The First Biennial Update Report (BUR)
Kingdom of Saudi Arabia

Designated National Authority (DNA)
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Foreword

The First Biennial Update Report (BUR1) of the Kingdom of Saudi Arabia to the United Nations Framework Convention on Climate Change is the outcome of sustained efforts of a team of highly qualified national scientists and experts. This report has been prepared by the Designated National Authority (DNA), in cooperation with all the relevant stakeholders, in accordance with decisions 1/CP.16 and 2/CP.17. It presents an updated overview of work carried out by Saudi Arabia in developing its national inventories of greenhouse gas emissions by sources and removals by sinks. The report also covers issues such as economic diversification initiatives of the Kingdom pursuant to decision 24/CP.18, and an analysis of the social and economic consequences of the implementation of climate change response measures. It further outlines Saudi Arabia's domestic measurement, reporting and verification framework.

The Kingdom has been pursuing a development-driven approach to climate change, on the basis of its national circumstances, sustainable development objectives and diversification of its national economy. The country is making good progress towards its goal of diversifying its economy away from a single source, by raising the contribution of the non-oil sectors to the national economy. These initiatives are essentially in the areas of energy efficiency, renewable energy, carbon capture, storage and utilization as well as utilization of natural gas and methane recovery and flare minimization.

Important progress has also been made in the field of energy efficiency by developing and enforcing regulations and guidelines for buildings, transportation, industry and urban planning and district cooling sectors for the efficient use and conservation of energy. Industries that utilize significant amounts of energy for their operations are also improving their energy intensity to reduce energy demand. Energy saving actions have also yielded a reduction in energy demand through the promotion of the use of insulating materials in design and construction of new buildings. Standards relating to energy efficiency of air conditioning units are being enforced. Regulations have also been approved for fuel economy of light vehicles.

Saudi Arabia has also developed a regulatory framework for the promotion of cleaner and renewable sources of energy to generate power in the Kingdom and the introduction of energy conservation measures to reduce peak load energy demand. The Kingdom has invested substantial resources to increase overall efficiency of power plants through conversion of inefficient single-cycle gas turbines to combined-cycle plants and also by installing new combined-cycle power plants, thereby reducing fuel consumption in the energy sector.

In pursuit of its economic diversification actions, the Kingdom has been investigating the potential of isolating carbon dioxide at the production, transportation and storage facilities and studying possible geological formations to determine the most suitable geological sites for carbon storage. Saudi Arabia is heavily involved in research and development activities on economically viable technologies that will convert carbon dioxide to valuable products through utilizing it as feedstock or fixing it in products.

This report further outlines some of the social and economic consequences of response measures to climate change implemented by Parties in their efforts to address climate change on Saudi Arabia's development agenda. It also identifies some of the barriers that must be addressed to minimize the adverse impacts of these measures and raise national resilience.

In line with its national circumstances, national experiences and a highly functional institutional arrangement for addressing climate change issues, Saudi Arabia has adopted a phased approach to the design, development and operationalization of its Domestic Measurement, Reporting and Verification system. The System is being developed by the DNA which is an inter-ministerial and inter-agency entity within Saudi Arabia responsible for coordinating climate change responses, under the guidance of the Ministry of Energy, Industry and Mineral Resources. The system when fully operationalized will not only be consistent with the national sustainable development objectives and priorities but will also be capable of providing relevant information and data to support the effective implementation of carbon management policies and strategies of the Kingdom of Saudi Arabia.

Finally, I would like to express my appreciation to the relevant ministries, government agencies, organizations, research institutes and academic institutions and universities for their active cooperation in providing necessary and updated data and information. I would also like to acknowledge the efforts of all national scientists and experts for the commendable work they have accomplished in producing such a high-quality report. The assistance provided by the UN Environment and the Global Environment Facility in facilitating the preparation of this report is gratefully acknowledged.

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Acknowledgement

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Executive Summary

The First Biennial Update Report (BUR1) of the Kingdom of Saudi Arabia has been prepared by the Designated National Authority (DNA) in cooperation with all the relevant stakeholders. The report is comprised of five sections namely: (i) National Circumstances; (ii) 2012 National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases (Not Controlled by the Montreal Protocol); (iii) Role of Economic Diversification in Addressing Climate Change Issues in the Kingdom of Saudi Arabia; (iv) Analysis of Socioeconomic Impacts of Response Measures and (v) Domestic Measurement, Reporting and Verification framework.

Saudi Arabia is an arid country with low rainfall and limited water resources. It is spread over an area of approximately 2.25 million square kilometers which includes deserts, plains, plateaus, mountains and lava flows. There are no perennial rivers and surface water is limited to rainfall runoff flowing through valleys. The three major bodies of sand in the Kingdom are the Great Nafud in the north, the Empty Quarter in the south and Ad-Dahna; a crescent-shaped body of sand connecting Nafud and Rub Al-Khali deserts.

The Kingdom is one of the leading oil exporting countries in the world and has a single source economy largely dependent on oil revenues. In the past, efforts were made in Saudi Arabia to diversify the economy. Ninth and tenth development plans gave a fresh impetus to economic diversification. More recently, Saudi Arabia's flagship development agenda, the "Vision 2030" is the central vehicle for the diversification of the Kingdom's economy. The Vision is based on three themes: a vibrant society, a thriving economy and an ambitious nation. The Vision aims to attain for the Kingdom, a leading position in the region in all fields and sought to identify the general directions, policies, goals and objectives of the Kingdom including economic diversification as the main vehicle of the economy.

Saudi Arabian vulnerability to the climate change stems from two directions: (i) Saudi Arabia is vulnerable to bio-physical impacts of climate change due to its arid environment and sensitive ecosystems and (ii) the impacts of climate change response measures by Annex I countries being dependent on a single source economy.

Saudi Arabia had an estimated population of 32.5 million in 2017, with a high population growth rate. This higher rate is due to two reasons (i) influx of the expatriate workers and (ii) the high natural growth of indigenous population. Urban population has increased from about 2.84 million in 1970 to about 26.22 million in 2015. A major concern related to population dynamics is that 48% of the growing Saudi population is below the age of 25 years implying significant challenges ahead in terms of education and employment. Hence from an economic policy perspective, the challenge that Saudi Arabia is facing is to provide quality education and training and generate sufficient employment opportunities within the next 10 years for this burgeoning labour force.

To address these challenges, the government of the Kingdom of Saudi Arabia is paying considerable attention to the industrialization, education, health, agriculture and on promotion of tourism.

Driven by population growth, a rapidly expanding industrial sector and high demand for air conditioning during the summer months have led to the growth in energy demand including demand for electricity. To meet these demands, the Kingdom has been working to: (i) expand the current installed capacity of electricity generation (ii) make power and desalination plants more energy efficient (iii) develop and deploy of technologies relating to energy efficiency in various other sectors of the economy and (iv) look for alternatives, in terms of fuel mix for power generation. Saudi Arabia possesses a natural potential for solar and wind power. As a result of the ever-increasing demand of primary energy resources in the Kingdom such as electricity, transportation, water and the industrial sectors, measures have been taken to control the escalating internal demand and to address this demand, in addition to taking other measures, by deploying renewable energy sources. The participation of private sector in developing reliable renewable energy sources in the Kingdom has been encouraged through implementing new and updated technologies and their application in the development process.

To fulfill the requirement of its BUR1, the Kingdom has prepared and reported the 2012 national inventory of anthropogenic emissions and removals by sinks of greenhouse gases for the three direct greenhouse gases, namely, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) following the Revised 1996 Guidelines of the Intergovernmental Panel on Climate Change (IPCC) for National Greenhouse Gas Inventories. The inventory includes emissions from five sectors, namely; energy, industrial processes, agriculture, land-use change and forestry and waste. The data for calculating the greenhouse gas emissions for the year 2012 was collected from selected ministries, organizations and companies. Appropriate emission factors were selected from the Revised 1996 IPCC Guidelines and the available more accurate country-specific information was also used in the study.

The total CO_2, CH_4 and N_2O emissions in Saudi Arabia in the year 2012 were estimated to be 498,853, 1,779 and 38.9 Gg respectively and CO_2 sinks were estimated to be 9,151 Gg. The energy sector with 444,473 Gg CO_2 emissions contributed 89.1% of the total CO_2 emissions, followed by 53,730.4 Gg by the industrial processes sector (10.8% contribution) and 82.7 Gg by the agriculture sector (0.1% contribution) of CO_2 emissions.

The source categories in the energy sector contributing to the CO_2 emissions were: electricity generation; 161,672.1 Gg (32.4%), road transport; 115,946.9 Gg (23.2%), desalination; 61,478.4 Gg (12.3%), petroleum refining; 37,169.9 Gg (7.5%), cement production; 28,596.8 Gg (5.7%), petrochemical industry; 24,597.2 Gg (4.9%), iron and steel production; 20,192.0 Gg (4.1%) and fuel combustion in cement industry; 12,813.3 Gg (2.6%) and others (miscellaneous) contributed 36,385.9 Gg (7.3%) of CO_2 emissions.

Out of a total of 1,779 Gg of CH_4 emissions, the waste sector contributed 1,144.1 Gg (64.3%) of CH_4, followed by the energy sector; 515.7 Gg (29%), agriculture sector; 82.7 Gg (4.6%) and the industrial processes sector; 36.5 Gg (2.1%).

The agriculture sector was the major contributor to N_2O emissions with 32.3 Gg (83.1%), followed by the waste sector; 4.04 Gg (10.4%) and energy sector; 2.54 Gg (6.5%).

The Kingdom of Saudi Arabia, pursuant to the decisions 1/CP.19 and 1/CP.20, submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat in November 2015. The Kingdom is engaged in actions and plans in pursuit of economic diversification that have co-benefits in the form of greenhouse gas (GHG) emission avoidances and adaptation to the impacts of climate change, as well as reducing the impacts of response measures. This will help the Kingdom to achieve its sustainable development objectives. These actions and plans outlined in its INDC are essentially adaptation in nature.

The steps taken by the Kingdom to achieve its INDC commitment include: (i) economic diversification initiatives with mitigation co-benefits; (ii) climate change adaptation initiatives, either as stand-alone or with mitigation co-benefits. The actions and plans which will generate mitigation co-benefits and contribute to economic diversification include: (i) energy efficiency, (ii) renewable energy, (iii) carbon capture, utilization and storage, (iv) utilization of gas and (v) methane recovery and flare minimization. Climate Change adaptation initiatives with mitigation co-benefits are urban planning, water and waste water management, marine protection and reduced desertification. Stand-alone adaptation initiatives include integrated coastal zone management, early warning systems and integrated water management.

Few of the recent major actions in the field of energy efficiency and renewable energy are; making power and desalination plants more energy efficient, development and deployment of technologies relating to Energy Efficiency (EE) in other sectors, development of Renewable Energy Sources (RES) especially solar energy and Rationale Use of Energy (RUE).

The Kingdom has made substantial progress in the field of energy efficiency by developing and enforcing regulations and guidelines for buildings, transportation, industry, urban planning and district cooling sector for efficient use and conservation of energy. Saudi Energy Efficiency Program (SEEP) was launched in 2012 with the objective of improving the Kingdom’s energy efficiency by designing and implementing initiatives and their enablers. SEEP’s scope is focused on demand side with three sectors (buildings, transport and industry) covering more than 90% of Saudi Arabia’s internal energy consumption. It is responsible for the development of energy efficient technologies and conservation policies. SEEP also targets households through awareness campaigns, strengthened minimum energy efficiency ratios for air conditioners and labels for electrical appliances. Energy intensive industries are also improving their energy intensity to reduce energy demand. The government has also restructured the electricity tariffs to discourage unnecessary use of electricity.

The other key area Saudi Arabia is working on is Carbon Capture, Utilization and Storage (CCUS). The Kingdom has planned to build the world’s largest carbon capture and utilization plant and few other projects are under way. It has also been encouraging investments for natural gas exploration and production and adopting measures to increase the share of natural gas in the national energy mix. Saudi Arabia operates the world's largest single gas collection system and is engaged in actions and plans to further minimize the flaring of raw gas production at all upstream facilities. The Kingdom has also adopted a zero-discharge technology at a number of well sites to recover oil and gas.

In pursuing their efforts to mitigate climate change, Parties to the UNFCCC and its Paris Agreement are implementing response measures which are designed primarily to limit emissions of greenhouse gases into the atmosphere. This report succinctly outlines a number of these climate change policies and measures that are essentially implemented by developed countries that do undermine the efforts of the Kingdom of Saudi Arabia to achieve its sustainable development objectives, since its economy is dependent on a single source of revenue.

The social and economic welfare losses arising from climate change response measures will increase the vulnerability of economic diversification and adaptation initiatives of the Kingdom. Additionally, the opportunities for addressing key requirements for achieving sustainable development such as poverty eradication and environmental sustainability will decrease with time. It is therefore urgent that the UNFCCC enhances its efforts to identify innovative and efficient adaptation technologies for addressing the impact of response measures such as the lack of international cooperation in the development of tools for quantitative ex-ante and ex-post analysis of impacts of response measures; unwillingness on the part of developed countries to share information and expertise of carbon pricing and its negative impacts on the international pricing of raw materials, processed goods and finished goods.

The Kingdom of Saudi Arabia continues to explore ways and means of minimizing these adverse impacts within the broader context of sustainable development and economic diversification. However, technical support is needed in performing rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of various climate change mitigation measures on Saudi society, economy and environment.

The Designated National Authority is the sole entity within the Kingdom of Saudi Arabia responsible for the design, preparation and implementation of a domestic Measurement, Reporting and Verification system (MRV) for the country. Due to its inter-ministerial and public/private inter-agency nature, the DNA has a strong and effective national platform for coordinating effective responses to climate change issues in Saudi Arabia. Taking into consideration its national circumstances, the MRV framework for the Kingdom would be built on national experiences and existing institutional arrangements for the preparation of national GHG inventories as well as experiences gained from the implementation of Clean Development Mechanism (CDM) projects. The development of the MRV system which would be based on a phased approach over a period of time, will “track” emissions avoidance attributed to specific economic diversification measures with mitigation co-benefits as well as adaptation measures which generate mitigation co-benefits. Others include sustainable development benefits arising from the implementation of projects outlined in its INDC; as well as climate change relevant support received in the form of technology cooperation and development and transfer of climate technologies.

The design and operationalization of the domestic MRV system for the Kingdom of Saudi Arabia will be rolled out in five stages from 2017 to 2020. The phased-out programme is sequenced as identification of the key elements of the MRV system; design and review of the MRV architecture; finalization of the design phase; implementation of a pilot MRV system and functional deployment of the MRV system.

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National Circumstances

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1.1 Location, Landforms and Climate

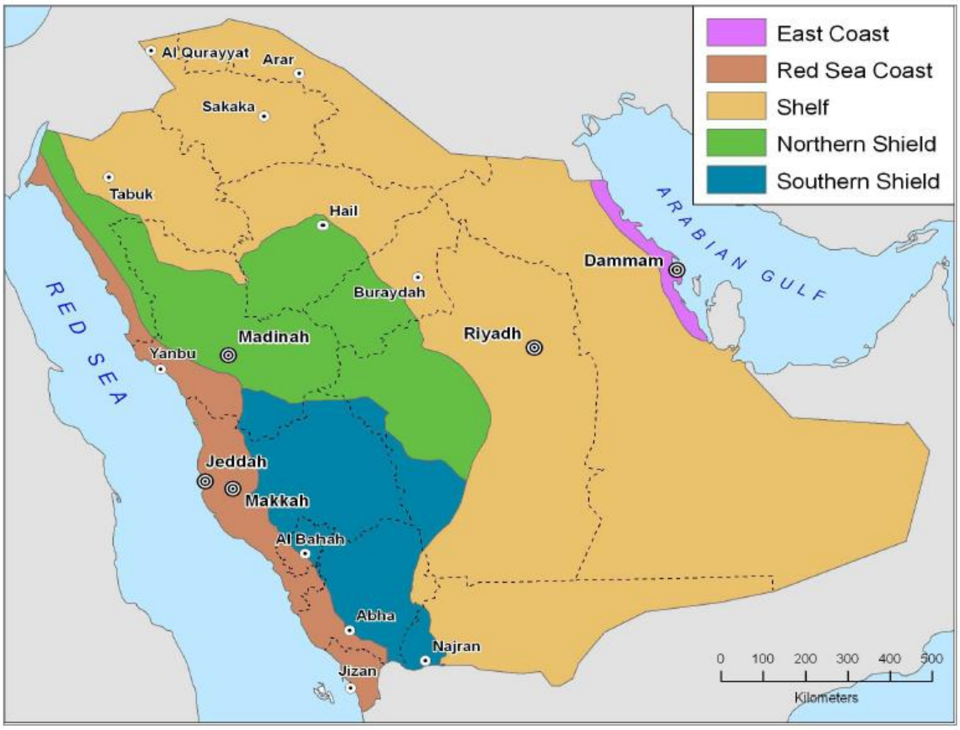
1.1.1 Location

Saudi Arabia is situated at the furthermost part of the southwest Asia. It occupies about four-fifth of the Arabian Peninsula, with a total area of approximately 2.25 million square kilometers of which about 38% are desert lands. The Kingdom lies within Latitude: 16.5°N–32.5°N; Longitude: 33.75°E–56.25°E.

1.1.2 Landforms

The Kingdom of Saudi Arabia consists of five distinct landforms namely: desert, plain, plateau, mountains and lava flows. About 30% of the Arabian Peninsula is covered with sand in the form of sand-seas. The three major bodies of sand are the Great Nafud in the north, the Empty Quarter (including the Al-Jafurah sand) in the south and crescent-shaped body of sand known as Dahna or Ad-Dahna connecting the two great bodies of sand. Several bodies of sand are also prominent along the side of the Tuwayq escarpment. The Great Nafud is a very large depression filled up with masses of sand and covers an area of almost 60,000 square kilometers. One striking aspect of this body of sand is lack of oases. A narrow, triangular strip of sand extending northwards from the Empty Quarter to east of Hofuf and then following the coastal plain is called Al-Jafurah. In contrast with the reddish hues of sand in the Nafud, the Ad-Dahna and rest of the Empty Quarter, the sands of Al-Jafurah are buff to tan in colour. Plain covers the coastal area of Saudi Arabia. The Plateau covers the middle part of Saudi Arabia. The mountains are located in the southwestern parts whereas lava flows cover the west and northwestern parts of Saudi Arabia.

Figure 1.1: Saudi Arabian Geological Settings (AlTokhais 2018)



Saudi Arabia is divided into two geological settings namely; the Arabian Shield and Arabian Shelf. Arabian Shield covers one third of the country and is composed of crystalline and metamorphic rocks of Precambrian age with volcanic lava flows of tertiary-quaternary age. Groundwater in the Arabian Shield occurs within valley (wadi) deposits and in few sub-basaltic deposits. Arabian Shelf covers two thirds of the surface area of the country and is composed of a thick sequence of sedimentary formations ranging in age from Cambrian to recent.

1.1.3 Climate

The climate of Saudi Arabia varies among regions due to its topographical features. Consequently, the summer is hot, dry in the interior regions and humid in the coastal regions. The winter is cool in the interior regions and mild in the coastal regions. The seasonal variation in temperature may range from 27^0C to 43^0C in the inland areas and 27^0C to 38^0C in coastal areas during summer. In winter, the temperatures range between 8^0C to 20^0C in the interior parts of Saudi Arabia while higher temperatures (19^0C-29^0C) have been recorded in the coastal areas of Red Sea (TNC, 2016). The average annual rainfall ranges from 50-100 mm in the central and northern regions and is about 25 mm in southern and northwestern areas. In the southwestern mountains, the rainfall occurs during summer and winter and average annual rainfall of 400-600 mm has been recorded. The average annual evaporation rates in the Kingdom range between 2500-4500 mm.

The total arable lands of the Kingdom are 52.68 million hectares (ha) or 24% of the total area of the Kingdom. In 2000, about 1.12 million ha or 2.2% of the arable lands were cultivated.

Saudi Arabia is particularly vulnerable to climatic change as most of Saudi Arabia has sensitive ecosystem. About 76% of its area is non-arable lands which include 38% of the area as deserts. These areas contain the range lands or the pasture areas which extend over about 171 million hectares. Most of pasture lands in Saudi Arabia are scattered herbs and shrubs with low density and low productivity. The rangelands sustain a large number of rural communities through their support for livestock grazing over the past hundreds of years. Although, the average annual rainfall in the Kingdom is low, the natural flora has managed to survive during the past under these extreme arid conditions. Renewable surface water is very limited and there are no lakes or rivers in the Kingdom. Groundwater from local aquifers (mostly non-renewable) is the major water supply source for domestic, agricultural and industrial purposes. Thus, water scarcity is common and changes in the water balance would have serious implications for, amongst other things, sensitive desert ecosystem, agriculture and water resources. Desalinated seawater fulfills approximately 70% of the potable water needs.

1.2 Directions of Development: Vision 2030 and National Transformation Program 2020

In April 2016, Saudi Arabia announced the Kingdom’s boldest, most innovative and far-reaching modernization and development plan in the country’s history, the “Vision 2030”. The “Saudi Arabia’s Vision 2030” was adopted as a methodology and roadmap for economic and developmental actions in the Kingdom of Saudi Arabia. In its aim to place the Kingdom in a leading position in all fields, Saudi Arabia’s Vision 2030 sought to identify the general goals and objectives, directions and policies of the Kingdom.

The Vision is based on three themes: a vibrant society, a thriving economy and an ambitious nation. This will enable KSA to build on its leading role as the heart of Arab and Islamic worlds. At the same time, it will use the investment power to create a more diverse and sustainable economy. Finally, it will use its strategic location to build its role as an integral driver of international trade and to connect the three continents: Africa, Asia and Europe. The first theme, a vibrant society, is vital to achieving the Vision and a strong foundation for economic prosperity. The second theme, a thriving economy provides opportunities for all by building an education system aligned with market needs and creating economic opportunities for the entrepreneur, the small enterprises as well as the large corporations. The Third theme, an ambitious nation is built on an effective, transparent, accountable, enabling and high-performing government. This Vision will be the point of reference for KSA's future decisions, so that all future projects are aligned to its content.

In order to build the institutional capacity and capabilities needed to achieve the goals of "Saudi Arabia's Vision 2030", the National Transformation Program (NTP) 2020 was launched across government bodies operating in the economic and development sectors in its first year. The program uses innovative methods to identify challenges, seize opportunities, adopt effective planning tools, activate the role of the private sector, bring about implementation and evaluate performances.

1.3 Saudi Arabian Vulnerability to Climate Change

Saudi Arabia is particularly vulnerable to climate change as most of its ecosystems are sensitive, its renewable water resources are limited and its economy remains highly dependent on fossil fuel exports, while significant demographic pressures continue to adversely affect the government's ability to provide for the needs of its population. The KSA Government is engaging in various adaptation measures to cope with adverse impacts of climate change as well as with response measures especially by the Annex I Parties of the UNFCCC, which are expected to have adverse economic and social impacts on the country.

Saudi Arabia is an arid country having harsh climate and sensitive ecosystem. Saudi Arabia is vulnerable to the climate change impacts from two directions (i) it is vulnerable to the bio physical impacts of climate change, being characterized by a harsh environment and sensitive ecosystem, (ii) the impacts of climate change response measures by Annex I countries being dependable on a single source economy. The implementation of greenhouse gas (GHG) emissions mitigation policies by Annex I countries will undoubtedly impact the economies of single source oil-exporting countries. The extent of impacts will depend on the reduction in oil demand and excessive price volatilities. The Saudi economy is particularly vulnerable to such volatilities because of high dependence on oil, strong demographic pressures and limited scope for diversification outside the hydrocarbon sector.

1.3.1 Demography and Population Dynamics

Saudi Arabia conducted censuses in the years 1974, 1992, 2004 and 2010. The recorded population during these censuses were 7,009,466, 16,948,388, 22,678,262 and 27,136,977 respectively. The demographic survey 2017 puts the estimated population at 32,552,336. The population growth in Saudi Arabia is due to two reasons (i) influx of the expatriate workers and (ii) the high natural growth of indigenous population. Growth rate in 2017 has been recorded to be at 2.52%. Urban population has increased from about 2.84 million of the total population in 1970 to about 26.22 million in 2015 as per data collected from population censuses and surveys 1974, 1992, 2004, 2010 and 2017, (Central Department of Statistics and Information - CDSI).

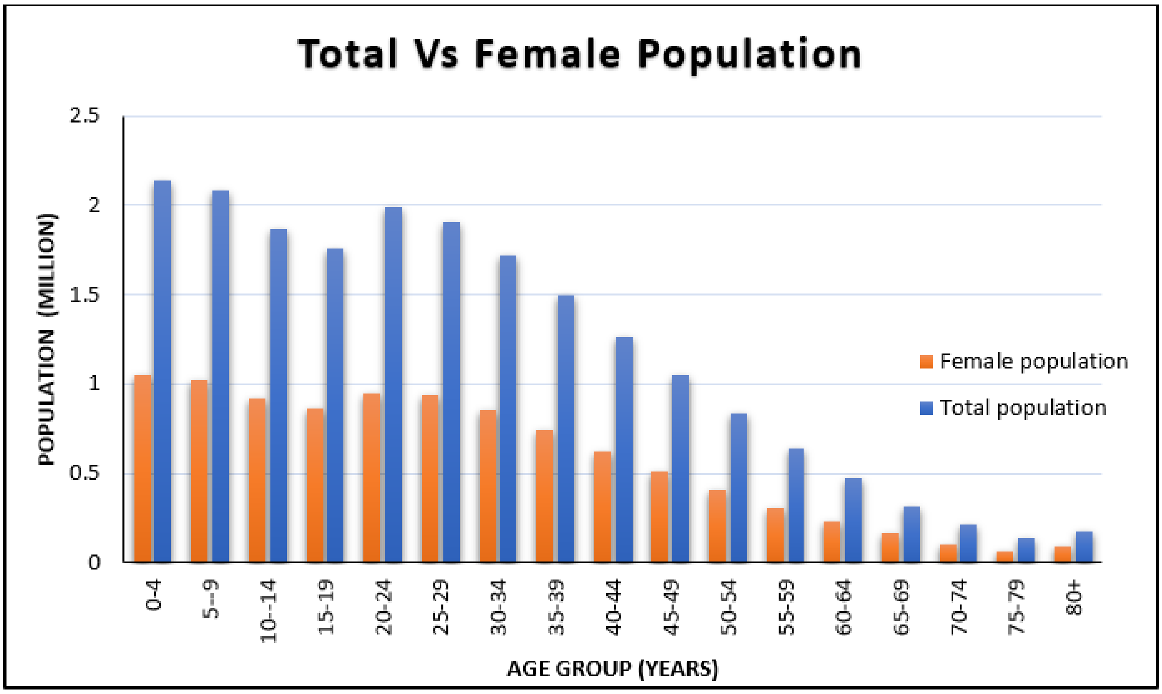
1.3.2 Population Dynamics

High Saudi population growth rates can challenge the future economic development of Saudi Arabia and may have adverse implications on the government's ability to spend on physical and social infrastructure. Following the oil shocks of the 1970s, Saudi Arabia's economy expanded due to income from surging oil prices resulting in the implementation of major domestic infrastructure projects. However, this situation continued to be vulnerable to changing conditions of the oil market. In addition, demographic pressures had become a major issue when population growth rates began to outstrip economic growth.

Concerns over the booming population and high Saudi unemployment in the 1990s have coincided with the slowdown of economic growth. This had become a serious concern for the government; namely, increasing financial burdens due to a growing population in the face of declining oil revenues. Employment of Saudi youth is currently a big challenge and the problem will further worsen if current collapse of oil prices continues and even worse if mitigation response measures of Annex I countries were to be added. A major current concern is that 48% of the growing population of Saudi citizens is below the age of 25 (Figure 1.2) implying significant challenges ahead in terms of education, training and employment. Hence from an economic policy perspective, the challenge that the Saudi government is currently facing is whether the Saudi economy can generate sufficient employment opportunities within the next 10 years for this burgeoning labour force.

There is a need for enhancing the quality of this potential labour force through better education and training and through reforming the education system. Economic diversification will require accelerated capacity building in cognitive skills and computer literacy for the Saudi workforce. The quality of education at all levels must be enhanced so that the Saudis can meet the demands of the 21st century. Major efforts on streamlining the education system and the labour market are already under way. However, the successful implementation of a major realignment of the education system will require scientific laboratories and educational know-how, which means that additional resources need to be channeled to scientific institutions to accommodate the growing Saudi youth population.

Figure 1.2: Population of Saudi Citizens (Total and Female) by Age (General Authority of Statistics, 2016)



1.4 Health

The health sector is one of the most important sectors in the Kingdom of Saudi Arabia and the Government of the Kingdom gives it a considerable attention for its development and upgrading by allocating significant share of the annual budget each year. The ministry of Health is the major and main health service provider in the Kingdom. The private sector also plays an important role to provide health services to the public.

The health care system has benefited from substantive investment in recent decades. It is envisaged to optimize and better utilize the capacity of hospitals and health care centers and enhance the quality of preventive and therapeutic health care services. The public sector will focus on promoting preventive care, on reducing infectious diseases and in encouraging citizens to make use of primary care as a first step. The public sector will focus on its planning, regulatory and supervisory roles in health care. KSA intends to provide health care through public corporations both to enhance its quality and to prepare for the benefits of privatization in the longer term. KSA has been working on developing private medical insurance to improve access to medical services and reduce waiting times for appointments with specialists and consultants. Doctors will be given better training to improve treatment for chronic diseases such as heart disease, diabetes and cancer.

1.5 Education

Education is the main pillar of human development and has expanded steadily since the start of the Kingdom’s First Development Plan in 1970 due to the sustained support and attention given to the sector by the government. The government of the Kingdom of Saudi Arabia has devoted significant resources to the development of human resources and manpower skills. It has therefore taken concerted measures in its successive national development planning processes to address its goal of enhancing educational achievement at all levels giving the Ministry of Education the role of supervising all general education; and emphasizing the effective implementation of educational strategies. Another equally important measure has been to enhance the role of the private sector in the provision and planning of educational facilities. However, the public sector remains the main provider of educational services, with a share of 89.9 percent of the total enrolment in primary schooling and 88.5 percent of the total enrolment in all stages of public education in 2010.

The tenth development plan (2015-2019) of the Kingdom of Saudi Arabia outlines the decision of the government to “transition to a knowledge-based economy and a knowledge society”, through the dissemination of knowledge, knowledge utilization, knowledge generation and knowledge management. It also focused on a number of fundamental policy developments that laid the basis for a move toward a knowledge-based economy. The Plan underscores the central role of education in achieving and strengthening human resources development, since education expands the scope of options available to citizens to gain knowledge and acquire skills, thus enabling them to benefit from the capabilities they acquire. It envisages the creation of an integrated, comprehensive educational system that will strive to lay down solid foundations for general education, with the help of well-trained, highly qualified education professionals who can develop students' capabilities and help them acquire different types of skills.

Moreover, the Plan emphasizes strategies aimed at establishing additional technical colleges, higher technical and vocational training institutes, as well as expand existing institutes; improving the vocational examination system to improve professional standards and licensing; and improving reliable data on employment needs to assess the expansion of training opportunities. Indeed, human resources’ development in the Kingdom has been a major concern since the initiation of development planning some four decades ago. Consequently, all levels of education have witnessed considerable expansion. Hence, Saudi Arabia pays special attention to education as it is an effective tool of a prime reflection for its prestigious culture.

Education is identified as a critical component and a catalyst of the nation's overall response to climate change. The relevance of education, training and public awareness in addressing climate change is internationally acknowledged and recognized in Article 6 of the United Nations Framework Convention on Climate Change ("UNFCCC") which urges Parties to promote (i) the development and implementation of educational and public awareness programmes on climate change and its effects; (ii) public access to information on climate change and its effects; (iii) public participation in addressing climate change and its effects and developing adequate responses; and (iv) training of scientific, technical and managerial personnel. It also encourages Parties to cooperate in and promote, at the international level and, where appropriate, using existing bodies through: (i) the development and exchange of educational and public awareness material on climate change and its effects; and (ii) the development and implementation of education and training programmes, including the strengthening of national institutions.

Moreover, the 13th Goal of the UN 2030 Agenda for Sustainable Development, called for amongst others, the “improvement of education, awareness-raising, human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning”. Training and capacity building are central to the climate change awareness process and thus requires some collaborative efforts from all stakeholders (government, private sector and non-government bodies).

Saudi Arabia enjoys a very high human development, reflecting “tangible improvements in all human development indicators such as the standard of living, health and education services, environmental conditions as well as potentials of comprehensive development.” It ranked 38th out of 188 countries in human development index in 2015 and its Human Development Index (HDI) trend reflects a remarkable steady progress, moving from 0.583 in 1980, to 0.773 in 2005, 0.815 in 2010 reaching 0.882 in 2015 (UNDP, 2016).

Saudi Arabia’s Vision 2030 and the National Transformation Program 2020 (NTP) sets out an ambitious road-map for education reforms in the Kingdom. The success of the Vision depends largely on reforms in the education system generating better opportunities for employment of young Saudis.

1.6 Electricity Generation and Consumption

Currently, the Kingdom has a single vertically integrated electricity company, Saudi Electricity Company (SEC), which owns all the three verticals of the power industry, including most of the generation, complete transmission and virtually all distribution capacities, with an exception in the industrial city of Yanbu, where Marafiq (a private integrated utility company) is responsible for generation, transmission and distribution of electricity. However, there are a considerable number of other private generators and Independent Power Producers (IPPs) that produce power and sell all of their generation to SEC or supply to isolated loads (not connected to the grid). Quite a few Industrial consumers, that have large demand, also have internal generation (captive generation), which is used to feed a substantial portion of their own load.
The Saudi electricity generation is heavily dependent on hydrocarbons, with crude oil accounting for 29% of electricity production in 2013, diesel (15%), heavy fuel oil (10%) and natural gas providing the remaining 46% (ECRA, 2014). The main drivers of electricity demand in the Kingdom are population growth, an expanding industrial sector and high demand for air conditioning during the summer months. The demand in the residential sector particularly remains strong, with the sector consuming 50% of the Kingdom’s total electricity production, the remaining being split among industry, commercial sector and governmental agencies (21%, 15% and 12% respectively). Climate is a major factor as 70% of the electricity sold is attributed to air conditioning (ECRA, 2014), adding to the seasonality of demand, with summer peak demand nearly twice the winter average.

The government has been very considerate to open the electricity market for restructuring. This decision to restructure the market and open it for competition primarily in the generation space would help the Kingdom in bridging gap between supply and demand. Also, with several IPPs coming up, alternative means of power generation would gain more importance. The government has reformed the electricity tariffs. Electricity and Cogeneration Regulatory Authority (ECRA) of the Kingdom has prepared a detailed restructuring plan under the banner of Electricity Industry Restructuring Plan (EIRP). EIRP is primarily divided into three major milestones detailed as follows:

a. Unbundling SEC from being a vertically integrated entity in creating a market for open generation and distribution.

b. Create a separate transmission company, which would operate independently of the generation, distribution and retail businesses.

c. Encourage the concept of the “Parallel Market” where large consumers can directly procure electricity from suppliers of their choice at a mutually agreed price and conditions.

The Kingdom’s leadership has been instrumental in pointing out the urgency to expand the current installed capacity and look for alternatives, in terms of fuel mix for power generation.

1.6.1 Renewable Energy

Saudi Arabia possesses a natural potential for solar and wind power and local energy consumption is projected to increase substantially by 2030. The Kingdom has taken initiatives and expects to increase the share of renewable energy capacity in the total energy mix by 9.5 GW by 2023 (NREP 2018). KSA will seek to localize a significant portion of the renewable energy value chain in the Saudi economy, including research & development and manufacturing. KSA is in the process of reviewing and developing the legal and regulatory framework that allows the private sector to invest in the renewable energy sector.

As a result of the ever-increasing demand of primary energy resources in the Kingdom of Saudi Arabia in sectors such as electricity, transportation, water and the industrial sectors, measures have been taken to control the escalating internal demand for the primary energy resources and also various measures have been taken to address this demand by including developing and deploying renewable energy sources in addition to other measures. Developing and deploying renewable energy have been considered among the most sustainable and reliable sources of energy in the Kingdom to meet the increased internal demand for the primary energy.

Renewable energy sources have tremendous advantages, including the potential to provide energy services in a sustainable manner, particularly, in addressing climate change, availability of a wide range of renewable energy technologies that can meet the full need from energy services with little or zero CO_2 emissions depending on the level of technical know-how and commercial scale of renewable energy technologies, an equitable and sustainable economic development, secure energy supply, energy access and environmental and health benefits.

The future energy mix is strategically important to the Kingdom to attain long-term prosperity, energy security and leading position in the global energy market. Building on some commercial and economical potential of renewable energy technologies, solar photovoltaic energy, concentrated solar energy and wind energy are envisaged as the most potential renewable energy sources in the Kingdom compared to the other technologies. The participation of private sector in developing reliable renewable energy sources in the Kingdom could be promoted through implementing some multi-level economic frameworks that could be selected on the basis of technologies, applications and goals of development process.

1.7 Natural Resources

1.7.1 Oil and Gas

The Kingdom of Saudi Arabia is one the largest oil exporting country in the world and is a member of Organization of Petroleum Exporting Countries (OPEC).

1.7.2 Mineral Resources

Saudi Arabia has been blessed with rich mineral resources such as aluminum, phosphate, gold, copper and other raw materials. Although the mining sector has already undergone improvements to cater to the needs of Saudi industries, its contribution to GDP has yet to meet expectations. This sector is considered to provide job opportunities by creating considerable number of new jobs in the process. A number of structural reforms including stimulating private sector investments by intensifying exploration, building a comprehensive database of the Kingdom's resources, reviewing the licensing procedures for extraction, investing in infrastructure, developing funding methods and establishing centers of excellence have been undertaken. KSA will also form strategic international partnerships and raise the competitiveness and productivity of national companies.

1.7.3 Water Resources

The Kingdom of Saudi Arabia (KSA) is located in an arid region with limited water supplies and the average annual rainfall in most parts of the country is below 150 mm throughout the year except the southwestern part where the rainfall occurs between 400-600 mm annually. The country lies in a harsh tropical and subtropical desert region with extremely high temperatures in summer and low temperatures in winter. Studies on potable water demand and water resources in the KSA indicate that there is a tremendous pressure on the existing water resources due to an increase in population as well as the rising living standards of the civil society (Zahrani, Al-Shayaa, & Baig, 2011).

The water resources in the Kingdom can be classified into four categories: surface water, groundwater, desalinated seawater and reclaimed wastewater. The non-conventional water resources, including desalinated seawater and treated wastewater (reclaimed wastewater) contribute to a small percentage but are important parts of the overall water supply.

1.7.4 Surface Water

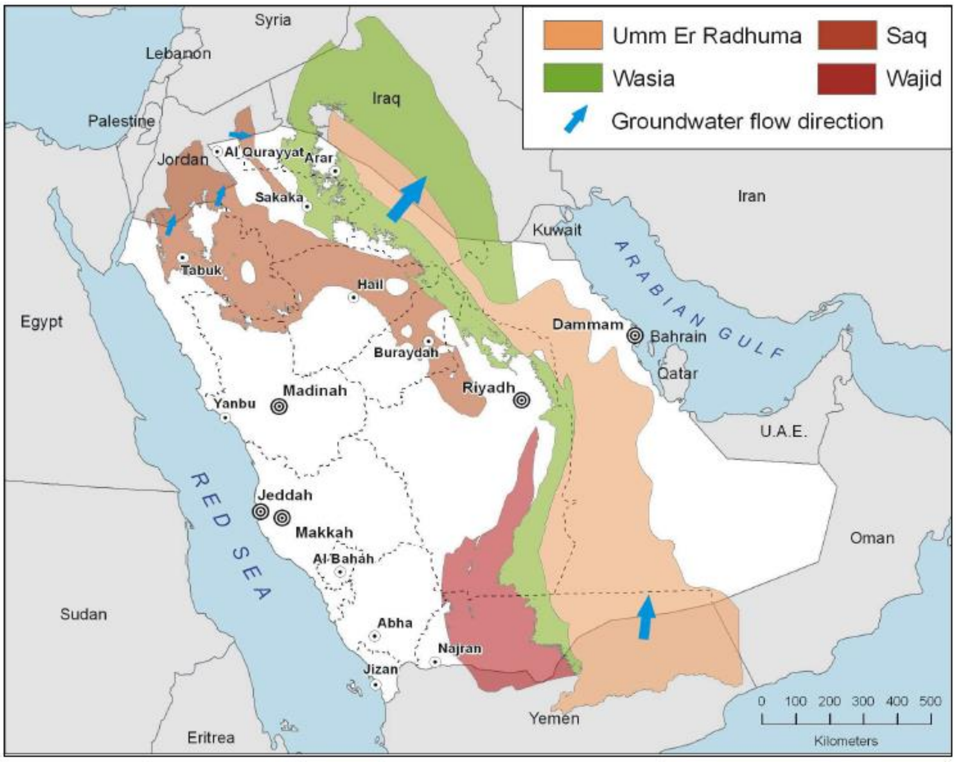
The extremely low and infrequent rainfall in most parts of the Kingdom has resulted in limited renewable surface water resources. Surface water resources are scarce in most parts of the Kingdom except in the mountainous areas of southwest where rainfall is relatively high and regular runoff occurs mainly in the form of intermittent flash floods. The surface water runoff infiltrates and recharges shallow aquifers such as Khuf, Aruma, Jauf, Sakaka and Jilh in basalt and alluvial areas.

The Ministry of Environment, Water and Agriculture (MEWA) has constructed a total of 482 dams across the Kingdom to store an estimated 2.084 BCM of the surface water runoff (MEWA, 2014, AlTokhais, 2018). These dams facilitate storage of surface water runoff, prevent flash floods, reduce surface water evaporation and increase infiltration to recharge aquifers (Tuinhof and Heederik, 2002). Among these dams, 92 were used for flood control with 892.4 MCM capacity, 02 dams with 51.5 MCM capacity for irrigation, 329 dams with a capacity of 683.7 MCM for aquifer recharge and 59 dams with a capacity of 456.2 MCM for drinking purposes (MEWA, 2014, AlTokhais, 2018).

1.7.5 Groundwater

Groundwater in Saudi Arabia is stored in geological formation ranging in age from Cambrian to recent. Formations are composed of limestones, sandstones, marl, shale, anhydrite, gypsum and alluvial deposits. Some of these rocks are known as aquifers. These aquifers in Saudi Arabia are classified into principal (main) and secondary aquifers according to their areal extension, thickness and hydraulic parameters. Principal aquifers include Saq, Wajid, Tabuk, Qassim, Minjur, Dhruma, Wasia, Biyadh, Umm er Radhuma, Dammam and Neogene Aquifers (Figure 1.3). Secondary aquifers include Al-Jauf, Khuf, Jilh, Marrat, Hanifa, Jubila, Arab, Sulaiy, Sakaka, Aruma, Basalts and Wadi (valley) sediments.

Figure 1.3: Some Principal Groundwater Aquifers and Flow Direction (AlTokhais 2018)

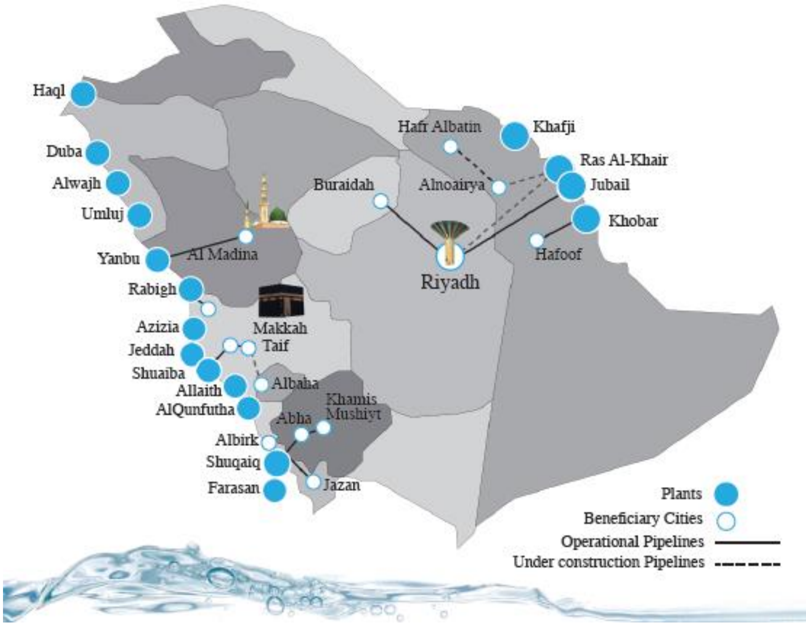


1.7.6 Desalinated Water

Saudi Arabia is the largest producer of desalinated water in the world. The desalination plants convert brackish sea water from the coasts of the Arabian Gulf and Red Sea into potable water by applying mainly Multistage Flash Systems (MSF), Multi Effect Desalination (MED) and Reverse Osmosis (RO) techniques. Large desalination plants have been constructed on the Gulf and Red Sea coasts in the last few decades to satisfy the Kingdom’s growing need for potable water. It is estimated that 70% of the required potable water as well as 5% of the electricity demand in the Kingdom are met by the desalination plants (SWCC 2014)

Saudi Arabian Saline Water Conversion Corporation has constructed a total of 30 desalination plants and more than 5,684 km of pipelines to convey the desalinated water from the coasts to various coastal and inland cities in the Kingdom. 24 desalination plants are on the Red Sea coast while 06 desalination plants are on the Arabian Gulf coast. SWCC accounts for 58% of the total desalinated water while the rest (42%) is produced by other entities. (Figure 1.4).

Figure 1.4: Desalination Plants on the Eastern and Western Coasts with Beneficiary Cities, Operational Pipelines and Under Construction Pipelines (SWCC, 2014)



The Saline Water Conversion Corporation (SWCC) reported the actual annual water and electricity production in the year 2014 as 1.1076 BCM; a 10% increase from 2013 and 29,690,432 MWh electricity; an increase of 19.3% from 2013. 550.1 MCM (49.7%) of the desalinated water was exported from desalination plants on the eastern coast and 557.5 MCM (50.3%) desalinated water was exported from the western coast of the Kingdom (SWCC 2014). However, the total desalinated water (SWCC plus other entities) produced in the Kingdom in year 2014 was 1,685 MCM. The desalinated water production was approximately 1,921 MCM in 2015 and more than 2,144 MCM is expected to be produced in 2018 with the construction and expansion of new desalination plants along the coasts.

1.7.7 Reclaimed wastewater

In Saudi Arabia, a small fraction of wastewater is reclaimed for agricultural, landscaping and industrial uses. The wastewater is treated in around 70 sewage treatment plants in the Kingdom (Chowdhury & Al-Zahrani, 2013). National Water Company (NWC) is responsible for wastewater collection, treatment and disposal (recycling and reuse). The wastewater collection and treatment systems were planned to cover 60% of the urban area of the Kingdom by 2014 (Ouda, 2013). NWC plans to increase the wastewater collection and treatment infrastructure to cover the whole population of the Kingdom. About 1,460 MCM of wastewater is generated in the country, of which about 671 MCM (46%) is collected and treated. Part of treated wastewater has been reused in many cities (e.g., Riyadh, Jeddah, Dammam, Yanbu and Jubail) for municipal park irrigation and urban area landscaping, estimated to be 240 MCM which is about 36% of the treated wastewater. The wastewater treatment plants in the Kingdom are generally secondary and tertiary level treatment plants producing a good quality reclaimed water.

1.8 Tourism

As tourism becomes a major driver of the Saudi economy with its huge employment-generating potential, Saudi Arabia has launched six major initiatives to stimulate the travel and tourism industry. The Saudi Commission for Tourism and National Heritage (SCTH) is reviewing its strategies to be in conformity with Vision 2030 and contribute in achieving the goals of the National Transformation Program (NTP) 2020.

Tourism has a huge potential for the Kingdom both as a field of employment and a source of income. The total number of international tourists to the KSA in 2011 was 17.5 million and domestic tourists amounted to 22.5 million (Tourism Information and Research Centre, 2012). The total expenditure of tourists was 85 billion SAR, which generated a value addition of 65.7 billion SAR (3% of GNP) and an employment of an estimated 670,000 (Tourism Information and Research Centre, 2012). Both indicators are growing faster than the average economic growth.

The holy city of Makkah takes a good share of the tourism industry. 55% of hotels and 18% of furnished apartments for tourists are in this province (Tourism Information and Research Centre, 2012). The majority of international tourists visited KSA for religious purposes, but pilgrims often transfer directly from the Airport terminal onto buses for Makkah or Medina. Jeddah is the only city in the KSA with a preserved historic downtown area. It possesses valuable and attractive historic assets such as the old town of Jeddah (Al Balad), which has been listed for consideration as a UNESCO World Heritage Site.

The surrounding areas have a number of highly desirable natural attractions, such as the coastline itself and the marine life as well as the unique and internationally recognized coral reefs. There are plenty of opportunities available for ecotourism and leisure visitors. Along the coastline, people have picnics at the beaches and go leisure fishing, kiting and undertake other recreational activities. Sailing and leisure fishing take place along the entire coastline and in particular close to existing marinas or ports. Scuba diving and snorkeling is undertaken at several places along the coast. Plenty of dive spots are located off Durat Al Arus in Jeddah and around the coral reefs of Eliza Shoals, north of Jeddah. There is, thus a broad range of activities and also a huge potential for more tourism along the Red Sea.

1.9 Agriculture

Saudi Arabia’s agriculture sector is witnessing major changes to meet its preset objectives and achieve sustainable food security in line with Vision 2030. This is driven by the new directions to develop the aquaculture, organic farming and green houses in the country.

The recent national development strategy launched by the Ministry of Environment, Water and Agriculture and the Agricultural Development Fund is looking to develop this sector through transforming the aquaculture into a real industry and increasing its contribution in the economy.

This plan will help achieve self-sufficiency in seafood products, increase the production capacity to 1 million tons by 2029 in addition to creating more than 400,000 job opportunities for young Saudis.

Over the past decades, the agricultural development in the Kingdom has significantly witnessed changes with new policies, aiming towards food security. Although the Kingdom's primary land area is a desert, it has regions where the climate supports agriculture. The government, in particular, has aided with this process by converting large areas of desert into agricultural fields. This was possible by implementing major irrigation projects and adopting large-scale mechanization.

Presently, agriculture in Saudi Arabia is focused on the production of wheat, dates, fish, poultry, etc. and exporting some of these volumes to neighboring countries and also to global players. The government has implemented many policies to ensure constant development. The Ministry of Environment, Water and Agriculture's (MEWA) primary goal is to frame agricultural policies, which will help both foreign and local suppliers. The Kingdom's other agencies include the Saudi Arabian Agricultural Bank (SAAB) – disbursement of subsidies and granting of interest free loans and the Grain Silos and Flour Mills Organization (GSFMO), who are responsible for purchase and storage of wheat, construction of flourmills and animal feed production. The government offers land distribution, reclamation programs and fund research projects. The private sector has played a major role in the Kingdom's agricultural development. This is primarily due to the government programs that offered long term, interest free loans, technical and support services and incentives, such as free seeds and fertilizers, low-cost water, fuel, electricity and duty-free imports of raw materials and machinery. Foreign joint-venture partners of the Kingdom's individuals or companies have been exempted from paying taxes up to 10 years.

Saudi Arabia has allocated substantial financial resources for improving roads, linking producing areas with consumer markets. Such programs encouraged the participation of private players in the market. Water is a key resource for agriculture. The Kingdom had successfully implemented a multifaceted program to provide the vast supply of water necessary to achieve the tremendous growth of the agricultural sector. This was possible by constructing dams in strategic locations to utilize the seasonal flood for irrigation. However, the scarcity of water has been increasing for the past few years, which thereby impacted the production of few crops.

1.10 Intended Nationally Determined Contribution (INDC) of the Kingdom of Saudi Arabia under the UNFCCC

The Kingdom of Saudi Arabia has submitted its Intended Nationally Determined Contributions (INDCs) to the UNFCCC Secretariat in November 2015. The INDC of the Kingdom is based on the principles listed in Article 3 of the UNFCCC and the approach specified in the economic diversification initiative adopted as UNFCCC decision 24/CP.18 in Doha in 2012. The Kingdom will engage in actions and plans in pursuit of economic diversification that have co-benefits in the form of greenhouse gas (GHG) emission avoidance and adaptation to the impacts of climate change, as well as reducing the impacts of response measures. This will help to move towards achievement of its sustainable development objectives.

The actions and plans which will generate mitigation co-benefits of economic diversification actions include: (i) energy efficiency, (ii) renewable energy, (iii) carbon capture, utilization and storage, (iv) utilization of gas and (v) methane recovery and flare minimization.

The following adaptation measures are expected to have mitigation co-benefits, depending on their degree of implementation and availability of funds to pursue planned activities (a) Water and waste water management (b) urban planning (c) marine protection and (d) Reduced desertification while development and Implementation of Integrated Coastal Zone Management Plan (ICZMP), development and operationalization of Early Warning Systems (EWS) and development and implementation of Integrated water management plan are adaptation measures to address climate change and raise resilience to its impacts

1.11 Institutional Arrangement for Biennial Update Report (BUR)

The focal point for preparation of the Biennial Update Report (BUR) is the "Designated National Authority (DNA)", which serves as the implementing entity (for details, refer to section 5.1).

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SECTION – 2

2012 National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases

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Section 2: 2012 National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases

2.1 Introduction

This section presents the *National inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol* for the year 2012. This inventory has been prepared in response to the Kingdom's commitment to the United Nations Framework Convention on Climate Change (UNFCCC) to submit its first Biennial Update Report which would include national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for Saudi Arabia. It is prepared according to the Revised 1996 Guidelines of the Intergovernmental Panel on Climate Change for National Greenhouse Gas Inventories, which is contained in 3 volumes (IPCC, 1997).

The Kingdom of Saudi Arabia ratified the United Nations Framework Convention on Climate Change in December 1994. This Convention aimed to stabilize the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Being a signatory to the UNFCCC, Saudi Arabia has agreed to develop periodic national inventories of emissions by sources and removals by sinks of greenhouse gases as part of its National Communications (NCs) and Biennial Update Reports (BURs). Accordingly, the Kingdom submitted its first, second and third national communications in 2005 (PME, 2005), in 2011 (PME, 2011) and 2016 (DNA, 2016) respectively.

The 2012 national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases for the Kingdom of Saudi Arabia was developed according to the Revised 1996 IPCC Guidelines.

2.2 Objective

The main objective of this section is to present a national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases for Saudi Arabia for 2012 covering the three direct greenhouse gases (i.e. CO_2, CH_4 and N_2O) as part of it's first Biennial Update Report to the UNFCCC.

2.3 Inventory Development Process

The inventory development process included the following major steps:

a. Identification of the types of data to be collected from each emission source category and sub-sectors (under each category) as proposed in the Revised 1996 IPCC Guidelines;

b. Preparation of a list of government ministries and other governmental, semi-governmental and private organizations that would be contacted to collect the required information (identification of the inventory data input sources);

c. Development of questionnaires or forms to collect the required information from the selected ministries and organizations (development of questionnaires);

d. Collection of inventory data from all the selected ministries and organizations (collection of information);

e. Tabulation of the collected data in the IPCC prescribed format;

f. Estimation of greenhouse gas emissions/sinks based on methodologies recommended by the Revised 1996 IPCC Guidelines; and

g. Development of the national inventory report and summary of total anthropogenic emissions by sources and removals by sinks of greenhouse gases.

2.4 Data Collection, Emission Factors and Methodologies

2.4.1 Preparation of Questionnaires

The Revised 1996 IPCC Guidelines were utilized in the preparation of questionnaires. These Guidelines are in three volumes. Volume 1 consists of general reporting instructions providing directions for assembling, documenting and transmitting completed national inventory data consistently, regardless of the method used to produce the estimates. Volume 2 contains instructions for calculating emissions of carbon dioxide (CO_2) and methane (CH_4), as well as some other trace gases, from six major emission source categories. Volume 3 provides a compendium of information on methods for estimation of emissions of greenhouse gases and a complete list of source types for each. It summarizes a range of possible methods for many source types. It also provides summaries of the scientific basis for the inventory methods recommended.

The Revised 1996 IPCC Guidelines for preparing the national greenhouse gas inventory were reviewed thoroughly to identify inventory input data requirements for each of the activities given in the documents. The workbook accompanying the Revised 1996 IPCC Guidelines was also checked thoroughly for additional and/or auxiliary information that may be required for calculating emissions of greenhouse gases. Custom-made questionnaires were developed for each targeted organization/company and forwarded to them for their input.

2.4.2 Selection of Target Organizations/Companies

Based on the input data requirements for calculating greenhouse gas emissions for each sector and sub-sector given in the Revised 1996 IPCC Guidelines, a list of potential government departments, private organizations and industrial companies, from which such information should be available, was prepared. All relevant information sources were consulted in preparation of this list.

2.4.3 Input Data Sources

The basic information sources prepared during the development of the first (PME, 2005), the second (PME, 2011) and the third (DNA, 2016) national communications for the Kingdom of Saudi Arabia were updated for selection of target organizations to obtain necessary data pertinent to direct greenhouse gas emission sources in the Kingdom. The custom-made questionnaires were prepared and mailed to each of the targeted organizations/companies. The inputs from these organizations/companies were carefully reviewed and analyzed for utilization in the calculations of greenhouse gas emissions. In addition to the questionnaires, various other sources of information were consulted.

2.4.4 Input Data Collection and Tabulation

The data collected through questionnaires and from other accessible sources were sorted for individual activities for which direct greenhouse gas emissions were to be calculated. Information obtained from different sources for a specific activity was combined, as appropriate. Some of the information requested in the questionnaires was not provided by the respondents. In such cases, appropriate assumptions were made to estimate the missing data.

2.4.5 Selection of Emission Factors and Calculation Methodologies

In addition to the basic inventory input data, emission factors were needed to calculate greenhouse gas emissions. These emission factors were adopted from the Revised 1996 IPCC Guidelines. Additionally, available more accurate (than the default emission factors suggested in IPCC Guidelines) country-specific information was also adopted in this study. Calculation methodologies in the Revised 1996 IPCC Guidelines were followed in estimating greenhouse gas emissions and removals in this study.

2.4.6 Uncertainties in Emissions Estimation

Due to the unavailability of certain source specific input data including emission factors, uncertainties are unavoidable when any estimate of national emissions or removals is made. It is therefore important to establish and express uncertainties quantitatively and/or with the acceptable confidence interval or range. The Revised 1996 IPCC Guidelines provide a general table for relative uncertainties associated with emission factors and activity data, which is limited to CO_2 and CH_4 emissions only.

Uncertainties in emissions estimation basically come from three major sources: input data, the assumptions used in selecting the emission factors and adopting extrapolated and/or averaged values in calculations.

Uncertainties related to input data depend mainly on the size and quality of data collection and record keeping. Uncertainties involved in selection of emission factors come from the fact that the default values provided in the Revised 1996 IPCC Guidelines (1997) were established for a certain group of activities that comprises a number of processes. The nature of a group of activities in a particular country may differ from the generalized nature of the group considered in derivation/establishment of the default emission factors. A similar analogy applies to the variation in source and/or sink characteristics in different countries. Therefore, the default emission factors may not exactly represent and characterize the actual conditions of source/sink activities. In such cases, using these factors to calculate the greenhouse gas emissions would result in high uncertainties.

Uncertainties also appear when the unavailability of input data compels the use of extrapolated and/or averaged values for a particular set of data. Uncertainty of extrapolated or averaged data cannot be quantified precisely because the uncertainties associated with the interpolation and/or averaging procedures also depend on the quality of the relevant data including data accuracy.

2.4.6.1 Input Data

The raw data provided by the government organizations were considered to be accurate while the raw data supplied by the private sectors were considered to be accurate in some cases and the uncertainty of raw data were considered to vary within 5% to 10% in others. As mentioned above, the uncertainties involved in estimation of missing data were not quantified since it was not possible to establish uncertainty levels associated with the extrapolated and/or averaged values adopted in emissions calculations.

2.4.6.2 Emission Factors

The uncertainties associated with the emission factors used in this study were taken from the Revised 1996 IPCC Guidelines (IPCC, 1997) and ranged between 7% and 55%.

2.4.6.3 Overall Emissions Estimation

The overall uncertainty of CO_2 and CH_4 emissions were estimated according to the Revised IPCC Guidelines (1997). Uncertainties in emission estimates for N_2O were not determined due to the unavailability of relevant data and/or methodology in the IPCC Guidelines.

2.5 Summary of Overall National Inventories of Greenhouse Gas Emissions and Sinks

2.5.1 Overview of 2012 National Inventories of Greenhouse Gas Emissions and Sinks

The 2012 greenhouse gas national inventory for Saudi Arabia is summarized in Table 2.1. The details of estimated greenhouse gas emissions from various activities associated with sub-sectors in each sector are presented in Table 2.2. The inventory included the direct greenhouse gases; namely, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emissions of these gases were calculated for the energy, industrial processes, agriculture, land-use change and forestry and waste sectors in the Kingdom. Greenhouse gas emissions from the various uses of paints and solvents have not been recommended by the Revised 1996 IPCC Guidelines, thus, they were not included in this report. The major findings pertaining to individual emissions/removals of greenhouse gases are summarized below.

CO_2 emissions in 2012 were 498,853 Gg and CO_2 sinks were 9,151 Gg. As shown in Table 2.1, the energy sector contributed 89.1% of the total CO_2 emissions, followed by the industrial processes sector (10.8%) and the agriculture sector (0.1%). The source categories (Figure 2.1) contributing to these CO_2 emissions were electricity generation (32.4%), road transport (23.2%), desalination (12.3%), petroleum refining (7.5%), cement production (5.7%), petrochemical industry (4.9%), iron and steel production (4.1%) and fuel combustion in cement industry (2.6%)

Table 2.1: Summary of National Inventories of Direct Greenhouse Gases for 2012

Source Sector	Quantity Emitted (Gg)		
	CO_2	CH_4	N_2O
Energy*	444,473.0 (89.1)**	515.70 (29.0)	2.54 (6.5)
Industrial processes	53,730.4 (10.8)	36.54 (2.1)	
Agriculture	649.2 (0.1)	82.72 (4.6)	32.32 (83.1)
Land-use change and forestry	-9,151.0*** (-1.8)		
Waste		1,144.07 (64.3)	4.04 (10.4)
Total Emissions	**498,853**	**1,779**	**38.90**
Net Emissions******	**489,702**	**1,779**	**38.90**

* *As per the IPCC Guidelines, emissions from International Aviation and Navigation Bunkers were not included in Total Emissions.*
** *Numerals in brackets are percentages of Total Emissions.*
*** *Minus sign indicates sink.*
**** *Total emissions minus sinks.*

Table 2.2: Overview of National Inventories of Direct Greenhouse Gases for 2012

SOURCE AND SINK CATEGORIES	CO_2 (Gg)	CH_4 Gg)	N_2O (Gg)
Total National Emissions	**498,852.6**	**1779.1**	**39.0**
Net National Emissions	**489,701.6**	**1779.1**	**39.0**
1. Energy*	**444,473.0**	**515.8**	**2.7**
A. Fuel combustion	442,244.0	34.0	2.7
1. Energy industries	198,842.0	6.1	1.1
2. Manufacturing industries and construction	48,481.4	3.6	0.2
3. Transport	120,494.0	22.3	1.1
4. Other Sub-sectors	74,426.6	2.0	0.3
B. Fugitive emissions from fuels	2,229.0	481.8	
2. Industrial processes	**53,730.4**	**36.5**	**0.0**
A. Mineral products	29,206.8		
B. Chemical industry	4,331.6	36.5	
C. Iron and steel production	20,192.0		
3. Solvent and other product use**			
4. Agriculture	**649.2**	**82.7**	**32.3**
A. Enteric fermentation		64.9	0.0
B. Manure management		16.6	10.5
C. Agricultural soils			21.8
D. Field burning of agricultural residues	649.2	1.2	0.0
5. Land-use change and forestry	**-9,151.0**		
A. Changes in forest and other woody biomass stocks	-8,976.4		
B. Forest and grassland conversion	-125.9		
C. Abandonment of managed lands***			
D. CO_2 emissions and removal from soil	-48.7		
6. Waste		**1,144.1**	**4.0**
A. Solid waste disposal on land		768.8	
B. Wastewater handling		14.2	
C. Human sewage			4.0
D. Industrial wastewater		361.1	

* *As per the IPCC Guidelines, emissions from international aviation and navigation bunkers were not included in energy total.*

** *Estimation of greenhouse gas emissions from the various uses of paints and solvents have not been recommended by the Revised 1996 IPCC Guidelines.*

*** *No abandonment of managed lands in Saudi Arabia was assumed.*

Figure 2.1: Relative Contributions of Source Categories to 2012 CO_2 Emissions of 498,853 Gg (Data from Table 2.3)

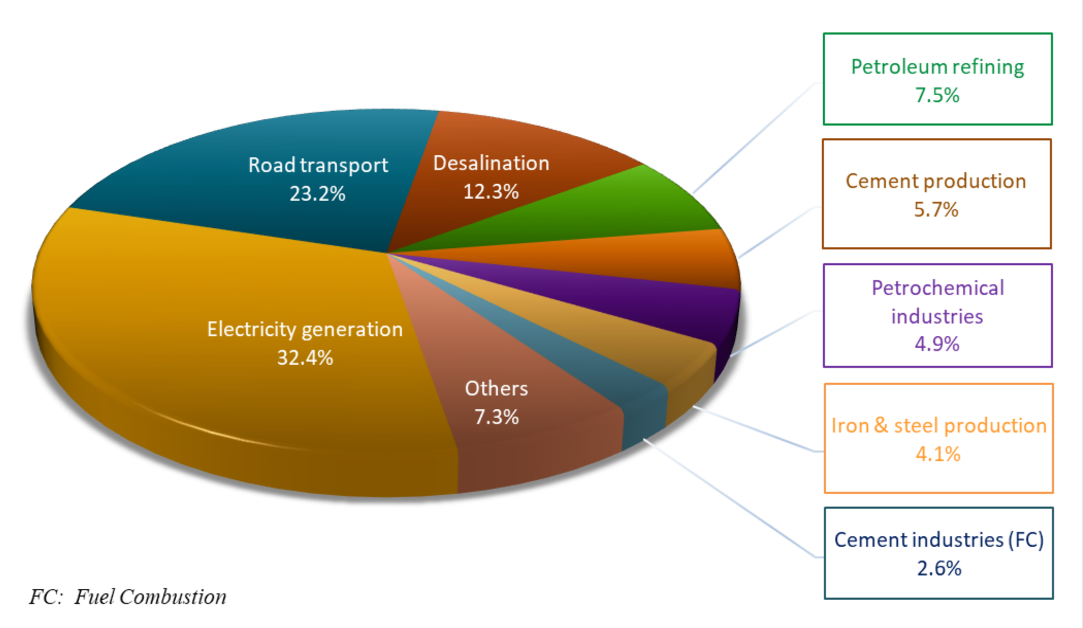


Table 2.3: 2012 Carbon Dioxide (CO_2) Emissions from Source Categories

Source Categories	CO_2 (Gg)	Percent of Total
Electricity generation	161,672.1	32.4
Road transport	115,946.9	23.2
Desalination	61,478.4	12.3
Petroleum refining	37,169.9	7.5
Cement production	28,596.8	5.7
Petrochemical industries	24,597.2	4.9
Iron & steel production	20,192.0	4.1
Cement industries (FC)*	12,813.3	2.6
Others **	36,385.9	7.3
Total	**498,853**	**100**

* Fuel Combustion

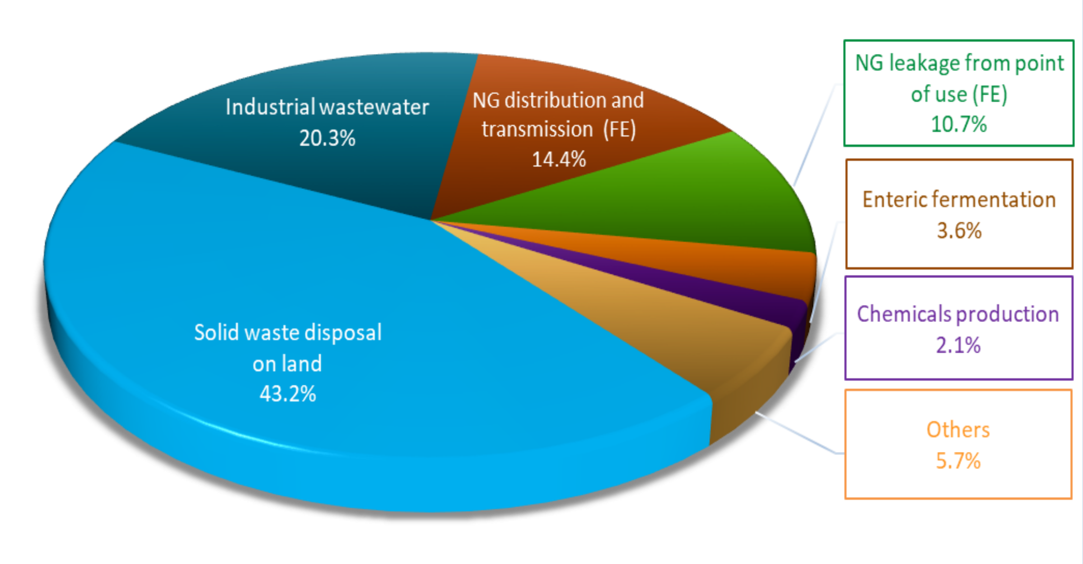
** Others include the following source categories:

Agriculture (FC) (9,239.5 Gg)
Fertilizer industries (FC) (9,014 Gg)
Ammonia production (4,331.6 Gg)
Residential (3,708.7 Gg)
Navigation (2,675.4 Gg)
Aviation (1,784 Gg)
Iron and steel (FC) (1,642.7 Gg)
*Oil refining (FE***) (892.5 Gg)*
Gas processing (FE) (750.7 Gg)
Field burning of crop residues (649.2 Gg)
Oil and gas production (FE) (569.1 Gg)
Limestone production and uses (473.0 Gg)
Other industries (FC) (414.2 Gg)
Soda ash uses (136.9 Gg)
Railways (87.8 Gg)
Oil and gas transportation (FE) (16.8 Gg)

*** Fugitive Emissions

CH_4 emissions were 1,779 Gg as shown in Table 2.1. The waste sector contributed 64.3% of the total CH_4 emissions followed by the energy (29.0%), agriculture (4.6%) and the industrial processes (2.1%) sectors. The source categories contributing to CH_4 emissions are shown in Figure 2.2.

Figure 2.2: Relative Contributions of Source Categories to 2012 CH_4 Emissions of 1,779 Gg (Data from Table 2.4)



FE: Fugitive Emissions

Table 2.4: 2012 Methane (CH_4) Emissions from Source Categories

Source Categories	CH_4 (Gg)	Percent of Total
Solid waste disposal on land	768.8	43.2
Industrial wastewater	361.1	20.3
NG distribution and transmission (FE)*	256.7	14.4
NG leakage from point of use (FE)	190.4	10.7
Enteric fermentation	64.9	3.6
Chemicals production	36.5	2.1
Others**	100.7	5.7
Total	**1,779.1**	**100**

* Fugitive emission

** Others include the following source categories (Gg):

Road transport (22.03)
Manure management (16.63)
Oil refining (FE) (14.58)
Wastewater handling (14.20)
Gas processing (FE) (8.78)
Oil and gas production (FE) (6.66)
Electricity generation (5.38)
Oil and gas transportation (FE) (4.67)
*Petrochemical (FC***) (2.20)*
Agriculture (FC) (1.26)
Field burning of crop residues (1.18)
Fertilizer industries (FC) (0.807)
Petroleum refining (0.694)
Cement industries (FC) (0.447)
Desalination (0.429)
Residential (0.296)
Navigation (0.175)
Iron and steel (FC) (0.147)
Aviation (0.049)
Other industries (FC) (0.011)
Railways (0.006)

*** Fuel Combustion

N_2O emissions were 38.9 Gg as shown in Table 2.1. The agriculture sector was the major sectoral contributor with 83.1%, followed by the waste (10.4%) and energy (6.5%) sectors. Source categories contributing to N_2O emissions are shown in Figure 2.3.

Figure 2.3: Relative Contributions of Source Categories to 2012 N_2O Emissions of 38.9 Gg (Data from Table 2.5)

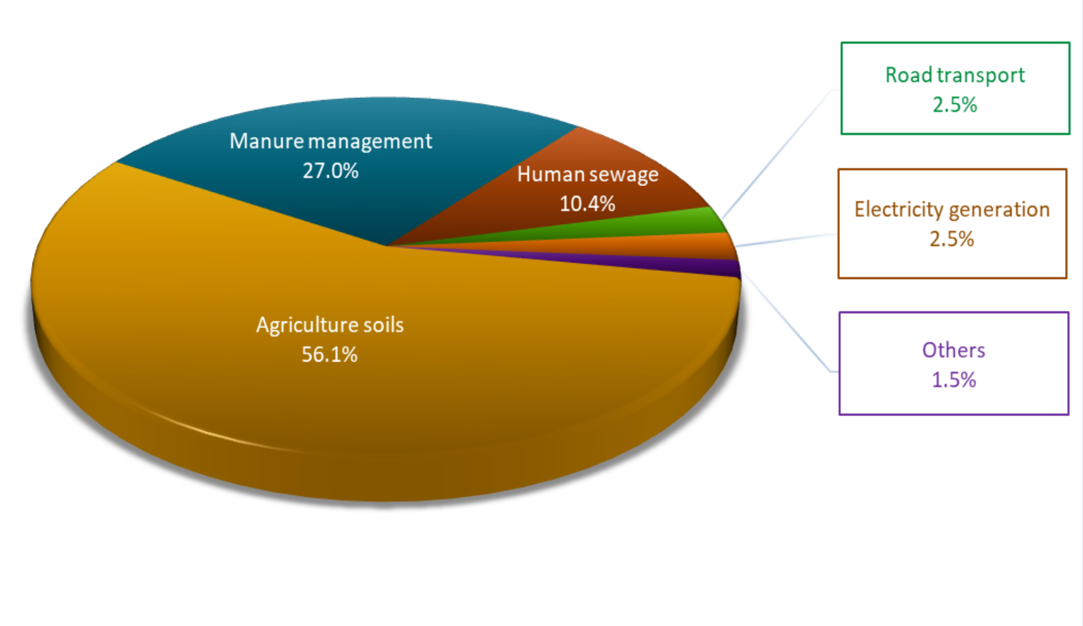


Table 2.5 - 2012 Nitrous Oxide (N_2O) Emissions from Source Categories

Source Categories	N_2O (Gg)	Percent of Total
Agriculture soils	21.816	56.1
Manure management	10.487	27.0
Human sewage	4.037	10.4
Road transport	0.984	2.5
Electricity generation	0.981	2.5
Others*	0.597	1.5
Total	**38.902**	**100**

* Others include the following source categories (Gg):

Desalination (0.181)
*Cement industries (FC**) (0.092)*
Petroleum refining (0.074)
Agriculture (FC) (0.076)
Aviation (0.060)
Petrochemical (FC) (0.044)
Navigation (0.021)
Field burning of crop residues (0.020)
Fertilizer industries (FC) (0.016)
Residential (0.006)
Other industries (FC) (0.003)
Iron and steel (FC) (0.003)
Railways (0.0007)

** Fuel Combustion

2.5.2 Uncertainties in Greenhouse Gas Emission Estimations

In this study, the raw data provided by the government organizations were considered to be accurate. The data reported by the well-known international organizations, which were verified were also considered to be accurate. However, the uncertainty of the raw data supplied by the private sectors was assumed to vary within 10%. The activity data used for estimation of more than 80% of the total greenhouse gas emissions were considered to be reasonably accurate. The overall uncertainties of CO_2 and CH_4 emissions were estimated to be in the range of 7-15% and 25-60%, respectively (as per the IPCC Guidelines). Uncertainties in emission estimates for N_2O could not be determined due to the unavailability of methodology and/or the emission factors in the Revised 1996 IPCC Guidelines. Uncertainties involved in using extrapolated values, yearly averaged values, or both were not established. Uncertainties due to exclusion of some sources were also not assessed.

2.6 Contributions of Major Sectoral Activities to 2012 Greenhouse Gas Emissions

The contributions of major sectoral activities associated with the energy, industrial processes, agriculture, land-use change and forestry and waste sectors in the Kingdom to the 2012 greenhouse gas emission inventory for Saudi Arabia are presented in Table 2.2. The main findings pertaining to individual greenhouse gases are summarized below.

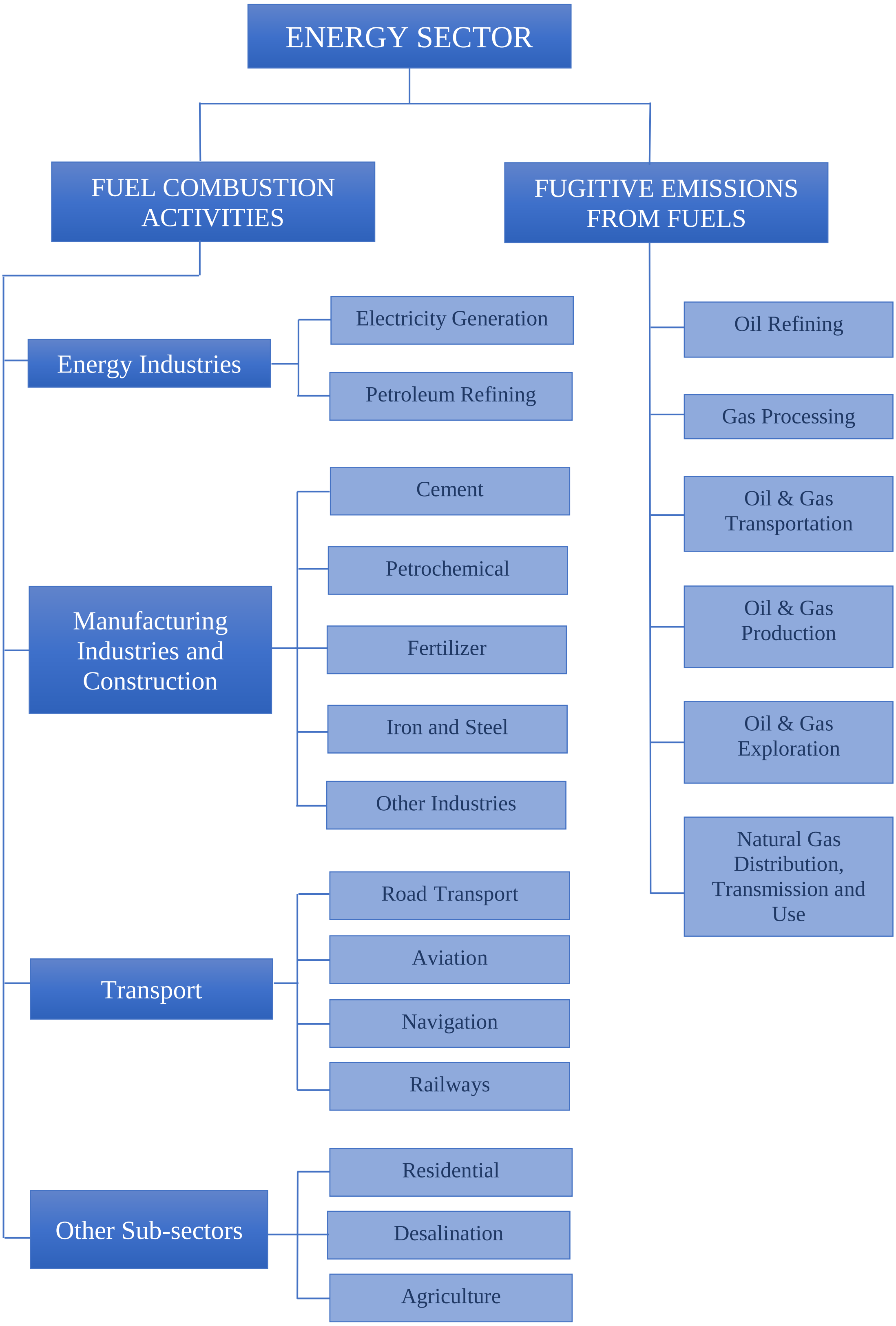
2.6.1 Energy Sector

The energy sector is the most important contributor to greenhouse gas emissions, especially to carbon dioxide (CO_2) emissions. Different activities considered in the energy sector are presented in Figure 2.4.

Greenhouse gas emissions from energy-related stationary and mobile combustion source categories were considered in this sector. These sources included electricity generation, petroleum refining, manufacturing industries and construction and transportation (road transport, civil aviation, navigation and railways). Residential, desalination, agriculture and fisheries and waste management activities were also accounted for. In addition to the combustion sources, fugitive emissions from fuels in the oil and gas industry and other usage, including venting and flaring, were considered.

The emissions of CO_2, CH_4 and N_2O from various activities in this sector were estimated and are summarized in Table 2.2. The total CO_2, CH_4 and N_2O emissions from this sector were 444,473 Gg, 515.7 Gg and 2.54 Gg, respectively.

Figure 2.4: Activities Considered in the Energy Sector



2.6.1.1 Emissions from Fuel Combustion

a. Emissions from the **electricity generation** category were 161,672.1 Gg CO_2, 5.38 Gg CH_4 and 0.98 Gg N_2O. Crude oil combustion accounted for 37.0% of CO_2 emissions, followed by natural gas (33.2%), diesel oil (22.3%) and residual fuel oil (7.5%). Combustion of crude oil, diesel oil, natural gas and residual fuel oil contributed 45.9%, 27.5%, 17.9% and 8.8% of CH_4 emissions, respectively. About 50.4% of N_2O emissions were contributed by the combustion of crude oil, followed by the combustion of diesel oil (30.1%), natural gas (9.8%) and residual fuel oil (9.7%).

b. The **petroleum refining** category encompasses activities related to oil refining, gas processing, oil and gas production, oil and gas transportation and oil and gas exploration. Emissions from petroleum refining were 37,169.9 Gg CO_2, 0.69 Gg CH_4 and 0.07 Gg N_2O. Fuel combustion associated with gas processing activities was the major contributor to CO_2 emissions. The oil refining and the gas processing activities were the major contributors to CH_4 and N_2O emissions.

c. The **manufacturing industries and construction** category consists of activities related to the cement industry, petrochemicals manufacturing, fertilizer industry, iron and steel industry and other industries. Total emissions from fuel combustion in these activities were 48,481 Gg, CO_2, 3.62 Gg CH_4 and 0.16 Gg N_2O. Activities related to the petrochemical, cement and fertilizer industries were the largest contributors to CO_2 and CH_4 emissions in this category. The cement industry was the major contributor to N_2O emissions from the manufacturing industries and construction category followed by petrochemical and fertilizer.

d. The **road transportation** category was one of the major sources of greenhouse gas emissions. Automobiles emitted 115,947 Gg CO_2, 22.03 Gg CH_4 and 0.98 Gg N_2O. Gasoline combustion was the major contributor to the emissions of the three direct greenhouse gases.

e. The **aviation** category was divided into national and international aviation combustion sources. The greenhouse gas emissions from national aviation combustion sources were 1,784 Gg CO_2, 0.05 Gg CH_4 and 0.06 Gg N_2O. The emissions from international aviation combustion sources were 4,697.9 Gg CO_2, 0.06 Gg CH_4 and 0.15 Gg N_2O. The emissions from the combustion for international aviation category were not included in the 2012 greenhouse gas emissions inventory as per the Revised 1996 IPCC Guidelines.

f. The **navigation** category was divided into national and international bunker combustion sources. The emissions from national bunker combustion sources (including fisheries activities) were 2,675.4 Gg CO_2, 0.18 Gg CH_4 and 0.02 Gg N_2O. The emissions from international bunker combustion sources were 8,957.5 Gg CO_2, 0.58 Gg CH_4 and 0.07 Gg N_2O. The emissions from the international combustion for navigation category were not included in the 2012 greenhouse gas emissions inventory as per the Revised 1996 IPCC Guidelines.

g. The emissions from the **railways activities** relate to the combustion of diesel oil. Emissions from fuel combustion in the railways activities category were 87.8 Gg CO_2 and very small quantities (<0.01 Gg) of CH_4 and N_2O.

h. The **residential activities** relate to the combustion of liquefied petroleum gas. Emissions from fuel combustion in the residential activities category were 3,708.7 Gg CO_2, 0.29 Gg CH_4 and <0.01 Gg N_2O.

i. The **desalination** plants combust heavy fuel oil, crude oil, diesel oil and natural gas. Emissions from fuel combustion in the desalination plants category were 61,478.4 Gg CO_2, 0.43 Gg CH_4 and 0.18 Gg N_2O.

j. In the **agricultural** category, off-road vehicles (such as tractors, bulldozers, etc.), irrigation and the activities related to poultry and dairy farms were considered (from fuel combustion only). Emissions from the agricultural category were 9,239.5 Gg CO_2, 1.26 Gg CH_4 and 0.08 Gg N_2O.

2.6.1.2 Fugitive Emissions from Fuels

The fugitive emissions (non-combustion and non-productive combustion emissions) were the major source of CH_4 in the **energy sector** (93.4%) and accounted for about 481.8 Gg CH_4. Oil refining, gas processing, oil and gas production, transportation, exploration, venting and flaring and leakage from distribution, transmission and point of use were considered in the above estimate. Approximately 86.7% of CH_4 emissions in this sector were generated from leakage of natural gas during distribution, transmission and use. Oil and gas related activities (i.e., exploration, production, transportation, processing, oil refining activities, flaring and venting) accounted for 6.7% of CH_4 emissions. All other activities accounted for about 6.6% of CH_4 emissions. Gas flaring from oil and gas related activities emitted 2,229 Gg of CO_2.

The relative contributions of the major activities to CO_2, CH_4 and N_2O emissions in the energy sector are presented in Figures 2.5, 2.6 and 2.7, respectively.

Figure 2.5: Relative Contributions of Various Activities to 2012 CO_2 Emissions from Energy Sector

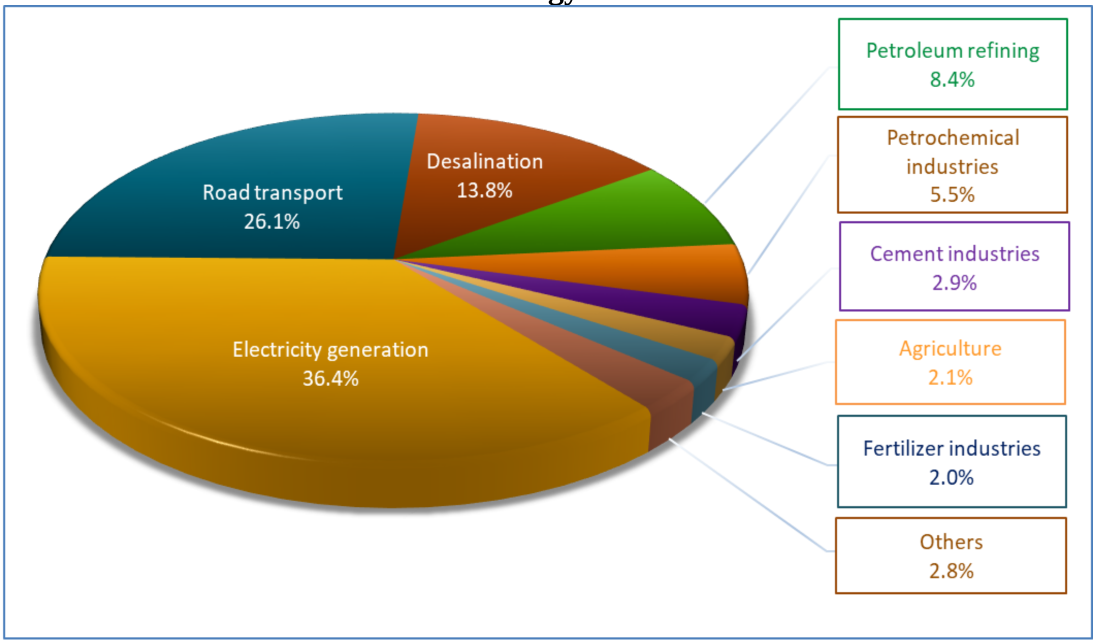


Figure 2.6: Relative Contributions of Various Activities to 2012 CH_4 Emissions from Energy Sector

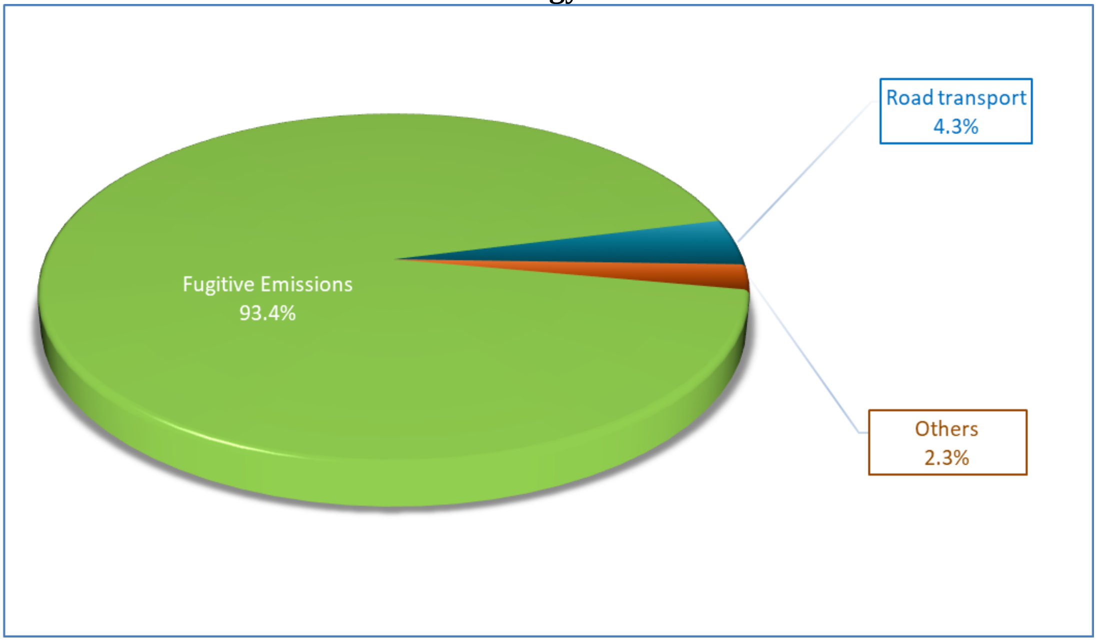
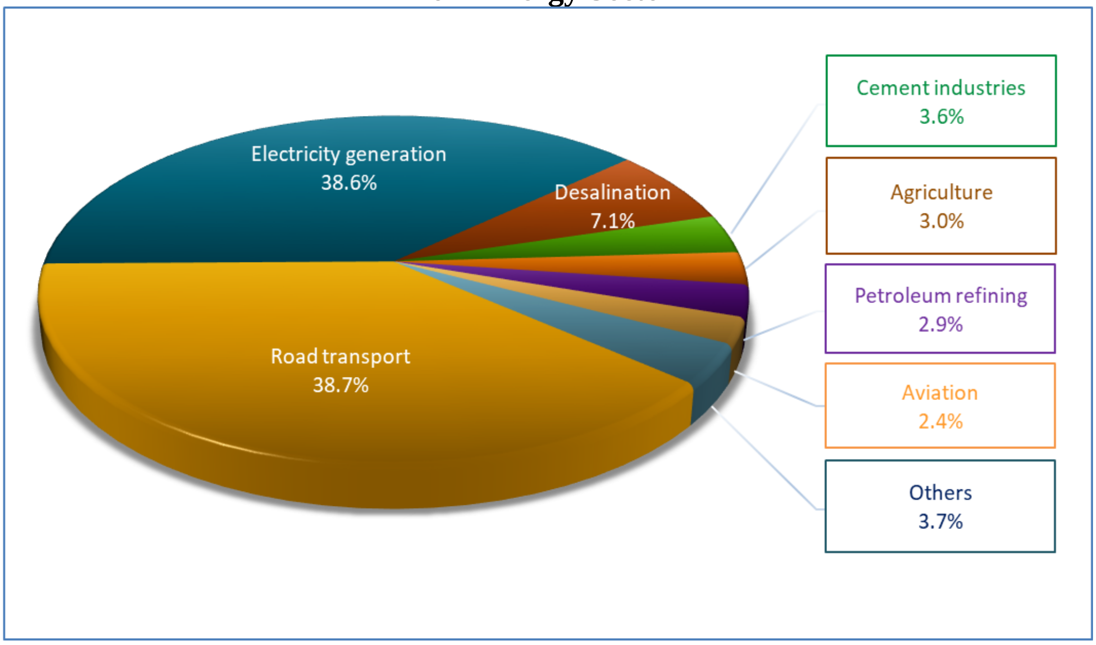


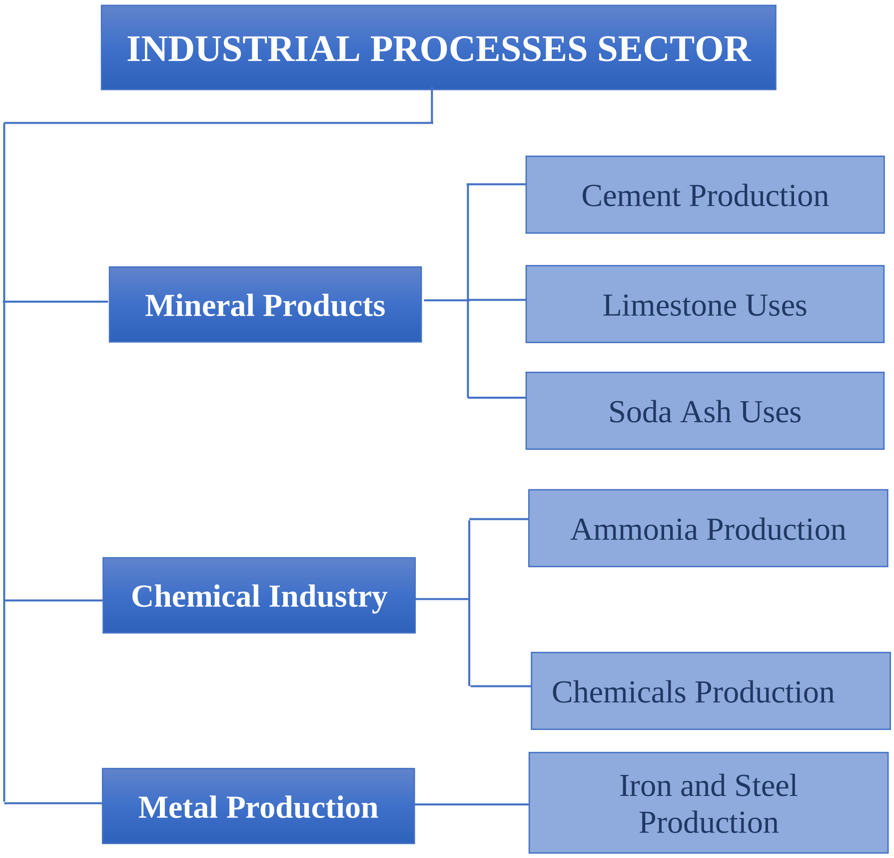
Figure 2.7: Relative Contributions of Various Activities to 2012 N_2O Emissions from Energy Sector



2.6.2 Industrial Processes Sector

Greenhouse gas emissions are produced from a variety of industrial activities which are not related to energy use. The main emission sources are industrial production processes, which chemically or physically transform materials to greenhouse gases. Cement production, limestone uses, soda ash uses, ammonia production, chemicals production and iron and steel manufacturing are some of the important activities of the Saudi industrial sector that are considered in this section. The source categories in industrial processes from which greenhouse gas emissions have been estimated are presented in Figure 2.8.

Figure 2.8: Activities Considered in the Industrial Processes Sector

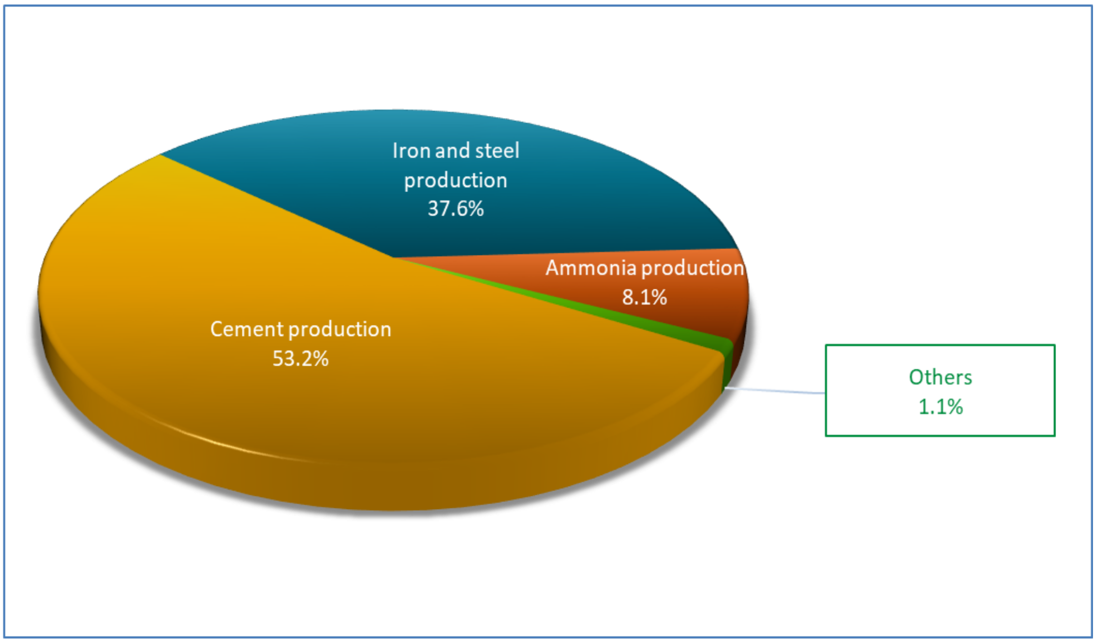


The emissions of CO_2, CH_4 and N_2O from various industrial processes were estimated and are summarized in Table 2.2. A total of 53,730.4 Gg of CO_2 was emitted from mineral products (54.3%), metal production (37.6%) and chemical industry (8.1%). Cement production emitted the highest amount of CO_2 (53.2%) followed by iron and steel production (37.6%) and ammonia production (8.1%).

The chemicals production was the sole contributor to a total of 36.54 Gg of CH_4 emissions in this sector. No N_2O was emitted from this sector.

The relative contributions of the major activities to CO_2 emission in the industrial processes sector are presented in Figure 2.9.

Figure 2.9: Relative Contributions of Various Activities to 2012 CO_2 Emissions from Industrial Processes Sector



2.6.3 Agriculture Sector

Saudi Arabia is a desert country where irrigation-based agriculture is neither well developed nor extensive. A shortage of good quality irrigation water is the foremost limitation. The Revised 1996 IPCC Guidelines recommended agricultural activities for use in estimating greenhouse gas emissions are presented in Figure 2.10.

Greenhouse gas emissions from livestock (enteric fermentation and manure management), soils and field burning of agricultural residues are considered in this section. Cattle, sheep, goats, camels and poultry constituted the livestock population in Saudi Arabia. CH_4 and N_2O emissions were the most important greenhouse gases emitted by the activities related to livestock.

The estimated greenhouse gas emissions from the agricultural sectors are presented in Table 2.2. The total CO_2, CH_4 and N_2O emissions from various activities of the agriculture sector were 649.2 Gg, 82.7 Gg and 32.3 Gg, respectively.

The CH_4 emissions from enteric fermentation, manure management and field burning of crop residues were estimated at 64.9 Gg, 16.6 Gg and 1.18 Gg, respectively. The N_2O emissions from manure management, agricultural soils (direct and indirect) and field burning of crop residues were estimated at 10.5 Gg, 21.8 Gg and 0.02 Gg, respectively. Field burning of crop residues also emitted 649.2 Gg CO_2. For agricultural soils, as per the IPCC Guidelines, only N_2O emissions were estimated.

Enteric fermentation, manure management and field burning of crop residues contributed 78.5%, 20.1% and 1.4% to the total CH_4 emissions from the agriculture sector, respectively. Agricultural soils accounted for 67.5% of the total N_2O emissions in the agriculture sector followed by 32.4% from manure management. Field burning of crop residues was the sole source of CO_2 in the agriculture sector.

The relative contributions of the major sectoral activities to CH_4 and N_2O emissions in the agriculture sector are presented in Figures 2.11 and 2.12 respectively.

Figure 2.10: Activities Considered in the Agriculture Sector

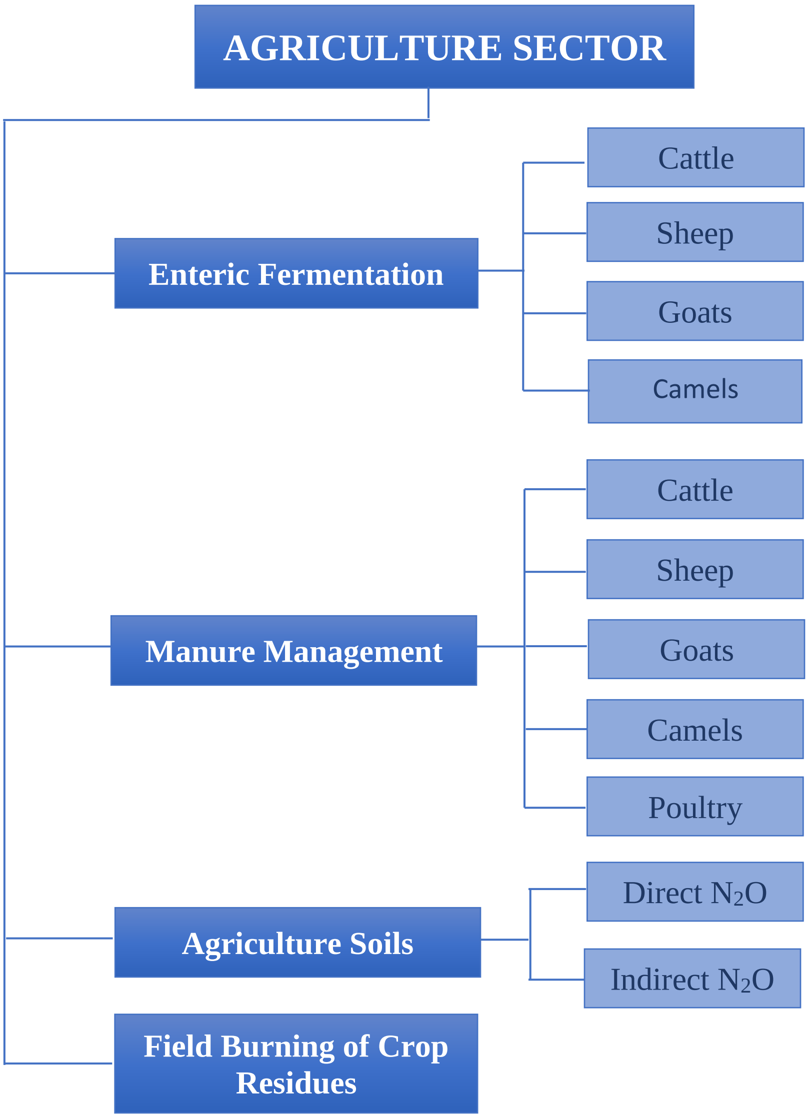


Figure 2.11: Relative Contributions of Various Sectoral Activities to 2012 CH_4 Emissions from Agriculture Sector

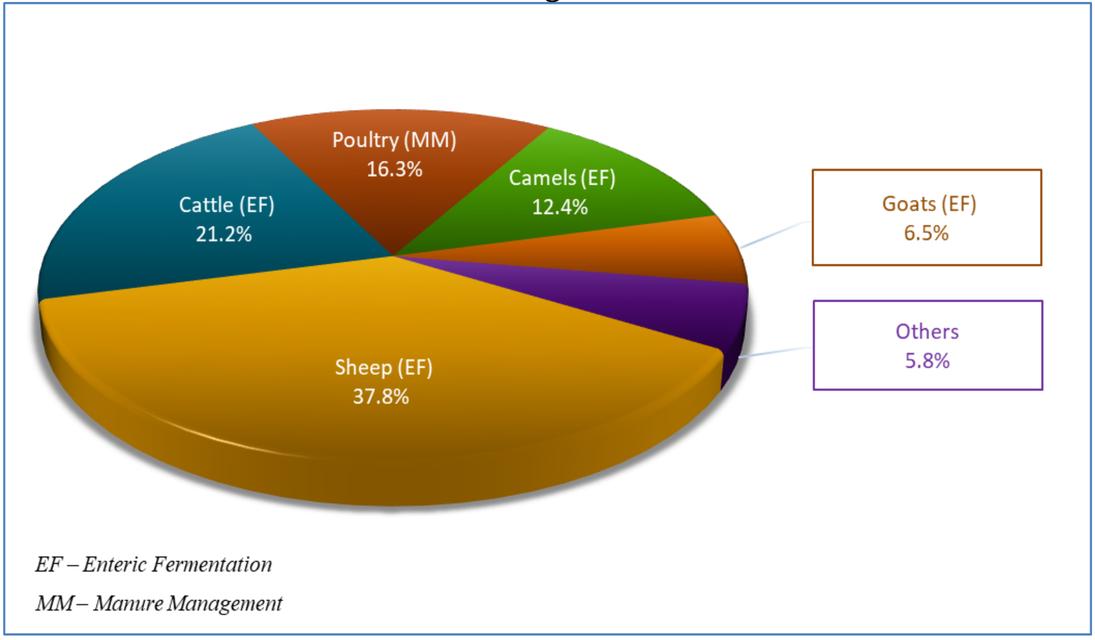
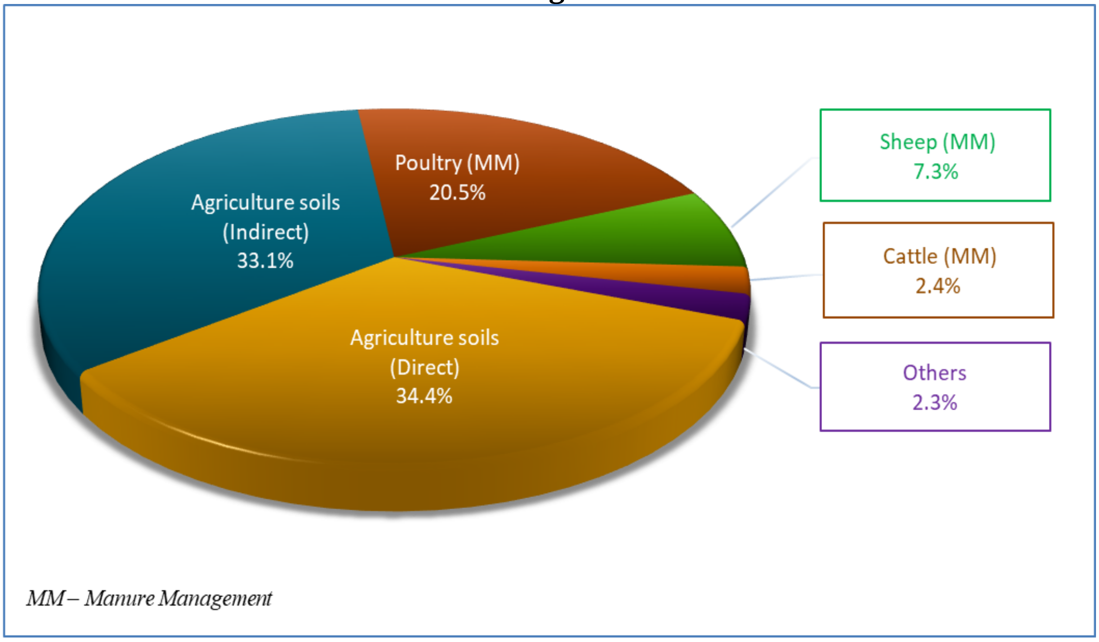


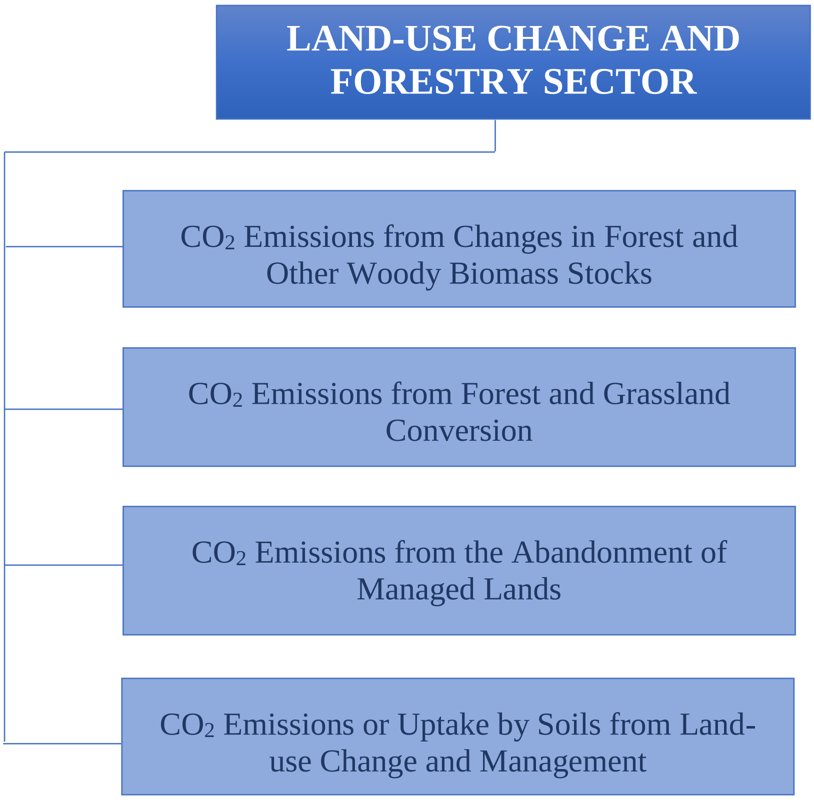
Figure 2.12: Relative Contributions of Various Sectoral Activities to 2012 N_2O Emissions from Agriculture Sector



2.6.4 Land-use Change and Forestry Sector

Calculations of emissions from land-use change and forestry focus upon four activities (Figure 2.13) that are sources or sinks of CO_2. Activities considered in this section include changes in forests and other woody biomass stocks, forest and grassland conversion, abandonment of managed lands and uptake by soil from land-use change and management. The estimated greenhouse gas emissions from this sector are presented in Table 2.2.

Figure 2.13: Activities Considered in the Land-use Change and Forestry Sector



2.6.4.1 Sinks

a. A total of 9,151 Gg of CO_2 sink was estimated from various activities related to this sector.

b. Changes in the forest and other woody biomass provided a sink for 8,976.4 Gg of CO_2.

c. Forest and grassland conversion to other land uses converted 125.9 Gg of atmospheric CO_2 to plant material (acting as a sink for CO_2).

d. Due to land-use changes, agricultural soils accumulated (acted as sinks) for 48.7 Gg of atmospheric CO_2.

e. In general, CO_2 exchange (i.e., uptake or release) by oceans are not anthropogenic. Therefore, marine sinks (the Arabian Gulf and the Red Sea) were not included in this inventory.

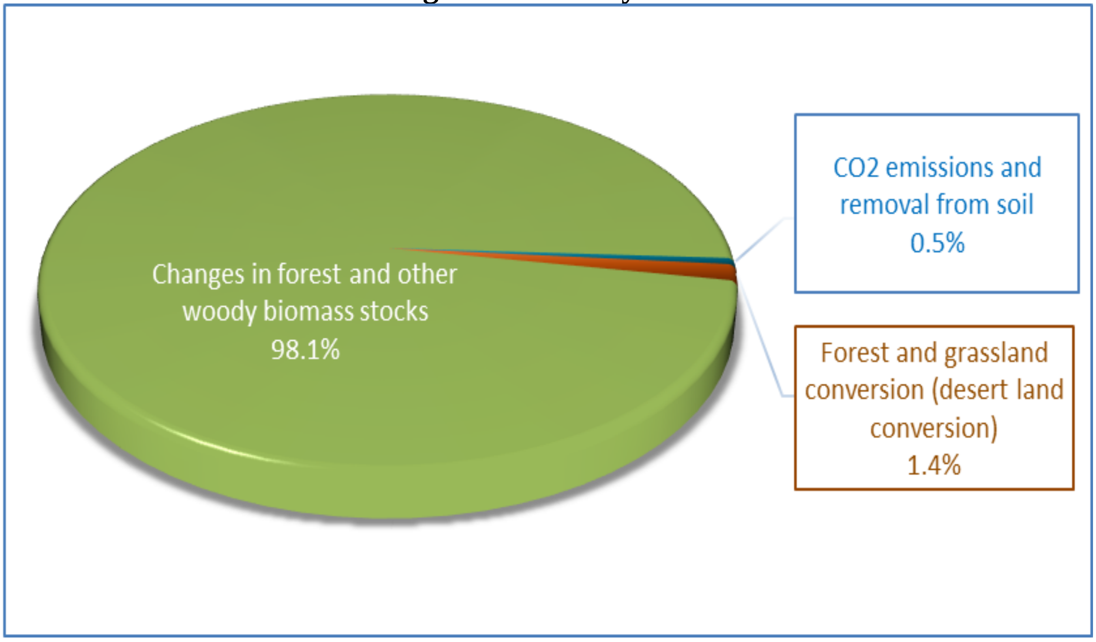
f. The possible intake of atmospheric CO_2 by the abandonment of managed land (due to decrease in total cultivated land area) is not considered due to the fact that the regrowth potential of these abandoned areas is expected to be a minimum, particularly under the prevailing harsh weather conditions in the Kingdom.

2.6.4.2 Emissions

No significant emissions of CO_2 from the land-use change and forestry sector is expected in Saudi Arabia considering that wood is not generally burned for fuel in the Kingdom.

The relative contributions of the major CO_2 sinks in the land-use change and forestry sector are presented in Figure 2.14.

Figure 2.14: Relative Contributions of Sinks to 2012 CO_2 Emissions from Land-use Change and Forestry Sector



2.6.5 Waste Sector

The Revised 1996 IPCC Guidelines recommend consideration of greenhouse gas emissions from landfilling of solid wastes, treatment of liquid wastes (wastewater) and waste incineration activities. Waste incineration activities in Saudi Arabia are prohibited by law and are not addressed. Solid wastes and wastewater disposal practices are considered in this section. The activities considered in the waste sector are shown in Figure 2.15. The emission estimations are summarized in Table 2.2.

The total CH_4 and N_2O emissions from various activities of this sector were 1,144.1 Gg and 4.04 Gg, respectively. Solid waste management practices emitted 768.8 Gg of CH_4. Municipal and industrial wastewater handling emitted 375.3 Gg of CH_4. N_2O emissions from human sewage were estimated to be 4.04 Gg. Solid waste disposal contributed 67.2% of total CH_4 in the waste sector followed by industrial wastewater handling (31.6%). The sole contributor to N_2O emission in the waste sector was human sewage.

The relative contributions of various activities to CH_4 emission in the waste sector are presented in Figure 2.16.

Figure 2.15: Activities Considered in the Waste Sector

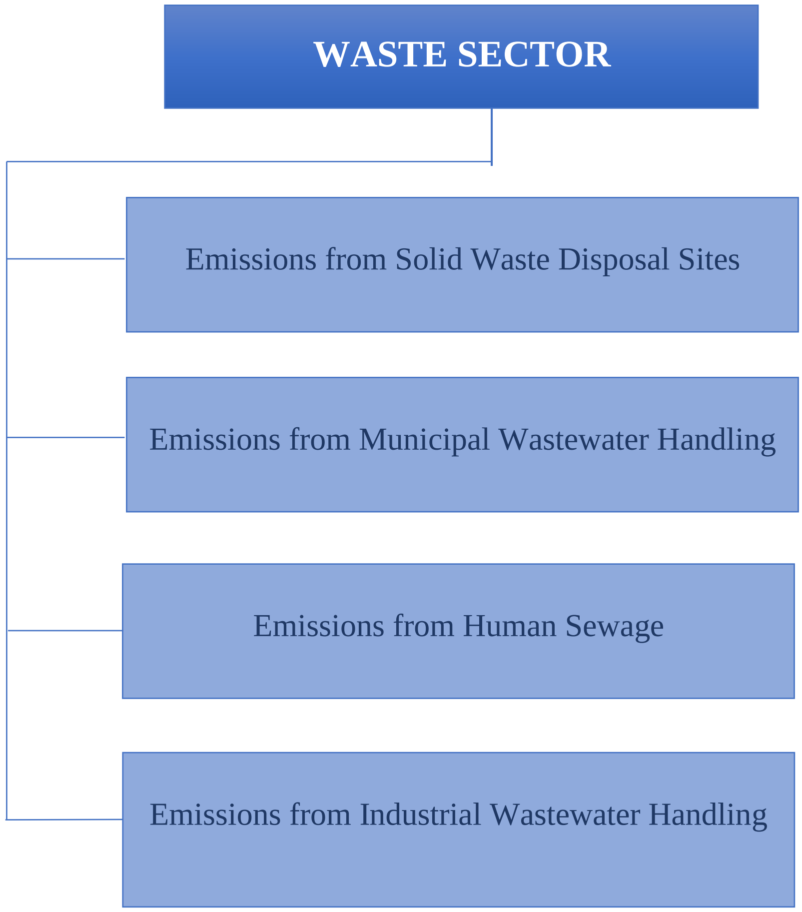
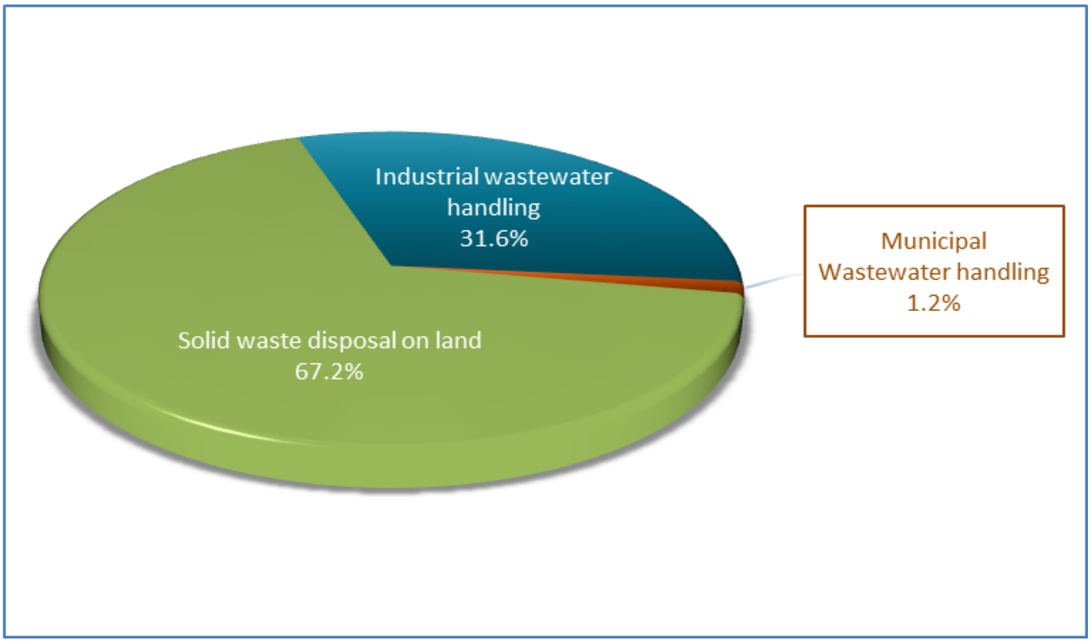


Figure 2.16: Relative Contributions of Various Activities to 2012 CH_4 Emissions from the Waste Sector



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3 PME[1] (2005). First National Communication for the Kingdom of Saudi Arabia – submitted to UNFCCC by the Presidency of Meteorology and Environment (PME), Jeddah, Saudi Arabia.

4 PME (2011). Second National Communication for the Kingdom of Saudi Arabia – submitted to UNFCCC by the Presidency of Meteorology and Environment (PME), Jeddah, Saudi Arabia.

[1] PME is now superseded by the General Authority of Meteorology and Environmental Protection (GAMEP).

SECTION – 3

Role of Economic Diversification in Addressing Climate Change Issues in the Kingdom of Saudi Arabia

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Section 3: Role of Economic Diversification in Addressing Climate Change issues in the Kingdom of Saudi Arabia

3.1 Introduction

Economic diversification is the process of structural transformation as resources are shifted out of primary (natural resource-based) sectors into secondary (manufacturing), and tertiary (service) sectors (Schuh and Barghouti 1988; Barghouti et al. 1990; Petit and Barghouti 1992). This change in economy, structure-driven by changes in demand, production technologies, and trade flows, actually defines modern economic development (Syrquin 1988). The underlying assumption of the structural transformation process is that economic structure should be unbalanced in favor of certain sectors and against others. The combination of growing and declining sectors facilitates the process of economic development (Harris 1989; Scitovsky 1989.

The diversification process implies the accumulation of productive capacity within either the manufacturing or the service sector. The term industry indicates a group of productive enterprises or organizations that produce or supply goods, services, or sources of income. Industrialization is the process of creating service industries like transportation, restaurants, tourism, financial services, insurance, banking, real estate services, repair and maintenance services etc. Diversification aims to create a variety of income sources for spreading risk while industrialization is the method of forming these diverse income sources.

The concept of economic diversification was identified by Parties as a potentially effective measure of reducing the adverse impacts of response measures at a workshop held in March 2000 (UNFCCC, 2000). The Kingdom of Saudi Arabia has submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC Secretariat in November 2015. The INDC of the Kingdom is based on the principles listed in Article 3 of the UNFCCC and the approach specified in the economic diversification initiative adopted as UNFCCC decision 24/CP.18 (UNFCCC, 2012).

3.2 Theories of Economic Diversification

The explanation of export development and diversification can be derived from different theoretical approaches: traditional trade theory, portfolio theory, economic geography theory and innovation and capabilities theory.

3.2.1 Trade Theory

The earlier trade interventionists' theories argued for expanding and promoting exports, inducing trade surpluses by reducing imports to accumulate wealth and national mercantile power. According to classical trade theories, each country has a comparative advantage in producing particular products and in exporting certain products.

A country will generate gains from trade through specialization in export lines. The gains from trade are maximized when a country specializes in certain products based on comparative advantage and then exports surplus for imports, with greater efficiency of resource use. When a country specializes to obtain gains from trade it will restructure and adjust its economy. These changes can cause short term financial, personal, and social costs which could be reduced with appropriate compensatory, complementary, and accompanying policies.

Compensatory policies may include budget transfers, relocation assistance, temporary income support and targeted safety nets etc.

Complementary policies include improvement of utilities and infrastructure support, superior market institutions, improved credit markets, better labor markets and labor mobility, simplified procedures for business establishment, improved information dissemination to all stakeholders and clarification of expectations.

Accompanying policies may include careful design and implementation of trade liberalization, taking into account lessons learned from the case studies of successful exporting countries (Samen, 2010). Some trade theories considering increasing returns, externalities and economies of scale, demand, product cycles to better explain technology intensive trade and international technology transfer (Dornbusch et al., 1977, Linder, 1961, Acemoglu and Zilibotti, 1997).

3.2.2 Portfolio Theory

Markowitz (1952) introduced the modern portfolio theory (MPT) based on the concept that the risk-averse investors can construct portfolios to optimize or maximize expected return depending on a given level of market risk, emphasizing that risk is an inherent part of higher reward. It is considered as one of the most important and influential economic theories dealing with both finance and investment. According to this theory, it is not enough to look at the expected risk and return of one particular product. A country can reap the benefits of diversification, particularly by a reduction in the riskiness of the portfolio. MPT quantifies the benefits of diversification which is known as “not putting all your eggs in one basket”. This theory can be used for quantifying diversification benefits for a country (Love, 1979). Many developing countries with low economic growth and depending heavily on a few commodities for trade, income, and employment could be benefitted from their economic diversification by selecting appropriate export portfolios that optimize market risks against anticipated returns (Samen, 2010).

3.2.3 Economic Geography Theory

According to economic geography theory, the export performance of a country is influenced in many ways through external geography including location, proximity to rapidly expanding export markets, and internal supply chain. The determinants of the internal supply capacity of a country are internal geography such as access to ports, and business environment including institutions quality (Samen, 2010).

3.2.4 Innovation and Capabilities Theory

Export diversification is linked with innovation (Hausmann and Rodrik, 2003). Cirera et al. (2015) explored firm level determinants of exports diversification using a firm-level data set from Brazil. Their findings suggested that efforts to develop new and unique technologies have an important role to play in the export performance of these firms.

Minondo (2011) argued that specialization bestows countries with some specific skills and assets. Those skills and assets in some countries can easily be redeployed in other products and facilitate diversification. In other countries skills and assets are more difficult to redeploy and offer limited diversification possibilities. According to Hausmann and Hidalgo (2010), there exists a systematic relationship between the diversification of a country's exports and the ubiquity of its products. Products differ in the number of countries that export them which is defined as their ubiquity. Each product requires a potentially large number of non-tradable inputs termed as the capabilities. A country can only make the products for which it has all required capabilities. Products requiring more capabilities will be accessible to fewer countries. On the other hand, countries that have more capabilities will have what is required to make more products and will be more diversified. The return to the accumulation of new capabilities increases with the number of capabilities already available in a country.

3.3 Drivers of Economic Diversification

According to Longmore et al. (2014) and Cadot et al. (2011), various drivers of economic diversification can be categorized into economic reforms, economic determinants, structural factors, macroeconomic variables, and non-economic determinants (Figure 3.1). Navarro-Garcia (2016) studied 212 exporting firms and classified the drivers as (i) internal drivers including export commitments and the experience level of staff and the structure of human resources and (ii) external drivers including competitive intensity and distances between the export firms and markets.

3.3.1 Economic Reforms

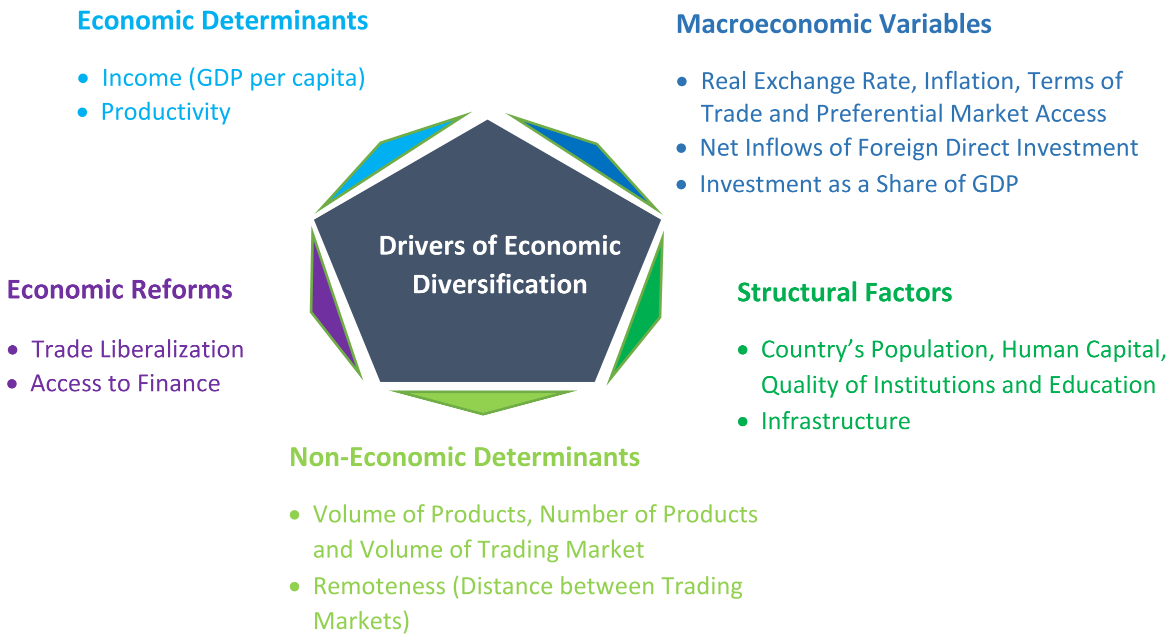
Trade liberalization and access to finance are positive drivers for export diversification at both intensive and extensive margins. It brings benefits to (i) consumers by making imported products available at low cost and (ii) companies by providing more opportunities to export. The availability of financial services to the firms positively impacts export diversification.

3.3.2 Economic Determinants

Xuefeng and Yasar (2016) examined the relationship between Chinese firms' export market diversification and their productivity. They found a U-shaped relationship between export diversification and firm productivity. At the initial phase of export, the firms face higher costs and thus lower productivity due to the lack of knowledge and experience. At the later stage, as export diversification crosses a threshold level and investments accumulate, export market expansion results in lower long-run average costs and thus higher productivity because of the learning curve, economies of scope, and economies of scale.

Imbs and Wacziarg (2003) investigated the evolution of sectoral concentration in relation to the level of per capita income and showed that various measures of sectoral concentration follow a U-shaped pattern across a wide variety of data sources. Initially, countries diversify and economic activity is spread more equally across sectors, but relatively late in the development process they start specializing again. Cadot et al. (2011) explored the evolution of export diversification patterns along the economic development path using a large database with 156 countries over 19 years. They observed a hump-shaped pattern of export diversification similar to what Imbs and Wacziarg (2003) found for production. Hausmann et al. (2007), observed a positive relationship between a country's growth and the income of the countries that import its products.

Figure 3.1: Drivers of Economic Diversification (Source: Longmore et al. (2014) and Cadot et al. (2011)



3.3.3 Structural Factors

The structural factors which have positive impact on economic diversification include population, human capital, and quality of institutions. The local firms will have access to larger market with increasing population and thus get benefitted from economies of scale. Economies can change their specializations towards knowledge-based manufactured goods with the availability of human capital. Political and economic institutions contribute to new business activities by creating an investment-friendly environment (UNFCCC, 2016).

3.3.4 Macroeconomic Variables

The real exchange rate, inflation, net inflows of foreign direct investment (FDI), terms of trade, and investment as a share of GDP are considered as drivers of economic diversification (UNFCCC, 2016). The exchange rate is one of the main concerns about diversification in developing countries. The mainstream economics recommend keeping the actual exchange rate as close as possible to its equilibrium level. However, a disequilibrium situation might be a second-best approach in countries facing other distortions which is similar to many developing countries (Sekkat, 2016).

3.3.5 Non-Economic Determinants

The non-economic determinants including volume of products, number of products, and volume of trading market positively impacts economic diversification while distance among trading markets negatively impacts economic diversification (UNFCCC, 2016).

3.4 Dimensions of Economic Diversification

Within political economy, diversification can take place through either horizontal diversification or vertical diversification. Vertical diversification encourages forward and backward linkages in the economy, as the output of one activity becomes the input of another, thus upgrading the value-added produced locally. Furthermore, vertical diversification entails a shift from one sector or industry to another, and generally from the primary to the secondary and tertiary sectors. For example, a mining company may expand from just extracting copper to engage in processing, transporting or retailing it. Parallel to this, the company shifts from extraction (primary sector) to manufacturing, for instance producing electric cables (secondary sector), and finally to transport or retail (tertiary sector). It follows that a country may attain three linked objectives through diversification: stabilizing earnings, expanding revenues and retaining or increasing value-added activities (Hvidt, 2013). Vertical diversification enhances further uses of domestically manufactured goods through increased value-added activities which entails a shift from the primary to the secondary or tertiary sector. Diagonal diversification refers to a shift from imported input into secondary and tertiary sector (Samen, 2010).

Horizontal diversification causes changes in the primary export mix and increases the number of export sectors. In this dimension, a country can either enlarge the share of products with increasing growth rates in export earnings, or it can add new products based on the growth rates of world prices (Ali et al., 1991). As a result, the dependency on a few sectors to lead export-oriented growth is reduced (Matthee and Naudé, 2008), and the export earnings stabilize (Al-Marhubi, 2000).

3.5 Rationale for Economic Diversification

A diversified economy is integrally more stable, less vulnerable to the boom and bust cycles of oil prices, more capable of creating jobs and opportunities for the next generation. Export diversification can lead to higher growth by helping the developing countries to overcome export instability or the negative impact of terms of trade in primary products. It does play an important role in structural transformation where countries move from producing "poor-country goods" to "rich-country goods." in this process (Tovonjatovo and Dong, 2015).

The rationale of economic diversification relies on certain considerations including (i) trends in terms of trade and price instability, (ii) depletion of mineral resources, (iii) economies of scale and external economies in manufacturing, and (iv) reduction of portfolio risk (Zhang, 2003).

Economic diversification at primary level is essential for combating poor market conditions, especially deteriorating terms of trade and price instability for primary commodities. The resulting instability could be more for an underdeveloped country compared to a developed one because the government is inadequately equipped to develop and implement required contra-cyclical policies for offsetting the internal repercussions of export instability (Guillaumont, 1999).

The depletion of mineral resources is a concern for economic sustainability. The building-up of other types of capital such as physical (manufacturing hardware and infrastructure), human (health, skills, and the learning ability), and natural capital for maintaining a non-declining flow of income in future (Pezzey, 1992).

Economic diversification especially in manufacturing is desirable because it offers greater scope for economies of scale and external economies (Romer, 1986). According to Romer (1990), the diversity of intermediate good inputs enhances productivity in the final goods sector.

Economic diversification provides the opportunity to spread investment risks over a wider portfolio. Average capital productivity will be enhanced through greater diversification in the long run due to better investment opportunities at lower risk (Zhang, 2003).

The level of economic diversification is generally linked with levels of employment, exports or income. The level of export concentration is a good indicator for measuring economic diversification. The indices of economic diversification can be categorized into two classes. One class of indices such as ogive index, entropy index, Herfindahl-Hirschmann index, Gini index, diversification index measures a country's absolute specialization. Second group of indices such as Theil index, relative Gini index, inequality in productive sectors measures a country's economic structure with respect to a reference class of industries (UNFCCC, 2016).

3.6 Economic Diversification in Saudi Arabia

The economy of Saudi Arabia relies heavily on oil. Depending on one specific income source can create long-term instability in the economy. The focus of the successive development plans on diversifying the national economic base has been inspired to lower the dependency on oil sector in generating GDP and financing government investments. The current instability of oil prices and the reliance of Saudi economy on a single source necessitates the other revenue-generating sectors in the country for economic diversification.

The dependence on specific income source puts the long run economic growth at risk (Alhowais and Al-shihri, 2010; Mobarak and Karshenasan, 2012). The creation of new job opportunities is also largely dependent on diversified economic activities (Devaux, 2013; Kayed and Hassan, 2011). The oil sector in the Kingdom is the major contributor to the country's GDP (i.e., 48.3% of economic contributions), while only 4.8% of the Saudi workforce is employed in this sector (SAMA, 2014). Hence, as a means of unemployment reduction, to generate a stable and sufficient income for the population, economic diversification can be a significant contributor.

Economies with a broad range of exports of goods and services are healthier and more productive than economies that depend on only a few commodities as their main exports (Herb, 2005). Furthermore, for balanced development between the rural and urban areas, economic diversification is a major tool. In case of less diversified economy like Saudi Arabia, most of the economic activities and employment opportunities are concentrated in the vicinity of mineral processing zones (Haber and Menaldo, 2011; Hertog, 2010). These also encourage the Kingdom to pursue a diversified economy.

3.7 Objectives of Economic Diversification in Saudi Arabia

In 2004, the Kingdom adapted a Long-Term Strategy for the period of 2005–24 (MEP 2004) in response to emerging challenges of providing productive employment to Saudi national manpower and improving the quality of life. The aim was to create jobs for the growing and young population, raise the national economy to the level of advanced economies through doubling the per capita income between 2004 and 2024, reducing the share of oil and gas in total exports from 72 per cent to 37 per cent and increasing the role of non-oil products in the economy.

The Ninth Development Plan of the Kingdom (2010-2014) aimed to deal with the unemployment problem, living standards, uneven growth at different regions and lack of international competitiveness for the Saudi economy (MEP 2010). The tenth Development Plan of the Kingdom (2015-19) has emphasized on private sector growth and education for achieving economic diversification. The major policy of the plan is improving the efficiency of government expenditure along with increasing the government’s non-oil revenues. On the one hand, the government will encourage the establishment of specialized investment banks and prompt existing banks to expand financing for employment-creating activities.

3.8 Tenth Development Plan and Economic Diversification

The 10th development plan of the Kingdom of Saudi Arabia (2015-2019) constitutes the strategic national push towards diversifying the economic base from three major dimensions namely vertical, horizontal and spatial diversification, which are briefly discussed below.

3.8.1 Vertical Diversification

According to the 10th development plan of the Kingdom, the vertical diversification is based on the objectives of raising utilization rates of mineral resources with aims of expansion in local production, processing and manufacturing of mining raw materials (MEP, 2015). The development of production and service activities are linked with oil and gas industries as well as oil and gas dependent upstream and downstream activities. Saudi Arabian industries are looking into the possibility of developing a crude oil-to-chemicals plant in Saudi Arabia.

3.8.2 Horizontal Diversification

The objectives of horizontal diversification include (i) expanding production capacities of the industrial sector, (ii) developing the services sector and increasing its contribution to GDP, (iii) diversifying economic activities in non-oil sectors, (iv) investing in projects related to diversification of energy sources, (v) developing non-oil exports and increasing their contribution to the total value of exports, (vi) encouraging local and foreign strategic partnerships to implement investment projects contributing to diversification of production base of the national economy, and (vii) developing low-water-consuming agricultural products as well as fishing activities (MEP, 2015).

3.8.3 Spatial Diversification

According to the 10th development plan of the Kingdom, the vertical diversification is based on the objectives of making use of the comparative advantages of the provinces in boosting spatial diversification of economic activities along with expansion in establishment of industrial zones and business and technology incubators to improve utilization of these advantages. Spatial growth is being directed by the ongoing development of up to six economic cities, as well as industrial developments.

Establishing the industrial developments throughout the country is a major option towards spatial diversification. As a part, at Rabigh, Hail, Madinah and Jazan, four new economic cities are due to be completed by 2020 with anticipated populations of 40,000, 80,000, 200,000 and 250,000 respectively (Oxford Business Group, 2017c). Furthermore, the expansion at Jubail on the east coast and Yanbu on the west coast by the Royal Commission of Jubail and Yanbu is also undertaken. In addition, a new industrial settlement at Ras Al Khair in the Eastern Province and a new mining-focused development at Waad Al Shammal near Turaif in the north of the country are also under development. The Kingdom’s movement towards diversified economy will receive a vast push-up through the development of these sectors.

3.9 Saudi Vision 2030

The Saudi Vision 2030 was declared in April 2016 which provides the roadmap of the economic diversification for the Kingdom. The Vision aims to reduce Saudi Arabia's dependence on oil and rely on alternative diverse economy and the development of service sectors such as health, education, infrastructure construction, recreation and tourism.

The Vision also aims to become a global investment powerhouse. The Vision aspires to stimulate the Saudi economy and diversify revenues. It is built around three themes: a vibrant society, a thriving economy and an ambitious nation. All these three themes will contribute to successful economic diversification. The Vision recognizes that diversifying Saudi economy is vital for its sustainability and mentions that the Kingdom has long-term plans to overcome the challenges associated with economic diversification. The Kingdom will also make use of its global leadership and expertise in oil and petrochemicals to invest in the development of adjacent and supporting sectors. The Kingdom has been planning to continue diversifying non-oil revenues in the coming years, by introducing new measures. In order to address the spatial dimension of the economic diversification, the Kingdom will create special zones in exceptional and competitive locations. It will take into account the comparative advantages of the Kingdom’s different regions, assess their feasibility for promising sectors, and then establish special zones, such as logistic, tourist, industrial and financial ones. Special commercial regulations to boost investment possibilities and diversify government revenues will be applied to these zones.

3.10 Intended Nationally Determined Contribution (INDC) of the Kingdom of Saudi Arabia under the UNFCCC

The Kingdom of Saudi Arabia has submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC Secretariat in November 2015. The INDC of the Kingdom is based on the principles listed in Article 3 of the UNFCCC and the approach specified in the economic diversification initiative adopted as UNFCCC decision 24/CP.18 in Doha in 2012. The Kingdom will engage in actions and plans in pursuit of economic diversification that have co-benefits in the form of greenhouse gas (GHG) emission avoidance and adaptation to the impacts of climate change, as well as reducing the impacts of response measures. This will help to move towards achievement of its sustainable development objectives.

The Kingdom ratified the United Nations Framework Convention on Climate Change (UNFCCC) by accession on 28 December 1994. It also acceded to the Kyoto Protocol on 31 January 2005 (UNFCCC, 2005).

The Intended Nationally Determined Contribution (INDC) of Saudi Arabia seeks to accomplish climate change mitigation co-benefits through economic diversification and adaptation measures. As a climate change adaptation strategy, it enhances economic resilience and reduces reliance on vulnerable economic sector(s). It also aims to reduce the adverse impacts of the climate change mitigation policies specially focusing on developing countries. The Kingdom puts forward its national climate change efforts, which clearly recognizes the broader imperatives of sustainable development and economic diversification. The Kingdom has been striving to develop and implement policies, plans and programs in pursuit of economic diversification which have co-benefits in the form of emission avoidance, adaptation to the impacts of climate change and response measures.

The steps taken by the Kingdom include: (i) economic diversification initiatives with mitigation co-benefits; (ii) climate change adaptation initiatives with mitigation co-benefits and standalone adaptation initiatives; (iii) R&D activities on climate change; and (iv) efforts to reduce impacts of international climate change policy responses.

The actions and plans which will generate mitigation co-benefits of economic diversification actions include: (i) energy efficiency, (ii) renewable energy, (iii) carbon capture, utilization and storage, (iv) utilization of gas, and (v) methane recovery and flare minimization.

The following adaptation measures are expected to have emission avoidances depending on their degree of implementation and availability of funds to pursue planned activities: (a) Water and waste water management (b) urban planning (c) marine protection and (d) Reduced desertification. However, development and Implementation of Integrated coastal zone management plan (ICZMP), development and operationalization of Early Warning Systems (EWS) and development and implementation of Integrated water management plan are adaptation measures to address climate change and raise resilience to its adverse impacts.

3.10.1 Contribution to Economic Diversification with Mitigation Co-benefits

Diversifying the economic base of the Kingdom of Saudi Arabia has been a fundamental objective of the socio-economic development. Few of the recent major actions in this direction are; making power and desalination plants more energy efficient, development and deployment of technologies relating to Energy Efficiency, development of Renewable Energy Sources (RES) especially solar energy and Rationale Use of Energy (RUE).

The government is also encouraging the reuse of the treated wastewater which may reduce dependence on the energy intensive desalination plants and to conserve water, a valuable resource.

The other key area the Kingdom is working on is Carbon Capture, Utilization and Storage (CCUS). The Kingdom has been engaged in the cooperative research with other countries to explore the potential of large scale commercialization and deployment of CCUS technologies. The Kingdom has planned to build the world's largest carbon capture and utilization plant and few other projects are under way. This section will elaborate on the efforts made by the Kingdom in different sectors to address climate change issues and achieve sustainable development.

3.10.1.1 Energy Efficiency (EE) and Rational Use of Energy (RUE)

The Kingdom has made substantial progress in the field of Energy Efficiency by developing and enforcing regulations and guidelines for buildings, transportation, industry and urban planning and district cooling sectors for efficient use and conservation of energy. Energy intensive industries are also improving their energy intensity to reduce energy demand.

To sustain and unify energy efficiency efforts, the Saudi Energy Efficiency Center (SEEC) was established in October 2010 by a Council of Ministers' Decision. SEEC is the custodian of demand-side energy efficiency in the Kingdom with the mission to Improve Saudi Arabia's energy efficiency and coordinate all activities among stakeholders. Its main tasks are to:

a. Develop a national energy efficiency (EE) program,
b. Propose energy efficiency policies and regulations and monitor their implementation.
c. Participate, as needed, in the implementation of pilot projects, and
d. Promote awareness about energy efficiency.

In 2012, the Saudi Energy Efficiency Program (SEEP) was launched with the objective of improving the Kingdom's energy efficiency by designing and implementing initiatives and their enablers. SEEP's scope is focused on demand side with three sectors (buildings, transport, and industry), which covers more than 90% of Saudi Arabia's internal energy consumption.

SEEP's objectives are:

(i) To improve Saudi Arabia's energy efficiency using bottom-up designed initiatives and their enablers.
(ii) To involve all stakeholders (government, businesses and the public) from inception.

The Saudi Energy Efficiency Program (SEEP) is a national program to rationalize and raise the efficiency of energy consumption in coordination with 30 government entities and many government institutions and enterprises and the private sector. SEEP aims to curtail the growth in peak electricity demand. It is currently focusing on the design of the first energy conservation law and national and regional regulations, preparation of a new national database on energy supply and demand, capacity development of energy efficiency managers and public awareness. SEEP has updated the energy efficiency standard (EER) for window and split type air-conditioners to be more energy efficient.

3.10.1.1.1 Energy Efficient Technologies and Energy Conservation

Saudi Arabia focuses on the development of energy efficient technologies and energy conservation policies. It provides services including (i) development of appropriate criteria of using energy in all sectors following specifications and standards as well as diffusing awareness in the fields of energy conservation, (ii) spreading the culture of energy rationalization in schools and other educational institutions, (iii) development of energy-efficiency databases in order to help electric-load management and (iv) further the study of appropriate methods and measurements to be applied through programs and technologies that are suitable for the Kingdom. In accordance with the Royal Decree (No. 6927/MB) dated 22/09/1431 H, the application of thermal insulation in all new residential and commercial buildings, or any facilities and other constructions like government buildings in major cities of the Kingdom is now mandatory. SEEC has been working to enhance its mandate by including the collection of data, the setting of targets and their enforcement.

3.10.1.1.2 Electricity Tariff Restructuring

The Kingdom of Saudi Arabia has taken steps aimed at restructuring the electricity tariffs. The tariff policy of Saudi Electricity Company was amended by the Council of Ministers Decision in 2009, which granted the board of directors of the electricity and co-generation regulatory authority (ECRA) the right to review and adjust the non-residential (commercial, industrial and governmental) electricity tariff and approve them taking into consideration, among other matters, the electrical consumption at peak times. The new tariffs were implemented from July 1, 2010.

Recently, the Council of Ministers' Decision No.95 dated 17/03/1437 H (29 December 2015) again changed the electricity tariff rates of the residential and commercial consumers in the Kingdom depending on consumption rates.

3.10.1.1.3 Energy Saving Actions

Initiatives have been taken to reduce energy demand by promoting and encouraging the use of insulating materials in design and construction of new buildings. Modified Energy Efficiency standards have been issued for licensing the air conditioning units. New technical regulations have been approved for fuel economy of light vehicles, which are effective from 2016 to 2020.

3.10.1.1.4 *Regulatory Framework for Energy Management*

In 2013, Saudi Arabia developed a national strategy for smart meters and smart grids in order to improve the reliability of the network and the quality of service, increase the efficiency of operation and realize better utilization of assets. The roadmap aims to (i) reduce complaints arising out of issuing the electricity bills, issue them in a timely manner and reduce the cost of reading more than seven million meters monthly, (ii) enable the renewable energy sources and facilitate their integration into the electricity system and (iii) provide additional services to consumers and increasing the efficiency and conservation of electricity consumption. The Electricity Distribution Code, which is effective since 2008, provides the rules and regulations for distribution of energy throughout Saudi Arabia and mandates, including a provision stating that designated enterprises provide loading and generation output information to the government, as well as a layout of requirements for generators and a call for demand forecasting and operational efficiency (ECRA, 2008). This Code has been playing an important role in electricity demand management.

Initiatives have been taken to develop regulatory framework for the promotion of clean and renewable sources of energy to generate power in the Kingdom. In 2013, ECRA, in cooperation with the King Abdullah City for Atomic and Renewable Energy (KACARE) conducted a study for developing a regulatory framework for the activities of electricity generation, cogeneration and water desalination production using atomic and renewable energy (ECRA, 2013). ECRA has been developing a comprehensive regulatory framework for the codes, procedures and license forms required for the electricity and water desalination projects that use atomic and renewable energy (ECRA, 2014a).

In addition to expanding the conventional generation capacity, the Ministry of Energy, Industry, and Mineral Resources (MEIM) is attempting to reduce the peak demand by establishing a demand-side management program and by setting restrictions on giant electricity consumers. The new development projects designed with large air conditioning loads are required to incorporate thermal energy storage systems. Another initiative is the proposal to privatize and reorganize the electricity sector into three independent sectors: generation, transmission, and distribution, and to allow private-sector participation in new power-generation projects.

3.10.1.1.5 *Energy Management in Different Sectors*

The Ministry of Energy, Industry and Mineral Resources has an Energy Conservation and Awareness Department for implementing energy conservation initiatives and reducing peak load demand. The Ministry has developed the following initiatives:

a. Implementation of procedures enabling the commercial, governmental, agricultural and industrial sectors to reduce consumption and shift peak loads.
b. Prohibition of irrigation during peak load times in the agriculture sector.
c. Publication and distribution of the first edition of the Energy Conservation and Load Management Consumers' Guide.

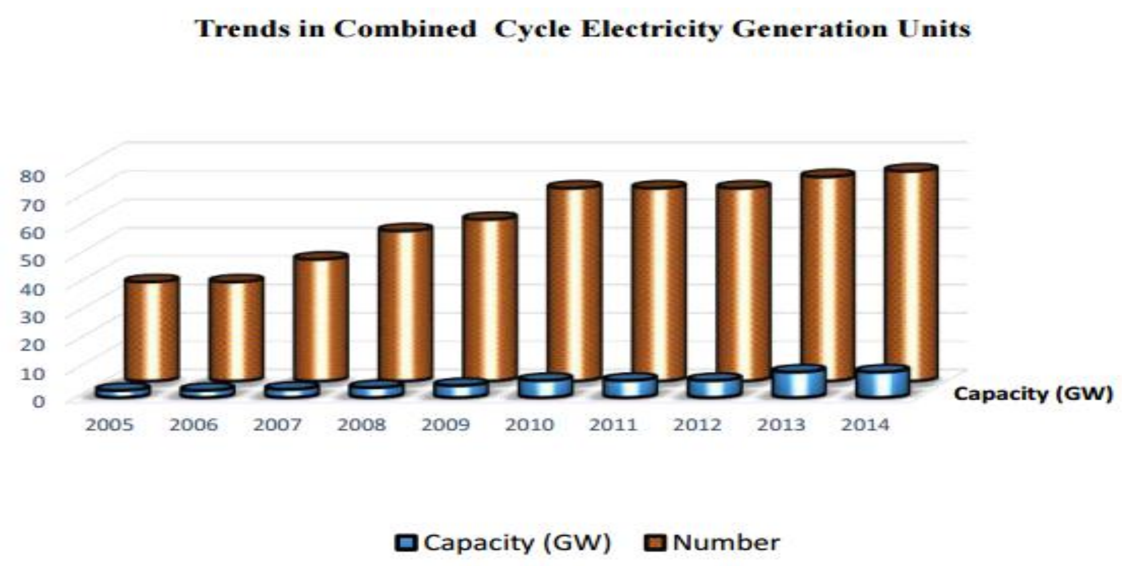
d. Organization of workshops and meetings to promote public awareness of energy conservation and

e. Arrangement of site visits to major consumers in the governmental sector to stress the importance of following energy conservation procedures and to introduce load reduction tools.

(i) *Power Generation Sector*

The Kingdom has been investing substantial resources to increase overall efficiency of power plants by adopting to combined-cycle operation. In this system, a heat recovery steam generator is employed to capture heat from high temperature exhaust gases to produce steam which is used in steam turbines to generate additional electricity. The reduction in fuel consumption is achieved through conversion of inefficient, single-cycle gas turbines to combined-cycle plants and by installing new combined-cycle plants (Matar et al., 2015). The deployment of combined-cycle electricity generation units has been increasing steadily in the Kingdom (Figure 3.2). The number of combined-cycle electricity generation units increased from 35 in 2005 to 74 in 2014. In the Kingdom, the production capacities of cogeneration entities in 2013 was 15,375 MW of electricity, 5,240,001 m^3/day of water and 14,374 ton/hour of steam (ECRA, 2013).

Figure 3.2: Growth of Combined Cycle Electricity Generation Units in the Kingdom (ECRA, 2012 and 2014b)



(ii) *Petroleum and Petrochemical Sector:*

The petroleum sector in the Kingdom has been adopting a number of energy initiatives to ensure rational use of energy resources. The cumulative energy conservation savings of this program were 112.81 thousand barrels of oil equivalent per day during 2000 to 2010. In 2013, the energy efficiency performance was enhanced by cogeneration facilities. It saved approximately 170 million cubic feet of gas per day compared to the national energy efficiency average. In 2013, The sector achieved a decrease in its energy demand intensity.

A zero-discharge technology is being implemented at onshore and offshore well-site operations in order to eliminate gas flaring and liquid hydrocarbon discharge. During 2013, the flaring was minimized from 0.89 percent to 0.72 percent of raw gas production at all upstream facilities. Energy conservation initiatives reduced refining energy intensity by 3% in 2014. 160.85 thousand barrels of oil equivalent per day savings were achieved in operations in this sector between 2002 to 2014 (Saudi Aramco, 2014).

In 2014, the oil industry in the Kingdom reached roughly 90% self-sufficiency in power generation. It commissioned a 420-megawatt cogeneration plant at Manifa, which made the facility self-sufficient in power generation (Saudi Aramco, 2014). The industry has been implementing projects to reach the target of producing 1,075MW of electricity and 4.4 million lb/h of steam from the cogeneration facilities since 2002. The facilities in this sector replaced incandescent lights by installing 500,000 LED light bulbs during 2014. This initiative saves 30 million kWh annually.

In order to reduce energy consumption, the petrochemical industry in the Kingdom implemented SEEC's energy efficiency standards. A reduction of 2% greenhouse gas (GHG) emissions intensity, 5% energy consumption intensity, 5% water consumption intensity and 10% material loss intensity were achieved in 2013 compared to the base year 2010 (SABIC, 2013).

In order to avoid GHG emissions and ensure improved efficiency, the process vent gas reutilization projects were executed by some petrochemical industries leading to reduced GHG emissions by 125,000 tons and savings of 784,000 GJ of energy annually (SABIC, 2011). In another petrochemical industry, an operational upgrade and retooling process boilers resulted in 15% reduction in GHG emissions and more than 9% decrease in energy usage (SABIC, 2013). Another petrochemical plant conducted a high-pressure steam extraction reliability project resulting in 1,040,000 ton/year of additional steam, 99,000 ton/year of natural gas saving, 4,160,000 GJ/year of reduction in energy consumption and 229,000 tons CO_2 eq/year of GHG emissions reduction (SABIC, 2011).

(iii) <u>Buildings</u>

The Kingdom of Saudi Arabia encourages the adoption of green building concept with the view to promoting the construction of energy efficient, resource efficient and environmentally responsible buildings.

The Kingdom currently has more than 300 green building projects and the area occupied by the green buildings in the Kingdom exceeded 20 million square meters by the end of 2014 (Ventures Middle East, 2015). It is estimated that the Kingdom accounted for approximately 15 percent of the green building projects in the Middle East. The Kingdom is planning to build 90,000 eco-friendly mosques across the Kingdom through utilizing solar and other renewable sources of energy as part of a bid to put green building on the national stage.

(iv) *Transportation Sector*

Initially, Saudi Arabia's efforts in transportation sector have focused most of its efforts on light duty vehicles (LDVs) with goals of enhancing the fuel economy of incoming vehicles and reduce the fuel consumption of on-the-road vehicles. Saudi Arabia plans to enforce the first phase of new rules for fuel-saving tires. It has planned to launch a campaign to reduce fuel consumption in the country targeting the drivers for more efficient driving and to rationalize energy consumption by choosing vehicles that consume less fuel. The Kingdom's fuel economy standards for incoming light duty vehicles (LDVs) (2016 – 2020) became effective in 2016 with (i) 10.3 km/liter for passenger cars tested and (ii) 9.0 km/liter for light trucks tested (SASO, 2016). Under the Saudi Energy Efficiency Program, multiple heavy-duty vehicles (HDVs) initiatives including anti-idling regulations, aerodynamic additives and retirement programs for old vehicles are currently under analysis. Both LDVs and HDVs will be subjected to rolling resistance and wet grip requirements.

3.10.1.1.6 Energy Technology Research and Innovation

The Kingdom has developed an Energy Technology Program consisting of seven priority technical areas namely (i) renewable energy generation, (ii) conventional energy generation, (iii) electricity distribution and transmission, (iv) energy conservation and management, (v) energy storage, (vi) fuel cell and hydrogen and (vii) combustion.

Saudi Arabia is striving to advance the knowledge, insight and understanding of energy challenges and opportunities. It is focusing on a number of research areas related to energy economics, policy, technology and the environment.

Saudi Aramco established a fuel research center in Paris, France which conducts research on developing more efficient combustion engines using modified petroleum formulations (Al-Meshari et al., 2014). It also established a Mobility Center in Detroit, USA which provides a platform for demonstrations, deployment and engagement with United States automobile manufacturers to develop suitable technological solutions for reducing the carbon emissions from mobile sources (Al-Meshari et al., 2014).

3.10.1.2 Renewable Energy

3.10.1.2.1 Solar Energy

The long term renewable energy strategy under Saudi Arabia's National Renewable Energy Program (NREP) is working towards carbon avoidance commitments and directly supported by Saudi Arabia's National Transformation Program (NTP) and Vision 2030. NREP desires to remarkably increase the share of renewable energy in the total energy mix by generating 3.45 GW of renewable energy by 2020 under the National Transformation Program (NTP), and 9.5 GW by 2023, towards Vision 2030. The Renewable Energy Project Development Office (REPDO) of Kingdom's Ministry of Energy, Industry and Mineral Resources has qualified a number of companies for the 300 MW solar PV project at Sakaka of Al Jouf province.

Many entities in the Kingdom including educational and research institutes, government and public-sector entities etc. have already established a number of solar energy source systems.

This included a solar thermal plant of 25 MWh in Riyadh in 2012. The General Authority of Civil Aviation (GACA) established ground mounted solar system to generate 9.3 GWh/year in June 2013. SEC and Showa Shell Sekiyu commissioned a pilot project of ground mounted solar array to generate 864 MWh/year in 2011 at Farasan Island, Jazan.

The oil industry in the Kingdom has been deploying a number of renewable energy sources mainly solar energy systems. It commissioned a car park mounted solar panel array in 2012 which generates 17.5 GWh/year. It established the King Abdullah University of Science & Technology (KAUST) solar park (rooftop mounted array), and solar powered streetlights in its residential compound and installed approximately 130 solar powered lighting bollards (Saudi Aramco, 2014). An evaluation program has also been initiated for emerging solar photovoltaic technologies in Dhahran from more than 30 technology vendors for testing, monitoring and understanding how different technologies perform under Saudi weather conditions.

A ground mounted solar system was commissioned in 2013 at King Abdullah Petroleum Studies and Research Center (KAPSARC) generating 5.8 GWh/year. Saudi Aramco commissioned a ground mounted solar system at KAPSARC Riyadh (KAPSARC II Project) to generate 3 GWh/year in 2014.

A solar rooftop mounted array was commissioned in King Abdullah Financial District Project, Riyadh in 2012 to generate 330 MWh/year. In 2018, Saudi Arabia will commission a utility-scale solar plant in Makkah to generate 385 GWh/year.

The Kingdom has been conducting major R&D activities in the field of solar energy on photovoltaic, solar thermal dishes, solar water heating, solar water pumping and desalination, solar hydrogen production and utilization, ultra-high concentration photo-voltaics (CPV) since late 1970s. It has conducted a number of international joint programs. The Renewable Energy Center of ERI is dedicated to continuing research activities in the utilization and adaptation of renewable energy sources for the sustainable development of the Kingdom.

The Kingdom has been collaborating to establish a water desalination plant powered by solar energy, which could significantly reduce water and energy costs (LePree, 2010). The developed technologies through this joint research initiative include ultra-high concentrator photovoltaic (UHCPV) and desalination membrane module development. This technology is capable of operating a CPV system at a concentration > 1500 suns (LePree, 2010). KACST signed an agreement with the Advance Water Technology Company (AWTC) for planning the design and construction of solar water desalination plant in Al Khafji with a production capacity of 60,000 cubic meters per day (Oxford Business Group, 2015). The first solar-powered desalination plant with a capacity of 30,000 cubic meters would be built in Al Khafji to serve 100,000 people. In the second phase, a desalination plant with a capacity of 300,000 cubic meters/day of water will be established. In the third phase, several water desalination plants using solar energy will be installed in various locations in the Kingdom (KACST, 2016).

The center for Clean Water and Clean Energy is established as a collaboration with Massachusetts Institute of Technology (MIT) and King Fahd University of Petroleum & Minerals (KFUPM) to conduct research on the technologies related to the production of fresh water and low-carbon energy. The research areas of this Center at MIT and KFUPM include:

(i) photovoltaic power including silicon and polymer devices and systems; (ii) desalination of seawater by advanced membranes and by thermal and solar power; (iii) applications of nanotechnology to solar and thermoelectric energy conversion; (iv) design and manufacturing of solar power systems and desalination systems; (v) advanced sensors for leak detection in water distribution networks; (vi) technologies for carbon capture; and (vii) remediation of water from oil and gas production.

A Center of Research Excellence in Renewable Energy was established at KFUPM in 2007. The Center aims to further enhance the scientific/technological development in all the major areas of renewable energy. The Center has developed four main research programs on (i) solar cell, (ii) solar cooling and heating, (iii) photovoltaics and (iv) energy storage and conversion. The Center has already established a research collaboration with Fraunhofer Institute of Solar Energy, Germany in the area of PV module and system reliability and performance; Stuttgart University, Germany in the area of solar absorption cooling and Umm-Al Qura University in the area of concentrated solar power. A research team of KFUPM manufactured a solar vehicle and the team participated in the World Solar Challenge 2011 in Australia. The cruising speed of the vehicle was 80 km/h and the maximum speed was 140 km/h.

3.10.1.2.2 <u>Wind Energy</u>

The rapid development in manufacturing and applications for the wind energy industry has increased the benefits of wind energy exploitation. The first Saudi Arabian Wind Energy Atlas was produced in 1987 based on the data collected from 20 meteorological stations for the period 1970-1982 (Al-Ansari et al, 1986). KSA has developed the renewable resource atlas of Saudi Arabia which provides newly collected and historical wind resource monitoring data and satellite-based modeled data for developers, researchers, government institutions and policy-makers (KACARE, 2016). Under the “Wind Energy Resources Measurement Project”, Saudi Arabia has identified forty (40) sites throughout the Kingdom, which will serve as future wind farms.

The Kingdom has embarked on the installation of three (3) towers on different sites and the installation process is moving ahead progressively in a number of sites throughout the Kingdom. Upon the completion of the Project, the Kingdom shall have such an integrated map that will measure wind resources thoroughly and accurately.

Feasibility studies have been conducted for potential wind project developments within the whole country starting from 2012. It received some encouraging data from the wind towers in Shedgum and the Gulf of Aqaba. The study is still going on. The Kingdom is planning to initiate 300 MW of solar photovoltaic and wind power projects at 10 remote locations across Saudi Arabia (Saudi Aramco, 2014). Saudi Aramco planned to install a 3.3 MW wind turbine at one of its facility at Turaif (Saudi Aramco, 2014) and two wind turbines each of 6 kW at two different remote locations to generate power for the communication towers.

The Renewable Energy Project Development Office (REPDO) of Saudi Arabia’s Ministry of Energy, Industry and Mineral Resources has qualified a number of companies for the 400 MW wind farm at Midyan for round one of the National Renewable Energy Program (NREP).

Global Wind Energy has contributed in data collection and has performed a feasibility study for a private project of 20 MW to be built on the Red Sea shore.

Wind energy research activities in the Kingdom cover the following:

a. Wind power meteorology data collection
b. Wind resource assessment
c. Prediction of wind resources,
d. Site selection for wind turbines,
e. Wind turbine modeling,
f. Wind energy conversion system development,
g. Grid integration of wind power and
h. Environmental impacts of wind turbines

3.10.1.2.3 Other Renewable Energy Resources

The major organizations of the Kingdom along with the Government have been taking wide range of initiatives related to renewable energy conversion (such as geothermal hybrid system development, geothermal energy system development). The adoption of energy efficient technologies and renewable energy sources supported by energy conservation policies plays an important role in maintaining sustainable development of the Kingdom (Belloumi and Alshehry, 2015). The Kingdom embarked on a massive experiment that can help in the assessment of the potential of the utilization of biomass as a source of energy (Aljarboua, 2009).

The use of geothermal energy is now recognized as a cost-effective standard for energy conservation. The geothermal resources encountered in Saudi Arabia are mainly of three categories: (i) low enthalpy resources represented by deep-seated aquifers that can be accessed only by deep oil wells, (ii) medium enthalpy resources (hot springs) encountered along the western and southwestern coastal areas and (iii) high enthalpy resources (Harrats) that are represented mainly by lava fields with fumarolic activity - Harrat Khaybar (Lashin et al., 2015).

The geothermal energy sources along the western shield margin are represented by hydrothermal and hot dry rock sources (Chandrasekharam et al., 2015a). The western part of Saudi Arabia is a region with high potential for geothermal energy development due to the high heat flow associated with the tectonic spreading of the Red Sea (Missimer et al, 2014). Lashin et al. (2014) described the entire western Arabian shield as the domain of both hydrothermal and enhanced geothermal associated systems and the most prominent sites of hydrothermal systems are located around Al-Lith and Jazan. According to Chandrasekharam et al. (2015b), Jazan province is characterized by high heat flow and high geothermal gradient and hosts several thermal and warm springs. It is estimated that the province may generate electricity of the order of 134×10^6 kWh (Chandrasekharam et al., 2015b).

Sharqawy et al. (2009) conducted a study which describes the in-situ experimental determination of the thermal properties of the underground soil for use in the design of

Borehole Heat Exchangers (BHE) which has been installed for the first time in Saudi Arabia. Al-Khouba geothermal resource at the Jazan province contains a geothermal potential of 17.847 MWt (Lashin and Al Arifi, 2014). The Wadi Al-Lith is considered one of the most promising geothermal targets with estimated heat energy of 1.713×1017 J (rock and fluid) and a geothermal reserve potential of 26.99 MWt (Hussein et al., 2013).

The Kingdom has planned to build a 550 MW natural gas-fired power plant integrated with an additional 50 MW solar combined cycle facility. The project was expected to be completed by the end of 2017 (Willliams, 2015).

The principal focus areas for future research include:

a. Determination of high potential locations for the development of geothermal systems.
b. Assessment of technological challenges in the design, construction and operation of geothermal energy systems.
c. Assessment of technologies to minimize costs and maximize efficiencies in geothermal energy system development and
d. Environmental assessment of geothermal energy systems.

3.10.1.3 Carbon Capture, Utilization and Storage (CCUS)

A number of research and development initiatives have been taken in the Kingdom to capture and store carbon dioxide emitted from industrial sources and other human-induced activities in an attempt to reduce the increasing rates of carbon dioxide emissions. Saudi Arabia was one of four countries signed up to the “Four Kingdoms” (i.e., Norway, the Netherlands, and the U.K.) initiative which aims to explore the environmental viability of carbon capture and storage (CCS) technology. The Kingdom’s initiatives have been investigating the potential of isolating carbon dioxide at production, transportation and storage facilities and study the possible geological formations to determine the most suitable geological sites for carbon storage. The initiatives are contributing to enhance the national capacity in the following areas:

a. Identification, quantification and monitoring of the sources of CO_2.
b. Minimization of CO_2 formation.
c. Reduction of CO_2 emissions.
d. Transportation and storage system development.
e. Identification of sequestration locations.
f. Development of sequestration technologies for depleted oil reservoir.
g. Development of carbon separation technologies using metal-organic frameworks (MOFs).
h. Development of carbon capture technologies using biological process and chemical-looping combustion.
i. Utilization of CO_2 to produce polycarbonates and polyurethanes.
j. Utilization of CO_2 for enhanced oil recovery.

k. Conversion of CO_2 into useful products.

Saudi Aramco is participating in a number of research and technology programs with leading national and international organizations to reduce greenhouse gas emissions by improving combustion efficiency, reducing carbon dioxide emissions and implementing Carbon Management (CM). The company developed a CM technology roadmap which aims toward enhancing petroleum presence in global CM technological development, leveraging petroleum industry resources and know-how and enhancing the value created from the carbon cycle.

Saudi Aramco's Uthmaniyah CO_2-EOR Demonstration Pilot Project, located in the Eastern Province of Saudi Arabia, is capturing and storing approximately 800,000 tonnes of carbon dioxide (CO_2) per year from a natural gas production and processing facility and includes pipeline transportation of approximately 85 kilometers to the injection site in the Uthmaniyah Field. The objectives of the project are determination of incremental oil recovery, estimation of sequestered CO_2, addressing the risks and uncertainties involved (including migration of CO_2 within the reservoir), and identifying operational concerns. The project has an elaborate monitoring and surveillance program to provide a clear assessment of CO_2 storage underground. Operation of the project commenced in July 2015.The project duration is expected to be three to five years. The design of the CO_2-EOR project is based on reservoir simulation studies and has a comprehensive monitoring and surveillance plan, including routine and advanced logging and testing and use of new technologies for plume tracking and for CO_2 saturation modelling (Saudi Aramco 2016).

Saudi Arabia has been conducting a number of research projects for developing a new frontier of capturing greenhouse gases in road transportation. A prototype vehicle has been presented which captures 10 percent of its emissions through a carbon capture unit using absorbent materials from the exhaust system, a tank used for compression and storage and a unit that recycles the heat produced by the vehicle to run the carbon capture system. In 2013, the carbon capture efficiency of the second prototype vehicle increased to 20 percent and the required size of the carbon capture unit is only one-eighth of the original size (Saudi Aramco, 2013).

Saudi Arabia has built and started operation of the world's largest plant for capturing and using 500,000 ton/year of carbon dioxide from ethylene glycol plants and purify it for use in petrochemical plants in the industrial city of Jubail (SABIC 2017).

3.10.1.4 Utilization of Natural Gas

The primary ingredient of natural gas is methane (CH_4), which has a higher energy content compared to other fuels (such as coal, diesel oil, gasoline, propane) and thus, it has a relatively lower CO_2-to-energy content (EIA, 2015). The Kingdom has been encouraging investments for natural gas exploration and production and adopting measures to increase the share of natural gas in the national energy mix.

3.10.1.5 Methane Recovery and Flare Minimization

The Kingdom adopted the initiative to measure methane emissions from oil and gas operating facilities using the Solar Occultation Flux technique to minimize methane emissions. It is also implementing Lead Detection and Repair (LDAR) protocol and program for oil and gas operation activities. It is piloting flare monitoring satellite technologies in order to control flaring activities and reduce methane emissions. The oil and gas facilities are installing flare gas recovery systems to limit gas flaring.

The Kingdom operates the world's largest single gas collection system (Master Gas Collection System) that reduced the flaring emission from oil and gas production activities by more than 99% during the period between 1997 and 2000. The flaring is minimized from 0.89 percent to 0.72 percent of raw gas production at all upstream facilities during 2013. The adopted zero discharge technology at 432 well sites resulted in recovery of 2.6 billion standard cubic feet of gas in 2014 and more than 215,363 barrels of crude oil was recovered in 2014. A flare gas recovery system to recover gas from the flare headers of Safaniyah Onshore Plant avoids the flaring of this gas into the atmosphere. It annually saves approximately 25,363 tons of CO_2 equivalent emissions at the flares.

3.10.1.6 Environmentally Friendly Energy Sources

The Kingdom has taken a number of research initiatives in order to ensure increased share of clean fuel in national fuel mix. A number of projects have already been implemented focusing on fuel cell technology, high octane compound production and biofuel production. Researchers have actively participated in fuel cell research since the 1980s and their current efforts are directed to develop a Proton Exchange Membrane (PEM) fuel cell system emphasizing three different aspects such as developing novel low cost proton conducting membranes, developing multifunctional catalyst system and development of hydrocarbon based fuel processing systems. The researchers investigated different candidate fuels for hydrogen generation using auto thermal-partial oxidation reforming and water-shift reaction technologies.

KACST funded a project titled “Saudi Arabia Bio-refinery from Algae” to screen lipid hyperproducers species in Saudi Arabian coastal waters. These species will be used for algal biofuel production (Zafar, 2014). The Kingdom planned to set up a biodiesel facility with the capacity of 40,000 metric ton per year that will use fats from meat rendering as locally produced feedstock.

After successfully acquiring ‘in-house’ know-how for developing half-cells, mono-cells and 100- and 250-W stacks a 1 kW PAFC stack was demonstrated at the ERI, KACST. The experience led to an improved design and fabrication of the 1 kW PAFC stack. These lessons will ultimately contribute in scaling-up the power-generating modules for power utility applications in remote areas. In one of the projects of ERI, KACST, locally available internal combustion engines and ceramic mantle gas lamps, have been modified to use hydrogen as a fuel for small-scale demonstration purposes (Alawaji, 2001). In ERI, a commercial thermoelectric power generator, supposed to be fueled by methane or propane, has been modified to operate using hydrogen.

The national R&D trends in clean fuel production place emphasis on the following areas:

a. Production of high octane compounds.
b. Transformation of heavy fuel oil to high-quality hydrocarbons.

c. Development of catalysts for refining processes, clean fuel additives and the desulfurization of crude oil.
d. Development of fuel cell technologies using nano carbon tubes.
e. Improvement of clean fuel production using biotechnology.
f. Development of efficient anode support and electrolyte layer for micro-tubular solid oxide fuel cells.
g. Investigation of the effects of polymer binder in electrolyte slurries and application for micro-tubular solid oxide fuel cells.
h. Development of miniaturized solid oxide fuel cells with pulsed laser deposition.
i. Synthesis and characterization of materials for solid oxide fuel cells.
j. Development of system for operating solid oxide fuel cell generator on diesel fuel.
k. Development of novel composite membranes for medium temperature fuel cell.
l. Development of efficient membrane materials for polymer electrolyte membrane fuel cells (PEMFC).

3.10.2 Adaptation Initiatives with Mitigation Co-Benefits

The adaptation initiatives with mitigation co-benefits primarily include (i) water and wastewater management, (ii) urban planning, (iii) marine protection and (iv) Reduced desertification.

3.10.2.1 Water and Wastewater Management

KSA has been facing a challenging water scarcity problem where water demand exceeds the sustainable yields of natural resources (Ouda, 2013). The Kingdom's long-term water resources are surface water, ground water, desalinated water, and reclaimed waste water. The leading industries of the Kingdom have been taking water and waste water management initiatives which contribute in avoiding GHG emissions.

The public and private industries including oil and petrochemical industries have been developing and implementing a number of strategies to reduce water demand and increase the use of treated waste water in their facilities. They have established their Water Conservation Strategies to;

a. Reduce fresh water consumption rates in their facilities.
b. Use treated sanitary waste water generated from the major cities for various applications inside their industries.
c. Increase the use of recycled sanitary wastewater for irrigation needs generated by its communities and facilities.
d. Injection of 85% of the produced water into oil reservoirs for maintaining pressure level, which has led to no increase in the quantity of fresh water withdrawn or consumed by oil and gas operations from 2012 levels.

e. Recycling the used water in manufacturing operations multiple times to minimize usage. This has resulted in reducing the water intensity in the petrochemical industry by 5% as compared to the base year 2010.

The research entities have been conducting a number to research projects to develop the sustainable future water supply roadmap of the Kingdom. The Saline Water Desalination Research Institute (SWDRI) of SWCC (Saline Water Conversion Corporation) has conducted more than 400 scientific studies. It has already developed a patent for a desalination method which uses both Nano-filtration membranes and thermal or reverse osmosis units. In 2012, the SWCC signed a memorandum of understanding with Dow Chemical for collaborative research.

The Kingdom also conducts research on water desalination and water reuse focusing on membrane-based technology. The efforts are made for developing new membranes, such as Membrane Distillation (MD) and Forward Osmosis (FO). In 2012, the Kingdom announced a chair in desalination research in one of its universities which was funded by the UN Education, Scientific and Cultural Organization (UNESCO) in order to: (i) examine the existing desalination technologies and patterns of national water consumption; (ii) propose potential uses of membrane-based desalination methods; and (iii) provide guidance on maintaining a sustainable desalination program.

Desalination is an important sector to avoid CO_2 emissions. The desalinated water production, which supplies nearly 70% of the potable water in the Kingdom, contributed 54,193.2 Gg (12%) of CO_2 emissions in 2010 (Saudi Arabian TNC). Due to increase in potable water demand, the Kingdom is planning to add new desalination plants between 2017-2021 which will lead to increased CO_2 emissions. Savings on water consumption by (i) reducing per capita consumption (ii) controlling and reducing leakages in water distribution system (iii) increasing the collection and storage capacity of surface water run-off and (iv) increasing the treated wastewater reuse, will reduce the load on desalination plants thus providing the opportunity to offset the need of new desalination plants and providing opportunity to avoid additional CO_2 emissions. The use of energy efficient technologies for desalination e.g. reverse osmosis instead of energy intensive multistage flash would also avoid CO_2 emissions substantially.

3.10.2.2 Urban Planning

The Kingdom has been implementing a number of projects aiming to build a sustainable transportation system focusing on mass transit.

The Kingdom established the Public Transport Authority (PTA) in October 2012 and allocated 200 Billion Saudi Riyals for public transport projects and for regulating the public transport services within and between cities. The Kingdom is currently implementing King Abdulaziz Project for Riyadh Public Transport which includes (i) 756 metro cars, 85 stations, 6 metro lines and a 176-km network; and (ii) 3,853 bus stops and stations, 24 bus routes, 1,150 km network and 956 buses.

The Al-Mashaaer AlMugaddassah Metro Line project in Makkah involves the construction of a 20 km long metro line. It connects the holy cities of Makkah, Arafat, Muzdalifa and Mina.

The metro line started functioning during the Hajj pilgrimage in 2010 (UITP, 2014). In 2015, the Mayor of Jeddah announced that 24 tunnel projects were completed in the past four and a half years and a public transportation system is expected to be completed in the next several years. The implementation of the Haramain High Speed Railway project linking the holy cities of Makkah and Madinah via Jeddah and King Abdullah Economic City is going on (Saudi Railways Organization, 2015). The railway line between Madinah and Rabigh and between Makkah and Jeddah is expected to be operational in 2018.

The railroads are considered more environmentally friendly than cars, trucks or airplanes. The Kingdom initiated the North-South Railway (NSR) project which is the world's largest railway construction and the longest route to adopt the European train control system (ETCS) to date. It is a 2,400 km passenger and freight rail line originating in the capital city Riyadh to Al Haditha, near the border with Jordan. The ongoing “Saudi Land Bridge” project aimed to construct a 950 km new railway line between Riyadh and Jeddah and a 115 km new railway line between Dammam and Jubail (Saudi Railways Organization, 2016).

The National Spatial Strategy (NSS) provides principles and guidance on ways to support development and address the social and environmental consequences of growth, including ways to integrate low-emissions approaches to urban planning. The Kingdom established urban observatories network in order to develop a knowledge base which is required to develop sustainable urban policies and monitoring human settlement dynamics. The National Urban Observatory Center is responsible for collecting, analyzing and developing urban indicators at all levels. The Center intends to ensure sustainable urban development planning. The network of urban observatories consists of thirteen regions and the City of Jeddah. The United Nations Development Program (UNDP) supported the Municipality of Al Madinah Al Munawarah Region to establish Al-Madinah Urban Observatory Network (MOUN) during the period 2003-2008. The urban observatories are also established for Makkah, Taif, Abha, Uhod Refaidah, Khamis Mushayt, Buraidah, Baha, Qurrayyat, Al Hassa and Najran. The main objective of building an urban observatory is to use available data to effectively and efficiently disseminate a city’s most current urban indicators, statistics, conditions and profiles.

3.10.2.3 Marine Protection

The coral reefs followed seasonal patterns in movement from shallow shore reefs to deep offshore. The Kingdom declared closed season for some specific period for specific coral reef species. In addition, according to the Council of Ministers Order no 1237513/4/1423 H), all coral reefs are considered as protected. The government and some private island owners are deploying artificial coral reefs on the Arabian Gulf for improving marine environment and increasing offshore fish production.

Saudi Arabia identified the optimal locations within the Arabian Gulf to establish artificial reefs and the most efficient design and configuration. Currently, various artificial reef modules have been deployed in 25 locations. These artificial reefs will create new fish habitats, thereby enhancing the fisheries resources and its coastal and offshore ecosystems. A monitoring program has been developed to study biodiversity and biomass development on the deployed reefs. A reef restoration program has also been established throughout the northwestern

Arabian Gulf by submerging 728 modular artificial reef habitats that will act as nurseries for corals and associated marine life.

An updated Marine Atlas of the Western Arabian Gulf has been published. It documents the diverse marine and coastal environments of the Arabian Gulf and includes images and detailed information that showcase one of the region's most diverse ecosystems (Saudi Aramco, 2012).

PERSGA is the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden. It is an intergovernmental body dedicated to the conservation of the coastal and marine environments in the Red Sea, Gulf of Aqaba, Gulf of Suez, Suez Canal and Gulf of Aden surrounding the Socotra Archipelago and nearby waters. The member states of PERSGA are Djibouti, Egypt, Jordan, Kingdom of Saudi Arabia, Somalia, Sudan and Yemen. PERSGA developed a number of protocols which include: (i) protocol concerning the conservation of biological diversity and the establishment of network of protected areas in the Red Sea and Gulf of Aden; and (ii) protocol concerning the protection of the marine environment from land-based activities in the Red Sea and Gulf of Aden.

In the coastal areas, carbon is stored in mangroves, seagrasses and organic soils of tidal wetlands which are known as "Blue Carbon". A regional initiative of collaboration between PERSGA and UNEP is undertaken to: (i) formulate Blue Carbon policy; and (ii) build capacities for streamlining such policies in eight countries including Yemen, UAE, Somalia, Sudan, Saudi Arabia, Jordan, Egypt and Djibouti. According to PERSGA (2010), Saudi Arabia has more than 100 mangrove stands on the Red Sea coast with an estimated area of 3,500 hectares. The stands are mainly concentrated on the coast of Jazan province and the Farasan islands.

The carbon stocks for coastal and marine ecosystems depend on the characteristics of vegetation and soil. Michaelowa and Nerger (2013) estimated the mangrove carbon stock of Saudi Arabia equivalent to approximately 6.2 million tons of CO_2. Saudi Arabia has planned to develop a mangrove eco-park on the Gulf coast to protect an area of over 63 square kilometers. This park was expected to be completed by 2017. Approximately 150,000 additional mangrove seedlings will be planted in the park. 400,000 mangrove seedlings have been planted along the Saudi coast since 2011 (Saudi Aramco, 2014).

3.10.2.4 Reduced Desertification

The Kingdom has been undertaking measures to enhance desertification management. It supports actions that will promote the stabilization of sand movements around cities and roads, while increasing sinks for capacity through using green belts as barriers. It has been developing and enhancing arid and semi-arid rural areas through various natural resource conservation activities, biodiversity and ecosystem-based adaptation efforts. The objective is to improve soil quality, water, pasture and wildlife resources through a system of protected areas and reserves.

3.10.3 Research and Development Activities on Climate Change

The Kingdom has been following an increasing trend of engaging in international collaboration in scientific research and technological development by direct cooperation between Saudi universities and research organizations and reputed foreign counterparts. The Ministry of

Education has taken the initiative to establish centers of research excellence in Saudi universities in accordance with the principle of mutual competitiveness and with the requirement that these centers adhere to criteria and standards necessary to reach the intended goals. The Ministry has already established centers of research excellence in different areas including renewable energy, water desalination, climate change, and nanotechnology. It also approved the establishment of a center of research excellence on natural disasters.

In the Ninth Development Plan (2010-2014), the Kingdom reported a clear mandate for developing a globally competitive knowledge economy which involves establishment a world-class science and technology sector so that innovative activity would emerge as a driving engine of economic growth (Alshumaimri et al., 2010). Accordingly, the research entities of the Kingdom have been collaborating with the leading research institutions of many countries.

KACST is responsible for building the required infrastructure for supporting scientific research including the management of research grants, set-up of communication networks and science and technology databases, and the execution of applied research (Khorsheed and Al-Fawzan, 2014). KACST developed the Comprehensive, Long-Term, National Science and Technology Policy which was approved by the Council of Ministers in 2002. This policy led to the National Science, Technology and Innovation Plan (NSTIP). It aims to establish programs for developing strategic technologies which are most important for the Kingdom. The Technology Development Center in KACST is responsible for contributing to technology localization and technological projects in the Kingdom.

The Center for Clean Water and Clean Energy was established as a partnership between the Massachusetts Institute of Technology (MIT) and KFUPM. The Center focuses on research in desalination, low carbon energy, and the related areas of design and manufacturing. The fast track and dynamic R&D initiatives resulted in more than 20 intellectual properties and 3 technologies developed in water related developmental activities. The carrier gas extraction technology for purifying extremely contaminated waters is currently used for commercial production of water in two oil/gas fields in the US (KFUPM, 2016).

In 2015, the Ministry of Education awarded KFUPM an authorization to establish a Center of Research Excellence in Natural Disasters (CoREND) in order to meet the requirements of developing necessary capability and tools which identify and quantify natural hazards risks in the Kingdom of Saudi Arabia. It will set out to establish and operate a national center of excellence in natural disaster research to support interdisciplinary, collaborative research bridging science and technology that will drive research projects toward a better understanding and enhancement of the Kingdom's capability to combat natural disasters. It will undertake and support highly innovative and goal-oriented research pertinent to identification, assessment, prediction, protection, and management of dangers of the important natural disasters facing the Kingdom. The CoREND will aggressively pursue basic and applied research, specifically focusing on various issues related to the potential dangers of: (i) floods; (ii) landslides, land collapses and rock falls; (iii) desertification and sand dune movements; (iv) earthquakes and volcanic activities; and (v) radiological pollution, with a scale and focus leading to outstanding national, regional, and international collaboration and recognition. The CoREND plans to actively collaborate with reputed international organizations including Commonwealth

Scientific and Industrial Research Organization (CSIRO), Macquarie University, University of Melbourne, Tohoku University, State University of New York at Buffalo, and Desert Research Institute for capacity development and technology transfer.

In order to implement the renewable energy roadmap in a sustainable manner, the Kingdom has been taking measures in different stages of the renewable energy supply chain. The Kingdom already possesses two factories producing flat plate collectors which also reflect the progress towards the use of solar energy (Doukas et al., 2006). The First Energy Bank along with an American company named Vinmar International announced plans to build a polysilicon plant in Saudi Arabia to meet the growing demand for solar energy with a production of 7,500 tons per annum. There is another joint venture to market and sell concentrated photovoltaic (CPV) systems. The IDEA Polysilicon Company is the first Middle East Integrated Polysilicon and Solar Wafers Company in Yanbu Industrial City which will produce 10,000 tons per annum of High Purity polysilicon ingots, and wafers.

Although the Kingdom has been working in enhancing capacity building and technological strength, it requires close cooperation and support of the developed countries. This will aid capacity building and technology localization in order to enrich the Kingdom's resilience to climate change and thereby reduce vulnerabilities for adapting to the international climate change response measures.

3.10.3.1 Technology Transfer and Development (TTD)

Promoting the effective technology transfer and development has become a strategic option for developing countries to achieve their objectives to attain sustainable development in a climate-friendly manner[2]. The Kingdom of Saudi Arabia has realized the significance of emphasizing the investment on technology transfer and high technology know-how through research, development and manufacturing processes to achieve its aspired socio-economic development objectives in a sustainable manner, particularly, the objective of diversifying the national economic base. The Economic Offset Program (EOP) with UK, USA, and France was among the first initiatives launched in 1984 to promote investment on technology transfer and high technology know-how in the Kingdom, and to benefit from technology transfer brought through private sector non-offset joint ventures.[3]

Technology assimilation has been considered as one of the means to expand the absorptive capacity of the national economy and to enhance its growth, stability and competitiveness through directing national and foreign investments towards high technology-content and high value-added sectors and encouraging creativity and innovation, and accelerating implementation of the NIS[4].

The 10th development plan of the Kingdom (2015-2019) constitutes the strategic national push towards diversifying the economic base from different dimensions, putting more focus on, expanding production capacities of the industrial sector that, mainly, comply with the strategic

2 www.unfccc.int

3 The Saudi economic offset program: a tool for technology transfer. http://download.springer.com/static/pdf

4 Ministry of Economy and Planning. The objectives of the 10th development plan (2015-2019). The Kingdom of Saudi Arabia. 2015.

areas highlighted by the National Industrial Strategy (NIS), promoting investment projects on diversifying energy sources, encouraging strategic partnerships at national and international levels to implement investment projects contributed to production base diversification of the national economy, and considering comparative advantages in boosting spatial diversification of economic activities along with expansion in establishment of industrial zones and business and technology incubators to improve utilization of these advantages.

3.10.3.1.1 Policies

A number of policies, initiatives and laws have been constituted and implemented in the Kingdom to promote the climate friendly technology transfer and development; to regulating ownership right, to invest, to manage intellectual property, to set incentives and rights for the researchers in order to promote innovation and invention.

3.10.3.1.2 Baseline Ecosystem

Analysis of the Technology Transfer and Development Ecosystem (TTDE) in the Kingdom revealed that foundation elements of TTD are already in place, including, research and development institutions, technology transfer offices (TTO), commercialization institutions, and intellectual property protection policies, etc. The analysis, also, revealed the great potential to enhance the TTD elements in the Kingdom.

3.10.3.1.3 Challenges

The smooth operation of the TTD in the Kingdom requires a proper identification of challenges and transformation of these challenges to opportunities.

The main challenges of the TTD in the Kingdom could be clustered into two main groups, namely, natural uncontrolled and unregulated flow of inbound technology transfer, and the limited successful flow of technology from research to commercialization[5].

- **Natural uncontrolled and unregulated flow of inbound technology transfer:**
  - **i.** The lack of attractive incentives to local and international firms and entrepreneurs to partner and/ or to engage in the technology transfer development process in the Kingdom.
  - **ii.** Insufficient regulations governing inbound horizontal technology transfer to the Kingdom and rights and obligations of all parties engaged in the technology transfer development process.
- **Limited successful flow of technology from R&D stage to commercialization stage:**
  - **i.** The lack of a clear connection between R&D outputs and market requirements.
  - **ii.** un coordinated roles and responsibilities of the key players of the technology transfer ecosystem including R&D institutions and TTD facilitators.
  - **iii.** Incomplete definition of revenue sharing mechanism between investors and the commercialization entities.

5 Booz and Co. Technology Transfer in KSA: Model and Regulatory Guidelines. 2014.

3.10.3.1.4 Technology Needs

The National Plan for Science, Technology and Innovation (Maarifah)[6], identified eleven (11) core strategic technology areas that assess the national technology needs and the inspired scientific and technical advancement requirements in the Kingdom. The identified technology areas include: water, oil and gas, petrochemicals, nanotechnology, biotechnology, information, electronics, communications and photonics, space and aeronautics, energy, environment, advance materials, and mathematics and physics.

The indicative list of climate Change technology areas/needs of the Kingdom include energy and environment technologies. The energy technology areas comprise seven tracks including renewable energy generation, conventional energy generation, electricity distribution and transmission, energy conservation and management, energy storage, fuel cell and hydrogen, and combustion. Environment technology areas comprise of four tracks including waste, pollution, air quality, and degradation of natural resources.

3.10.3.1.5 Key Success Indicators

Building research and development infrastructure is a key component of the advancement of TTD's value chain in the Kingdom, which strategically aspire to develop and localize technologies and know-how, to produce and commercialize highly efficient and cost effective technologies in areas that the Kingdom has competitive advantages and/or has a potential to diversify the national economy, to provide promising investment opportunities to the private sector, and to build competent human resources pertinent to science and technology sector.

The followings are some selected achievements of the R&D initiatives in the Kingdom, with emphasis on climate Change technologies- Promoting scientific research and development

a. Supporting technology entrepreneurs and innovators to establish and develop high growth technology business ventures.
b. Increasing industrial cooperation and patent commercialization activity.
c. Identifying a positive trend within the Kingdom[7].

3.10.3.1.6 Commercialization and Entrepreneurship

The Kingdom has directed itself toward knowledge-based economy in alignment with the objective 3.5 in the 10th national development plan "utilizing the results of scientific research" and "the transformation of knowledge into wealth"[8]. However, there is a gap between the outcomes of R&D (e.g., innovations, patents, industrial solutions) and the implementation of the results of these projects. This gap could be filled by technology commercialization and

6 The National Plan for Science, Technology and Innovation (Maarifah) is the implementation plan for the National Policy for Science and Technology of the Kingdom.

7 Thomson Reuters. Research Performance Indicators Report. The 4th Report, 2014

8 Ministry of Economy & Planning, "The Objectives & Policies of the 10th National Development Plan," Ministry of Economy & Planning, Riadh, 2015

entrepreneurship activities from laboratories, research centers, and universities to the industries.

3.10.3.1.7 National Industrial Strategy (NIS)

In line with the objective 4.10 of the 10th national development plan i.e. “Accelerating implementation of the National Industrial Strategy” an effort was made to bridge the gap between the implementation entities (e.g., industries) and the R&D centers through launching the National Industrial Strategy (NIS) vision on the future of the industry in the Kingdom in 2020[9]. The vision of NIS was based on knowledge-based industry as indicated in the vision “A globally competitive industry based on innovation”.

Enhancing the technology content in Saudi industry from 30 per cent (as in 2007) to 60 percent in 2020 was set as a national target and as an indicator to the achievement of the goal by the end of 2020. However, to achieve these ambitious targets, many programs are set such as building technology clusters and complexes which is in alignment with axis 2 of the NIS, and in line with the objective 22.7 of the 10th national development plan “establishing creativity and innovation clusters in various regions of the Kingdom through strengthening the relations between the private sector, universities and research centers”. Other programs included in the NIS are listed below[10]:

a. Industrial innovation coordination program.
b. Industrial research developing and commercialization program.
c. Industrial innovation fund program.
d. Industrial technology centers program.

3.10.3.1.8 Investment in Research

Three technology-based companies were launched in 2010-2011 in order to invest in the outcomes of R&D and scaling up the developed and invented technologies: TAQNIA (2011), Riyadh Techno Valley Co. (2010), and Dhahran Techno Valley Co (2010). Furthermore, BADIR program for technology incubators has established about 84 startups with a market value of about 185 million SAR, clients' revenue of about 7.8 million SAR, and successfully created more than 3,000 jobs[11].

TAQNIA chose energy industry sector as one of the highest opportunities along with water technology, and advanced materials. TAQNIA used four parameters to assess each industry sector in order to find the best industry opportunities: strategy relevance, economic attractiveness, risk profiles, and competitive dynamics. Going through this assessment processes, six startup companies were established including TAQNIA Energy (2014) and Advanced Water Technology Co (2012). TAQNIA Energy is working on the transfer of solar energy and waste to energy[12].

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9 Ministry of Commerce & Industry, "National Industry Strategy to 2020," Kingdom of Saudi Arabia, Ministry of Commerce & Industry, 2007.

10 Ministry of Commerce & Industry, "National Industry Strategy to 2020," Kingdom of Saudi Arabia, Ministry of Commerce & Industry, 2007.

11 BADIR Program for Technology Incubators. King Abdulaziz City for Science and Technology. 2015.

12 TAQNIA, "TAQNIA Industries," Riyadh, 2015.

Riyadh Techno Valley (RTV) Co. was established under the umbrella of King Saud University in 2010. RTV chose to work in three industry sectors; among which, renewable energy and sustainable resources. RTV has been successful to initiate six startup companies[13].

Dhahran Techno Valley (DTV) Co. was established under the umbrella of King Fahad University of Petroleum and Minerals (KFUPM) in 2010 in Dhahran city. Six fields of industry sectors were chosen by DTV to startup companies, among which, renewable energy, energy storage and efficiency, and carbon management[14].

3.10.3.1.9 International Treaty, Plan, Policy and Program Initiatives

The Kingdom of Saudi Arabia has been maintaining its sincere role in Climate Change Issues through active engagement with relevant international treaties, plans, policies, and programs. The major relevant international initiatives are:

a. Saudi Arabia agreed to the United Nations Framework Convention on Climate Change on 28 December 1994.
b. The Kingdom has signed Montreal Protocol for phasing-out Ozone Depleting Substances (ODS) and within the framework of a national strategy industrial facilities/plants are gradually stopping the use of certain ozone depleting chemicals.
c. The World Bank selected King Abdulaziz University (KAU), as represented by its Center of Excellence for Climate Change Research (CECCR), established in 2009, to lead an Arab research team for a study on climate change in the Arab World. It is working on collecting and compiling relevant climate data for the Kingdom which can be used for policy development.
d. The Kingdom of Saudi Arabia is a member of the Carbon Sequestration Leadership Forum (CSLF). This voluntary initiative focuses on the development of cost effective technologies for the separation and capture of CO_2 for its transport and safe storage (Liu et al., 2012). Its mission is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles. It also promotes awareness and champion legal, regulatory, financial, and institutional environments encouraging to such technologies.
e. Saudi Arabia, Norway, the Netherlands, and the UK initiated the Four-Kingdom CCS initiative for potential collaboration on CCS in order to advance its development and deployment.
f. Saudi Arabia is a member of the Regional Organization for the Protection of the Marine Environment (ROPME) which is involved in the protection of the marine environment of the Arabian Gulf and PERSGA, which is the regional organization for the conservation of the environment of Red Sea and the Gulf of Aden.
g. The Kingdom joined Global Methane Initiative (GMI) in January 2014 and will participate in the Oil & Gas Subcommittee, for knowledge sharing in methane capture and reuse in the areas of flare management and fugitive emissions control for oil and gas operations.

13 Riyadh Techno Valley Co. , "Riyadh Valley Co.," [Online]. Available: http://rvc.com.sa/. [Accessed 17 1 2016].

14 Dharan Techno Valley Co. , "DTV Ecosystem," [Online]. Available: http://www.dtvc.com.sa/. [Accessed 14 1 2016].

h. The Kingdom is conducting the feasibility study for the Gulf Rail Project which starts from Kuwait via Dammam in the Kingdom of Saudi Arabia to the Kingdom of Bahrain through the proposed causeway to be built parallel to the King Fahd Causeway. The length of the track inside the Kingdom of Saudi Arabia under the project is approximately 663 km.

i. The Gulf Cooperation Council (GCC) will establish a Center of Excellence in Renewable Energy Research in Saudi Arabia. The center is to be set up under auspices of UNESCO and the Islamic Educational, Scientific and Cultural Organization (ISESCO).

3.10.3.1.10 Education and Public Awareness

The Kingdom has initiated a number of public awareness campaigns by giving additional emphasis on renewable energy education programs. The Saudi government has been supporting the development of public awareness regarding the climate change. The increasing climate change awareness in the Kingdom is also reflected in international studies.

KSU offers a post-graduate study program on renewable energy with the specialization in solar energy technology, wind energy technology, and hydrogen energy technology. The Sustainable Energy Technologies Center of KSU offers short courses and trainings in different fields of nuclear and renewable energy including: (i) nuclear energy; (ii) peaceful applications of nuclear energy; (iii) radiation protection and health physics; (iv) renewable energy; (v) introduction to renewable energy; and (vi) grid integration issues of renewable energy. Initially, the program will focus on solar, wind, hydrogen and nuclear energy. The program will also include plans for regional and global academic and industrial collaboration.

The departments of architectural and mechanical engineering at KFUPM offer graduate-level courses on: (i) solar systems in buildings; (ii) energy conservation and management in buildings; (iii) computer-aided building energy analysis; (iv) solar energy utilization; and (v) thermal environment and energy analysis. The Ministry of Education established the Center of Research Excellence in Renewable Energy at KFUPM which emphasizes increasing public awareness. Different departments of KAUST offer courses on: (i) clean fossil fuels and biofuels; (ii) membrane science and membrane separation process; (iii) solar cell materials and devices; and (iv) sustainable energy engineering.

The Solar and Photovoltaic Engineering Research Center at KAUST aims to contribute to student education, renewable energy awareness for decision makers and community, and active engagement with industry and technology development.

SEEC continues its energy-rationalization awareness campaign for students of the primary stage under the banner “Together to Save Energy” which targets about hundred and fifty thousand (150,000) students in various cities including Riyadh, Al-Kharj, Al-Khobar, Dhahran, Dammam, and Jubail. The Minister of Water and Electricity inaugurated the activities of the Saudi Forum and Exhibition for Energy Efficiency 2014 organized by SEEC at KACST over two days at KACST's Headquarter at Riyadh. In 2014, the Energy Efficiency Pavilion, a part of iThra Knowledge program toured the Kingdom, raised awareness about energy efficiency and wise energy choices. More than 2 million people visited the iThra Knowledge program in four cities in 2013–2014 and at least 70% of them were estimated to visit the Energy Efficiency Pavilion.

The first national "Solar Communication and Coordination Workshop" was hosted by KAUST. Apricum, a strategic consultancy specialized in renewable energies initiated and conceptualized the conference. More than one hundred and fifty representatives of the Saudi Arabian industry, government and research institutions that have a significant influence on the development of solar energy in the country attended on May 16, 2010. The Solar plaza organized two editions of the Solar Trade Mission Saudi Arabia in November 2013 and September 2014.

The Royal Commission for Jubail and Yanbu (RCJY) organized an international conference on modern technologies in recycling and reusing industrial waste in Jubail Industrial City from December 3-4, 2014.

The Saudi Arabia Smart Grid 2015 (SASG) conference at Jeddah was organized in order to bring together researchers, designers, developers and practitioners interested in the advances and applications in the field of smart grids, green information and communication technologies, sustainability energy, awareness systems and technologies. The Ministry also arranged the conferences on Smart Grid in 2014, 2013, and 2011. The first annual Saudi HVAC CONFEX 2013, was held in Riyadh over three days under the patronage of the Ministry of Water and Electricity, Saudi Arabia. The Ministry of Commerce and Investment is planning mandate that all automobile vendors post the appropriate energy saving label on all 2015 model cars.

The Global Methane Initiative (GMI) workshop was organized in 2015 at Al Khobar to disseminate technical information, present profit-generating technologies and share best practices that cost-effectively reduce methane emissions. The event was organized in cooperation with Saudi Aramco, the US Environmental Protection Agency (EPA) and the UN Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC).

The Water Arabia 2013 Conference and Exhibition was held under the patronage of the Ministry of Water and Electricity. The theme of the conference was "Innovative Water and Wastewater Technologies for a Sustainable Environment".

The 2nd International Recycling and Waste Management exhibition was held over four days at Riyadh and demonstrated the widespread recycling business presence in the Kingdom.

KACST completed one-month energy saving campaign starting from February 15, 2015 in order to educate consumers about the importance of energy savings and the associated economic and environmental implications.

3.11 Climate Change and International Policy Responses

3.11.1 Efforts to Reduce the Impacts of Response Measures

The Parties to the UNFCCC have recognized the need for developed countries to reduce GHG emissions and take action to mitigate the adverse effects of climate change (UNFCCC, Article 3). They also have recognized that initiatives taken by the developed countries to mitigate climate change (known as response measures) could negatively impact developing economies and impede sustainable development efforts (UNFCCC, Article 4). The implementation of unilateral response measures taken by developed countries in many cases will hinder economic development in developing countries, specifically if the measures affect international trade. This issue is addressed in UNFCCC by declaring that “measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade (UNFCCC, Article 3)”. The oil exporting non-Annex I nations are disproportionately affected by response measures due to their dependence on oil revenues. The impacts are attributable to negative shifts in trade and reduction in fossil fuel consumption.

The investigations of response measures by the developed countries to mitigate climate change are the cornerstone to develop the roadmap to reduce the impacts and to adapt to these impacts.

A study of McKay Consultants revealed that: (i) technology-related policies have the lowest impact; (ii) technology-development-based measures have the lowest impact on oil demand and thus provide lower negative spillover effects on oil producing developing countries; (iii) technologies such as CCS provide solutions to address climate change and adverse effects of the policies and measures; and (iv) efficiency measures also provide good solutions with minimum impact. In the sixth CSLF Ministerial Meeting, carbon capture technologies and structured carbon management roadmaps are considered as solutions to reducing rising levels of GHG (CSLF, 2015). It was also advocated to adopt clean energy policies that support CCS along with other clean energy technologies.

The Kingdom already has developed its carbon management research and technology development roadmap focusing on CCS which includes the following five elements.

3.11.1.1 Carbon Capture from Stationary Sources

The program aims to develop and demonstrate improved cost-effective technologies for the separation and capture of carbon dioxide from stationary CO_2 sources. The research and technology development plans include: (i) characterizing national CO_2 emissions; (ii) CO_2 capture from combustion systems; and (iii) CO_2 capture from non-combustion systems.

3.11.1.2 Carbon Capture from Mobile Sources

This program aims to develop carbon management solutions supporting the continued use of petroleum liquid fuels in the transportation sector. The research and technology development basis include: (i) developing an on-board vehicle carbon capture system; and (ii) adapting stationary pre- and post-combustion technologies to suit marine vessel and rail-train applications.

3.11.1.3 Industrial Applications for Carbon and Carbon Dioxide

This program aims to convert captured carbon dioxide and carbon generated during production of oil and gas and derived from petroleum fuel combustion to make valuable products. The research and technology development basis include: (i) production of various carbon containing materials from carbon or carbon dioxide; and (ii) enhanced oil recovery.

3.11.1.4 Carbon Dioxide Geological Sequestration

This program aims to develop technologies to help sequester CO_2 in saline aquifers safely and to monitor the movement of CO_2 underground and at surface. The research and technology development basis include: (i) assessment of sequestration potential in major candidate aquifers; (ii) investigation of mitigating problems in CO_2 storage; and (iii) identification and development of the monitoring and verification technologies.

3.11.1.5 Carbon Dioxide – Enhanced Oil Recovery (CO_2-EOR)

This program aims to demonstrate at a pilot scale the technical and economic viability of CO_2-EOR by injecting CO_2 from in-Kingdom sources into a candidate oil reservoir. The research and technology development basis include: (i) CO_2 research and laboratory studies; (ii) reservoir simulation; and (iii) a CO_2-EOR pilot project.

3.12 Challenges

The challenges of successful economic diversification in the Kingdom are both in demand and supply sides. Extensive reform in the general framework for macroeconomic management is required on the demand side, while on the supply front, developing the growth of human capital, restructuring the public sector, eradicating labor market distortions and building an industrial base to boost exports are necessary (Bakr, 2015). Reformation in demand policies through the general framework for macroeconomic management aims to strengthen the macroeconomic stability. This framework is the main macroeconomic policies used in aggregate demand management, namely fiscal policy, monetary policy and exchange rate policy.

In supply policies, strengthening the macroeconomic stability in general framework and reformation should be convoyed parallel to demand side. The diversification in production base and diverting the sources of income away from the hydrocarbon sector and associated industries are the major challenges. The overall diversification of production structures seems to be a long-term challenge which requires the integral effort from reforming the public and private sectors, developing human capital buildup, and building an industrial base that supports the process of diversification (Bakr, 2015).

The major risk associated with economic diversification are low growth rates, lack of public and private incentives to accumulate human capital and lack of competitiveness in manufacturing (El-Kharouf et al. 2010). Researchers have suggested multidimensional influences on the lack of success of the Kingdom on economic diversification strategy (Bassam, 2015). These include the lack of a clear plan addressing the detailed process of diversification, lack of detailed plan for supporting non-oil sector e.g., agriculture and tourism are major ones. The other factors are that the majority of government support is concentrated towards oil based industry (i.e., petrochemical) and the complete reliance of private sector on government projects and funding.

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SECTION – 4

Analysis of Socioeconomic Impacts of Response Measures

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4.1 Response Measures and Policies – Global Perspectives

There is an increasing recognition that the implementation of climate change policies can have significant socio-economic cross border impacts on other countries. Actions that do result in reductions in emissions of greenhouse gases curtail demand for hydrocarbon and depresses their international prices, causing direct revenue losses for hydrocarbon exporters. Implementation of climate change measures and policies can also create spillover effects through the international trade channels. Measures that lead to restrictions on the use of hydrocarbon energy in all countries, whether through prices and taxes or through direct control, increase production costs and hence prices of exportable goods and services. As long as the majority of developing countries import goods from Annex I markets, the mitigation action of industrialized countries will effectively translate into an adverse movement in terms of trade for developing countries. As a major oil exporter with a highly liberated economy, Saudi Arabia will be greatly impacted upon through both channels.

A much better appreciation of the socioeconomic impacts of response measures is gained when response measures are viewed within the context of sustainable development. There are, however, several implications of response measures on developing countries' ability to achieve sustainable development that have been identified which include the negative impacts on oil exports, agricultural exports, food security, tourism, energy access, employment and migration.

In accordance with decision 24/CP.18 (UNFCCC, 2012), Saudi Arabia has pledged to pursue economic diversification as the framework for the implementation of its national contribution to address global climate change. Since the inception of the climate change policy-making process in 1991, the Kingdom of Saudi Arabia has called for a developmental and needs-driven approach to global and national efforts to address climate change. Such an approach should be based on national circumstances, equity, cost-effectiveness, efficiency and optimum use of technology-based solutions which are supportive of national development plans and priorities. Addressing climate response measures requires the establishment of a new paradigm to enhance the understanding of the impacts of these measures and to ensure the proper treatment of their implications. It is within this framework that Saudi Arabia has called for the right of developing countries to sustainable development, encompassing all its economic, social and environmental dimensions. These three-dimensional aspects of sustainable development must be designed in such a way to ensure that developing countries are able to build resilience not only to the adverse bio-physical impacts of climate change but also to the negative impacts of response measures and spill-over effects; particularly for economically vulnerable countries that highly depend on a single source of income. Therefore, minimizing the impact of climate change policies on developing countries that are heavily reliant on oil exports was recognized from the inception of the Climate Change Convention. Since many policies and measures to address climate will impact these economies disproportionately, it is imperative that assistance is provided to these countries to help them adapt to the negative impacts of these measures and policies.

As a result of these concerns, several provisions have been made within the framework of these treaties to attempt to address them. The provisions include Articles 4, paragraphs 8 and 10 of the UNFCCC, Articles 2, paragraph 3 and Article 3, paragraph 14 of the Kyoto Protocol as well as Article 4, paragraph 15 of the Paris Agreement. Further to these provisions, several decisions have been taken by Parties relating to the economic and social impacts of Response Measures. They include decisions 5/CP.7, 1/CP.10, 1/CP.13, 1/CP.16, 2/CP.17, 8/CP.17, 1/CP.18 and 31/CMP.1. By means of these provisions and decisions, Parties to these agreements have agreed to give full consideration to specific needs of developing countries that are particularly vulnerable to the adverse effects of climate change and who at the same time bear a disproportionate or abnormal burden under these Climate Change Agreements. It is also recognized that the implementation of unilateral response measures taken by developed countries to mitigate climate change in many cases will hinder economic development in developing countries, specifically if the measures affect international trade. This issue is addressed in UNFCCC by its Article 3, declaring that “measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade”.

As of 5 December 2017, 165 INDCs have been submitted (UNFCCC, 2017) and the most recent UNFCCC Secretariat synthesis report (UNFCCC, 2016a) covers the 161 NDCs submitted by 5 April 2016. These INDCs out of 189 Parties to the UNFCCC and Paris Agreement, cover nearly 88% of global emissions. The UNFCCC synthesis report indicates that renewable energy (approx. 55% of INDCs), energy efficiency (approx. 50% of INDCs) and transport (approx. 45% of INDCs) are priority areas for INDC implementation. These sectors are considered important in addressing the issue of impacts of the implementation of response measures, especially on Parties that are heavily dependent on export revenues from fossil fuels.

More than 40% of INDCs highlighted the link between climate change action and development priorities. However, less than 10% of all INDCs provided information on the adverse impacts of international policy responses to climate change, with a number highlighting the importance of understanding the issue of response measures and their potential impacts.

Developed countries have been mandated to report on their actions to minimize the adverse impacts of climate change actions in accordance with Article 3.14 of the Kyoto Protocol through their National Inventory Reports (NIRs). The UNFCCC secretariat compilation reports (UNFCCC, 2017) indicate that developed countries are aware of the impacts of the implementation of response measures and have put in place mechanisms to minimize these impacts. However, these measures (such as impact assessments and sectoral support schemes) are in many cases geared towards domestic impacts, with lesser attention for cross-border impacts (UNFCCC, 2016b). Actions to minimize impacts mentioned in NIRs include capacity building, technology transfer and cross-border cooperation and investments in infrastructure and renewable energy, but do not, at this time include measures that would help developing country Parties in their efforts to identify, quantify and address these impacts.

4.1.1 Forum and Improved Forum on the Impacts of Implementation of Response Measures

To address the growing concern over avoiding or minimizing the negative impacts of response measures, the Conference of the Parties (COP) at its 16th session in Cancun Mexico in 2010 agreed to establish a *forum* on the impact of implementation of response measures. The forum was convened with the objective of developing a work program to address these impacts. COP 17 in 2011, by its decisions 2/CP.17 and 8/CP.17, decided to establish the forum on the impact of the implementation of response measures mandated to meet under a joint agenda item of the subsidiary bodies to enhance the consolidation of all progressive discussions related to response measures. It also adopted a work program with the objective of improving the understanding of the impact of the implementation of response measures in eight distinct areas namely:

a. Sharing of information and expertise, including reporting and promoting understanding of positive and negative impacts of response measures;

b. Cooperation on response strategies;

c. Assessment and analysis of impacts;

d. Exchanging experience and discussion of opportunities for economic diversification and transformation;

e. Economic modelling and socio-economic trends;

f. Relevant aspects relating to the implementation of decisions 1/CP.10, 1/CP.13 and 1/CP.16 and Article 2, paragraph 3 and Article 3, paragraph 14 of the Kyoto Protocol;

g. Just transition of the workforce and the creation of decent work and quality jobs and

h. Building collective and individual learning towards a transition to a low greenhouse gas emitting society.

The 21st Conference of Parties to the UNFCCC (COP21) requested the Chairs of the subsidiary bodies to convene *the improved forum* in order to implement the work program on the impact of the implementation of response measures and that the improved forum shall meet twice a year in conjunction with the sessions of the subsidiary bodies, with its first meeting taking place at the 44th sessions (May, 2016) of the subsidiary bodies. It further requested the subsidiary bodies, in order to advance the work of the improved forum, to constitute Ad Hoc technical expert groups, to elaborate on the technical work under the improved forum. The work program of the improved forum shall comprise the following areas; (a) economic diversification and transformation; and (b) just transition of the workforce and the creation of decent work and quality jobs. The subsidiary bodies will review every three years, beginning at their 49th sessions (November, 2018) of the subsidiary bodies, the work program of the improved forum, including the modalities for its operation.

The Paris Agreement recognized this matter and instructed that Parties in the implementation of this Agreement take into account the concerns of Parties with economies most affected by the impacts of response measures, particularly developing country Parties. It also decided that the improved forum on the impact of the implementation of response measures, under the subsidiary bodies, shall continue and shall serve the Agreement.

The Paris Agreement has further recommended that the modalities, work program and functions of the forum on the impact of the implementation of response measures be revisited to address the effects of the implementation of response measures under the Agreement through enhancing cooperation amongst Parties on understanding the impacts of mitigation actions under the Agreement and the exchange of information, experiences and best practices amongst Parties to raise their resilience to these impacts;

4.2 Economic Diversification Initiatives within the Framework of the INDC of Saudi Arabia

The economic diversification efforts of the Kingdom of Saudi Arabia have started showing results as indicated by the increasing share of the non-oil sectors to the national gross domestic product. Few of the major policy initiative taken in this direction are making power and desalination plants more energy efficient, development and deployment of technologies relating to Renewable Energy Resources (RES) especially solar energy and Rationale Use of Energy (RUE). The government is also encouraging the reuse of the treated wastewater to reduce dependence on the energy intensive desalination plants and to conserve a valuable resource. Energy intensive industries are also improving their energy intensity to reduce energy demand. The other key area the Kingdom is working on is Carbon Capture, Utilization and Storage (CCUS). In this regard, Saudi Arabia has been engaged in the cooperative research initiatives with other countries to explore the potential of large scale commercialization and deployment of CCUS technologies. The Kingdom has planned to build the world's largest carbon capture and utilization plant and few other projects are under way. Adaptation actions with mitigation co-benefits include: water and wastewater management, urban planning, marine protection and reduced desertification.

A dynamic baseline has been developed on the basis of a combination of two scenarios. One scenario assumes economic diversification with a robust contribution of oil export revenues and the other is premised on an accelerated domestic industrialization based on sustainable utilization of all indigenous resources including oil, gas and minerals.

4.2.1 Energy Efficiency

Energy efficiency is an essential resource for sustained socio-economic development agenda of all countries. Investment in energy efficiency can provide many benefits to different stakeholders. These benefits include but not limited to the reduction of energy demand and associated costs, which allow investment in other goods and services. It also promotes other benefits such as healthier indoor environments and enhancing industrial productivity.

Energy efficiency can therefore be considered as energy resource in the context of national and international efforts to achieve energy security, competitiveness and environmental sustainability.

4.2.2 National Efforts in Energy Efficiency

In an effort to diversify its economy away from single source income and broaden opportunities for expanding its industrial sector, the Kingdom of Saudi Arabia since 2010 has made significant progress in the field of energy efficiency by developing and enforcing regulations and guidelines for the buildings, transportation, industry and urban planning and district cooling sectors to support efficient use and conservation of energy. Energy intensive industries are also improving their energy intensity to reduce energy demand. Saudi Arabia has also been raising rationalization awareness and enhance energy consumption efficiency. To give effect to its national energy efficiency policy, it has established demand-side management program covering the building, transport, industry, urban planning and district cooling sectors.

Industry is the largest sector in the Kingdom and represents around 41% of the total energy consumption, out of which 80% of energy consumed is in the petrochemicals, cement and iron and steel sectors. Since 2014, new regulations were passed, requesting all plants (new and existing) to achieve energy intensity based on international benchmarks. All plants are required to achieve the energy intensity targets at the average of the first quartile of international benchmarks. The existing plants framework utilizes a flexibility mechanism where credits and deficits are generated on a plant basis (vs. the targets). However, plants owned by the same company will be able to transfer credits in order to fill in any gaps caused by energy deficits in other plants. In respect of product control, a strong enforcement program has been developed to ban inefficient electrical appliance, tires and electrical motors from reaching the final consumer.

In the building sectors, the Saudi Energy Efficiency Program covers insulation products regulation and mandatory thermal insulation for new buildings; minimum energy efficiency ratios for air-conditioning units; white products such as refrigerators, washing machines and phase out of inefficient lighting products. In the transport sector, multiple initiatives in energy efficiency of light duty vehicles are in force and they include development of a fuel economy label to raise consumer awareness towards energy efficiency. Tires rolling resistance standards have also been established.

Urban planning energy efficiency guidelines were developed in partnership with key government and private stakeholders responsible for urban planning. The guidelines have been embedded in the regulations of urban planning government entities.

4.3 Social and Economic Risks and Vulnerabilities of Non-Annex I Countries

The scope and extent of policies and measures that Annex I Parties have pursued in the past and continue to do to minimize the emissions of GHGs (IPCC, 2014) include but not limited to the following:

(a) Economic Instruments such as taxes (e.g. carbon and energy taxes, tradable allowances, trade-distorting measures and Renewable Portfolio Standards (RPS) for Renewable Energy (RE) as well as energy audits and fiscal incentives for fuel switching);

(b) Regulatory Approaches (e.g. efficiency and environmental performance standards, fuel economy performance standards, fuel quality standards and regulatory restrictions to encourage modal shifts (road to rail));

(c) Information Programs (e.g. fuel labelling, vehicle efficiency labelling, energy audits and energy advice programs);

Climate change response measures instituted to minimize emissions of greenhouse gases often exert profound adverse effect on sustainable development plans and programs of many developing countries. These effects are particularly severe on those countries whose economies are heavily dependent on a single sector or single commodity such as hydrocarbons and tourism.

The impacts arising from the implementation of response measures are also pertinent in the areas of agriculture and food security, water availability, energy access, health, livelihoods, employment and the sustainability of economy's growth. Most developing countries have middle to low income economies and suffers from low productivity and surplus of labour, with very significant proportion of their population living below poverty level. These people also lack access to essential modern energy, water and sanitation services. Many African countries, least developed countries and Small Island Developing States of such category are vulnerable to response measures due to the (a) geographical distance from main export markets, (b) high dependency on food exports, (c) high dependency on exporting commodities, (d) high dependency on a single commodity; (e) unsustainable land use and land-use change patterns and (f) insufficient relevant data and information for assessing, measuring and forecasting economic fluctuations (UNFCCC, 2014).

The sectors which might be subject to significant vulnerability due to impacts of response measures are (a) conventional oil, gas and coal fuels, (b) energy-intensive trade-exposed goods (aluminum, iron and steel, cement, chemicals and pulp and paper), (c) tourism and (d) agriculture (UNFCCC, 2016). Others include consumer goods subject to eco-labelling and standards, air-freighted goods and marine-transported goods.

The workforce of developing countries is inherently vulnerable to economic downturns and certain climate change mitigation actions and policies add stress on industries and markets, specifically in countries with growing young populations, making it harder to provide sufficient and quality jobs. There are risks of job losses and specific vulnerabilities of the workforce as a result of transition and transformation. Some of the measures implemented by developed countries including provision of agricultural subsidies and the imposition of standards and tariffs could hinder economic and social development and poverty eradication in developing countries and, therefore, affect the workforce in those countries.

Many developing countries are still dependent on a small basket of product exports. Many Least Developing Countries (LDCs) are dependent upon different agricultural commodities and many African and GCC countries are resource-dependent. The problems inherent in dependence on a small number of product exports are numerous, including lower levels of economic growth but the primary concern is the vulnerability to price shocks.

The social vulnerabilities resulting from adverse impacts on social development and poverty eradication, referring to spillover costs, such as those relating to migration, disease, loss of livelihoods and food security for Import-Dependent States and higher food prices linked to biofuels. Some response measures initiatives may lead to increased vulnerability of economic growth, income distribution, employment, the environment (e.g. biodiversity, water availability), health and food security in developing country Parties.

The climate policies induced industrial restructuring and consolidation and rising mechanization in the fossil fuels sector have brought adverse employment changes in the world. The result will be further job losses in the fossil fuel sector – in coal mining, in exploration and production of oil and gas and at fossil fuel-powered power plants. The European Union (EU) reported in its National Inventory Report (NIR) for 2014 that all scenarios have reduced fuel consumption compared with the reference scenario. Specifically, solid fuel consumption declines substantially in all scenarios; oil consumption also declines and much faster in scenarios with policies that promote electrification of transportation and natural gas absolute consumption declines in general less sharply than oil and slightly more in scenarios that include renewable targets. Net energy import decreases significantly, by about 50 per cent in most scenarios by 2050. Hence, the future fuel consumption in the EU will have an economic impact on fuel prices as well as trade effects for fuel-exporting countries.

The capability of developing countries whose economies are based on exports of fossil fuels to diversify their assets is much less than developed economies or fossil fuel companies. The time and costs to convert fossil-fuel-related assets into other nonrelated assets and the development of other strong productive sectors will define the future of the diversification initiatives. Countries are tied, geographically and constitutionally, to ownership of fossil fuel reserves, which cannot be sold completely and shifting of capital and capabilities into renewable energy technologies or other activities is difficult. It is difficult to turn the oil, gas and coal assets into cash and they can only be converted into other assets only after the countries develop, produce and sell fuel. Using past reserve-to-production ratios as a guide, most countries must wait 45 years on average to liquidate their fossil fuel wealth (Cust et. al., 2017).

The specific national circumstances and needs of the Saudi Arabia, make the Kingdom highly vulnerable to the adverse effects of global climate change response policies as well as global warming and other climate change-induced extreme weather phenomena due to its semi-arid to hyper arid climate. The country has therefore to manage the challenges to achieve a balance between attending to its economic development needs and climate change impacts. The impacts of climate policies on oil demand, arising from response measures, would demonstrate itself essentially through income and substitution effects.

4.3.1 Impacts on the Aviation Sector

An aviation carbon tax will have significant impact on the developing economies heavily dependent on tourism due to the change in travel behavior (Wold et al., 2014). Such taxes may reduce number of tourist visits to distant destinations such as isolated islands or a long way from the richest markets. However, such a tax would also affect short-haul flights because of the emission during take-off and landing. Aviation carbon taxes will negatively impact the developing countries relying on air freight for exporting goods. In order to compensate the higher rates to send products overseas, the manufacturers in developing countries have to lower profit margin or increase the product price. The product would be less competitive in the foreign market for the increased price (Wold et al., 2014).

4.3.2 Biofuel Production Mandates and Renewable Fuel Standards

Biofuel production mandates and renewable fuel standards are methods for reducing dependency on fossil fuels and ensuring that a portion of energy use comes from renewable resources. These measures have been creating a new frontier of energy production from traditional food crops (Lane, 2012). The U.S. ethanol production which is mainly from corn, increased from 3.4 billion gallons in 2004 to 14.3 billion gallons in 2014 (Flugge et al., 2017). The Renewable Fuel Standard (RFS) of USA included a schedule of required biofuel use that rose to 7.5 billion gallons by 2012. The Revised Renewable Fuel Standard included a schedule of required biofuel use that began at 9 billion gallons in 2008 and increased to 36 billion gallons in 2022. The corn ethanol's mandate was 15 billion gallons annually in 2015 through 2022 (Flugge et al., 2017). These standards are the main driving force for increasing the use of U.S. corn in ethanol production from fourteen percent in 2005 to thirty-eight percent in 2011. Similar mandates exist in Canada, Brazil, the European Union and many other countries (Lane, 2012).

The impacts of different biofuel production mandates and renewable fuel standards include: (i) diversion of corn from the food system (Wise, 2012), (ii) reduction in supply of corn as food (Wise, 2012), (iii) switching production of soybeans and some other crops to corn for meeting the grown demand of ethanol (Martin, 2008) and (iv) increased food prices (Wise, 2012). The increased food prices disproportionately affect the developing countries where grain comprises a significant share of the food budget (Rajagopal et al, 2007). The food grains constitute a larger portion of diets in least developed world than in the developed countries. The developing countries rely heavily on imported basic food products are thus vulnerable to negative impacts caused from biofuel production (Ng, Francis and Aksoy, A. 2008). The increased food prices increase social unrest (Bellemare, 2014). Arezki and Bruckner (2014) analyzed the effects of the international food prices on the political stability focusing on low income countries and concluded that the social stability deteriorates during the period of international food price increased in the net food exporter countries. The riots and political instability in Haiti during 2008 was mainly caused by higher food prices.

If the policies to support Annex I Parties for biofuels as a low-carbon alternative to fossil fuels for transport reaches a significant scale, the competition between feedstock for biofuels and food and feed crops could result in increased food prices. This may cause negative social consequences, in particular for those whose food budgets are a high percentage of their total income. Rosegrant (2008) estimated that biofuels demand is responsible for 21 per cent of global rice price increases and 22 per cent of wheat price increases. The lower income non-Annex I Parties may suffer severely from the potential consequences of measures such as the production of biofuels.

Governments may mandate the use of a particular technology or goods in an effort to combat climate change. The biofuel-use mandates applied in several OECD countries are a good example. These policies and measures may have positive impacts for foreign exporters of the technology or goods in question, provided their exporters are allowed to benefit from the scheme. Conversely, they will have negative impacts on those foreign exporters that produce substitutes for the good or technology in question. Depending on the magnitude of demand created by the mandate in question, indirect impacts may be important. To take the biofuel example once again, if biofuel mandates create enough demand for feedstocks, there may be indirect social consequences (rising global food prices) or environmental impacts (increased deforestation for feedstock cultivation).

4.3.3 Carbon Taxes (CT)

Currently, carbon taxes or levies have been implemented in many countries. Based on the carbon content of the covered items and focused on energy products such as fuels, the tax may vary. Although carbon taxes are typically assessed at the consumer level, these are intended to decrease fossil fuel consumption which negatively impacts the demand. As a result, the hydrocarbon-exporting countries may be impacted significantly due to widespread carbon taxes. A global scale carbon tax may result in a four percent decline in GDP of Middle Eastern economies by 2030 (Bagnoli et al., 2008).

4.3.4 Border Carbon Adjustments (BCA)

The Border Carbon Adjustments is a type of Border Tax Assessments (BTAs) which are import taxes levied by carbon-taxing countries on goods manufactured in or service associated with non-carbon-taxing countries (Metcalf and Weisbach, 2009). The BCA, being contemplated by a number of developed countries is of a measure that will have a devastating impact on African countries and will compound the challenges faced by them during their transition to a low GHG emitting society (UNFCCC, 2013a).

Even after imposing the import taxes on goods manufactured in developing countries, manufacturers continue producing as long as there are customers. The additional expense generally passed to customers, which keeps the prices up and eventually leads to a decrease of import demand (Ling Tang et al., 2015). Developed countries will import goods from other countries with border tax to support BTAs and developing countries like China will significantly shift its exports towards other regions without BTAs. The purchase ability of low income people in developed countries will be affected accordingly by being forced to purchase more expensive products made in regions with BTAs.

Border carbon adjustment provides scope for back-door trade policy since it can work as a substitute for strategic tariffs, shifting the economic burden of emission reduction from abating countries to non-abating countries (Böhringer et al., 2011). Tariffs on embodied carbon could be perceived as a means for back-door trade policy, where industrialized countries exploit international market power at the expense of trading partners in the developing world. Carbon tariffs levied by industrialized countries change the terms of trade against the developing world, thereby shifting the burden of emission abatement and exacerbating existing income inequalities.

Developing countries are most vulnerable to climate change impacts due to lack of resources. When financial and technical assistance for adaptation and mitigation are urgently needed in developing countries, BTAs will only serve to inefficiently reallocate resources from developing countries to developed countries. This frustrates the transition towards a sustainable society in developing countries. Not only will the low-income communities be adversely and disproportionately affected, but they will also hardly have a chance to get meaningfully involved. For large populations of migrant workers, the estimated unemployment rate that will be caused by BTAs will result in serious social problem and counteract the transition to a sustainable economy. Therefore, BTAs are in no way a win-win strategy for developed and developing countries.

4.3.5 Labelling Scheme

In response to growing concern about climate change and to reduce the greenhouse gas emissions, carbon labelling is being considered as a possible mitigation mechanism. There is growing evidence that some environmental labelling schemes that are currently being trailed by developed countries could create obstacles to market access.

The low-income countries will face greater difficulties in exporting in a climate-constrained world where carbon emissions need to be measured and certification obtained to enable participation in carbon labelled trade. The products produced locally get an advantage in terms of carbon emissions and on the effects of size. Exports from low-income countries typically depend on long-distance transportation and are produced by relatively small firms and tiny farms which will find it difficult to participate in complex carbon-labelling schemes.

The small firms and tiny farms of low-income countries will be the major victim of any size bias in the carbon-labelling schemes, in terms of the costs of measuring emissions and of verifying those measurements, will translate into a heavy burden on the competitiveness of such small players. The development and imposition of the Global GAP standard by a group of primarily UK and Dutch agro-food industries retailers is the major reason behind the marginalization of small farmers from horticultural export markets (Graffham and MacGregor, 2006).

Carbon labeling schemes may unfairly restrict trade, especially with low income countries. This may arise if the labelling criteria reflect local technologies and tend to exclude ‘acceptable products’ produced with different processes in overseas locations, as might occur if the process of developing the labelling scheme is liable to capture by domestic interests. Similarly, there may be discrimination against imported products if the carbon emissions of products are indirectly derived using parameters based on data in the importing country and which may overestimate the emissions in the producing country (Deere, 1999).

4.3.6 Embodied Carbon Tariffs

Embodied carbon tariffs (ECT) do not comply with the General Agreement on Tariffs and Trade (GATT) provisions of the World Trade Organization (WTO). The article II of GATT states that imported products have to be equally taxed and it says that the importing country may only apply tariffs and taxes at the border. Article III of GATT says that “like products” of foreign and domestic origin have to be equally taxed (Messerlin, 2010; Charnowitz, 2007).

Tariffs, in contrast to taxes, are only imposed on a selected group of foreign countries. Therefore, they discriminate between imports of different origins and between domestic and foreign products. Hence, carbon tariffs conflict with the provisions GATT article II and III and the WTO agenda (Messerlin, 2010). Moreover, the GATT allows for taxes on specific exported products, but it prohibits direct taxes on export-exposed industries or firms. Nevertheless, emission-related subsidies and taxes are set at an industry or firm level.

4.3.7 Impacts on Employment Sectors

The fundamental restructuring of the energy supply sector through moving away from the fossil fuel-based system to clean, renewable sources have both qualitative and quantitative impacts on employment. The quantitative impacts or the number of employment can be affected through creation, substitution, elimination or transformation and redefinition of job (UNEP, 2008; Strietska-Ilina et al., 2011).

Certain polluting, energy and materials intensive economic activities like large-scale mining and burning of coal may be reduced or eliminated completely. To reduce overcapacity and address the climate change response measures, the Chinese government announced a plan to close thousands of coal mines which will cause loss of an estimated 1.3 million jobs in the coal sector, along with 500,000 jobs in the steel industry equivalent to about 20 per cent and 11 per cent of China's total workforce in these two sectors (Yan, 2016).

The geographical and temporal disconnection poses additional challenges in this context. The low energy incentive economy may not create sufficient numbers of jobs in the same locations of job lost in the conventional economy. Similarly, the green jobs creation may not happen at the same time, or at the same place as conventional job losses occur. In order to minimize the dislocation and human suffering, these disconnects need to be bridged by transition policies.

4.4 Modelling Approach

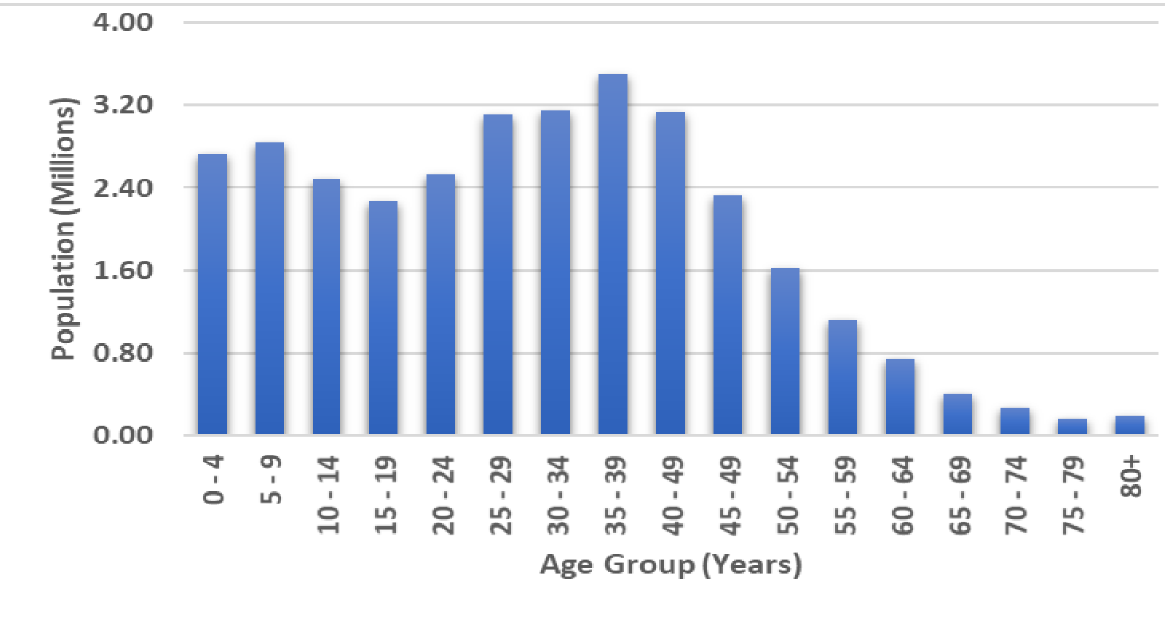
The IPCC Third Assessment Report (TAR) suggests that there are adverse impacts of response measures on oil exporting developing countries and further work is needed to assess the magnitude of the impact of response measures on individual countries. The limitations of using economic models highlighted in the report are (a) the way models generally treat policy affects the assessment outcome differently, depending on whether they are top-down, bottom-up, computable general equilibrium (CGE), input-output or macroeconomic models; (b) market imperfections are not well represented; and (c) most models are not able to reflect technology advances or accurately estimate the geographic diffusion of existing technologies (IPCC, 2001: Mitigation).

The current models for evaluating the effects of response measures need to be expanded in their coverage of countries and of issues for refining methodologies to assess the impacts on developing countries of policies already implemented by Annex I Parties. During the 17th session of SBI, a workshop was held on the status of modelling activities to assess the adverse effects of climate change and the impact of response measures already implemented on individual developing country Parties, including on how to enhance the participation of developing country experts in such efforts. It was proposed that modelling efforts was required to improve the effectiveness of current modelling activities for assessing the impact of implemented response measures on data sets (technology, energy data, economic and social indicators); effectiveness and speed of the process and reduce costs (UNFCCC, 2002).

4.5 Economic and Social Consequences of Response Measures for Saudi Arabia

Saudi Arabia's economy is highly dependent on hydrocarbon exports and climate change mitigation actions do have adverse effects on Saudi government's revenues and thus impede its ability to provide for the needs of its growing population (Figure 4.1). Hence, minimizing the impact of response measures on oil dependent developing nations was recognized from the inception of the Climate Change Convention in 1992. Major shifting towards a low-carbon world and mitigation policies have far-reaching and long-lasting consequences for labor markets, enterprises and workers of Saudi Arabia.

Figure 4.1: Population Distribution of Saudi Arabia by Age Group for 2017



Source: General Authority for Statistics, Kingdom of Saudi Arabia, 2017. Demographic Research Bulletin 2016 |https://www.stats.gov.sa/en/43

Saudi Arabia has taken steps towards diversifying its economy by opening its market, allowing foreign investments, privatization of certain industries; and becoming a member of the World Trade Organization. However, the Kingdom considers that significant cooperation with other countries is essential for achieving the necessary diversification, especially through investments and technology transfer.

There are a number of climate change policies implemented by other countries that have significant social and economic consequences for Saudi Arabia. They include: (i) carbon taxes, (ii) carbon taxes in aviation sector, (iii) biofuel production mandates and renewable fuel standards, (iv) subsidies for the production or consumption of low-carbon technologies or goods, (v) carbon labelling scheme, (vi) border carbon adjustments and embodied carbon tariffs, (vii) mitigation measures in international shipping and (viii) cumulative climate change mitigation measures.

4.5.1 Carbon Taxes

Although carbon taxes are typically assessed at the consumer level, these are intended to decrease fossil fuel consumption which negatively impacts the demand. Implementation of carbon tax will cause increase in the price of Saudi products in the CT implementing countries and consequently the demand of Saudi products will decrease. The global oil consumption and oil price will decrease and thus the oil market share and the revenue of KSA will be negatively affected. A study estimated that a global scale carbon tax may result in 4% decline in GDP of the Middle Eastern economies by 2030 (Bagnoli et al., 2008). The Kingdom also emphasizes on the need of support in conducting rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of carbon taxes at a global scale and specifically for the Kingdom.

4.5.2 Carbon Taxes in the Aviation Sector

As a result of the implementation of response measures through the imposition of carbon taxes in aviation, the trade of exporting goods which rely on air freight will be negatively impacted. Consequently, the increased air freight cost of the export goods by air will become less competitive. The global demand for oil and its price will decrease and it will affect the overall oil market share. In future, the market share of biofuel and other renewable fuels will become more competitive compared to the oil and the oil market share and hence the revenue of Kingdom will be negatively affected. The carbon taxes in aviation sector may increase the cost of performing the Hajj as well.

The social and economic welfare of the population directly or indirectly dependent on the energy sector and related industries will be negatively impacted due to such decline in oil market share, while in compound impacts, the overall social and economic consequences are expected to be moderate. As a consequent of social and economic welfare losses, national efforts aimed at enhancing the diversification of the Kingdom’s economy as well as the implementation of adaptation initiatives will be undermined. Simultaneously, opportunities for addressing key requirements for achieving sustainable development such as poverty eradication, environmental sustainability, improving technology and social organization and inter-generational equity will diminish.

4.5.3 Biofuel Production Mandates and Renewable Fuel Standards

With the reduction of dependency on fossil fuels, the global demand of oil and it’s price will decrease. It will negatively affect the oil market share and the revenue of Saudi Arabia. The population directly or indirectly dependent on the energy and related industries will be negatively impacted. Due to the compound and spillover impacts, the overall social and economic consequences are expected to be moderate to high in the course of time. The Kingdom emphasizes on technological and capacity building supports for increasing economic diversification and adaptation initiatives for conducting rigorous and comprehensive scientific studies to model, predict and evaluate the biofuel production mandates and renewable fuel standards specifically for the Kingdom.

4.5.4 Subsidies for the Production or Consumption of Low-Carbon Technologies or Goods

Subsidies to domestic producers of environmentally sound technology may pose negative effects for foreign competitors. The major form of subsidies granted to the production or consumption of low-carbon technologies or goods, such as biofuels or solar photovoltaic power. Production subsidies would typically be available only to domestic producers and thus would have the consequence of decreasing market share for foreign producers of those goods or their substitutes. On the other hand, consumption subsidies in local markets do not discriminate between foreign and domestic producers and would potentially have positive impacts for foreign exporters. Because of such subsidies, the oil consumption will decrease and consequently, the world oil demand will decrease with the decrease in oil price. Thus, the oil market share and the oil revenue of Saudi Arabia will be negatively affected.

4.5.5 Carbon Labelling Scheme (CLS)

In response to growing anxiety about climate change and to reduce the greenhouse gas emissions, carbon labelling is a possible mitigation mechanism considered by policy-makers, firms and consumers. Well-designed schemes of carbon labelling will create incentives for production of various parts of the supply chain to move to lower emission locations and enables consumers to join the battle against climate change. The developing countries will face the greater difficulties in exporting in a climate-constrained world where carbon emissions need to be measured and certification obtained to enable participation in carbon labelled trade. As a consequence of carbon labelling, the price of Saudi products will increase in the CLS implementing countries due to costs associated with measuring emissions and verifying those measurements. As a result, the demand of Saudi products may decrease in the CLS implementing countries. In addition, the global oil consumption may decrease to reduce carbon footprints and consequently, the world oil demand will decrease with the decrease in oil price. This will negatively affect the oil market share and the revenue of Saudi Arabia. The approaches of the Kingdom to risk management associated with CLS include the use of financial risk management tools, insurance and stabilization funds in the short-term and economic diversification in the long-term.

4.5.6 Border Carbon Adjustments (BCA)/Embodied Carbon Tariffs (ECT)

Embodied carbon tariffs may be regarded as a shift of abatement costs from OECD countries to developing countries. Tariffs, in contrast to taxes, are only imposed on a selected group of foreign countries. Therefore, they discriminate between imports of different origins and between domestic and foreign products. The implementation of carbon-embodied tariffs requires product differentiation based on the product’s carbon footprint. The exact distinction and assessment of production processes for each product and country makes the implementation of carbon embodied tariffs a complex process (Messerlin, 2010). The justification of one global price for carbon emissions irrespective of the countries’ historical carbon emissions will be perceived as discriminatory by developing countries like KSA. The developed countries have the resources and technologies to mitigate carbon emissions. In contrast, developing countries like Saudi Arabia have to focus on further economic development, the fight against unemployment and adaptation measures for climate change. In the current challenging world trade, Saudi Arabia has to carry the burden of carbon emission reduction in order to maintain competitiveness of its products. The demand of Saudi products may decrease in the BCA or ECT implementing countries.

4.6 Summary of Social and Economic Consequences of Response Measures for Saudi Arabia

The NDCs of eleven Parties to the Paris Agreement were analyzed for response measures that could have cross-border impacts on developing countries, including specific focus for the Kingdom of Saudi Arabia. These include eight developed countries - the European Union, United Kingdom, Germany, France, Japan, Canada, Italy, the United States and the Russian Federation. For some of the developed countries their NIRs were also analyzed, as their NDC contained overall targets, but no concrete examples of mitigation measures. A wide variety of mitigation policies were identified in the INDCs and NIRs and discussed under the following headings:

a) Emissions Trading Systems (and Free Allocation);
b) Renewable Energy Support Schemes;
c) Energy Efficiency Policies;
d) Measures aimed at Aviation and Maritime Transportation;
e) Measures aimed at Land Transportation;
f) Carbon Capture and Storage;
g) Border Carbon Adjustments

Identified response measures were analyzed individually for their potential impacts, with specific reference to the Kingdom of Saudi Arabia's economic diversification strategy. Investments in Carbon Capture and Storage (CCS) technology can have some benefits for developing countries including the Kingdom of Saudi Arabia, as it improves the possibility and timetable for CCS to become economically attractive as climate change policy. This could lead to continued use of fossil fuels as their impact on the global carbon budget is significantly reduced.

Climate policies related to energy efficiency also have co-benefits for developing countries. As technologies mature and prices plummet, their global uptake by other countries, including developing countries, becomes cheaper. Investments in and support for, energy efficiency enables other countries to reach their related targets and aspirations more easily in the future.

Emissions Trading System (ETS), such as cap-and-trade schemes, offset mechanisms and benchmark-and-credit schemes could impact sectors importing from jurisdictions with emissions trading schemes. Developing country industries, including those from KSA, as well as consumers that depend on imports of raw materials, processed goods and finished good from the jurisdictions with emissions trading systems, could be faced with increased prices of imports as carbon costs are incorporated into production costs. Currently, ETS in different jurisdictions cover a variety of sectors such as energy and carbon intensive industries (e.g. glass, steel, chemicals).

Social impacts may also materialize from job losses and from decreased purchasing power for households due to price increases.

Free allocation is a cost containment measure and measure to address carbon leakage and competitive concerns for industries covered by an ETS. However, under certain conditions, free allocation for an ETS could constitute support for sectors and actors, beyond the costs imposed by emission trading - in which case it could be seen as state support. This may give those sectors and actors a competitive advantage in the international arena and could affect developing country industries, including KSA, such as the petro-chemical industry, which is competing with sectors covered by ETS and which receive free allocation.

Some countries use carbon and energy taxes to implement their NDCs. Carbon and energy taxes have comparable possible impacts on the economic diversification agenda through limiting the demand for fossil fuels. This would also result in KSA being able to rely less on revenues from hydrocarbons, resulting in higher probability of relying on Scenario 2 in the KSA INDC. In addition, KSA industries and consumers that depend on imports of raw materials, processed goods and finished good from the jurisdictions with carbon and/or energy taxes could be faced with higher prices for imports, as carbon and energy taxes lead to increased production and transportation costs.

Renewable Energy Support schemes, such as feed-in tariffs, investment programs, direct subsidies, tax breaks and electricity market reforms, may limit demand for oil products and derivatives, but only if they replace or crowd out demand for oil-based energy (for example petroleum-fueled electricity generation). In addition, renewable electricity is frequently used to expand electrification to rural areas and grow existing capacity to follow increased demand.

Fuel efficiency policies such as fuel efficiency standards for vehicles and engines, are aimed at improving fuel efficiency of farming machinery and special vehicles and IMO policies on improving energy efficiency on board of vessels have the potential of reducing consumption of fossil fuels.

Included in Table 4.1 are some of the measures contained in the submitted NDCs and NIRs (National Inventory Reports) designed to reduce emissions from the land transportation sector. Some of these measures include car efficiency standards, bio fuels, electric vehicles, railways and mass transit systems.

Most of the response measures identified have very similar expected consequences for the Kingdom of Saudi Arabia – reduced demand and imports into the implementing jurisdiction of oil, derivative products and other fossil fuels. Demand is reduced by displacing fossil fuels with other energy sources such as renewable energy. As demand is reduced, oil and oil derivatives exports and linked revenues for the Kingdom of Saudi Arabia might decrease, dependent on the structure of the international oil market. This could result in the Kingdom of Saudi Arabia being less able to rely on revenues from hydrocarbons results in higher probability of relying on Scenario 2 for the economic diversification strategy, mentioned in the Kingdom of Saudi Arabia INDC.

Table 4.1 below outlines the social and economic consequences on Saudi Arabia arising from the response measures action; the challenges and barriers to address the consequences and support needed to address them.

Table 4.1: Summary of Information on Economic and Social consequences of response measures for Saudi Arabia

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
TRANSPORT SECTOR **1.** Measures introduced in this sector include the introduction of: - Fuel and vehicle standards - Biofuel subsidies - Vehicle purchase subsidies for procurement of electric vehicles - Feebates - Fuel economy performance standards - GHG emission performance standards - Regulatory restrictions to encourage modal shifts (road to rail) - Fuel labelling - Vehicle efficiency labelling - Low-emission vehicle procurement	**1.1** GHG mitigation policies and measures in the transport sector do have the potential to devalue fossil fuel assets of Saudi Arabia and reduce fossil fuel consumption and consequently the Kingdom's revenues from fossil fuel exports. **Economic Impact:** Medium economic impact is expected in the short-to-mid-term through reduced demand for oil and derivative products, in the transportation sector of countries implementing these types of policy and measures. High impacts are expected in the long term. **Social Impact:** There are also high expected social impacts for workers employed in oil exporting sectors and its derivatives in Saudi Arabia. **1.2** Measures aimed at land transportation, such as promotion of electric vehicles, railways and mass transit systems are also expected to lead to decreased demand for fossil fuels. **Economic Impacts:** There will be medium expected economic impact in the short-to-mid-term through reduced exports of oil and its derivatives. **Social Impact:** Medium expected social impacts for workers employed in oil exporting sectors and its derivatives.	➢ Investment on clean energy R&D for oil and gas to ensure less to zero emission of carbon to the atmosphere. ➢ Wide deployment of energy efficiency technology for oil and gas. ➢ Investment on carbon capture and utilization to convert CO_2 from emission into value by using it as feedstock or fix it into products. ➢ Lack of capacity and technology to participate in the emerging international market for carbon neutral modes of land transportation ➢ Financial markets focus is on phasing out fossil fuels rather than removing emissions ➢ Impacts on stability of international oil markets ➢ Reliance on one export product as main source of budget revenue	➢ Raise capacity in assessing international impacts resulting from international climate policy actions and measures ➢ Assist countries in developing and implementing national actions and strategies to raise resilience to negative consequences ➢ Promote Technology and policy neutrality to ensure maximum reduction at least cost ➢ Promote International cooperation for developing and transferring technology for cleaner oil and gas fuel formulations, better combustion and mobile post carbon capture utilization and storage units for the road transportation sector ➢ Promote International cooperation for developing industrial sectors in the field of carbon-neutral land marine and aviation transportation ➢ Encourage cooperation on non-energy uses of oil and gas

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
OTHER SECTORS **2.** Taxes such as carbon and energy taxes	**2.1** Carbon and energy taxes have comparable possible impacts on the Saudi Arabia economic diversification agenda through limiting the world demand for fossil fuels. Consequently, the price oil will fall and this implies a reduction in revenues from hydrocarbons, resulting in higher probability of Saudi Arabia having to rely on Scenario 2 outlined in its submitted INDC. Additionally, KSA industries and consumers that depend on imports of raw materials, processed goods and finished good from the jurisdictions with carbon and/or energy taxes could be faced with higher prices for imports, as carbon and energy taxes lead to increased production and transportation costs. Also, the price of Saudi products will increase in the carbon tax implementing countries and the demand for Saudi products will inevitably decrease in carbon tax implementing countries. A study estimated that a global scale carbon tax may result in four percent decline in GDP of the Middle Eastern economies by 2030 (Bagnoli et al., 2008). **Economic Impact:** Medium economic impact expected in the short to medium term through reduced exports of oil and derivative products. **Social Impacts:** Medium social impacts are expected in the short to medium term for workers employed in oil exporting sectors and its derivatives.	➢ Impacts on stability of international oil markets ➢ Reliance on one export product as main source of revenue ➢ Lack of international cooperation in the development of models for quantitative ex-ante and ex-post analysis of impacts and co-benefits of taxes.	➢ Support for developing appropriate financial risk management tools and approaches to address short- and long-term financial instability focusing on the impact of carbon tax on various countries on developing countries ➢ Support for conducting rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of carbon tax in various countries of the world including countries that rely heavily on one sector for development including oil and gas exporters ➢ Development of carbon capture and storage and other technologies that can reduce the carbon intensity of KSA exports of hydrocarbons. ➢ Implement equivalent measures (mitigation co-benefits of adaptation measures) in KSA and seek international cooperation for recognition of equivalent measures

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
3. Subsidies for the production or consumption of low-carbon technologies or goods	**3.1** The oil consumption will decrease and consequently, the world oil demand and price will both fall. The oil market share and the revenue of KSA will be negatively affected. **Economic Impact:** Medium expected economic impact in the short to medium term as subsidies exerts an impact on the economic diversification strategy and just transition of the work force in KSA through reduced demand for oil and derivative products. **Social Impacts:** The welfare of the population directly or indirectly dependent on the energy and related industries will be negatively impacted	➢ Lack of modeling tools as well as capacity to estimate the impact of subsidies for the production or consumption of low-carbon technologies or goods ➢ Impacts on stability of international oil markets. ➢ Reliance on one export product as a main source of budget revenue.	➢ Develop methods of post facto evaluation of impacts ➢ Support in research, innovation, technology development and capacity building for (a) enhancing economic diversification and adaptation initiatives, (b) low carbon advanced fossil-fuel technologies and (c) for non-energy uses of fossil fuels and crude oil conversion to high-value petrochemicals. ➢ Cooperation in establishing favourable international investment environment in the sectors suitable for economic diversification and adaptation initiatives.

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
4. Renewable Energy Support Schemes, such as feed-in tariffs, investment programs, direct subsidies, tax breaks and electricity market reforms as well as biofuel production mandates and renewable fuel standards	**4.1** Renewable Energy Renewable energy support schemes may limit demand for oil products and derivatives, but only if they replace or crowd out demand for oil-based energy (for example petroleum-fueled electricity generation). Biofuel and renewable fuels will become more competitive compared to the oil and the oil market share and the revenue of KSA will be negatively affected. **Economic Impact:** Low-to-medium expected economic impact in the short-to-medium term through reduced exports of oil and its derivatives, due to current low percentage of oil-powered electricity generation in many developed countries.	➢ Lack of modeling of impacts of renewable energy support schemes ➢ Lack of methods of post facto evaluation of impacts of Response Measures. ➢ Resilience of Renewable Energy support schemes which meet multiple objectives not only aim at climate.	➢ Ensure compliance with international trade and other agreements ➢ Promote interaction of KSA energy actors in RE support schemes in other jurisdictions. ➢ Support for conducting rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of biofuel production mandates and renewable fuel standards for the Kingdom. ➢ Support for developing appropriate financial risk management tools and approaches to address short- and long-term financial instability focusing on the impact of biofuel production mandates and renewable fuel standards on the Kingdom. ➢ Ensure compliance with international trade and other agreements

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
5. Emissions Trading System (ETS), such as cap-and-trade schemes, offset mechanisms and benchmark and credit schemes as well as free allocation under an Emissions Trading System.	**5.1** Kingdom of Saudi Arabia industries and consumers that depend on imports of raw materials, processed goods and finished goods from the jurisdictions with emissions trading systems, would be faced with increased prices of imports as carbon cost are incorporated into production costs. The severity of the impact depends strongly on cost containment policies enacted in the jurisdiction implementing emissions trading. Currently, Emissions Trading System (in different jurisdictions cover a variety of sectors such as energy and carbon intensive industries (e.g. glass, steel, chemicals). Free allocation is a measure and measure to address carbon leakage and competitive concerns for industries covered by an ETS. However, under certain conditions, free allocation for an ETS could constitute support for sectors and actors, beyond the costs imposed by emission trading which in this case constitute State support. This gives those sectors and actors, a competitive advantage in the international arena and could affect KSA industries, such as the petro-chemical industry, which is competing with sectors covered by ETS and which receive free allocation. **Economic Impact:** This could lead to medium expected economic impact in the short-to-mid-term for the sector. **Social Impacts:** There would be some high expected social impacts for workers in affected sectors, such as oil production and chemical industry.	➢ Unwillingness of countries applying such schemes to transparently share information and expertise on carbon pricing, their negative impacts on the international pricing of raw materials, processed goods and finished goods as it affects KSA ➢ Lack of interest/motivation on the part of industrialized countries to address the adverse impacts of Response Measures (RM) in ETS in all implementing jurisdictions ➢ Lack of interest from AI Parties to support capacity building activities in developing countries to accurately analyze and identify actions needed to minimize the impact of carbon pricing in other jurisdictions on the economy of KSA. ➢ Lack of support and cooperation on the part of developed countries to assist in developing models to verify and quantify both ex-ante and ex-post adverse impacts of RM including free allocation. ➢ Lack of interest of developed countries to release data and information of the impact of free allocation on economic sectors in ETS implementing jurisdictions on developing countries such as KSA.	➢ Assistance to develop the requisite capacity to enable Saudi Arabia effectively participate in carbon markets consistent with its development priorities and economic diversification initiatives. ➢ Continued support to facilitate investment in and focus on lowering the GHG intensity of the Kingdom of Saudi Arabia products for export and the domestic market. ➢ Cooperate in the development of general tools to address comprehensively, the impacts of identified response measures on the economy of Saudi Arabia to enhance its economic diversification initiatives. ➢ Capacity building to assess the impacts of carbon prices on international pricing of raw materials, processed goods and finished goods for Saudi Arabia. ➢Standards for development of CO_2 capture, utilization and recycling technologies ➢ Access to international cooperative approaches, including market and non-market approaches to finance CCS. Modeling to assess the quantitative impact of any over allocation.

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
6. Border Carbon Adjustments (BCA) or Embodied Carbon Tariffs (ECT)	**6.1** Saudi Arabia has to carry the burden of carbon emission reduction in order to maintain competitiveness of its products. The demand of Saudi products may decrease in the BCA or ECT implementing countries. The oil consumption may decrease in order to reduce carbon footprints and consequently, the world oil demand will decrease and the oil price will decrease. The oil market share and the revenue of KSA likely to be negatively affected. **The social and economic welfare** of the population directly or indirectly dependent on the energy and related industries will be negatively impacted. Due to the compound and spillover impacts, the overall social and economic consequences are expected to be moderate.	➢ Lack of agreement on the correct forum to challenge the legal; and technical basis of a BCA (WTO or UNFCCC) ➢ Decrease opportunities for addressing key requirements for achieving sustainable development such as poverty eradication, environmental sustainability, improving technology and social organization and inter-generational equity.	➢ A better understanding on how to comply technically with BCA specificities, once formulated ➢ Need for capacity building and transfer of technology to compete in the global marketplace in terms of carbon footprint ➢ Support for conducting rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of BCA and ECT on Saudi Arabia. ➢ Support for developing appropriate financial risk management tools and approaches to address short- and long-term financial instability focusing on the impacts of BCA and ECT on Saudi Arabia.

Response measures action	Social and economic consequences from the response measures action	Challenges and barriers to address the consequences	Support needed to address the consequences
7. Carbon labeling scheme (CLS)	**7.1** The price of Saudi products will increase in the CLS implementing countries due to costs associated with measuring emissions and verifying measurements. The demand of Saudi products may decrease in the CLS implementing countries. The oil consumption may decrease in order to reduce carbon footprints and consequently, the world oil demand will decrease and the oil price will also decrease. As a result of compound and spillover impacts, the overall social and economic consequences are expected to be moderate to high in the course of time.	➢ The social and economic welfare losses will increase vulnerability of economic diversification and adaptation initiatives. ➢ Decreased opportunities for addressing key requirements for sustainable development such as poverty eradication, environmental sustainability, improving technology and social organization and inter-generational equity.	➢Support for conducting rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of CLS on Saudi Arabia. ➢Support for developing appropriate financial risk management tools and approaches to address short- and long-term financial instability focusing on the impacts of CLS on Saudi Arabia.

4.7 Conclusions

Response measures to climate change do have significant adverse impacts on the social and economic development plans and programmes of most developing countries relying on limited sources of income. These effects are particularly severe on those countries such as Saudi Arabia, whose economies are heavily dependent on a single sector or single commodity such as hydrocarbons. To facilitate the building of resilience against the adverse impacts of the implementation of response measures, several Parties in particular those belonging to the Gulf Cooperation Council (GCC) have pledged to pursue economic diversification measures coupled with actions to maximize avoidance of emissions as an integral part of their national contributions to address global climate change impacts consistent with their national circumstances and their national development objectives.

The following policies and measures to address climate change have the potential of exerting significant adverse effects of the socioeconomic development objectives of developing countries, in particular those whose economies depend on single resource: (i) carbon and energy taxes in a number of national economic sectors, (ii) biofuel production mandates and renewable fuel standards, (iii) subsidies for the production or consumption of low-carbon technologies or goods, (v) carbon labelling scheme, (vi) border carbon adjustments and embodied carbon tariffs, (vii) mitigation measures in international shipping and (viii) cumulative climate change mitigation measures. The challenges and barriers confronting the Kingdom of Saudi Arabia in its efforts to mitigate against the adverse impacts of response measures include those relating to the lack of international cooperation in the development of tools for quantitative ex-ante and ex-post analysis of impacts. Others include unwillingness on the part of developed countries in particular to share, in a transparent manner, information and expertise of carbon pricing and its negative impacts on the international pricing of raw materials, processed goods and finished goods as it affects all developing countries relying on one source of energy including Saudi Arabia.

To raise national resilience to such impacts, economic diversification strategies are being increasingly implemented by countries whose economies are driven primarily by sectors that are sensitive to climate change and mitigation policies, within climate sensitive sectors such as tourism, agriculture, fisheries, forestry and energy production. In this context, countries diversify their economies either by expanding to new industrial sectors or by promoting adaptation measures in vulnerable sectors to increase resilience within those sectors.

The scope and severity of these adverse impacts require that a comprehensive and structured assessment framework is established to provide technical assistance and other forms of assistance to developing countries consistent with Articles 4.8 and 4.10 of the UNFCCC, Articles 2.3 and 3.14 of the Kyoto Protocol as well as Article 4.15 of the Paris Agreement to address the impacts of these measures on their socio-economic development agendas. The support should include developing methodologies and raising capacity building to strengthen modeling expertise to undertake national assessments of the impact of response measures.

The social and economic welfare losses will increase the vulnerability of economic diversification and adaptation initiatives. The opportunities for addressing key requirements for achieving sustainable development such as poverty eradication, environmental sustainability, improving technology and social organization and inter-generational equity will be decreased with time. Saudi Arabia is expecting enhanced efforts of the UNFCCC for identifying innovative and efficient adaptation technologies for addressing the impact of response measure. The approaches of the Kingdom to risk management include the use of financial risk management tools, insurance and stabilization funds in the short-term and economic diversification in the long-term. Technical support is needed in performing rigorous and comprehensive scientific studies to model, predict and evaluate the impacts of various climate change mitigation measures on its society, economy and environment.

To help cope with these adverse impacts, Saudi Arabia will continue to embark on a comprehensive economic diversification initiative as its principal means of addressing climate change and adapting to its economic and ecosystem impacts. Saudi Arabia will welcome technical cooperation and support from developed countries to diversify its economy in order to adapt to the impacts of potential climate change related policies.

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SECTION – 5

Domestic Measurement, Reporting and Verification

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Section 5: Domestic Measurement, Reporting and Verification

5.1 Introduction

Since the entry into force of the United Nations Framework Convention on Climate Change (UNFCCC) on 21 March 1994 until 10 December 2010 (COP 16), measurement and reporting framework of a Party's progress in meeting its obligations under the Convention has been provided for by Articles 4 paragraph 4 and 12 of the UNFCCC. However, the concept of Measurement, Reporting and Verification (MRV) was first introduced into the UNFCCC architecture in December 2007 with the adoption of the Bali Action Plan (decision1/CP.13).

The Designated National Authority (National Committee for Clean Development Mechanism) (DNA) is the sole entity within the Kingdom of Saudi Arabia responsible for the design, preparation and implementation of a domestic measurement, reporting and verification system for the country. Due to its inter-ministerial and public/private inter-agency nature, the DNA has a strong and effective national platform for coordinating effective responses to climate change issues in Saudi Arabia.

The Authority was established by the Council of Minister's Decision No. 208 on 22/06/1430 H (15/06/2009) initially to promote the development of Clean Development Mechanism (CDM) projects in the Kingdom of Saudi Arabia. Subsequently, however, its duties and functions were expanded in accordance with the Council of Minister's Decision No. 31577 on 07/08/1435 H (05/06/2014). The DNA now has the responsibility of preparing nationally determined contributions to reduce greenhouse gas emissions, in accordance with the United Nations Framework Convention on Climate Change agreement and future climate change agreements ratified by the Kingdom of Saudi Arabia. The responsibilities of DNA also include programs that yield emission avoidance and are nationally appropriate under the umbrella of the Kingdom's economic diversification initiative, as well as the preparation of national communication reports, the baseline emissions of greenhouse gases and emissions report (biennial update report) to be submitted every two years to the Secretariat of the Convention.

The DNA is supervised by H.E. the Minster of Energy, Industry and Mineral Resources and chaired by His Royal Highness Prince Abdulaziz Bin Salman Bin Abdulaziz, State Minister for Energy Affairs at the Ministry of Energy, Industry and Mineral Resources, supported by a team of experts, technical and administrative staff. The current membership of the National Committee includes (i) Ministry of Energy, Industry and Mineral Resources; (ii) Ministry of Transportation; (iii) Ministry of Municipal and Rural Affairs; (iv) Ministry of Health; (v) Ministry of Environment, Water and Agriculture; (vi) Ministry of Commerce and Investment; (vii) Royal Commission for Jubail and Yanbu; (viii) Saline Water Conversion Corporation; (ix) Saudi Arabian Oil Company; (x) Saudi Basic Industries Corporation; (xi) Saudi Electricity Company; (xii) King Abdulaziz City for Science and Technology; (xiii) King Abdullah City for Atomic and Renewable Energy; (xiv) General Authority of Meteorology and Environmental Protection; (xv) Saudi Arabian Mining Company; (xvi) Saudi Industrial Property Authority; and (xvii) Electricity and Co-Generation Regulatory Authority.

5.2 Evolution of the concept and practice of Measurement, Reporting and Verification under the United Nations Framework Convention on Climate Change

The Bali Action Plan called for enhanced national/international action on mitigation of climate change, including the consideration of nationally appropriate mitigation actions by developing countries in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner (UNFCCC, 2007). In Cancun 2010, the COP by its decision 1/CP.16, brought together for the first time, all aspects pertaining to transparency in the climate change regime. At COP 16, all Parties agreed to submit National Communications every four years and in between every two years, less comprehensive biennial reports (BRs) from Annex I countries and biennial update reports (BURs) from Non-Annex I countries (UNFCCC, 2010). Further elaboration on the guidelines to facilitate the operationalization of MRV were provided at COP 19 at Warsaw, Poland in 2013 (UNFCCC, 2013).

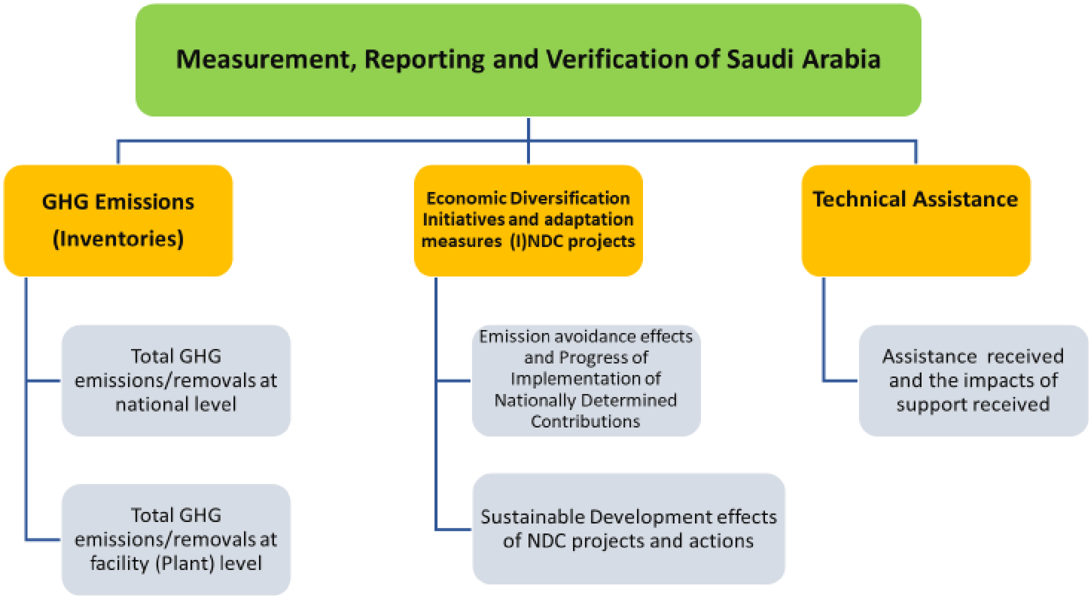
Measurement, Reporting and Verification (MRV) is the practice that incorporates three independent, but related processes to effectively mitigate climate change (Ninomiya, 2012). These three processes of MRV were defined by Dagnet et al. 2014, as follows: Measurement (M) - measure or estimate relevant data and information on emissions, mitigation actions and support; Reporting (R) - report by compiling the data and information collected into inventories and other standardized formats in order to provide access to a set of users at the national and international levels; and Verification (V) - verify the reported data and information by periodically reviewing or analyzing or performing an independent assessment to ensure completeness and reliability.

5.3 Domestic Measurement, Reporting and Verification framework for Saudi Arabia

Taking into consideration the national circumstances of Saudi Arabia, the MRV framework for the Kingdom would be built on national experiences and existing institutional arrangements for the preparation of national GHG inventories as well as experiences gained from the implementation of clean development mechanism (CDM) projects. Establishing an integrated MRV system for GHG emission avoidance projects and actions within the Kingdom is seen as a capacity-building initiative and a “learning-by-doing” process for Saudi Arabia. The Kingdom has a well-established process of preparing its national inventories of GHGs as well as implementing CDM and other related projects.

Although Saudi Arabia does have a functional and effective GHG inventory preparation system that has enabled the Kingdom to prepare its initial, second and third national communications, it does not currently have the complete set of requisite elements needed to facilitate the development and operationalization of a domestic MRV system consistent with the Kingdom’s sustainable development objectives and national priorities as outlined in its Vision 2030. Saudi Arabia plans to develop such a MRV system which will be based on a carefully designed “learning-by-doing” process over a period of time. The Kingdom’s MRV system will aim to “track” its national emissions by sources and removals by sinks of GHGs as well as: (a) GHG emissions avoidance attributed to specific economic diversification measures that have co-benefits in the form of greenhouse gas (GHG) emission avoidances (at the actions and projects levels) as well as adaptation measures with mitigation co-benefits; (b) sustainable development benefits arising from the implementation of actions and plans contained in its INDCs and (c) climate change relevant support received by developing country Parties in the form of technology cooperation, development and transfer as well as capacity development initiative designed to support the implementation of its nationally determined contribution (Figure 5.1).

Figure 5.1: Measurement, Reporting and Verification framework for Saudi Arabia



MRV of GHG emissions: This involves estimating, reporting and verifying actual emissions annually at the national or facilities' levels as appropriate to meet national (domestic) and international requirements.

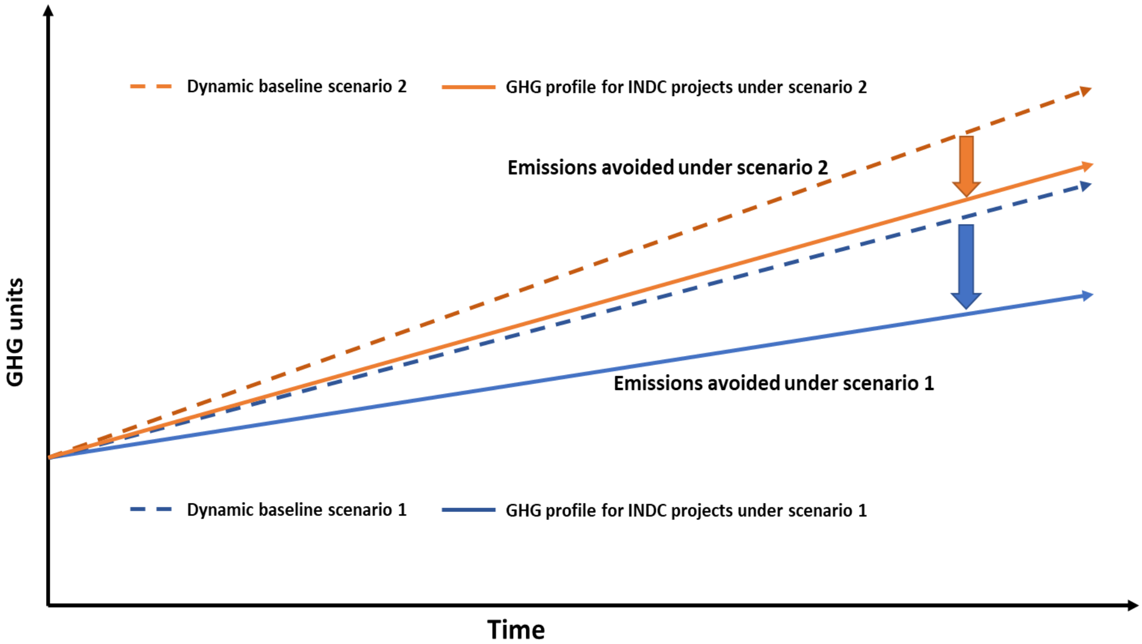
MRV of emission avoidance actions relates to the assessment (ex-ante or ex-post) of GHG emissions avoidance and/or sustainable development (non-GHG) effects of projects/actions, as well as monitoring their implementation progress. It also involves an overall assessment of progress toward emission avoidance ambitions from those projects actions contained in the INDC of Saudi Arabia.

MRV of support covers the monitoring receipt of technical knowledge and capacity-building needs offered through bilateral or multi-lateral channels and evaluating the results and impact of these support.

Due to the unique circumstances of the Kingdom of Saudi Arabia as a single source economy, two scenarios have been applied for determining dynamic baselines to guide the implementation of the Kingdom's nationally determined contribution to the UNFCCC for the period up to 2030. Scenario 1 assumes economic diversification with a robust contribution of oil export revenues. Export revenues will be channelled into investments in high value-added sectors such as financial services, medical services, tourism, education, renewable energy and energy efficiency technologies to enhance economic growth. The ambitions outlined in the

Saudi Arabia's INDC are set under this scenario. Scenario 2 is premised on an accelerated domestic industrialization based on sustainable utilization of all indigenous resources including oil, gas and minerals. A heavy industrial base built to use domestic oil resources as feedstock or energy source. Increasing contributions of petrochemical, cement, mining and metal production industries to the national economy. Economic growth will be much slower under this scenario and will be difficult for the Kingdom to finance its INDC ambitions with domestic resources. Emission profiles of INDC projects implementation on the basis of dynamic baseline scenarios 1 and 2 are illustrated in Figure 5.2.

Figure 5.2: Emission Profile of INDC projects Implementation under the basis of Dynamic Baseline Scenarios 1 & 2



5.4 Nationally Determined Contribution of the Kingdom of Saudi Arabia

The Kingdom of Saudi Arabia is implementing a flagship development agenda known as Vision 2030. This development blueprint is the central vehicle for the diversification of the Kingdom's economy away from its reliance on income generated from a single source. Hence, the Kingdom's actions and projects contained in its nationally determined contribution to the UNFCCC are designed in a manner that accelerate the nation's economic diversification initiatives consistent with Vision 2030. Those actions and projects which are adaptation in nature do additionally generate mitigation co-benefits either in the form of avoided emissions or carbon sequestration. They include: energy efficiency, renewable energy, carbon capture, utilization and storage, utilization of gas and methane recovery and flare minimization. Others are urban planning, water and waste water management, marine protection and reduced desertification.

Under the energy efficiency focal area, the identified actions and projects encompass the introduction of efficiency standards in the building and transportation sectors of the economy as well as the implementation of energy efficiency measures, in various industrial establishments across the Kingdom. Others include measures that encourage and expedite the conversion of single cycle power plants to combined cycle power plants to enhance efficiency of power generation.

Actions and projects in the area of renewable energies, cover the investment and implementation of programs which increase the contribution of renewable energy resources to the Kingdom's energy mix. These would include the development of solar photovoltaics, solar thermal, wind and geothermal energy and waste to energy systems. Under carbon capture, utilization and storage, a project would be undertaken to build the world's largest carbon capture and use plant. This plant aims to capture and purify about 1,500 tons of CO_2 per day for use in other petrochemical plants. Saudi Arabia will also operate on pilot testing basis, a Carbon Dioxide – Enhanced Oil Recovery (CO_2-EOR) demonstration project to assess the viability of CO_2 sequestration in oil reservoirs and any other useful applications. Additionally, forty million standard cubic feet a day of CO_2 that will be captured and processed, will be injected into the Othmaniya oil reservoir. This pilot project has comprehensive monitoring and surveillance plans. The success of this pilot will determine the extent this program will contribute to the Kingdom's ambition in addressing climate change.

As regards utilization of gas, actions would be undertaken to encourage investments on exploring and producing natural gas to significantly increase its contribution to the national energy mix. The success of realizing the mitigation co-benefit ambition in this area will depend on the success of exploring and developing natural gas. Actions to be undertaken in respect of methane recovery and flare minimization initiatives include the conservation, recovery and reuse of hydrocarbon resources and minimize flaring and fugitive emissions.

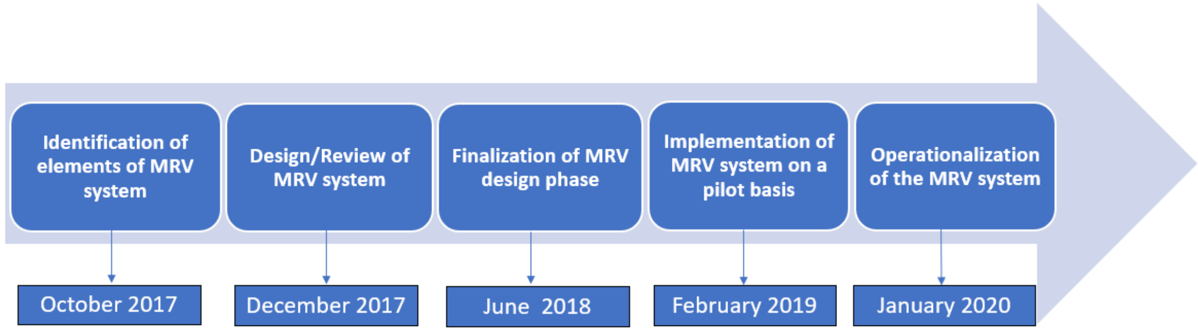
The INDC of Saudi Arabia also include a number of actions and projects which are designed to enhance the Kingdom's resilience and adaptive capacity to climate change, while at the same time yield GHG mitigation co-benefits. These are in the areas of water and waste water management. The implementation of the actions and projects in this area will promote and encourage the reduction, recycle and reuse of water and wastewater in the municipal, industrial and commercial sectors in a manner that will reduce energy consumption, desalinated water production and unground leakage. As regards to urban planning, actions and projects would promote the development and use of mass transport systems in urban areas. Necessary actions have been taken to expedite the development of the metro system in Riyadh. Additionally, the metro systems in Jeddah and Dammam are in the planning phase. In the area of marine protection, actions are being taken to increase the sinks for blue carbon and the maintenance of related ecosystems, support the planting of mangrove seedlings along its coasts as well as strengthen and enhance the coral reef restoration program throughout the north-western Arabian Gulf.

As regards to reduced desertification, actions and projects are being taken to enhance desertification management through the promotion of stabilization of sand movements around cities and roads, while increasing sinks for capacity through using green belts as barriers. A number of natural resource conservation activities, biodiversity and eco-system-based adaptation efforts are being undertaken to develop and enhance arid and semi-arid rural areas. These actions collectively aim to improve soil and water quality, pasture and wildlife resources through a system of protected areas and reserves. Mitigation co-benefits derived from these adaptation projects and actions include those relating to reducing land degradation and improving land management practices, especially for agriculture and forestry. Ambitions outlined in this INDC are set under scenario 1. The Kingdom's INDC projects and actions would be subjected to the domestic measurement, reporting and verification system of Saudi Arabia (Figure 5.1) which would be operationalised by 2020.

5.5 Timeline for the Development of Measurement, Reporting and Verification System for Saudi Arabia

The design and operationalization of the domestic MRV system for the Kingdom of Saudi Arabia will be rolled out in 5 stages from 2017 to 2020. The phased-out programme is sequenced as follows: (i) identification of the key elements of the MRV system; (ii) design and review of the MRV architecture; (iii) finalization of the design phase; (iv) implementation of a pilot MRV system; and (v) functional deployment of the MRV system. The Kingdom of Saudi Arabia is presently at the design and review phase of the development of its domestic MRV system. Key entities within the Kingdom and their roles in the MRV structure have been mapped by DNA. At this stage the focus is on the review of the proposed system to make it more responsive to national development and priority needs to allow for continuous information and data collection relevant to all the projects and plans identified in the Kingdom's INDC submitted to the UNFCCC in November 2015. It is expected that by February 2019, a prototype of domestic MRV architecture with its IT support infrastructure will be put into operation on a pilot basis and the system would be fully functional by 2020 (Figure 5.3).

Figure 5.3: Timeline for the development and operationalization of domestic Measurement Reporting and Verification System



The MRV system of Saudi Arabia will cover reporting on (a) GHG inventories; (b) emission avoidance arising from the implementation of economic diversification initiatives as well as adaptation measures with mitigation co-benefits (estimation of avoided emissions at the project level as contained in its INDC); and (c) Technical assistance/capacity-building /technology transfer and their effects.

As for domestic verification process, KSA would verify its national GHG inventories by utilizing its domestic QA/QC procedures. Within the framework of domestic MRV system contained in the BUR of KSA and as a developing country, the national GHG inventories prepared will not be verified internationally. The BUR would rather undergo an international consultation and analysis process as defined by Annex III of decision 2/CP.17 and decision

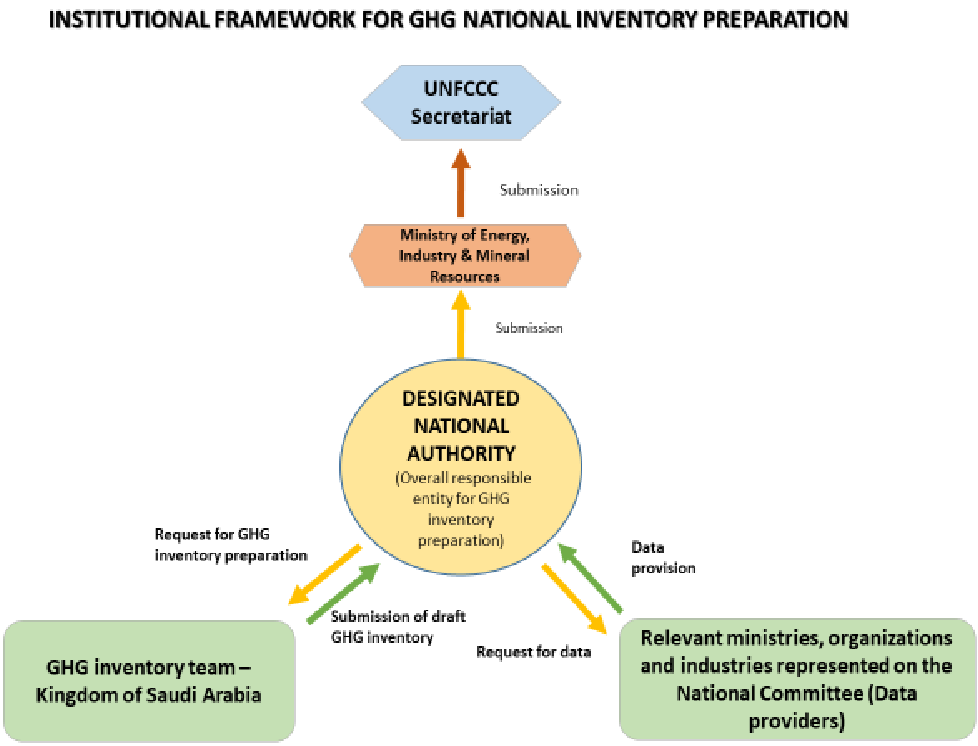
20/CP.19. International Consultation and Analysis (ICA) process includes two steps: technical analysis of BURs by a team of technical experts and a facilitative sharing of views with the country concerned (UNFCCC, 2014).

5.6 National GHG Inventory Practices in Saudi Arabia

Institutional Arrangement for Preparation of National GHG Inventories

The DNA is the sole entity within the Kingdom of Saudi Arabia entrusted with the responsibility of identifying and collecting all datasets at the national level for the purpose of preparing the national GHG inventories for Saudi Arabia

Figure 5.4: Institutional Arrangement for Preparation of National GHG Inventories



Brief description of GHG Inventory process, Methodology and Data sources

KSA has, over the past 12 years, systematically developed a functional national greenhouse gas inventory system capable of supporting the preparation of national inventories of GHG emissions by sources and removals by sinks on a continuous basis. Saudi Arabia has established a streamlined mechanism for data collection from various organizations and entities within the Kingdom.

The GHG Inventory cycle of Saudi Arabia follows through a clearly defined process involving the planning, collection and collation, estimation, report preparation, improvement and finalization stages before submission of the report as part of its biennial update report or national communication.

The ***planning stage*** covers the development/updating of data collection templates, identification of available data and choice of methods as well as interaction with sectoral experts and data providing entities.

The ***collection and collation stage*** involves the collection and organization of activity data and emission factors and performing quality control on the data and information collated.

The ***estimation stage c***overs the preparation of the initial estimates and performing quality control and key category analysis

The ***report preparation stage*** involves the preparation of draft inventory report performing quality control of the draft report. Quality assurance of the draft report is also carried out by national inventory specialists who are not directly involved in the compilation of the draft inventory report

The ***finalization stage*** involves addressing the review comments of the quality assurance team, preparation of final inventory report and archiving of data and information and submission of report to the UNFCCC.

The Kingdom of Saudi Arabia is using Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for measuring and reporting of emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. The estimation of the GHG emissions by sources and removals by sinks in Saudi Arabia employs a combination of: (a) country-specific methods and data; (b) IPCC methodologies and; (c) Emission Factors (EFs). These methods are consistent with the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1996). Tier 1 IPCC methodology was generally applied and the methodology has seen some improvements over the previous years. Emission factors were obtained from: facility-level plants; country-specific or regional and international studies and IPCC Emission Factor Database (IPCC EFDB). Default emissions factors from the IPCC EFDB were commonly used, however, in some cases where country or region-specific emission factors existed, priority was given to it.

The DNA has a very comprehensive online database system that hosts all GHG inventory data and related information. The database helps to streamline documentation and archiving of all GHG data and information, reports and publications. The database contains (a) all inputs data from each sector, (b) datasheet for each sector, (c) emission estimates from the IPCC software for all sectors for 1990, 2000, 2010 and 2012, (d) IPCC 1996 software database, (f) completed QA/QC templates for sectors and (g) all reports, documentations. The Information Technology infrastructure of the database (server, backend database resources) is managed by the DNA.

The estimation of the GHG emissions and sinks used a combination of: (a) country-specific methods and data; (b) IPCC methodologies and; (c) Emission Factors (EFs). These methods are consistent with the 1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories and GPG are to the extent possible, in line with international practice.

Generally, Tier 1 IPCC methodology was applied and this has seen some improvements over the previous years. Emission factors were obtained from: facility-level plants; country-specific or regional and international studies and IPCC Emission Factor Database (EFDB). Default emissions factors from the IPCC EFDB were commonly used, however, in all cases where country or region-specific emission factors have been determined or identified, priority was given to them.

Verification of National GHG Inventories at the National level

Quality Assurance/Quality Control (QA/QC) procedures have been established by Saudi Arabia within the framework of preparing the national GHG inventories of emissions by sources and removals by sinks. This has contributed to the development of national GHG inventories that can be readily assessed in terms of quality and completeness. The quality control activities carried out essentially mainly by inventory compilers in Saudi Arabia serves to control the accuracy of estimated GHG emissions and removals, as the inventories are being developed. These activities help provide, amongst others, the routine and consistent checks and documentation points in the inventory development process to verify data integrity, correctness and completeness; as well as identify and reduce errors and omissions;

Quality Assurance (QA) activities which include review and audit procedures is conducted by personnel within the Kingdom of Saudi Arabia not actively involved in the inventory development process. Their work serves to verify that data quality objectives were met and to reduce or eliminate any inherent bias in the inventory processes.

Emission avoidance measures in KSA will be implemented without international financial support; therefore, actions resulting in mitigation co-benefits funded through domestic sources will only be subjected to domestic verification and would follow domestic standards and processes. As for domestic verification, KSA would verify national GHG inventories by utilizing its QA/QC procedures. The national GHG inventories prepared by non-Annex I Parties are not verified internationally. However, the inventories are subject to ICA as part of BURs (UNFCCC, 2014).

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ACRONYMS

BCA	Border Carbon Adjustments
BCM	Billion Cubic Meter
BHE	Borehole Heat Exchangers
BTA	Border Tax Assessments
BUR	Biennial Update Report
CAFE	Saudi Arabia Corporate Average Fuel Economy Standard
CCAC	UN Climate and Clean Air Coalition
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CDM	Clean Development Mechanism
CDSI	Central Department of Statistics and Information
CECCR	Center of Excellence for Climate Change Research
CGE	Computable General Equilibrium
CH_4	Methane
CLS	Carbon Labeling Scheme
CM	Carbon Management
CO_2	Carbon Dioxide
CO_2-EOR	Carbon Dioxide – Enhanced Oil Recovery
COP	Conference of the Parties
COREND	Center of Research Excellence in Natural Disasters
CPV	Concentration Photo-Voltaics
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSLF	Carbon Sequestration Leadership Forum
CT	Carbon Tax
DNA	Designated National Authority
DTV	Dhahran Techno Valley
ECIF	Extension Centers for Integrated Farms
ECRA	Electricity and Cogeneration Regulatory Authority
ECT	Embodied Carbon Tariffs
EE	Energy Efficiency
EFDB	Emission Factor Database
EIRP	Electricity Industry Restructuring Plan
EOP	Economic Offset Program
EPA	US Environmental Protection Agency
ERI	Energy Research Institute
ETCS	European Train Control System

ETS	Emissions Trading System
EU	European Union
EWS	Early Warning Systems
FC	Fuel Combustion
FDI	Foreign Direct Investment
FE	Fugitive Emission
GACA	General Authority of Civil Aviation
GAMEP	General Authority of Meteorology & Environmental Protection
GAP	Good Agricultural Practices
GATT	General Agreement on Tariffs and Trade
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GJ	Giga Joules
GMI	Global Methane Initiative
GNP	Gross National Product
GSFMO	Grain Silos and Flour Mills Organization
GW	Giga Watt
HDI	Human Development Index
HDV	Heavy Duty Vehicles
HVAC	heating, ventilation and Air Conditioning
ICA	International Consultation and Analysis
ICZMP	Implementation of Integrated Coastal Zone Management Plan
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel for Climate Change
IPP	Power Producers
ISESCO	Islamic Educational, Scientific and Cultural Organization
KACARE	King Abdullah City for Atomic and Renewable Energy
KACST	King Abdulaziz City for Science and Technology
KAPSARC	King Abdullah Petroleum Studies and Research Center
KAU	King Abdulaziz University
KAUST	King Abdullah University of Science & Technology
KFUPM	King Fahad University for Petroleum and Minerals
KSA	Kingdom of Saudi Arabia
KSU	King Saud University
LDAR	Lead Detection and Repair

LDC	Least Developing Countries
LDV	Light Duty Vehicles
LED	Light-emitting Diode
MCI	Ministry of Commerce & Industry
MCM	Million Cubic Meter
MD	Membrane Distillation
MED	Multi Effect Desalination
MEIM	Ministry of Energy, Industry and Mineral Resources
MEP	Ministry of Economy and Planning
MEWA	Ministry of Environment, Water and Agriculture
MIT	Massachusetts Institute of Technology
MOUN	Madinah Urban Observatory Network
MPT	Modern Portfolio Theory
MRV	Measurement, Reporting and Verification system
MSF	Multistage Flash Systems
MW	Mega Watt
N_2O	Nitrous Oxide
NDC	Nationally Determined Contribution
NIR	National Inventory Reports
NIS	National Industrial Strategy
NREP	National Renewable Energy Program
NREP	National Renewable Energy Program
NSR	North-South Railway
NSS	National Spatial Strategy
NSTIP	National Science, Technology and Innovation Plan
NTP	National Transformation Program
NWC	National Water Company
OBG	Oxford Business Group
ODS	Ozone Depleting Substances
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PAFC	Phosphoric Acid Fuel Cells
PEM	Proton Exchange Membrane
PEMFC	Polymer Electrolyte Membrane Fuel Cells
PERSGA	Regional Organization for Conservation of Environment of the Red Sea & Gulf of Aden
PME	Presidency of Meteorology and Environment
PTA	Public Transport Authority
PV	Photo-Voltaics

QA	Quality Assurance
QC	Quality Control
RCJY	Royal Commission for Jubail and Yanbu
RE	Renewable Energy
REPDO	Renewable Energy Project Development Office
RES	Renewable Energy Sources
RFS	Renewable Fuel Standard
RM	Response Measures
RO	Reverse Osmosis
ROPME	Regional Organization for the Protection of Marine Environment
RPS	Renewable Portfolio Standards
RTV	Riyadh Techno Valley
RUE	Rationale Use of Energy
SAAB	Saudi Arabian Agricultural Bank
SABIC	Saudi Arabia Basic Industries Corporation
SAMA	Saudi Arabian Monetary Agency
SAR	Saudi Arabia Riyal
SASG	Saudi Arabia Smart Grid
SASO	Saudi Arabian Standard Organization
SBI	Subsidiary Body for Implementation
SCTH	Saudi Commission for Tourism and National Heritage
SEC	Saudi Electricity Company
SEEC	Saudi Arabian Energy Efficiency Center
SEEP	Saudi Energy Efficiency Program
SOLERAS	Solar Energy Research American-Saudi
SWCC	Saudi Arabian Saline Water Conversion Corporation
SWDRI	Saline Water Desalination Research Institute
TAQNIA	Saudi Technology Development and Investment Company
TAR	Third Assessment Report
TNC	Third National Communication
TTD	Technology Transfer and Development
TTO	Technology Transfer Offices
UAE	United Arab Emirates
UHCPV	Ultra-High Concentrator Photo Voltaic
UK	United Kingdom
UN	United Nation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

UNESCO	UN Education, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WTO	World Trade Organization