



Natural Gas Potential of Pakistan an Important Parameter in Mitigating Greenhouse Gas Emissions

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Abstract

Climate change is one of the most challenging issues in Pakistan and has affected humans in every sphere of life. Pakistan is ranked on 8th in the world among the countries emitting Greenhouse gases (GHG). Such an extensive emission of GHG is due to the growing number of industrial units and urban centres consuming fossil fuels that emit GHG at a large scale. Mitigating the GHG emission indeed is a challenge for Pakistan. This manuscript highlights the GHG emission status and provides recommendations with suitable alternatives to mitigate the emission. Simultaneously, the study explores the impact of switching over the fuels from conventional fossil fuels to unconventional natural gas as a source of energy for domestic use, transportations and industrial sectors to mitigate the GHG emission. Natural gas is considered as green fuel due to the low carbon emission ratio as other fuels e.g. coal and oil. If Pakistan becomes successful in exploring and exploiting the indigenous untapped natural gas resources, that will eventually support in reducing the GHG emissions. This is only possible by making new natural gas reservoir discoveries. Discovering new gas reservoirs from unconventional resources is also very challenging and requires investment and modification in existing energy policies. In addition, the government should encourage the Exploration Production (EP) companies to exploit the hidden natural gas potential that will assist in both alleviating the energy deficit and reducing the GHG emission. The findings of the present study analysis have substantial implications regarding GHG mitigation, energy transition, and economic development.

Keywords: Unconventional natural gas, CO₂ mitigation, Greenhouse gases, Energy

Introduction

Pakistan shares its boundaries with countries includes China, India, Iran and Afghanistan, as well as with the Arabian Sea and lies on the 24–371 North latitude and 61–761 East longitude [1]. The country is embraced with enormous land covering a total area of about 803, 940 km² [1]. Pakistan is ranked sixth among the countries in the world that are most densely populated [2]. The main drawback to the countries is that its population distribution is unevenly scattered in its five different

provinces. The present day population of the country reported stands at around 188 million. Around 40% of the world population share belongs to Pakistan, China, and India and these countries are in their development stage which requires energy on large scale to fulfill their increased energy demand due to population growth and industrialization [2, 3]. The world's main energy dependency is on fossil fuels (67.9%) and is followed by nuclear (10.9%), hydropower (16.2%) and the lowest

supply of renewable [4]. An adequate supply of energy and provision of all facilities related to human life is a key basis for economic growth and is crucial for most of the developing countries. Hence, it is essential to seek and to exploit all possibilities that help in alleviating the energy deficit, with a particular focus on the sustainable supply of low carbon emission energy resources. For developing countries ensuring a sustainable supply of low carbon emission is challenging and has significant impact on country's economy and environment. More specifically, it is challenging for the developing countries which are in transition phase to restructure their policies, adjust their energy supply and demand strategies as well as infrastructures. Especially, for the developing countries, assessing energy demand and switching towards low carbon emission fuels will not only affect energy market, economic development, environment protection & hazards, sustainable energy supply and accomplishment of the energy demand, adjusting the gap, and all other relevant aspects related to energy policies planning that will help in mitigating the GHG emissions. Hence, accurate energy estimations could lead to impressive suggestions, guidance and new directions for policy makers to develop new policies and, to modify the existing policies on energy planning. Furthermore, efficient energy and power planning can assist to manage the energy supply and demand imbalances and to provide green fuel to the nation [5, 6]. Generally, the energy requirements of Pakistan are mostly met by fossil fuels such as oil, coal and natural gas, renewable, nuclear, hydropower, solar, biofuels, geothermal and wind sources [7, 8]. Except for fossil fuels, the contribution of other sources is very small in the overall energy mix. Specifically, fossil fuels e.g. coal and oil consumption are very high in Pakistan and are more likely to emit GHG. Sustainable exploitation and development of low carbon

energy resources are very challenging for the developing countries to meet the energy demand with the lowest impacts on the regional climate and the environment in the ensuing years [9, 10].

According to the British Petroleum (BP) statistical review (2017), the energy consumption is expected to reach to the maximum level of around 3542.9 billion cubic meters in 2018 [11]. This massive increase in energy demand may be the result of increased industrial units, urbanization and population growth. Ensuing years will be a great threat to the environment due to the increase in GHG emission resulting from the increasing industries and urban centres. This will further tend to unpredictable changes in the temperatures and climate system as well as increased emission of GHG into the environment [12]. Subsequently, the increased earth's temperature is essentially the growing industrial revolution [12]. It is reported that GHG emission was quite high more than 60% higher in 2014 compared to 1990. Moreover, it could be realized that the 1880 concentration of CO₂ has climbed from 290 ppm to 430 ppm (Fig. 1). More specifically, fossil fuel consumption for electricity generation and heat production is a major source of GHG emission compared to all other sources [13].

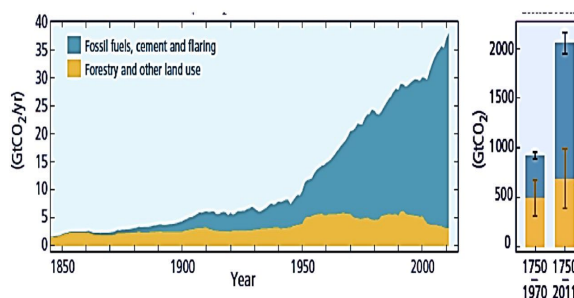


Figure 1. Illustration shows the anthropogenic CO₂ emissions from the use of fossil fuel, forestry, cement production and flaring around the world [30]

To cope with this issue several countries around the globe have taken initiatives already and effective measures on

the revision of their policies to mitigate the GHG emission. The countries have instigated several projects that capture carbon and store it underground [14,15]. Many studies have developed numerical models in regard to CO₂ sequestration [16-18]. Additionally, energy efficient building projects known to be smart cities will assist in reducing carbon emissions.

GHG emissions reduction involves taking into consideration the enduring processes that challenge the standard operative procedures from the different viewpoints of reducing CO₂ emissions [19-22]. It is generally believed that every industry or processing plant makes every effort to enhance its operations for efficient production of their desired results. However, it is observed that in past, CO₂ reduction in industries was not considered to be taken into consideration to mitigate its emissions. More recently, it is expected that the CO₂ must be mitigated by introducing the hybrid system of energy just like hybrid fuel powered cars that will play a significant role in reducing carbon emission worldwide [19, 20, 22, 23]. Moreover, it is believed that hydrogen fuel could be used as a clean fuel that after burning it produces water, which results in less CO₂ emissions. Climate neutrality from the GHG emission perspective requires developing strategies that make elevated use of hydrogen as a fuel. Oil and gas companies are planning towards boosting hydrogen power [24-26]. Though, the studies have designated that in the year 2040 sale of hybrid power and electric powered cars would reach up to forty-one million as per their analysis tending to a tremendous reduction in carbon emission and global warming [13-16]. Furthermore, the developed countries like the USA, UK, Canada, Sweden, and other European countries have in switching over their transportation system and have decreased the energy dependency from fossil fuels to the hybrid system [26, 27]. Pakistan must focus

on the exploitation of unconventional natural gas potential to increase the low carbon emission energy mix ratio to mitigate GHG emissions. To date, renewables energy has also occupied a very small space in the fuel mix [28, 29]. The renewables have recently emerged in Pakistan in the fuel mix with a smaller contribution to overall energy requirement. Although, the energy demand of Pakistan is mainly fulfilled by the use of fossil fuels such as oil, coal and gas that tended to emit GHG in massive quantities. Hence, this current scenario of increased consumption of fossil fuels such as oil, coal tends increase in GHG emission and warrants Pakistan to switch over the viable low carbon energy resources as well as sustainable energy alternatives to mitigate the adverse impacts on global warming and environmental pollutions. To encounter with this alarming emission of GHG, Pakistan needs urgent solutions through energy transitions towards natural gas. To our best of knowledge, no study is present in public domain regarding switching over the fossil fuel consumption towards low carbon emission unconventional fuels perspective. The present study's focus is to fill this knowledge gap. The goal of the present manuscript is to provide a comprehensive review on the concept of CO₂ mitigation along with their different substitutes, applications, benefits, that will help in mitigation GHG emissions. In addition, various possible alternatives are suggested, and their aptitudes to amalgamate into that when used will not emit enough CO₂ are discussed.

Status of CO₂ Emission

Globally, climate changes are thought to be a serious issue and many studies have acknowledged as it is dangerous for human health and the environment that adversely affect generations [31, 32]. The entire world status of CO₂ emissions from 1971–2020 is shown in Table 1 [13]. The developed

countries around the world have already initiated projects to mitigate the emissions of GHG by commencing the carbon capture and storage projects or by lessening the fuels that are emitting more carbons in large quantities. Pakistan as a developing country has many urban growing centers and emerging improved living standards all together are likely responsible for the emission of CO₂ in massive quantities. Additionally, Pakistan's population growth, urbanization, increased vehicles need for transport and domestic use, increased industry and improved GDP are the main causes of increased emission of carbon. Fossil fuel consumption trends have changed abruptly more recently due to the improved living standards of urban life. The consumption of fuel varies from one city to another depending upon locality and life patterns. Furthermore, the emission is dependent on the demography, population congestion as the population increase demand for the electrical energy requirements enhances; hence the resulting demand for electricity would be fulfilled by the power generating sector that eventually used fossil fuel and emits GHG in the country. The major sector in Pakistan that consumes fossil fuels are the power generations sectors and is believed to be the largest fuel consumer. Power sectors consume fossil fuels more than 68% to generate electricity [33]. The status of CO₂ emission from all energy sectors in Pakistan is shown in Fig. 2 [13].

Table 1. Status of the CO₂ emission trend of the world from 1971–2020 [13].

Year	1971	2000	2010	2020
CO ₂ emission (Mt)	13,654	22,639	27,453	32,728
Coal (%)	38	39	37	37
Petroleum (%)	47	40	40	39
Natural Gas (%)	15	21	23	24

Furthermore, the transportation systems of developed countries of the world have switched towards hybrid oriented

vehicles or solar generated power plants. Although, Pakistan is still dependent on fossil fuels to generate electricity by use of either furnace oil or coal [13]. To date, the Pakistan supply of electricity to the nation is led by thermal power projects which are emitting CO₂ in large quantity. In near future the electricity demand will also increase realizing the fact that fuel consumption will ultimately be enlarged up to 56% by 2040 [12], this will result in huge CO₂ emissions in the environment.

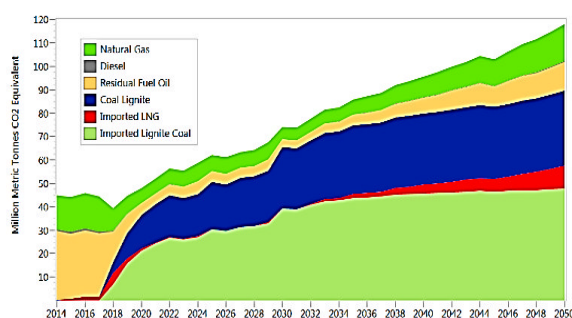


Figure 2. Illustration shows the emission of CO₂ by fuel type used [13]

Moreover, Pakistan possesses huge coal reserves that are discovered in Sindh province which is the third largest in the world [34]. The Fig. 3 is also evidence of the increasing CO₂ emission trend from various energy sectors in Pakistan. Furthermore, it is recommended that industrial units also are run on natural gas and transportation system if not shifted to electric generated hybrid vehicles soon the CO₂ emissions per capita will rise from 858 kg/yr to 1650 kg/yr by 2030 [13].

The nation needs cheap energy; the government focuses on the development of power plants that generate low-cost energy e.g. coal power generating plants as many of these are under construction in Pakistan by the funding provided by China–Pakistan Economic Corridor (CEPEC). Thus the usage of coal will be very hazardous for the environment. Even though, the government of Pakistan is installing coal-based power plants at various locations around the country. One

such example of coal generated power generating project with a capacity of 1,320 MW electricity generations was commenced at Sahiwal, Punjab province of Pakistan and is generating electricity under commercial operation [33]. Additional coal fueled power plants are in pipeline to be installed under the national power policy based projects to make the country self-sufficient in the energy sector [33]. Additionally, few other projects are in the development phase e.g. Sindh Engro Coal Mining Company (SECMC) did a joint with Sindh Government and Engro power to work together on developing the Block-I and II in district Tharparkar. Unfortunately, the government presently has focused upon the fulfillment of energy needs however, it is essential to develop strategies to mitigate the GHG emission from such industrial units that will adversely affect the environment. Hence, it is necessary to develop policies and make strategies to initiate carbon capture and storage (CCS) projects. Mitigation of GHG emissions will ultimately improve the quality of life.

Further to make energy policies and environment protection regulations accurate estimation of CO₂ emissions is essential from the use of fossil fuel along other fuels based energy consumption. It is expected that the GHG emission will likely increase in the ensuing years due to the transition of fuel from oil and natural gas to coal as many of the coal fuelled power plants are currently under construction.

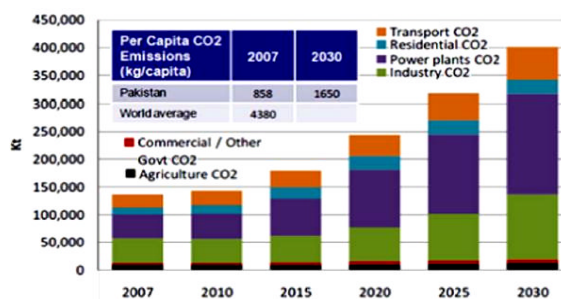


Figure 3. Illustration shows the CO₂ emissions status of Pakistan from all energy sectors [13]

Fuel Supply and Demand scenario and CO₂ emission

Pakistan is an energy deficit country; with an average annual growth rate for the natural gas demand is projected at an average rate of 2% from the year 2012 [2]. However, during the past few decades, Pakistan had fulfilled the energy demand for gas from its indigenous sources, without imports. The gas consumers in the country were served by supplying 4 billion cubic feet per day (BCFD) in Pakistan with its very vast pipeline network of over 12,02 km transmission line encompasses 119,736 km distribution line with 32, 8233 km services pipelines [35]. Furthermore, the country's transmission companies Sui Southern Gas Company and Sui Northern Gas Company Limited (SSGC & SNGPL) have extended their network by the addition of more transmission and distributions of pipelines to supply gas to small towns and villages around the country. A generalized map of the country's regional gas pipe line network and gas field infrastructure is shown in Fig. 4 and assertively perceives to encounter the country's ever increasing domestic energy demands. The balance between supply and demand of natural gas was reported to have been fulfilled by its domestic supply in past years. However, the industrial revolution and unexpected population rise have increased with time. The industrial growth in various sectors such as power, fertilizers, and cement industry to provide the product to build more houses, vehicles and shifting of transport systems to Compressed Natural Gas (CNG) from gasoline and associated public infrastructure has extremely increased the demand of gas. The recent details about the status of consumption by different industrial sectors are depicted in Table 2.

Table 2. Pakistan's sector-wise average gas consumption in MMSCFD [11].

Sector	For the Period July 1, 2015 To Feb 29, 2016			For the Period July 1, 2016 to Feb 28, 2017		
	Gas Consumption in MMSCFD	RLNG	Total	Gas Consumption in MMSCFD	RLNG	Total
Power	961	143	1,104	980	116	1,096
Domestic	777	0	777	801	-	801
Commercial	92	0	92	89	-	89
Transport (CNG)	155	17	172	150	43	193
Fertilizer	633	0	633	611	64	675
General Industry	594	15	609	613	187	800
Total	3,212	175	3,387	3,244	410	3,654

Hence, more recently, it has been noticed that there was a considerable deficit of natural gas has arisen resulting in a shortfall of 1,200 Million Cubic feet per day (MMSCFD). More specifically, for the upcoming years, the demand for gas is projected to rise about 13.27 BCFD; meanwhile, the domestic supplies are expected to drop approximately by 2.17 BCFD due to the depletion of gas reserves of existing fields. The depletion of natural gas reserves leading to a huge deficit of about 12 BCFD by the fiscal year 2025.

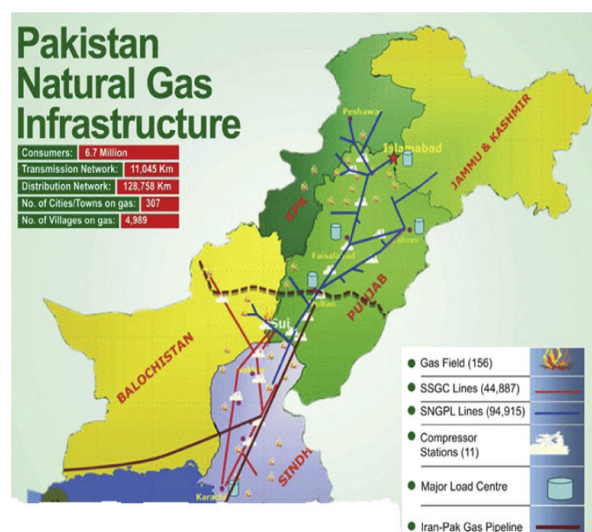


Figure 4. Illustration is the natural gas infrastructure in Pakistan [11]

The energy supply status from fossils fuels during 2011 and 2012 was documented as 64.7 million tons of oil equivalents (MTOE) for the country as per Pakistan

energy yearbook statistics. In these years there was a record of energy deficit reported. During these years most of the petroleum products were imported to fulfill the energy demand of the country and the import cost was quite high. However, Pakistan possesses tremendous gas potential throughout various basins, country requires investment to be developed and exploited for the production of natural gas. According to the ministry of petroleum and natural resources and Pakistan energy yearbook (2013) assessment, the country possesses around 28.9 trillion cubic feet (TCF) of natural gas reserves. In addition to this recent studies have reported the conventional natural gas country is embraced with huge potential of gas within tight formations ranging from 24 TCF to 40 TCF. The current production of natural gas reported for the year 2011 and 2012 was 4.0 BCFD, a substantial amount of it was utilized as fuel for electricity production (27.2%), the consumption followed by industrial units (23.5%) and domestic usage. The projected demand supply and consumption from existing fields, unconventional potential and imported via different projects and expected to rise in gas demand projections are depicted in Fig. 5. Alleviation and mitigation of GHG emissions could be managed by decreasing high carbon emission fuel mix for industrial units of the country and switching transportation system of the country to a hybrid fuel system for ensuing years.

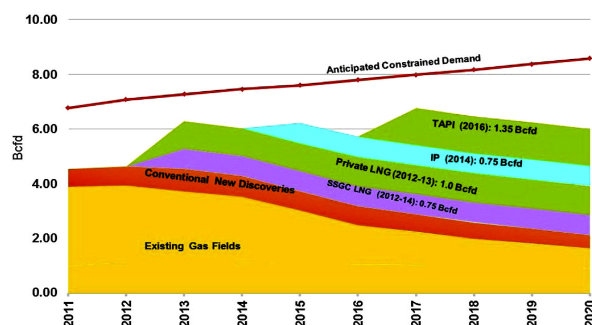


Figure 5. Gas demand & supply projections (Inter State Gas Systems, 2013)

Contribution of the Unconventional Gas Potential of Pakistan Towards Energy

Natural gas is the leading source of energy for Pakistan. The country's demand has been fulfilled with natural to meet energy requirements. To date; the country's need for gas is around 8 BCFD, however, the supply is slightly less than this hence country fulfills the requirement by the import of Liquefied Natural Gas (LNG). Pakistan possesses tremendous unconventional gas potential. The reported reserves of shale gas reserves in Pakistan are around 201 TCF, which are technically recoverable and are the proven reserves [9]. Pakistan's reported shale gas accumulations are found to present in various rock formations e.g. Sembar, Ranikot and Talhar formation in the Upper and Middle Indus Basins of Pakistan. The Pakistan's recognized unconventional gas potential within the country is shown in Fig. 6. The reported reserves of gas were based on the independent agency studies along with their collaborative partners e.g. U.S. Agency for International Developments (USAID) or International Energy Agency (IEA) assessment [31, 36]. The initial assessments of unconventional gas reserves are widely cited by many researchers [7, 15]. According to recent assessments, the tight gas potential of Pakistan is believed to be in the range of 24 TCF to 40 TCF in different basins of the country [9, 12]. The tight gas potential is also

found in the prevailing (D&P) Development and Production Leases of the country [22-24]. The Goru formation along with some limestone and Siltstones in the sedimentary basin of Pakistan also possesses tight gas potential in large quantity [37]. Presently, several Exploration & Production (E&P) companies with their joint partners are working on exploiting the tight gas potential under the license provided by the ministry of Petroleum production and exploration wing, Islamabad. One of the tight gas fields recently discovered near Quetta, Balochistan possesses large gas reserves to be exploited. In the exploration of tight gas potential many companies are actively involved includes the Polish Oil and Gas Company (PGNIG), Eni, Pakistan, Orient Petroleum (OPI), Pakistan Petroleum Limited (PPL). All aforementioned companies are bound to follow the Pakistan's Tight Gas E&P Policy, 2011. Though, such huge resources of shale gas and tight gas developed and exploited successfully, which in turn result into reduction of the country's import of fuel dependency. On the other hand, the transitions from coal generated power plants and other industrial units to be switched which will eventually mitigate the GHG emissions in large quantities which in turn will be less hazardous compared to utilization of coal as a fuel for power generation.

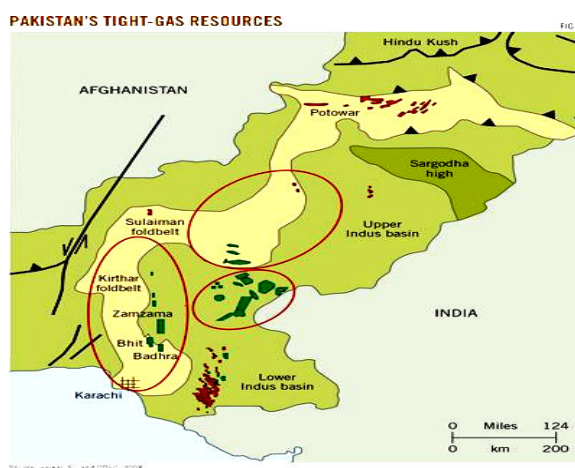


Figure 6. Pakistan's recognized unconventional gas potential [38]

Conclusion

In this paper, we have highlighted the status of GHG emission and recommendations are provided to develop strategies in light of energy transition from conventional fossil fuels towards the low carbon emissions unconventional fuels to mitigate the greenhouse gas emissions for the upcoming years. Mitigation of GHG emissions for ensuing years is essential for the country to shift fuel from oil and coal to natural gas or hydrogen as a clean fuel. Though, it would be far better to plan for a fuel transition strategy from coal and oil however its implementations depend on the government policies and strong initiatives to support such policies. Moreover, modification is needed to the existing fuel/energy policies by exploring new ventures and making new gas discoveries, and switching over the existing coal-based power projects and industrial units to hydrogen or gas-based fuel that will assist in mitigating the GHG emissions. Furthermore, well-designed, reliable, vibrant and more efficient climate-related policies and recommendations could help in mitigating GHG emissions. Besides, the government needs to initiate the CO₂ reducing projects e.g. Carbon Capture and Storage (CCS) technology be assimilated.

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