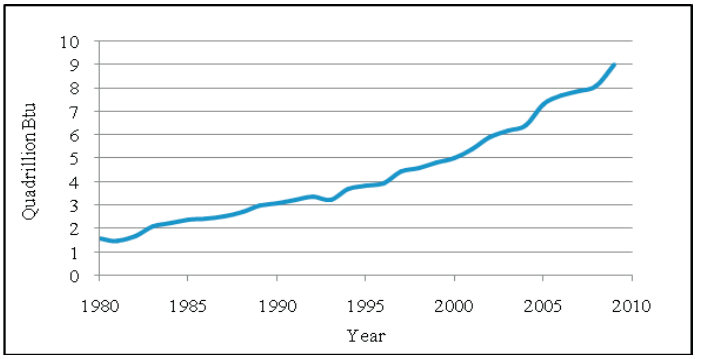

Fig. 3. Total primary Energy Consumption in Iran [7]

In addition, special status of Iran justifies the implementation of CCS; Iran has the second largest natural gas reserves (33.5 trillion cubic meters) and is the forth owner of conventional oil reservoirs (150.6 billion barrels of oil equivalent) among all other countries. Iran is one of the prominent consumers of fossil fuels (9.015×10^{15} Btu in 2009) (see Fig 3) and according to 2010 report of World Bank, %99.67 of required energy in 2009 has been supplied from fossil fuels reserves. Share of each primary energy carrier in energy supply of Iran in 2010 has been depicted in Fig 4. Also, Iran is in eighth place in terms of CO_2 emission in 2010 and had the emissions amount of 560.335 million tons of CO_2 in this year.

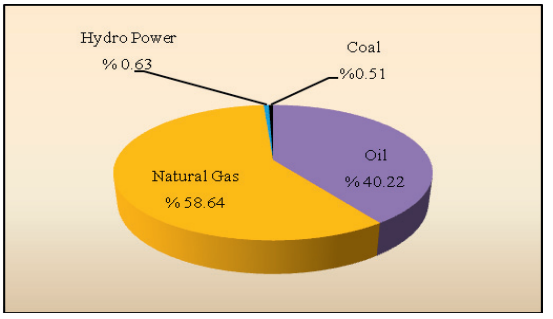

Fig. 4. Share of energy carriers in primary energy consumption in Iran in 2010 [8]

3. Barriers to CCS Analysis

During the recent decade, CCS has been studied as a significant option among all the climate change mitigation strategies, but the implementation of this technology in a great scale is along with some barriers. So, the main gaps in perception and understanding of non technical aspects of CCS must be recognized and addressed and solutions for these gaps can be provided. The most important barriers to

CCS technology in Iran are the absence of a regulatory framework, commercial development and necessary market creation for this technology.

3.1. Legal & Regulatory Framework

In general, investigation of CCS deployment in every country requires the development of a regulatory basis in order to eliminate the legal and regulatory risks for CCS projects implementation. This requires addressing the existing legal and regulatory gaps and a framework for evaluating them.

From the legal point of view, the main gap seems to be concerned to domestic laws in Iran. Existing regulations must be evaluated and in case modified with an implementing approach, so that they can remove the gaps and provide certainty in CCS accomplishment. Regulations related to mining, oil and gas operations, pollution control, industrial waste disposal, piping, ownership, and liabilities of industrial and administrative plants, might be relevant and extensible to CCS projects. In addition, clarification and correction of marine protection treaties which are capable of acting as an obstacle to CCS activities, is very important.

Available regulations, laws and treaties in Iran have been studied in order to recognize their relevant aspects to development of a legal system for CCS and determine the gaps for secure and safe deployment of this technology in this country. The results can be found in Table 2.

Table 2. Environmental regulations ratified by Iran in relevance to implementation of CCS

Domestic Laws		
Title	Date of Ratification	Remarks
Environmental Protection and Improvement Act	18 June 1974 (modified on 15 Nov. 1992)	- protecting and improving environment and prevention from any kind of pollution and any malicious act that may cause environmental imbalance and fitness - Article 9: definition of pollution - definition of areas and regulations by the competent
Sea and Border River Protection from Pollution with Oil Products	24 Jan. 1976	- monitoring of pollution from the discharge or spill of oil or any oil mixed in waters under the eligibility of this rule - discharges or spills from pipelines, drilling platforms, artificial islands, tanks and other facilities - defined fines and compensation
Law on Air Pollution Prevention	23 Apr. 1995	- air pollution sources: 1) vehicle, 2) Factories, workshops and power plants, and 3) commercial and domestic resources, and miscellaneous sources - penalty definition; fines and criminal
Cabinet decision on standards for limiting the factories and industrial workshops emission	18 Nov. 2000	- carbon dioxide has not been mentioned as a pollutant - in Executive Regulations for Law on air pollution, carbon dioxide is not mentioned
Waste Management Law	9 May 2004	- extraterritorial transfer provisions of the Basel Convention - domestic transport corresponding to procedure adopted by the Council of Ministers - explaining crime cash - revenues from fines will be sent to the Treasury General Account Deposit to be allocated for education, culture, and remove pollution caused by waste, protect the environment and provide the necessary resources for the implementation of this Act - the issue of funding and facilities necessary for the operation of disposal sites

The mentioned texts are different from each other in orientation, content, scope and also, ultimate goal. The most important and significant items in these regulations and laws which are directly or indirectly connected to CCS technology deployment, have been discussed in the remarks column of Table 2. One of

the issues to be considered is that carbon dioxide has not been specifically defined under none of these regulations and it is not clear that it should be considered as a pollutant, waste or a valuable substance.

3.2. Market creation for CCS technology

If CCS expected to participate greatly in CO_2 emissions abatement, its commercial deployment is necessary. Commercial deployment policies affect the market through 2 mechanisms [9]:

1) Market penetration goal

Achievement of this goal would ensure a specific market share for CCS technology in the future.

2) Cost reduction goal

This goal is obtained through increasing of innovation, so that CCS would be a compatible option in long term, even without any supporting policy.

Two types of policies support these goals. The policies which provide incentives for investment in commercial projects and market creation are the market pull policies. These policies act as a motivation for the technology demand. The second type of policies is technology push policies which reinforce the variety in technology supply by supporting innovation [9].

Market pull can be exerted through different mechanisms. These mechanisms is categorized in 3 groups; carbon pricing, mandates and subsidies.

Technology push policies which accelerate the innovative activities for CCS are as below:

1. fund spending in research, development and demonstration (RD&D) activities
2. indirect incentives for RD&D activities by private section
3. supporting the knowledge transfer opportunities

3.3. Analysis and evaluation

Mandates policies are necessary for achievement of market penetration goal and indirectly can support the cost reduction goal through innovation process. Impassibility of these mandating policies to technology costs, causes the inefficiency of them in achieving cost reduction in long-term. Therefore, a mandating policy will become a costly and adverse policy in long-term.

On the other hand, although pursuing the market penetration goal is possible just by means of subsidies, but a guaranteed level of market diffusion might occur through a costly one. So, concentration on cost reduction goal along with using market penetration policies such as subsidies in short- and medium-term which their vigor shrinks through time will be more efficient.

To wrap up, combination of both type of policies, mandating policies and subsidies, will be more effective in achievement of mentioned goals.

4. Impact assessment of policy instruments on CCS deployment in Iran

National and international initiatives for CCS technology are dominant preconditions for CCS deployment, but will not explicitly boost market penetration.

Market-based instruments, including subsidies, carbon taxes and emission trading systems in national and international level, in case providing the required fiscal incentives, will act as a great stimulus for CCS development in this country. An international emission trading is the policy instrument with the popularity for utilization in reinforcement of carbon abatement efforts, as it offers cost effective solutions. This instrument probably will be the central instrument in CCS deployment stimulation. Albeit, its effect depends on the definition of emission limit values; if these values defined low enough, emission trading will be a great incentive for CCS development. Nevertheless, considering the geographical position of

Iran and emission status of its neighbours and their attitude toward environmental issues, an emission trading system in national and regional level may not have significant influence on CCS deployment in Iran.

In national level, more effective instruments are different kinds of subsidies and regulate emission taxes which would greatly stimulate CCS implementation in Iran. State government performance in Iran's energy systems paves the way for taking advantages from subsidies and appropriations for the related projects.

Also, the act of defining the maximum allowed emission targets and taxes on excess emissions is possible only by participation of government in almost every kind of government systems, and according to the performance of government in Iran, this precondition has already been provided. As a result, these instruments (subsidies and carbon taxes) have the most influence on CCS deployment in Iran.

5. Evaluation of CCS for Iran

Evaluation of CCS in Iran is performed by means of scenarios from IPCC SRES. For this purpose, the IPCC data for Africa, Latin America and Middle East (ALM) regions have been qualitatively analyzed. ALM countries are consistent in using specific energy carriers and so, argue about Iran on the base of these regions data would be valid. Considering Iran's attitude toward environmental issues, 3 scenarios, A1FI, B1, and B2, which are more consistent with this approach have been selected from IPCC SRES [10].

5.1. A1FI scenario

In this scenario, high economic growth and intense international cooperation will lead to rapid technological changes. A1FI is one branch of the family A1 scenario which is characterized by heavy reliance on fossil fuels and hence greater emissions of carbon dioxide.

According to centrality of fossil fuels and high international cooperation in this scenario, CCS technology will deploy at great pace and dimension. High quantity of CO_2 emission in combination with high carbon prices would cause diffusion of CCS in depicted scenario. Predicted statistical data for ALM countries shows that dominant primary energy carrier through the first half of the century is oil. Oil and gas will keep a great share in primary energy use to the end of the century, see Fig 5.

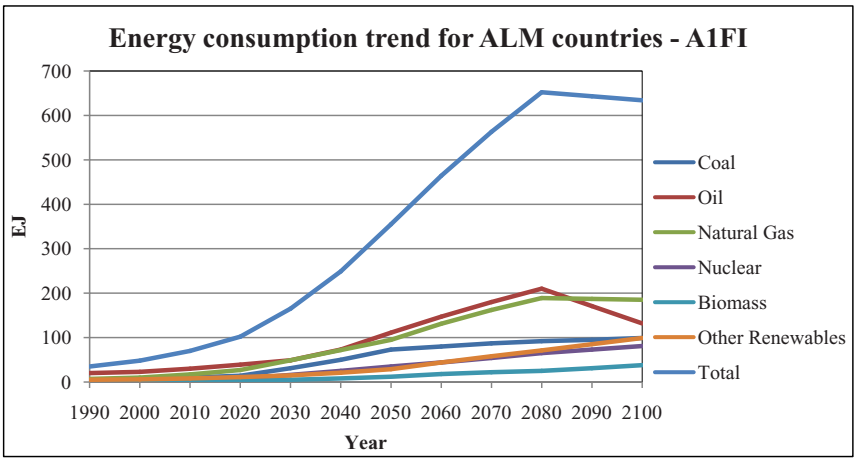

Fig. 5. Energy consumption trend for ALM countries by A1FI scenario

Although nuclear energy, biomass and other renewable energies have considerable growth rate but they do not have great contribution in energy supplement of these regions. Therefore, the increasing trend of CO_2 emission in these regions continues and CCS can be a dominant mitigation option.

Also, Iran is a considerable country for CCS implementation, as it has great emission amount, high consumption of fossil fuels and also, large storage capacities according to great volume of oil and gas reservoirs (as discussed before) which make EOR and EGR necessary.

5.2. B1 scenario

This scenario depicts a sustainable future for energy systems which is accompanied by balanced economical progresses and high international cooperation on environmental issues. Although this scenario does not involve any particular action on climate change, carbon dioxide emissions show relatively low quantities.

According to ALM countries data from IPCC SRES, the consumption of oil and coal will be decreased through the century but natural gas keep a dominant share in primary energy supplement which implies that CO_2 emissions rate will be continue growing. Although renewable energies experience good development in the world by this scenario, in ALM regions gas and biomass will be the majors which guarantee the opportunity for CCS deployment, see Fig 6. In addition to analysis of related data of Middle East, Iran's specific conditions which discussed before head, make CCS a continuing option.

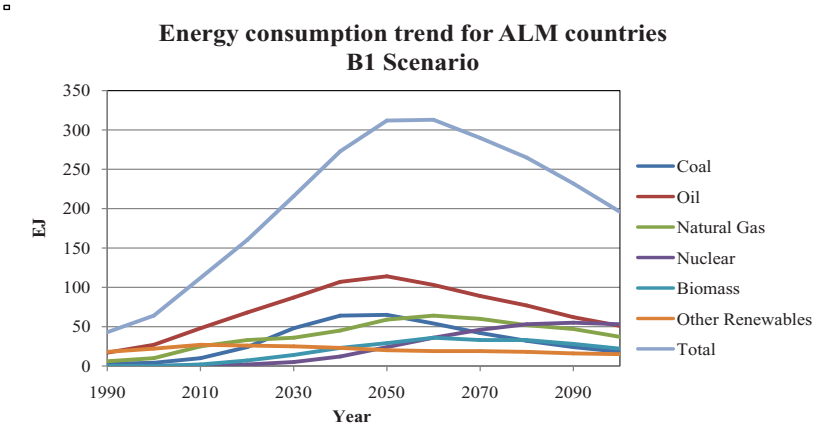

Fig. 6. Energy consumption trend for ALM countries by B1 scenario

5.3. B2 scenario

B2 scenario family is comprised of high environmental considerations. Nevertheless, it is limited to national and local decision-making which prevent the effective global cooperation on climate change.

CO_2 emission reduction in this scenario is occurred not only as a result of CO_2 omission, but also, because of great development of renewable technologies. These progresses are also take place in ALM regions and it can be inferred from the models results that renewable energy technologies, especially nuclear energy, will experience a considerable growth rate. Nevertheless, oil will remain a dominant energy carrier in these areas, see Fig 7, and so, CO_2 emission from ALM regions need a removal option such as CCS, as renewable energy technologies do develop only by the end of the century.

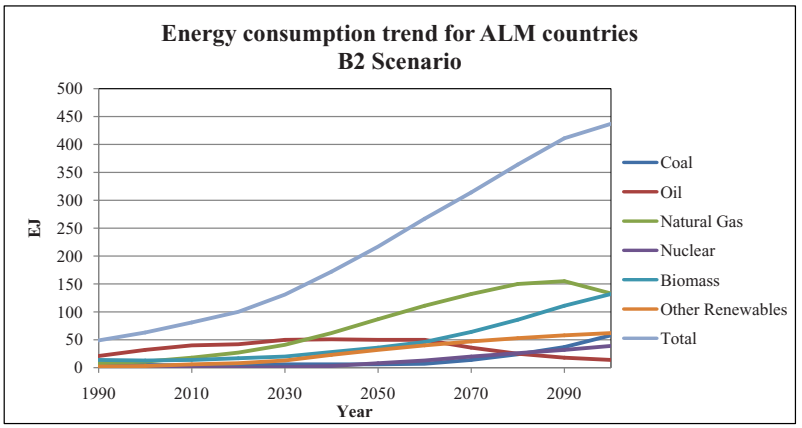

Fig. 7. Energy consumption trend for ALM countries by B2 scenario

In Iran, availability of fossil fuels, clearly keep this country dependant to its fossil-based technologies and so, it can easily be a beneficiary of CCS which helps this country accompanying the climate change mitigation activities while using its mentioned technologies and CCS would not remain a temporary mitigation option for Iran.

6. Conclusions

Iran's strategic conditions make it a considerable option for implementation of CCS:

1. Iran has wide access to rich reserves of fossil fuels (oil and gas).
2. It owns great volume of oil and gas reservoirs which CO_2 can be used for oil or gas recovery from the ones with pressure drops and stored in the depleted ones.
3. This country has high quantity of CO_2 emission (560 million tons of CO_2 in 2010 which causes Iran to be the eighth great GHG emitter in the world) with considerable growth rate which requires mitigating efforts.
4. Predicted data from IPCC Scenarios shows that Iran will remain dependent on fossil fuels, especially natural gas, at least for 50 years which would cause the continuity of increasing in emission amounts.

According to all of the above issues, CCS is one of the most suitable options for being implemented in Iran, especially taking into account that development of renewable energies is performed in low pace in this country. So, its approach proves that taking advantage from this technology would continue.

References

[1] IEA. “Carbon Capture and Storage – Legal and Regulatory Review” Paris, France: International Energy Agency; 2011

[2] IEA. “Carbon Capture and Storage – Model Regulatory Framework” Paris, France: International Energy Agency; 2010.

[3] Backstrand, K., Meadowcroft, J., Oppenheimer, M., Mar. 2011. “The politics and policy of carbon capture and storage: Framing an emergent technology”. Global Environmental Change 21(2011), p.275-281

[4] Vallentin, D., “Inducing the International Diffusion of Carbon Capture and Storage Technologies in the Power Sector”, Master Thesis, Roskilde University, Department of Environment, Technology and Social Studies, March 2006

[5] U.S. Energy Information Administration (EIA) – International Energy Statistics; http://www.eia.gov/cfapps /ipdbproject/iedindex3.cfm?tid=90&pid=44&aid=8&cid=IR,&syid=1980&eyid=2010&unit=MMTCD – Accessed August 4 2012

[6] Iran Energy Balance 2010 – Office of Electricity and Energy metropolitan planning, Ministry of Petroleum of Islamic Republic of Iran

[7] http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=44&aid=2&cid=IR,&syid=1980&eyid=2009&unit=QBTU – Accessed May 14 2012

[8] http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2 – Accessed May 14 2012

[9] Environmental Protection and Improvement Act, June 1974

[10] Sea and Border River Protection from Pollution with Oil Products, Jan 1976

[11] Law on Air Pollution Prevention, April 1995

[12] Cabinet decision on standards for limiting the factories and industrial workshops emission, Novemeber 2000

[13] Waste Management Law, May 2004

[14] Hamilton. M.R., “An Analytical Framework for Long Term Policy for Commercial Deployment and Innovation in Carbon Capture and Sequestration Technology in the United States”. Master Thesis, Massachusetts Institute of Technology, Technology and Policy Program, Engineering Systems Division, December 2009

[15] IPCC Special Report on Emission Scenarios, 2000. Cambridge University Press, Cambridge, United Kingdom