Kingdom of Saudi Arabia

The Second Biennial Update Report (BUR2)

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Introduction

The Kingdom of Saudi Arabia has emerged as an important and key member of the international community in the global fight against climate change, positioning itself as a proactive contributor to addressing climate challenges. The Kingdom's commitment underscores the necessity of comprehensive solutions that involve all sectors of society while balancing economic development with national and global energy security. The Kingdom is taking a leading role in mitigating climate change impacts and accelerating science-based solutions to reducing emissions. The Kingdom of Saudi Arabia emphasizes the potential for innovative solutions to meet developmental goals while addressing climate challenges, particularly in a region with some of the world's fastest-growing economies. With significant investments in research and development, the Kingdom aims to minimize climate change impacts while sustaining economic growth.

The Kingdom's arid environment, limited water resources, dependence on oil revenues, and exposure to both biophysical and socioeconomic impacts of climate change underscore the need for proactive measures to enhance resilience and sustainability. This requires coordinated efforts at the national, regional, and international levels to mitigate emissions, adapt to impacts of climate change, and promote sustainable development.

The Kingdom is among one of the most efficient oil producing countries having one of the lowest carbon intensity footprint per barrel of oil produced. In addition, the Kingdom is also among the lowest methane emission intensity countries in the world compared to other major oil and gas producing countries because of its efficient gas collection system. The Kingdom of Saudi Arabia recognizes the need of a comprehensive and integrated approach to mitigate the adverse impacts of climate change and its response measures. Economic diversification offers a pathway to reduce vulnerability to climate variability and market fluctuations. The Kingdom has been continuously and steadily moving on its transformative journey by evolving its role from solely an oil supplier to an energy supplier

The Kingdom of Saudi Arabia adopted circular carbon economy (CCE) framework which reflects the Kingdom's commitment to sustainability having four R's namely reduce, reuse, recycle and remove as a way to reduce the Kingdom's carbon footprints. The CCE approach was endorsed by the G20 leaders in 2020 during the Kingdom's Presidency of G20 countries. The CCE approach has been aligned with the Kingdom's developmental plans and economic diversification efforts under Saudi Vision 2030.

By focusing on human capital, the Kingdom aims to build a knowledge-based economy that is less reliant on oil revenues and more resilient to fluctuations in global energy markets. This involves investing in education, training, research and development, entrepreneurship, and innovation to empower its citizens and unlock their full potential. Furthermore, by prioritizing human capital development, the Kingdom can enhance its competitiveness in the global economy, attract foreign investment, and foster sustainable development that benefits all segments of society. This strategic shift aligns with broader national development goals and aspirations for a prosperous and diversified economy that creates opportunities for all its citizens while protecting the climate system.

Through Vision 2030, the Kingdom strives to diversify its economy from an oil-based economy to an integrated energy powerhouse, incorporating renewables, gas, and chemical sectors, indicating a shift towards sustainable and multifaceted energy solutions. The Kingdom intends to transforming the domestic energy mix by 2030 by (i) reducing the consumption of oil and increasing the share of gas in the power, desalination, industrial and agriculture sectors, (ii) increasing the share of renewable energy in the electricity coming from renewable sources such as solar, wind and geothermal, (iii) planning to enhance Saudi Energy Efficiency in various sectors of the economy by implementing the new energy efficiency standards across power generation, water desalination, and electricity transmission and distribution (iv) aims to lead the world in the production and export of clean and green hydrogen and (v) intends to enhance the role of carbon capture, utilization and storage of carbon dioxide and use captured carbon to produce chemicals and synthetic fuels . These measures have been proposed to be implemented under the two green initiatives namely the Saudi Green Initiative (SGI) and a regional Middle East Green initiative (MGI) launched by HRH Prince Mohammed Bin Salman, the Crown Prince, and Prime Minister in 2021. Some other initiatives proposed under SGI were (vi) transformation of waste management sector in Riyadh diverting the waste away from landfills to compost (vii) ambition to plant trees in Saudi Arabia as part of afforestation efforts and (viii) plans to increase the terrestrial and marine protected area in the Kingdom.

This report, the Second Biennial Update Report (BUR2) of the Kingdom of Saudi Arabia has been prepared by the Designated National Authority (DNA) under the guidance, support and direction of HRH, the Minister of Energy and in close cooperation and coordination of relevant sector ministries, and entities and Research Institute of King Fahd University of Petroleum and Minerals (KFUPM/RI).

The report is comprised of four (4) sections namely:

(i) National Circumstances

(ii) Institutional Arrangement

(iii) 2019 National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol.

(iv) Impacts of Climate Change Response Measures – Role of Economic Diversification as a Tool

The National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol included in this BUR2 has been prepared for the year 2019 instead of 2020 as the later year was marked by the global COVID-19 pandemic, which caused substantial disruptions across various sectors of the economy including significant reduction in industrial production. Lockdown measures, restrictions on transportation and travel resulted in anomalous levels of greenhouse gas emissions, making the year 2020 nonrepresentative benchmark year.

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National Circumstances

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1.1. LOCATION, TOPOGRAPHY, CLIMATE AND DEMOGRAPHIC CHARACTERISTICS

Location, Topography and Climate

Saudi Arabia is situated in the southwest Asia occupying an area of approximately 2.25 million square kilometers at a latitude of 16.5°N - 32.5°N and a longitude of 33.75°E - 56.25°E. The country comprises about 80% of Arabian Peninsula and is bordered by two major water bodies: the red sea to the west with a coastline of approximately 1,760 kilometers and Arabian Gulf to the east with a coastline of approximately 650 kilometers (NC4, Kingdom of Saudi Arabia, 2022). The countries sharing borders with Saudi Arabia are the Kingdom of Bahrain, Qatar, and United Arab Emirates on the east and Jordan, Iraq and Kuwait on the north.

Saudi Arabia is a vast and geographically diverse arid country with deserts, mountain ranges and coastal plains. Generally, the temperatures are high with high evaporation rates. There are no perennial rivers or permanent freshwater bodies. The rainfall is scarce in most parts of the country with 50-100 mm precipitation annually. However, the southwestern mountainous areas record an annual average rainfall of approximately 300 mm or more. The maximum temperatures recoded in the country: during winter season; 20 – 30°C (from December to February): during the spring season; 30 – 40°C (from March to May), during summer season 35 – 45°C (from June to August) and during autumn season 25 – 35°C (from September to November) (MEWA, 2023). The temperatures in summer range from 27°C to 43°C in inland areas while it ranges between 27°C to 38°C in coastal areas. In winter, the temperatures range between 8°C to 20°C in the interior parts of Saudi Arabia while higher temperatures have been recorded in the coastal areas of Red Sea (19°C – 29°C). Some areas such as Turaif recorded temperatures below zero degrees Celsius (NC3, Kingdom of Saudi Arabia). There are several mountain ranges also, the well-known Assir mountains are in the southwest of the country. The peak of these mountains is approximately 3,000 meters high.

Furthermore, adding to the country's geological diversity, the Kingdom's northern region features distinctive volcanic plateaus and lava fields. This includes the Harrah volcanic field, renowned for its black basaltic rock formations and volcanic cones. These formations demonstrate the country's rich geological history.

Demography

The total population of Saudi Arabia in 2023 stands at 32.18 million, of which 18.8 million are Saudis and 13.4 million non-Saudis, with highest density in Riyadh region of 8.59 million. 19.7 million are males accounting to 61% of the population, while females account for 12.5 million or 38.8%. The average age of population in Saudi Arabia is 29 years, while the average age of Saudi nationals is 25.5 years, with the highest number of Saudi nationals is in the 5-9 age group with around 2.3 million. The lowest number of people exist in the age group 75-79+ at 110,571. The census also shows that the Kingdom has a young population, with the median age of 29 and the population of Saudis under 30 making up 63% of the total population. (Saudi Census, 2022). This high youth population of 63% under the age of 30 highlights the challenges facing the Kingdom to diversify the economy away from oil and create jobs, provide more opportunities for education, training and capacity building for this young population. The Kingdom is making huge investments into the transformation plan, the Vision 2030, which includes building up local industry and opening up the Kingdom for tourism and business to create new jobs for Saudi young population.

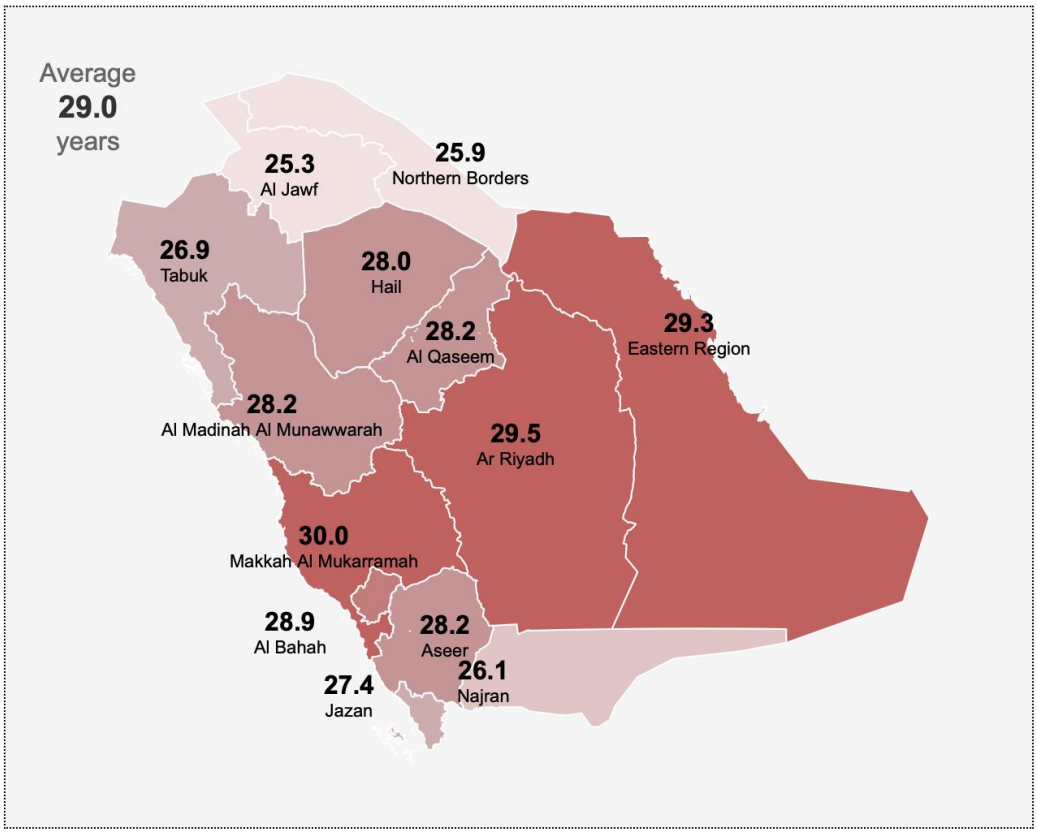

Figure 1.1: Region-wise distribution of population (Saudi Census, 2022)

1.2. SAUDI VISION 2030

The Kingdom of Saudi Arabia launched "Saudi Vision 2030" in April 2016. It is a transformative and ambitious plan with the main objective to diversify the Kingdom's economy to become more sustainable and resilient. The main goal of Vision 2030 is to raise the share of non-oil exports in non-oil GDP from 16% to 50% (Saudi Vision 2030).

Since its announcement, Saudi Vision 2030 has provided a roadmap towards achieving sustainable development through social and economic reforms, consisting of 96 objectives across different themes, namely: (i) Social Change; (ii) Business and Economy; (iii) Tourism and Heritage; (iv) Environment and Nature. Clean energy and sustainability are at the forefront of the Kingdom's efforts, addressing energy and climate challenges with innovative solutions such as the Circular Carbon Economy (CCE) and an increasingly diverse energy mix, with 50% of energy sources will be from renewable energy by 2030 (Refer to section 4 for more details).

1.3. EDUCATION

The Kingdom gives sustained support and attention to the education sector and has devoted significant resources to the development of human resources and manpower skills since the start of the Kingdom's first development plan in 1970.

Considering the high importance of education, the Kingdom of Saudia Arabia allocated 19.4% budget to the Ministry of Education (MoE) in 2022. This support led to the country ranking third in the 2022 Global Competitiveness Report by the World Competitiveness Report.

Saudi Vision 2030 also aims to provide opportunities for both men and women in Saudi

Arabia's education field. The total number of graduates from all levels of higher education in Saudi Arabia stood at 233,000 during the academic year 2019/2020. Of these, 59.0 percent were female graduates, and 41.0 percent were male graduates (SAMA, 2021).

1.4. HEALTH

The healthcare sector is a key focus area of the ambitious Saudi Vision 2030 and National Transformation Program 2020 (NTP) that aims to enhance 'healthcare services and facilities' quality' throughout the Kingdom of Saudi Arabia. The Kingdom allocated 8% of the total budgetary expenditure for health in 2022, which further increased in 2023 (Ministry of Health, 2023). The health sector transformation program has four main priorities: prevention, public health, innovation, and sustainability. It aims to expand e-health services and digital solutions, improve the quality of health services, and transform the healthcare system in the Kingdom to make it more comprehensive and integrated.

1.5. ENERGY PROFILE

1.5.1. Oil and Gas

The Kingdom of Saudi Arabia, the largest oil exporter, produced around 3,330.52 million barrels of Oil annually, 438 million barrels of Natural Gas Liquids annually and around 929.850 million Barrel of refined products annually in 2021. The Kingdom exported around 2,272.98 million barrels of Crude Oil and 490.33 million barrels of refined products in 2021 (SAMA's annual statistics, 2021).

1.5.2. Power Generation

The total available power generating capacity in the Kingdom in the year 2021 was 83,036 MW. Total peak load was 64,161 MW. The total electric energy produced in 2021 was 359 TWh while total electric energy consumption was 302 TWh in the year 2021.

The residential sector accounted for the highest consumption of electric energy, at 47.25% of the total, followed by the industrial sector at 19.47%, the commercial sector at 15.09%, the government sector at 12.64%, the agriculture sector at 1.88%, and other sectors at 3.67% (GASTAT, 2022). Saudi Arabia added a total of 700 MW of renewable energy in 2022 which has been connected to the national grid with 400 MW wind power plant and 300 MW solar PV power plant while the current renewable energy production in the Kingdom is over 2.8 GW (SGI Newsletter, January 2024).

In 2019, the percentage contribution of different types of power generation technologies were 34.7% by gas turbines, 44.7% by steam turbines, 0.5% each by diesel generators and renewables. The installation of energy efficient combined cycle power plants has been increasing steadily in the Kingdom.

The SEC has strategically diversified its electricity generation mix and fuel sources to enhance efficiency. This involves integrating solar power with combined cycle capacity investments. There has been a substantial increase in combined cycle power production, rising from 8% in 2010 to 31%. Simultaneously, the use of open-cycle turbines, an energy intensive technology, has decreased significantly from 50% in 2010 to 24% (SEC ESG, 2021). Saudi Arabia is working on a plan to install four power plants of 1,800 MW each using natural gas combined cycle technology along with carbon capture to help the Kingdom achieve net zero GHG emissions by 2060 (SGI Newsletter, January 2024).

As part of its initiative to enhance consumer energy efficiency through digital transformation,

Saudi Arabia installed more than 10 million smart meters nationwide (SEC ESG, 2020).

1.6. INDUSTRIAL AND ECONOMIC DEVELOPMENT

To achieve economic diversification, increase competitiveness, and attract investments, the Kingdom of Saudi Arabia has developed multiple industrial zones and economic cities. These industrial zones and economic cities are briefly described below:

1.6.1. Industrial Zones and Economic Cities

1.6.1.1. Industrial Cities and Technology Zones

Saudi Authority for Industrial Cities and Technology Zones (MODON)

The Saudi Authority for Industrial Cities and Technology Zones (MODON) is a governmental organization established in 2001 and is tasked with the development and management of industrial cities and technical areas. It currently oversees 36 existing and under development industrial cities across the Kingdom in addition to private industrial cities and complexes. The number of productive industries in these industrial cities is 6,299 while 1,283 factories are ready for production (MODON, 2023). MODON Contributes to the Kingdom's Vision 2030 objectives through the promotion of industrial innovation and increasing the Saudi economy's competitiveness on a national and global scale.

Royal Commission for Jubail and Yanbu (RCJY)

The Royal Commission for Jubail and Yanbu, RCJY, was established in 1975 and is responsible for the planning, promotion, development, and management of petrochemical and energy intensive industrial cities, located in the cities of Jubail, on the eastern coast of Arabian Gulf and Yanbu, on the western coast of Red Sea. RCJY has played a pivotal role in transforming these areas into thriving industrial and economic hubs, attracting investments on a local and international level, and promoting technological innovation. In addition, RCJY has been tasked with the development and management of mining industries in Ras Al-Khair and developing plans for future expansions for the establishment of a city for mining industries.

Knowledge Economic City (KEC), Madinah

The Knowledge Economic City (KEC) in Madinah is dedicated to knowledge-based industries, including education, hospitality, tourism, housing, and healthcare etc. The Knowledge Bureau, situated in KEC, conducts activities related to knowledge in areas such as the economy, culture, and training. For the development of managerial competencies, the Madinah Institute for Leadership & Entrepreneurship offers high-quality training programs.

Jazan Economic City (JEC)

Jazan Economic City (JEC) is a major economic project strategically located along the Red Sea coast in the Jazan region. It aims to actively contribute to the diversification of the Kingdom's economy through a range of industrial, commercial, and infrastructure projects. JEC focuses on key sectors like petroleum refineries, petrochemical industries, mining, heavy industries, and food processing and packaging industries. It plays a crucial role in advancing the goals set out in Vision 2030, which aims to reduce dependence on oil revenues and stimulate economic growth.

By emphasizing industrial innovation, attracting investments, and creating job opportunities, JEC has become a vibrant center for petrochemicals, manufacturing industries, logistics, and commerce. The city's strategic location, proximity to global shipping routes, and well-designed infrastructure make it a central player in Saudi Arabia's efforts to expand its

industrial base and enhance international trade capabilities. Jazan Economic City embodies a forward-thinking approach, showcasing Saudi Arabia's commitment to sustainable economic development and lasting prosperity.

1.6.1.2. Economic Cities and Special Zones Authority

The Economic Cities and Special Zones are briefly illustrated below (ECZA, 2023).

King Abdullah Economic City (KAEC) and Special Economic Zone, Rabigh

Situated in Rabigh along the Red Sea Coast, King Abdullah Economic City and Special Economic Zone (KAECSEZ) is one of the prime examples of Vision 2030 and offers a unique opportunity for investment. It offers a number of economic incentives. The KAECSEZ is facilitated by the King Abdullah Port on the Red Sea coast, which was considered by the World Bank as the most effective port in the world, is well-connected through air, road and rail networks, including the Haramain High-Speed Railway. Located just an hour from Jeddah, Holy Cities Makkah, and Al Madinah, KAECSEZ features the "Industrial Valley" designed to function as the city's industrial hub in the pharma, packaging, and Fast-Moving Consumer Goods (FMCG) and ICT sectors hosting more than 2,500 manufacturing and logistics service companies. KAEC accommodates educational and training institutions such as the National Aviation Academy and Prince Mohammad bin Salman College of Business & Entrepreneurship (ECZA, 2023).

Ras Al-Khair Special Economic Zone (RAKSEZ)

Ras Al-Khai Special Economic Zone (RAKSEZ) launched in April 2023 is situated in the Ras Al-Khair industrial city of mining, in a total area of approximately 20 Km^2, on the coast of Arabian gulf is to focus and include four sectors of economy namely marine industries, offshore rigs, floating platforms and offshore services. The zone is situated about 60 km from Jubail industrial city under the Royal Commission of Jubail and Yanbu (RCJY), Jubail project (RAKSEZ, 2023).

Jazan Special Economic Zone (JSEZ)

JSEZ was also launched in April 2023 with a total area of 24.6 Km^2 near the industrial port of Jazan, the biggest port in the region developed for the export of targeted industrial plants in the region and within the boundaries of the first phase of Jazan industrial city of basic and transformational industries. The main industrial sectors of JSEZ are food industries, manufacturing and mining industries and logistics services (JSEZ, 2023).

Cloud Computing Special Economic Zone

Announced in April 2023, this virtual special economic zone is part of King Abdulaziz City of Science and Technology (KACST) and belongs to the cloud computing sector. This SEZ is aimed at digital services with the ability for businesses to build and operate data centers from all over the Kingdom. There is no physical location for this SEZ but it is virtually centered in the innovation tower at KACST (ECZA, 2023).

Riyadh Integrated Special Logistics Zone (RISLZ)

This special logistics zone is situated close to the King Khalid International Airport in Riyadh. The advantage of this location is the close proximity to the air connectivity. The sectors covered by this zone are consumer products, computer parts, pharmaceuticals, nutritional and medical supplies, aerospace spare parts, luxury goods, jewelry and precious metals (ECZA, 2023).

1.7. WATER RESOURCES

One of the world's most water-scarce countries, the Kingdom of Saudi Arabia experiences an average annual rainfall of around 50-100 mm in most parts of the country while the southwestern region received an average of around 300 mm of rainfall. The low and variable rainfall further adds to the water scarcity challenges across the country.

The water resources in the Kingdom fall into four distinct categories: surface water, groundwater, desalinated water, and reclaimed wastewater. These water categories are discussed and elaborated below.

1.7.1. Surface Water

Surface water runoff, because of rainfall, collected in the dams is the primary surface water resource in the Kingdom of Saudi Arabia (KSA). In 2021, the estimated surface water runoff storage capacity was 2.59 billion m^3 with a total number of 574 dams in different parts of the Kingdom. The main purpose of these dams was to combat flooding, provision of drinking water and to recharge the farmer's irrigation wells (MEWA, 2021).

1.7.2. Ground Water

The groundwater sources in the Kingdom are categorized into shallow and deep aquifers. Shallow aquifers are located within alluvium soil, while deep aquifers are formed within sandstone and limestone sediments. These deep rock aquifers have limited natural recharge and are considered non-renewable water resources, established over millennia (Alodah, 2023; Fanack Water, 2021)

1.7.3. Desalinated Water

Saudi Arabia is the largest producer of desalinated water in the world. Approximately 70% of the potable water needs are fulfilled by desalinated water. The total production capacity of desalinated water in the Kingdom in 2022 was 11.5 million cubic meters per day (SWCC Sustainability Report, 2022) from 30 desalination plants and 139 purification stations. The Kingdom is increasing the use of energy efficient and environmentally friendly Reverse Osmosis (RO) technology replacing the energy intensive thermal MSF and MED technologies (SWCC Sustainability Report, 2022).

1.7.4. Reclaimed Wastewater

There were 143 sewage treatment plants in the year 2022. The total volume of sewage treated in these plants was 1.925 billion m^3. A total of 434 million m^3 i.e. 22.55% of treated wastewater was reused (MEWA, 2023). The Kingdom is focusing on the increased utilization of treated sewage effluent (TSE) as an alternative water resource to conserve ground water resources. The goal encompasses raising the percentage of TSE reuse to 25% by 2025 (NWC, 2023).

1.8. TOURISM

Saudi Vision 2030 has provided a roadmap towards achieving sustainable development through social and economic reforms, consisting of 96 objectives across different themes. One of the themes is "tourism and heritage". Therefore, the Kingdom of Saudi Arabia is working towards developing the tourism sector as part of its economic diversification efforts and developing a number Giga projects to position the country as a prominent global tourism destination.

1.8.1. Giga Projects in Development

Saudi Arabia has initiated a range of large-scale tourism projects as a part of its Vision 2030 program. These projects are distinguished by their considerable scale, innovative features, and emphasis on establishing top-tier attractions and experiences. Some of the notable Giga tourism projects in Saudi Arabia are:

1.8.1.1. NEOM

NEOM is an innovative planned city and economic zone. The total planned area of Neom is 26,500 km^2. The city's plans include multiple regions, including a floating industrial complex, global trade hub, tourist resorts and a city powered by renewable energy sources. It was launched in 2017 by HRH Prince Mohammed bin Salman, the Crown Prince and Prime Minister. It foresees a forward-looking destination driven by sustainable energy and cutting-edge technology. While its central emphasis is on innovation and industry, NEOM integrates elements of tourism and leisure to appeal to both business travelers and tourists. The commitment is to provide a variety of top-notch amenities and experiences within NEOM's framework.

1.8.1.2. Red Sea Project

The Red Sea Project, situated along the Red Sea coast, represents an ambitious initiative focused on developing a series of luxury resorts, islands, and entertainment destinations. This comprehensive endeavor includes high-quality beaches, coral reefs, and exceptional natural landscapes. Aspiring to emerge as a global center for sustainable tourism, the Red Sea Project places a significant emphasis on environmental preservation while offering unique and immersive experiences for its visitors.

1.8.1.3. Qiddiya

Qiddiya is an expansive entertainment city currently under development on the outskirts of Riyadh. It will include theme parks, sports facilities, cultural attractions, and various entertainment venues. Qiddiya aims to serve both residents and tourists, positioning itself as a central hub for leisure and entertainment activities within the country.

1.8.1.4. Amaala

Amaala stands as an opulent tourism destination situated on the northwestern coast of Saudi Arabia. Its objective is to provide exclusive experiences encompassing upscale resorts, wellness centers, and cultural attractions. Amaala is dedicated to drawing in discerning travelers seeking luxury and tranquility within an unspoiled natural setting.

1.8.1.5. Diriyah Gate

It is situated in the historical city of Diriyah near Riyadh. The project is dedicated to conserving and showcasing Saudi Arabia's rich cultural and historical legacy. The initiative involves the restoration of historical sites, the establishment of museums, and the hosting of cultural events. Diriyah Gate aspires to attain recognition as a UNESCO World Heritage site (UNESCO, 2023), solidifying its position as a prominent destination for cultural and heritage tourism.

1.8.1.6. AlUla

The AlUla project in Saudi Arabia is a significant initiative aimed at transforming the ancient city of AlUla into a global cultural and heritage destination. AlUla, located in the northwestern

part of the Kingdom, boasts a rich history, with archaeological sites dating back thousands of years. One of the major highlights of the AlUla project is the development of Maraya, an architectural marvel and the largest mirrored building in the world. Maraya serves as a versatile venue for various events, including conferences, exhibitions, and cultural performances.

The project also focuses on preserving and restoring AlUla's historical sites, such as Hegra. Hegra is home to well-preserved tombs and monuments that showcase the Nabataean civilization's architectural prowess. The AlUla project seeks to create sustainable tourism in the region, balancing economic development with environmental conservation.

These extensive tourism initiatives underscore Saudi Arabia's dedication to broadening its economic base and engaging with the international community. Aligned with the overarching vision of augmenting the country's international standing, boosting tourism revenues, and fostering job and investment prospects, these projects are set to reshape the tourism panorama in the region. They aim to provide travelers with a diverse array of distinctive experiences and attractions (Saudi Giga Projects, 2023).

1.9. COASTAL AND MARINE ECOSYSTEM

Saudi Arabia possesses diverse coastal and marine ecosystems along its extensive Red Sea and Arabian Gulf coastlines, which are integral to the nation's biodiversity, fisheries, and tourism sectors. Saudi Arabia has approximately 1,760 km long coastline on the Red Sea and 650 km long coastline on the Arabian Gulf. These coastal and marine ecosystems play a pivotal role in the broader context of the global marine environment. Red Sea is renowned for its unspoiled and vibrant coral reefs and mangrove forests and their diverse marine life including fish, and other invertebrates. Stringent conservation measures are implemented to safeguard the fragility of these ecosystems.

As part of the Saudi Green Initiative (SGI, 2021), Saudi Arabia aims to protect 30% of its terrestrial and marine areas by 2030 compared to 16.9% in 2021. These initiatives underscore Saudi Arabia's unwavering commitment to environmental stewardship and the sustainable management of marine resources.

1.10. AGRICULTURE

The soils in Saudi Arabia are predominantly sandy with low fertility in the arid landscape of Saudi Arabia, where rainfall is low, and water resources are scarce.

Consequently, implementing innovative agricultural technologies and practices, along with ensuring the efficient use of water resources, presents a formidable challenge. Despite these obstacles, achieving sustainable food security remains a top priority. To address these challenges, Saudi Arabia has undertaken extensive projects focusing on date palm cultivation, poultry farming, dairy product production, and aquaculture.

While Saudi Arabia is a net importer of various food items, it also boasts significant exports in the dairy, date, poultry, and vegetable sectors, with notable surpluses observed in dairy products (118%), eggs (117%), and dates (124%). The ratio of self sufficiency for tomatoes reached 67% whereas onions recorded 44% self-sufficiency. Fish self-sufficiency was recorded at 48% in the year 2022 (GASTAT, 2022).

The total agricultural imports in 2022 were recorded to be 29,376 thousand tons with the highest share of grains at 45.2%. The total quantity of agricultural exports reached 3,687 thousand tons in 2022 achieving a growth of 14% compared to 2021.The exports of dairy products, eggs, and natural honey constitute 20.1% out of total agricultural exports in 2022

(GASTAT, 2022).

Saudi Arabia's agricultural landscape is undergoing significant transformations aligned with its predetermined objectives, aiming to achieve sustainable food security in accordance with Saudi Vision 2030. This shift is propelled by the strategic focus on the development of aquaculture, organic farming, and greenhouses within the country.

As a fundamental component of the Saudi Green Initiative, the Kingdom continues its efforts to enhance vegetation cover and address desertification through careful planning of afforestation initiatives nationwide. As of 2022, the cumulative efforts have resulted in the planting of 18 million trees, the rehabilitation of 60,000 hectares of degraded land, and the cultivation of 250,000 shrubs in AlUla nurseries.

In addition, within the framework of the National Program for the Development of fish resources, the Kingdom has strategized to increase fish production to 100,000 tons per year by 2020 and further elevate it to 600,000 tons per year by 2030. This involves the optimal utilization of the Kingdom's natural resources in the domain of fish resources.

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SECTION - 2

Institutional Arrangement

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SECTION 2: Institutional Arrangement

The Kingdom of Saudi Arabia has evolved a robust and functional institutional arrangement for addressing the climate change issues in the country. This institutional arrangement has been effective in preparing and submitting national communications and biennial update reports to the United Nations Framework Convention on Climate Change (UNFCCC).

The Designated National Authority (DNA) has prepared this BUR2 in close coordination and cooperation of a number of relevant national institutions and stakeholders.

His Royal Highness, the Minister of Energy is the Supervisor and Chairman of the National Committee of Clean Development Mechanism. The Committee, which acts as the Designated National Authority is represented by members of national entities from both public and private sectors. Figure 2.1 shows the members of the National Committee.

Figure 2.1: Members of the National Committee

The Designated National Authority acts as the Secretariat of the National Committee headed by the Secretary General and supported by a team of experts and technical and administrative staff.

The responsibilities of the Designated National Authority include (i) Preparing and submitting national communication reports (NCs) and biennial update reports (BURs) under the UNFCCC, preparing and submitting Biennial Transparency Reports (BTRs) and National Inventory Reports (NIRs) to UNFCCC every two years from 2024 onwards under the Paris Agreement; (ii) Developing, coordinating and reviewing the Kingdom's Nationally Determined Contributions; (iii) Implementing and internally reviewing the NDC every year with the relevant stakeholders and follow up and review of the NDC at the international level every five years; (iv) Developing the necessary guidelines for the Enhanced Transparency Framework (ETF) and the global stock-take every five years; (v) Developing the Kingdom's greenhouse gas mitigation mechanisms, and (vi) Taking necessary measures to develop carbon market

mechanism.

The DNA has represented the Kingdom at multiple international forums and is a focal point and active member of many international initiatives such as Mission Innovation (MI), Clean Energy Ministerial (CEM), Green Climate Fund (GCF), Climate Technology Centre & Network (CTCN), Global Methane Initiative (GMI), and Carbon Sequestration Leadership Forum (CSLF) etc.

The following subsections highlight recent key initiatives of DNA.

2.1 GREENHOUSE GAS CREDITING AND OFFSETTING MECHANISM (GCOM)

HRH, the Minister of Energy and Chair of DNA announced the operationalization of Saudi Arabia's voluntary domestic Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) during the Middle East and North Africa (MENA) Climate Week held in Riyadh, Saudi Arabia in October 2023. The operationalization of GCOM was an implementation of the voluntary domestic market mechanism announced in November 2022 at the Saudi Green Initiative Forum during COP27 in Sharm el-Sheikh, Egypt, reflecting the Kingdom's commitment to addressing the climate change issues. The Designated National Authority (DNA) acts as the regulator of GCOM.

The main purposes of GCOM have been to increase cooperation among national entities seeking to fulfill their climate ambitions, mobilize finance in all sectors of the Saudi economy, achieve national emission reduction and/or removal levels in the most cost-effective manner, and drive positive social, environmental, and economic impacts beyond emission reductions and/or removals. GCOM would also help achieve Saudi NDC and net zero emissions by 2060. While issuing carbon credits, the GCOM has been designed to ensure transparency, credibility, and alignment with international standards and to avoid double counting. Additionality is the guiding principle of GCOM.

2.2 CARBON MANAGEMENT SYSTEM

The DNA established a Carbon Management System (CMS) which is a comprehensive platform designed to facilitate a diverse array of analyses crucial for effective carbon management in Saudi Arabia. Tailored to address the complexities of greenhouse gas emissions, the CMS offers a suite of tools encompassing source and sink activity data inventory and analyses. One of its key features is the intuitive interface that facilitates seamless data collection from various stakeholders, ensuring a holistic representation of the carbon landscape. Moreover, the CMS utilizes advanced mathematical formulas to predict emissions, contributing to informed decision-making processes. The establishment of an information bank dedicated to the management of greenhouse gas emissions is an important aspect of CMS. This repository serves as a valuable resource, consolidating knowledge and insights essential for steering environmental initiatives and fostering sustainable practices.

The system allows stakeholders to submit their Nationally Determined Contributions (NDCs), providing a centralized platform for the documentation and tracking of these crucial commitments. By maintaining a comprehensive record of submitted NDCs, the CMS becomes a dynamic tool for monitoring progress, fostering collaboration, and facilitating informed policy decisions.

SECTION - 3

National inventory of anthropogenic emissions by sources and removal by sinks of greenhouse gases not controlled by the Montreal Protocol for the year 2019

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SECTION 3: National inventory of anthropogenic emissions by sources and removal by sinks of greenhouse gases not controlled by the Montreal Protocol for the year 2019

3.1 INTRODUCTION

This section presents the "National inventory of anthropogenic emissions by sources and removal by sinks of greenhouse gases not controlled by the Montreal Protocol for the year 2019". The baseline year of 2019 was selected for the GHG inventory instead of 2020 as the later year was marked by the global COVID-19 pandemic, which caused substantial disruptions across various sectors of the economy including significant reduction in industrial production. Lockdown measures, restrictions on transportation and travel resulted in anomalous levels of greenhouse gas emissions, making it nonrepresentative benchmark year.

This GHG inventory has been prepared in response to the Kingdom's commitment to the United Nations Framework Convention on Climate Change (UNFCCC) to submit its second Biennial Updated Report (BUR) which would include national inventory of anthropogenic emissions and removals by sinks of greenhouse gases for Saudi Arabia. This inventory is prepared according to the 2006 Guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2006).

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 significant potential changes to the global climate. Being a signatory to the UNFCCC, Saudi Arabia has agreed to develop periodic national inventories of greenhouse gas emissions and sinks as a part of its National Communications and Biennial Update Reports. Accordingly, the Kingdom submitted its first, second, third, and fourth national communications in 2005 (PME, 2005), in 2011 (PME, 2011), 2016 (DNA, 2016), and 2022 (DNA, 2022) respectively. The Kingdom submitted its first Biennial Update Report in 2018 (DNA, 2018).

The 2019 national inventory of anthropogenic emissions of greenhouse gases by sources and removal by sinks for the Kingdom of Saudi Arabia was developed according to the 2006 IPCC Guidelines. The major findings, including a brief description of the inventory development process are presented in the following sub-sections.

3.2 OBJECTIVES

As mentioned above, the main objective of this section is to present a national inventory of anthropogenic emissions of greenhouse gases by sources and removal by sinks for Saudi Arabia for 2019 addressing the three direct greenhouse gases i.e., Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) as an integral part of the Kingdom's Second Biennial Updated Report (BUR 2) to the UNFCCC.

3.3 INVENTORY DEVELOPMENT PROCESS

The inventory development process included the following major steps.

- Identification of the types of data to be collected from each emission source category and sub-sectors (under each category) as proposed in the 2006 IPCC Guidelines. Preparation of a list of government ministries and other governmental, semi-governmental, and private sector organizations that were contacted to collect the required information (identification of the inventory data input sources);
- Development of questionnaires or forms to collect the required information from the selected ministries and organizations (development of questionnaires);

- Collection of inventory data from all the selected ministries and organizations (collection of information);
- Tabulation of the collected data;
- Estimation of greenhouse gas emissions/sinks based on methodologies recommended by the 2006 IPCC Guidelines; and
- Development of the national inventory report of the total anthropogenic emissions of greenhouse gases and their removals by sinks.

3.4 DATA COLLECTION, EMISSION FACTORS AND METHODOLOGIES

3.4.1 Preparation of Questionnaires

The 2006 IPCC Guidelines were utilized in the preparation of questionnaires. These guidelines are in five volumes (IPCC, 2006a,b,c,d,e). Volume 1 (IPCC, 2006a) consists of general reporting instructions and identifies sectors, sub-sectors, and categories of activities that are considered in developing a greenhouse gas inventory of sources and sinks. It includes information pertinent to data collection approach, uncertainty analysis approach, methodological choice and identification of key categories, time series consistency, QA& QC and verification, precursors and indirect emissions, and reporting guidance. The remaining four volumes (IPCC, 2006a,b,c,d) provide sector specific guidance.

The 2006 IPCC Guidelines for preparing the greenhouse gas inventory were reviewed thoroughly to identify inventory input data requirements for each of the activities given in the documents. The software and other resources accompanying the 2006 IPCC Guidelines were 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.

3.4.2 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 2006 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 the preparation of this list.

3.4.3 Input Data Sources

The basic information sources prepared during the development of the first (PME, 2005), the second (PME, 2011), the third (DNA, 2016) and the fourth (DNA, 2022) national communications, and the first biennial update report (DNA, 2018) 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.

3.4.4 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.

3.4.5 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 mainly adopted from the 2006 IPCC Guidelines. Calculation methodologies in the 2006 IPCC Guidelines were followed in estimating greenhouse gas emissions in this study.

3.4.6 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 GHG 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 2006 IPCC Guidelines provide detailed information related to uncertainties associated with emission factors and activity data.

Uncertainties in emissions estimation basically come from three major sources: input data, the assumptions used in selecting the emission factors, and adopting interpolated and/or extrapolated 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 IPCC Guidelines (2006) were established for a certain group of activities that comprises several 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 factor. A similar analogy applies to the variation in source and/or sink characteristics in different countries. Therefore, the default emission factor 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 interpolated and/or extrapolated values for a particular set of data. Uncertainty of interpolated and/or extrapolated data cannot be quantified precisely because the uncertainties associated with the interpolation and extrapolation procedures also depend on the quality of the relevant data including data accuracy.

3.4.6.1 Input Data

The raw data provided by the government organizations were assumed to be accurate while the raw data supplied by the private sectors were also considered to be accurate in some cases. Mainly, the 2006 IPCC guidelines were consulted for ascertaining the uncertainty associated with the activity data.

3.4.6.2 Emission Factors

The uncertainties associated with the emission factors used in this study were taken from the 2006 IPCC Guidelines (IPCC, 2006).

3.4.6.3 Overall Emissions Estimation

The uncertainty analysis was conducted following the Approach 1 Uncertainty Calculation for each sector based on 2006 IPCC guidelines. The overall uncertainties of the energy sector and the industrial processes and product use sector (IPPU) are expected to be less than10% and 20%, respectively. The uncertainty of the agriculture sub-sector and waste sector could be high due to the high uncertainty of emission factors. Due to the unavailability of relevant

information, the uncertainty of the forestry and other land-use sub-sectors could not be determined.

3.5 SUMMARY OF OVERALL GREENHOUSE GAS EMISSIONS AND SINKS

3.5.1 Overview of 2019 National Greenhouse Gas Emissions and Sinks

The 2019 greenhouse gas emission inventory for Saudi Arabia is summarized in Table 3.1. The details of estimated greenhouse gas emissions from various activities associated with sub-sectors in each sector are presented in Table 3.2. 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 and product use, agriculture, forestry, and other land-use, and waste sectors in the Kingdom. Greenhouse gas emissions from the various uses of paints and solvents have not been recommended by the 2006 IPCC Guidelines, thus, they were not included in this report. The major findings pertaining to individual greenhouse gases are summarized below.

- CO_2 emissions in Saudi Arabia in 2019 were 610,154.97 Gg and CO_2 sinks were 7,519.7 Gg. As shown in Table 3.1, the energy sector contributed 87.39% of the total CO_2 emissions, followed by the industrial processes and product use sector (12.32%) and the agriculture sub-sector (0.29%). The major source categories contributing to these CO_2 emissions (cumulative contributions ≥ 95% of the total emissions) were electricity generation (25.80%), road transport (21.76%), desalination (18.47%), fuel combustion in petrochemical (4.91%), petrochemical production (4.24%), petroleum refining (4.12%), cement production (3.88%), fuel combustion in fertilizer industry (3.55%), fuel combustion in cement industry (2.48 %), iron and steel production (2.09%), other industries (1.42%), ammonia production (1.32%), fugitive emissions in well testing (0.85%), and residential (0.80%) (Table 3.3).

Table 3.1. Summary of 2019 direct greenhouse gas emissions inventory for Saudi Arabia

Source Sector or Sub-Sector	Quantity Emitted (Gg)		
	CO_2	CH_4	N_2O
Energy*	533,207.40 (87.39) **	290.03 (15.12)	8.90 (29.61)
Industrial processes	75,163.02 (12.32)	127.89 (6.67)	-
Agriculture (sub-sector)	1,784.55 (0.29)	125.16 (6.53)	16.71 (55.61)
Forestry and Other Land-Use (sub-sector)	-7,519.72*** (-1.23)	-	-
Waste	-	1,374.66 (71.68)	4.44 (14.78)
Total Emissions	**610,154.97**	**1,917.74**	**30.05**
Net Emissions****	**602,635.25**	**1,917.74**	**30.05**

* *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 3.2. Overview of 2019 national direct greenhouse gas emissions inventory for Saudi Arabia (CO_2 in Gg, CH_4 and N_2O in ton).

SOURCE AND SINK CATEGORIES	CO_2 (Gg)	CH_4 (tons)	N_2O (tons)
Total National Emissions	**610,154.97**	**1,917,738.38**	**30,053.34**
Net National Emissions	**602,635.25**	**1,917,738.38**	**30,053.34**
1. Energy*	**533,207.39**	**290,025.65**	**8,898.67**
A. Fuel combustion	523,287.23	48,309.45	8,476.72
1. Energy industries	182,606.25	5,354.85	915.60
2. Manufacturing industries and construction	79,051.80	1,885.0	274.79
3. Transport	140,004.96	37,105.66	6,774.67
4. Other Sub-sectors	121,624.22	3,963.94	511.66
B. Fugitive emissions from fuels	9,920.17	241,716.21	421.95
2. Industrial processes and product use	**75,163.0**	**127,894.8**	
A. Mineral products	26,711.9		
B. Chemical industry	34,173.4	127,894.8	
C. Metal production	14,159.2		
D. Lubricant use	118.5		
**3. Agriculture (Sub-Sector) ** **	**1,784.55**	**125,160.57**	**16,711.97**
A. Enteric fermentation		114,959.90	
B. Manure management		9,332.61	1,177.56
C. Agricultural soils			15,511.91
D. Field burning of agricultural residues		868.06	22.51
E. Lime and urea application	1,784.55		
**4. Forestry and other Land-Use (Sub-sector) ** **	**-7, 519.71**	**0.0**	**0.0**
A. Forest land remaining forest land	-2,428.87		
B. Land converted to forest land	-4,014.45		
C. Soil organic carbon changes in mineral soils	-1,076.39		
5. Waste		**1,374,657.31**	**4,442.69**
A. Solid waste disposal on land		609,508.90	-
B. Solid waste composting		1,793.06	107.58
C. Wastewater handling		92,754.87	-
D. Human sewage		-	4,335.11
E. Industrial wastewater		670,600.48	-

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

** *Agriculture and forestry, other land-use sector are two sub-sectors of the agriculture, forestry, other land-use sector.*

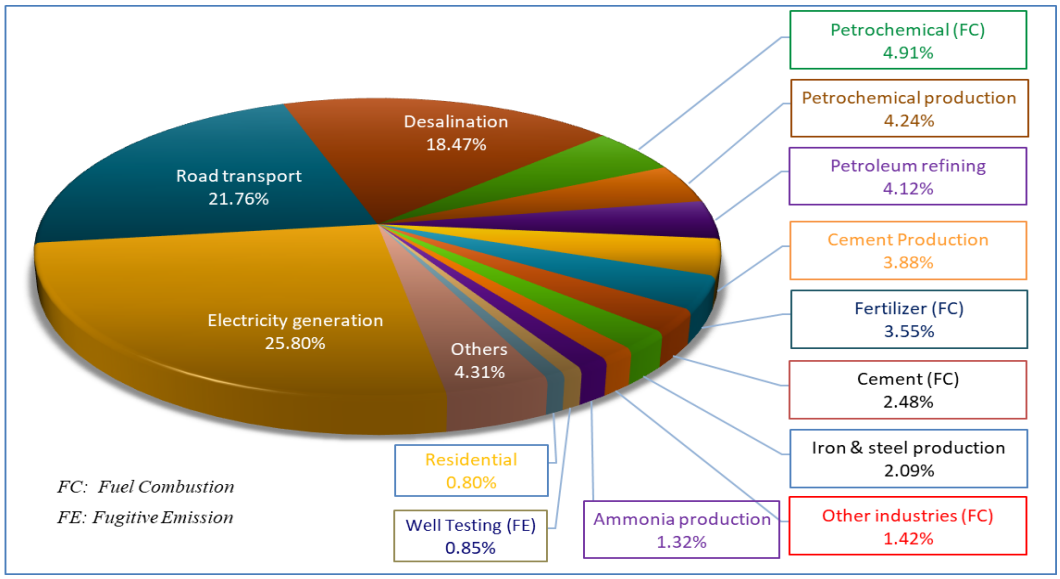

Figure 3.1. Relative contributions of major source categories to 2019 CO_2 emissions of 610,154.97 Gg (data from Table 3.3).

Table 3.3. 2019 carbon dioxide (CO_2) emissions from major source categories.

Source Categories	CO_2 (Gg)	Percent of Total
Electricity generation	157,441.79	25.80
Road transport	132,752.85	21.76
Desalination	112,692.08	18.47
Petrochemical (FC)*	29,930.64	4.91
Petrochemical production	25,879.35	4.24
Petroleum refining	25,164.47	4.12
Cement production	23,684.30	3.88
Fertilizer (FC)	21,648.30	3.55
Cement (FC)	15,129.24	2.48
Iron & steel production	12,728.46	2.09
Other industries (FC)	8,680.90	1.42
Ammonia production	8,063.38	1.32
Well Testing (FE)**	5,170.50	0.85
Residential	4,866.47	0.80
Others ***	26,322.24	4.31
Total	**610,154.97**	**100**

* Fuel Combustion
** Fugitive Emissions
*** Others include the following source categories:
*Oil Production (FE)** (4677.4 Gg)*
Navigation (4268.1 Gg)
Agriculture (FC) (4065.7 Gg)*
Iron and steel (FC) (3662.7 Gg)*
Aviation (2871.9 Gg)
Lime Production (2370.2 Gg)
Lime application (1447.8 Gg)
Aluminum production (1240.9 Gg)
Urea application (336.8 Gg)
Limestone Use (272.6 Gg)
Titanium dioxide Production (230.7 Gg)
Glass Production (218.8 Gg)
Zinc Production (189.8 Gg)
Soda Ash Use (166 Gg)
Lubricant Use (118.5 Gg)
Railways (112.1 Gg)
*Well Drilling (FE)** (57.5 Gg)*
*Gas Processing (FE)** (12.1 Gg)*
*Natural Gas Liquids Transport (FE)** (1.1 Gg)*
*Well Servicing (FE)** (1.1 Gg)*
*Gas Production (FE)** (0.3 Gg)*
*Oil Transport (FE)** (0.2 Gg)*
*Gas Distribution (FE)** (0 Gg)*
*Gas Transmission & Storage (FE)** (0 Gg)*

- CH_4 emissions were 1,917.74 Gg as shown in Table 3.1. The waste sector contributed 71.68% of the total CH_4 emissions followed by the energy sector (15.12%), the industrial processes and product use sector (6.67%) and the agriculture sub-sector (6.53%). The major source categories contributing to CH_4 emissions (≥ 95% of the total emissions) are shown in Figure 3.2.

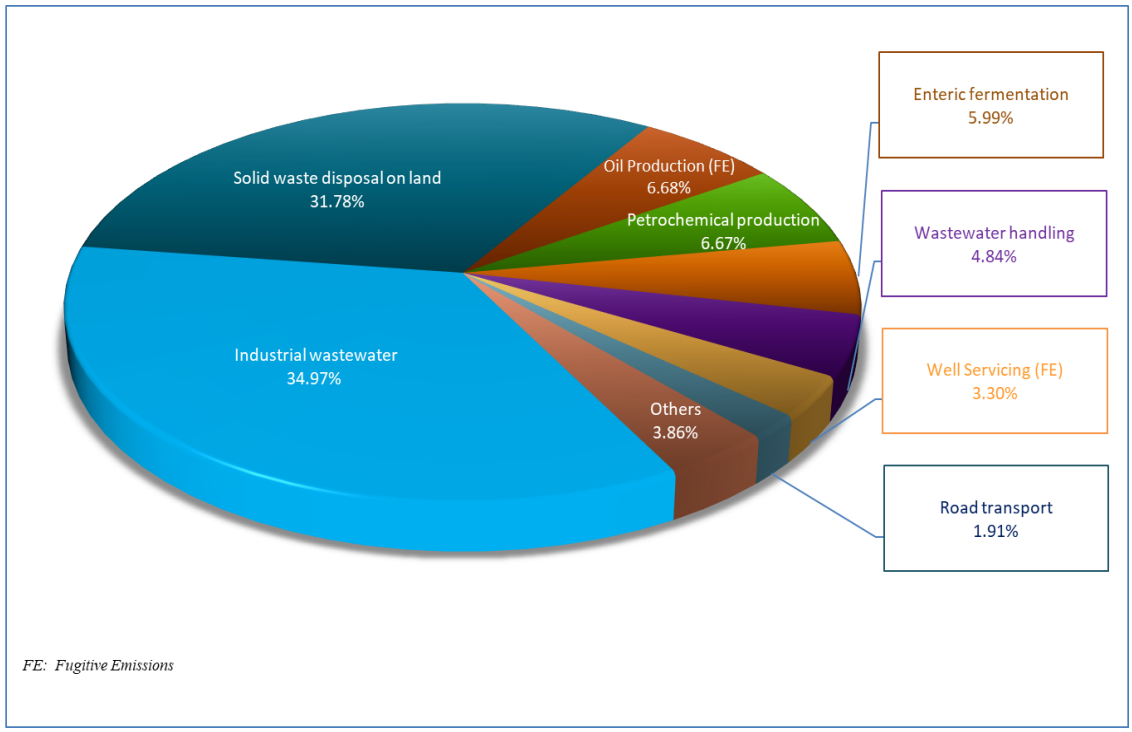

Figure 3.2. Relative contributions of major source categories to 2019 CH_4 emissions of 1,917.74 Gg (data from Table 3.4).

- N_2O emissions were 30.05 Gg as shown in Table 3.1. The agriculture sub-sector was the major contributor to N_2O emissions with 55.61%, followed by the energy (29.61%), and waste (14.78%) sectors. Major source categories contributing to N_2O emissions (≥ 95% of the total emissions) are shown in Figure 3.3.

3.5.2 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.

The uncertainty analysis was conducted following the Approach 1 Uncertainty Calculation for each sector based on 2006 IPCC guidelines. The overall uncertainties of the energy sector and the industrial processes and product use sector are expected to be less than 10% and 20%, respectively. The uncertainty of the agriculture sub-sector and waste sector could be high due to the high uncertainty of emission factors. Due to the unavailability of relevant information, the uncertainty of the forestry and land-use sub-sector could not be determined.

Table 3.4. 2019 methane (CH_4) emissions from major source categories.

Source Categories	CH_4 (ton)	Percent of Total
Industrial wastewater	670,600.48	34.97
Solid waste disposal on land	609,508.90	31.78
Oil Production (FE)	128,094.06	6.68
Petrochemical production	127,894.84	6.67
Enteric fermentation	114,959.90	5.99
Wastewater handling	92,754.87	4.84
Well servicing (FE)*	63,195.06	3.30
Road transport	36,680.02	1.91
Others**	74,050.24	3.86
Total	**1,917,738.37**	**100**

* Fugitive emission
** Others include the following source categories:
*** Fuel Combustion

Well Testing (FE) (29299.5 ton)*
Well Drilling (FE) (18958.5 ton)*
Manure Management (9332.6 ton)
Electricity Generation (4902.8 ton)
Desalination (2932 ton)
Oil Transport (FE) (1860.5 ton)*
Solid Waste Composting (1793.1 ton)
Field Burning of Crop Residues (868.1 ton)
*Cement (FC)*** (549.1 ton)*
*Agriculture (FC)*** (548.7 ton)*
*Petrochemical (FC)*** (533.5 ton)*
Residential (483.3 ton)
Petroleum Refining (452 ton)
Navigation (387.5 ton)
*Fertilizer (FC)*** (385.9 ton)*
*Other Industries (FC)*** (351.2 ton)*
Gas Production (FE) (107.2 ton)*
Gas Distribution (FE) (101.4 ton)*
*Iron and Steel (FC)*** (65.3 ton)*
Gas Processing (FE) (42.8 ton)*
Gas Transmission & Storage (FE) (34.4 ton)*
Aviation (31.9 ton)
Natural Gas Liquids Transport (FE) (22.7 ton)*
Railways (6.3 ton)

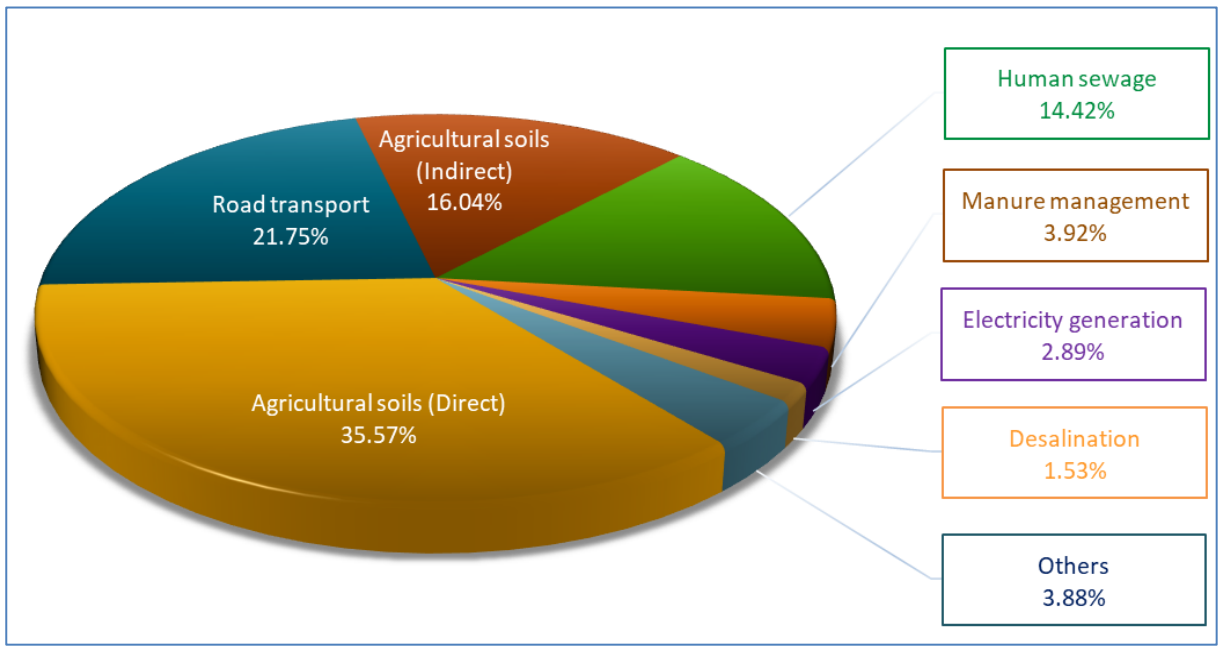

Figure 3.3. Relative contributions of major source categories to 2019 N_2O emissions of 30.05 Gg (data from Table 3.5).

Table 3.5. 2019 nitrous oxide (N_2O) emissions from major source categories.

Source Categories	N_2O (ton)	Percent of Total
Agricultural soils (Direct)	10,691.33	35.57
Road transport	6,535.94	21.75
Agricultural soils (Indirect)	4,820.58	16.04
Human sewage	4,335.11	14.42
Manure management	1,177.56	3.92
Electricity generation	869.79	2.89
Desalination	460.00	1.53
Others*	1,163.03	3.88
Total	**30,053.34**	**100**

* Others include the following source categories
** Fugitive Emission
***Fuel Combustion
*Oil Production (FE)** (367.7 ton)*
Navigation (110.7 ton)
Solid waste composting (107.6 ton)
*Cement (FC)*** (106.1 ton)*
Aviation (84.7 ton)
*Other Industries (FC)*** (70.2 ton)*
*Petrochemical (FC)*** (53.4 ton)*
Petroleum refining (45.8 ton)
Railways (43.3 ton)
*Well Testing (FE)** (39.1 ton)*
*Fertilizer (FC)*** (38.6 ton)*
*Agriculture (FC)*** (32.9 ton)*
Field Burning of Crop Residues (22.5 ton)
Residential (18.7 ton)
*Gas Processing (FE)** (9.3 ton)*
*Iron and Steel (FC)*** (6.5 ton)*
*Gas Production (FE)** (5.9 ton)*

3.6 CONTRIBUTIONS OF MAJOR SECTORAL ACTIVITIES TO 2019 GREENHOUSE GAS EMISSIONS

The contributions of major activities associated with the energy, industrial processes and product use, agriculture, forestry and other land-use and, waste sectors in the Kingdom to the 2019 greenhouse gas emission inventory for Saudi Arabia are presented in Table 3.2. The main findings pertaining to individual greenhouse gases are summarized below.

3.6.1 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 3.4.

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, and agriculture are also accounted for. In addition to the combustion sources, fugitive emissions from fuels in the oil and gas industry were considered.

The emissions of CO_2, CH_4 and N_2O from various activities in the energy sector were estimated and are summarized in Table 3.2. The total CO_2, CH_4 and N_2O emissions from this sector were 533,207.4 Gg, 290.03 Gg, and 8.90 Gg, respectively.

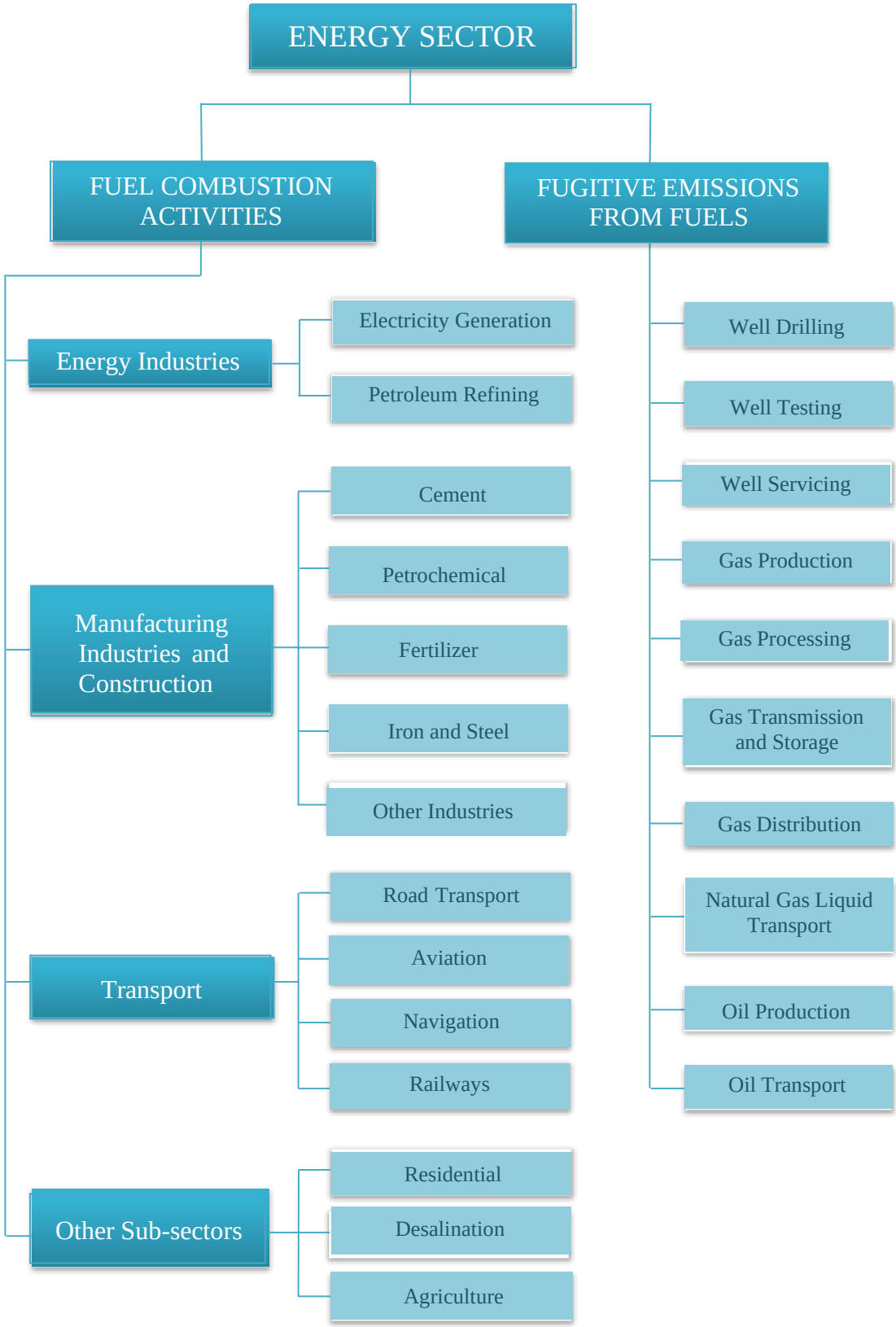

Figure 3.4. Activities considered in the energy sector.

3.6.1.1 Emissions from Fuel Combustion

- Emissions from the **electricity generation** category were 157,441.8 Gg CO_2 (Table 3.3), 4.9 Gg CH_4 (Table 3.4), and 0.87 Gg N_2O (Table 3.5). Natural gas combustion accounted for 39.47% of CO_2 emissions, followed by residual fuel oil (29.66 %), crude oil (24.96 %), and diesel oil (5.91 %). Combustion of residual fuel oil, crude oil, natural gas, and diesel oil contributed 36.9 %, 32.8 %, 22.6 %, and 7.7 %, of CH_4 emissions, respectively. About 41.63 % of N_2O emissions were contributed by the combustion of residual fuel oil, followed by the combustion of crude oil (36.97 %), natural gas (12.74 %), and diesel oil (8.66 %).

- 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 25,164.5 Gg CO_2 (Table 3.3), 0.45 Gg CH_4 (Table 3.4), and 0.046 Gg N_2O (Table 3.5). Fuel combustion associated with oil refining activities was the major contributor to CO_2 emissions. The oil refining and the oil and gas production activities were the major contributors to CH_4 and N_2O emissions.

- 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 79,051.8 Gg CO_2 (Table 3.3), 1.89 Gg CH_4 (Table 3.4), and 0.28 Gg N_2O (Table 3.5). Activities related to the petrochemical, fertilizer, cement, and iron & steel 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.

- The **road transportation** category was one of the major sources of greenhouse gas emissions. Automobiles emitted 132,752.8 Gg CO_2 (Table 3.3), 36.68 Gg CH_4 (Table 3.4), and 6.54 Gg N_2O (Table 3.5). Gasoline combustion was the major contributor to the emissions of the three direct greenhouse gases.

- The **aviation** category was divided into national and international aviation combustion sources. The greenhouse gas emissions from national aviation combustion sources were 2,871.9 Gg CO_2 (Table 3.3), 0.03 Gg CH_4 (Table 3.4), and 0.08 Gg N_2O (Table 3.5). The emissions from international aviation combustion sources were 8,604.4 Gg CO_2, 0.05 Gg CH_4, and 0.25 Gg N_2O. The emissions from the combustion for international aviation category were not included in the 2019 greenhouse gas emissions inventory as per the 2006 IPCC Guidelines.

- The **navigation** category was divided into national and international bunker combustion sources. The emissions from national bunker combustion sources (including fisheries activities) were 4,268.1 Gg CO_2 (Table 3.3), 0.39 Gg CH_4 (Table 3.4), and 0.11 Gg N_2O (Table 3.5). The emissions from international bunker combustion sources were 10,500.3 Gg CO_2, 0.95 Gg CH_4, and 0.27 Gg N_2O. The emissions from the international combustion for navigation category were not included in the 2019 greenhouse gas emissions inventory as per the 2006 IPCC Guidelines.

- The emissions from the **railways activities** relate to the combustion of diesel oil. Emissions from fuel combustion in the railways activities category were 112.1 Gg CO_2 (Table 3.3), small quantities (<0.01 Gg) of CH_4 (Table 3.4), and 0.04 Gg of N_2O (Table 3.5).

- The **residential activities** relate to the combustion of liquefied petroleum gas. Emissions from fuel combustion in the residential activities category were 4,866.5 Gg CO_2 (Table 3.3), 0.48 Gg CH_4 (Table 3.4), and <0.01 Gg N_2O (Table 3.5).

- The **desalination** plants combust heavy fuel oil, crude oil, diesel oil, and natural gas. Emissions from fuel combustion in the desalination plants category were 112,692.1 Gg CO_2 (Table 3.3), 2.93 Gg CH_4 (Table 3.4), and 0.46 Gg N_2O (Table 3.5).

- 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 4,065.7 Gg CO_2 (Table 3.3), 0.55 Gg CH_4 (Table 3.4), and 0.03 Gg N_2O (Table 3.5).

3.6.1.2 Fugitive Emissions from Fuels

Fugitive emissions from fuels were the major source of CH_4 in the energy sector (83.5%). Approximately 91.26% of CH_4 emissions in this sector were generated from oil production, well servicing, and well testing. Activities related to, well drilling, oil transport, gas production, gas distribution, gas processing, gas transmission and storage, and natural gas liquid transport accounted for about 8.74% of CH_4 emissions in this sector. Road transportation accounts for 12.7% of the total emission. Total fugitive CO_2 emissions were 9,920.17 Gg.

The relative contributions of the major activities (cumulative contributions ≥ 95% of the sectoral total) to CO2, CH4, and N2O emissions in the energy sector are presentedin Figures 3.5, 3.6, and 3.7, respectively.

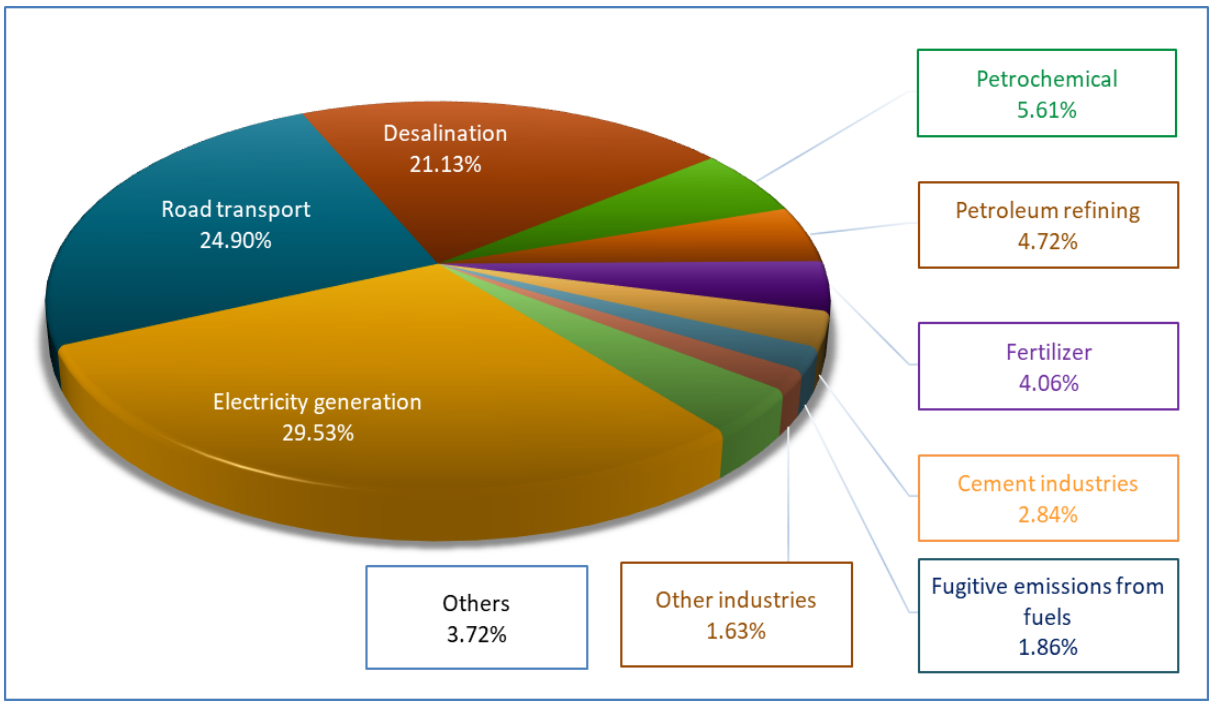

Figure 3.5. Relative contributions of major activities to 2019 CO_2 emissions from energy sector.

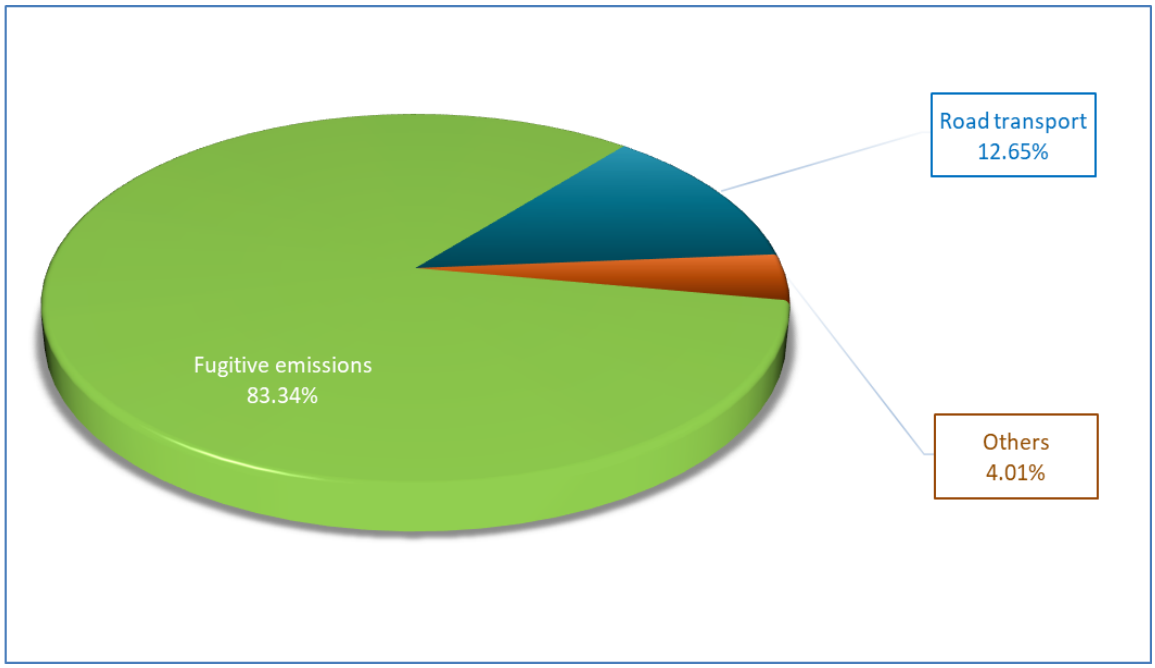

Figure 3.6. Relative contributions of major activities to 2019 CH_4 emissions from energy sector.

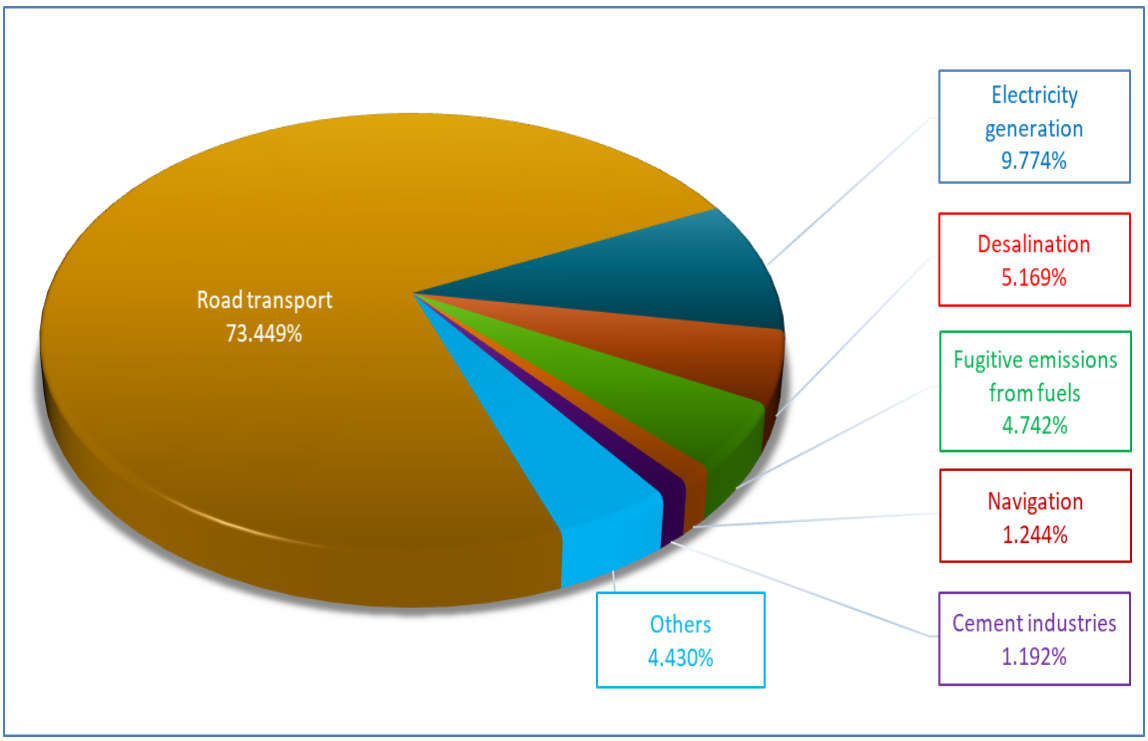

Figure 3.7. Relative contributions of major activities to 2019 N_2O emissions from energy sector.

3.6.2 Industrial Processes and Product Use 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, lime production, glass production, limestone uses, soda ash uses, ammonia production, titanium dioxide production, chemicals production, iron and steelmanufacturing, aluminum production,

zinc production, and lubricant use are some of the important activities of the Saudi industrial sector that are considered in this section.

The major source categories in industrial processes from which greenhouse gas emissions have been estimated are presented in Figure 3.8.

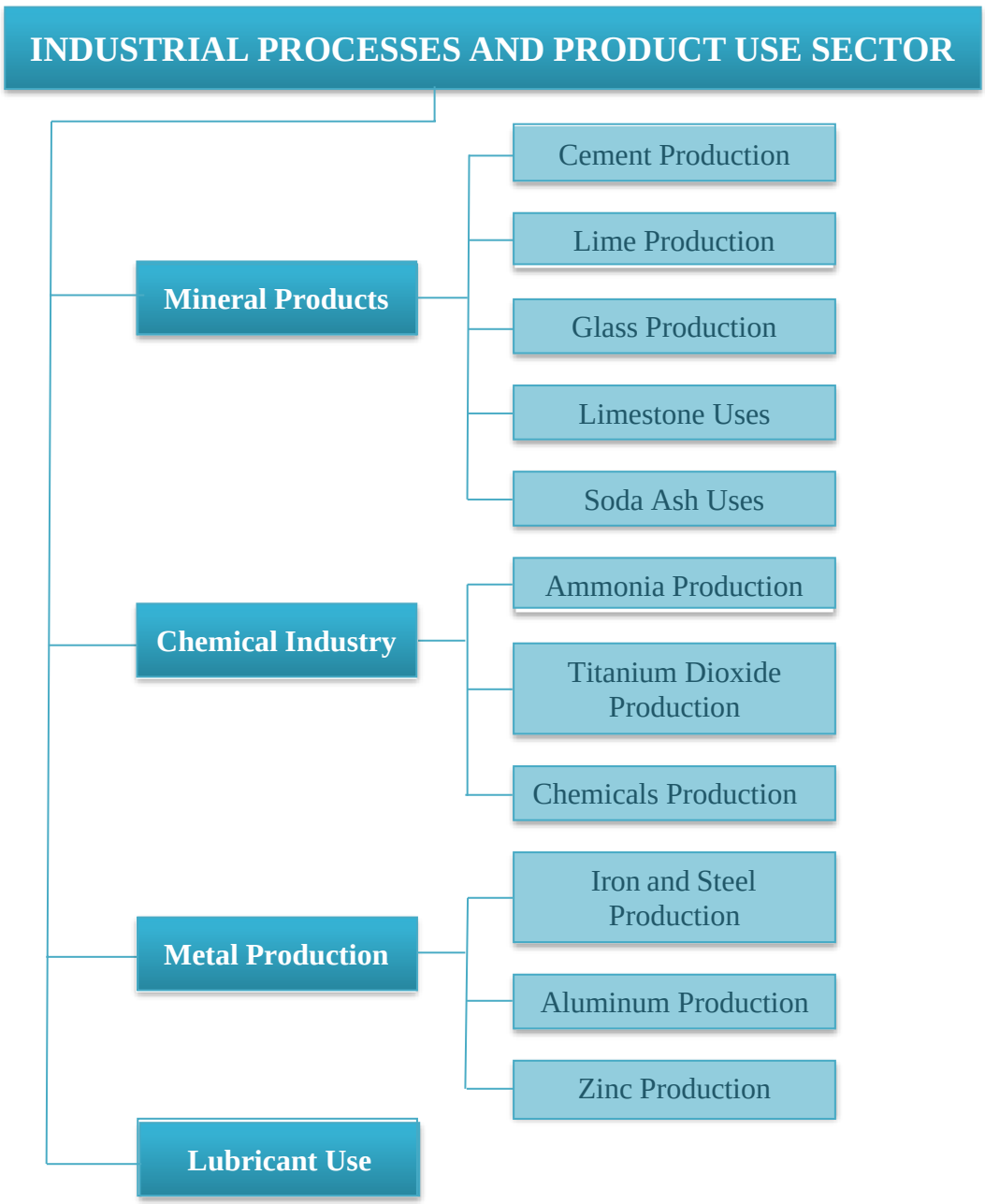

Figure 3.8. Activities considered in the industrial processes and product use sector.

The emissions of CO_2, CH_4, and N_2O from various industrial processes were estimated and are summarized in Table 3.2. A total of 75,163.0 Gg of CO_2 was emitted from chemical industry (45.466%), mineral products (35.539%), metal production (18.838%), and lubricant use (0.158%). Petrochemical production emitted the highest amount of CO_2 (34.43%) followed by cement production (31.51%), iron and steel production (16.93%), and ammonia production (10.73%).

The chemicals production was the sole contributor of 127.89 Gg of CH_4 emissions in this sector. No N_2O was emitted from this sector.

The relative contributions of the major activities (cumulative emissions ≥ 95% of the sectoral total) to CO_2 emission in the industrial processes and product use sector are presented in Figure 3.9.

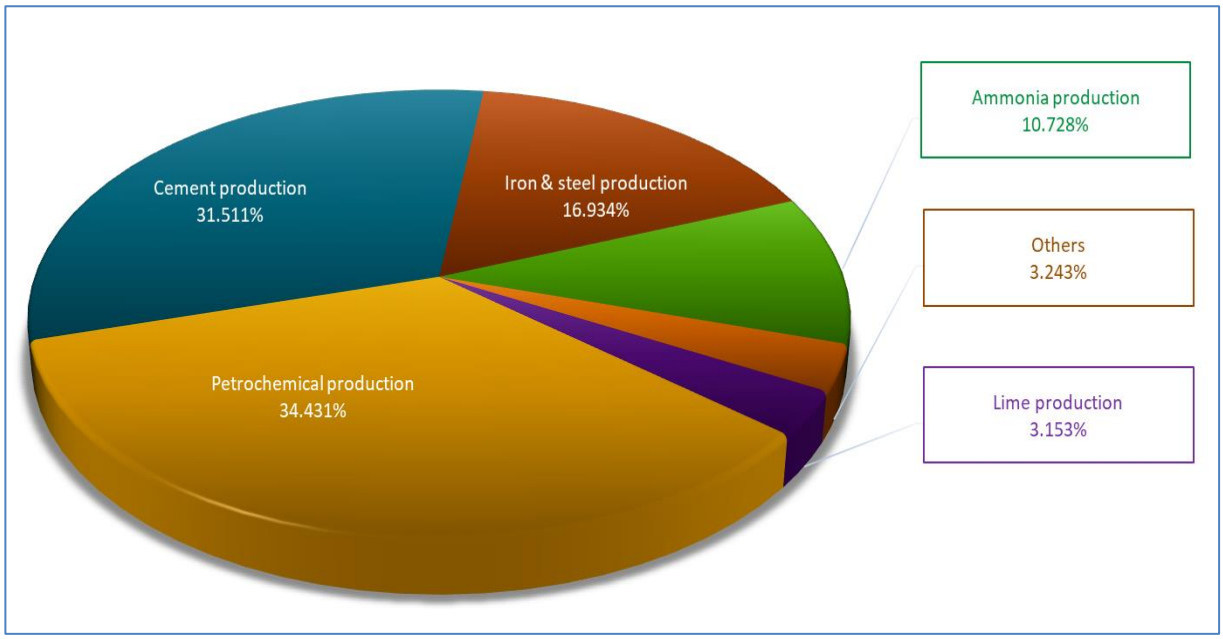

Figure 3.9. Relative contributions of major activities to 2019 CO_2 emissions from industrial processes and product use sector.

3.6.3 Agriculture, Forestry, and Other Land Use Sector

3.6.3.1 Agriculture Sub-Sector

Saudi Arabia is a desert country. A shortage of good quality irrigation water is the foremost limitation. The 2006 IPCC Guidelines recommended agricultural activities for use in estimating greenhouse gas emissions are presented in Figure 3.10.

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 sub-sector are presented in Table 3.2. The total CO_2, CH_4, and N_2O emissions from various activities of the agriculture sub-sector were 1,784.55 Gg, 125.16 Gg, and 16.71 Gg, respectively.

The CH_4 emissions from enteric fermentation, manure management, and field burning of crop residues were estimated at 114.96 Gg, 9.33 Gg, and 0.87 Gg, respectively. The N_2O emissions from agricultural soils (direct and indirect), manure management, and field burning of crop residues were estimated at 15.51Gg, 1.18 Gg,and 0.02 Gg, respectively. Lime and urea application emitted 1,784.55 Gg CO_2.

Enteric fermentation, manure management and field burning of crop residues contributed

91.85 %, 7.46 %, and 0.69% to the total CH_4 emissions from the agriculturesector, respectively. Agricultural soils accounted for 92.82 % of the total N_2O emissionsin the agriculture sub-sector followed by 7.05% from manure management. The emission from lime and urea application was the sole source of CO_2 in the agriculture sub-sector.

The relative contributions of the major activities (cumulative emissions ≥ 95% of the sectoral total) to CH_4 and N_2O emissions in the agriculture sub-sector are presented in Figures 3.11 and 3.12, respectively.

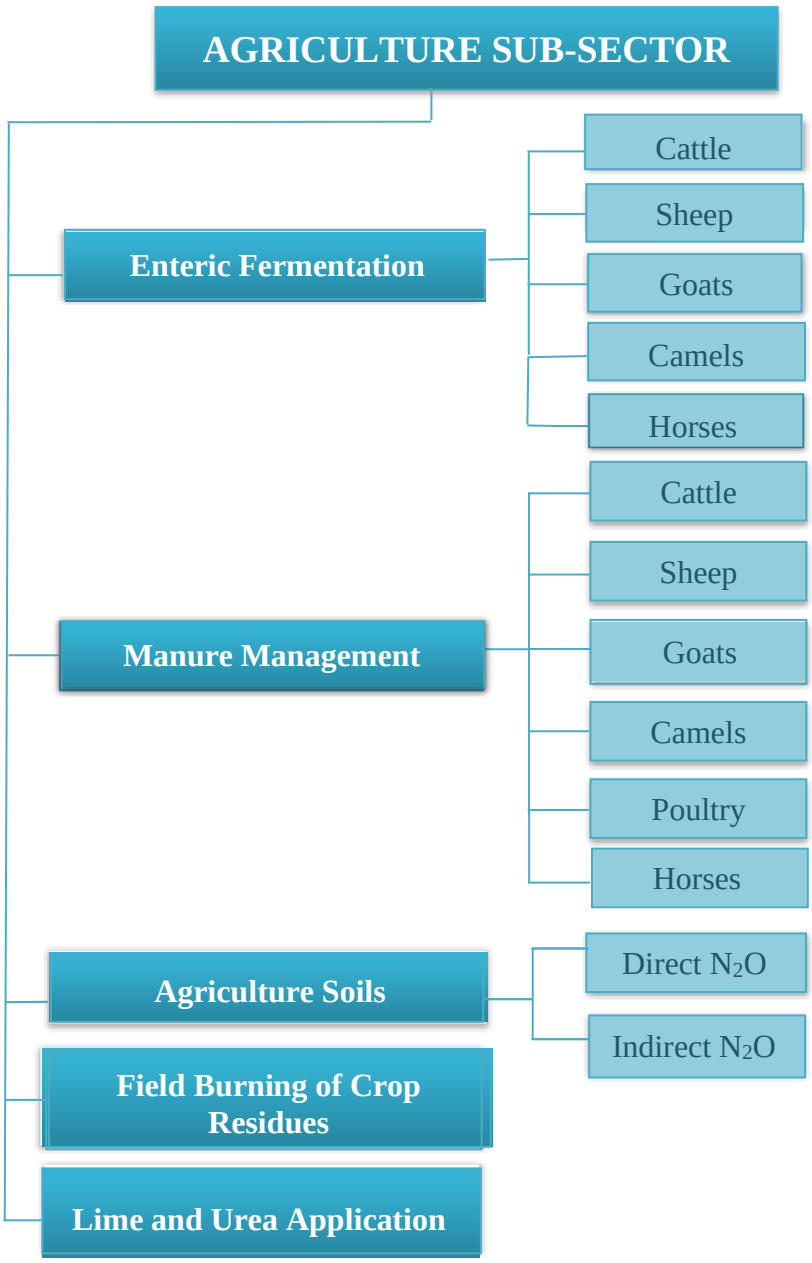

Figure 3.10. Activities considered in the agriculture sub-sector.

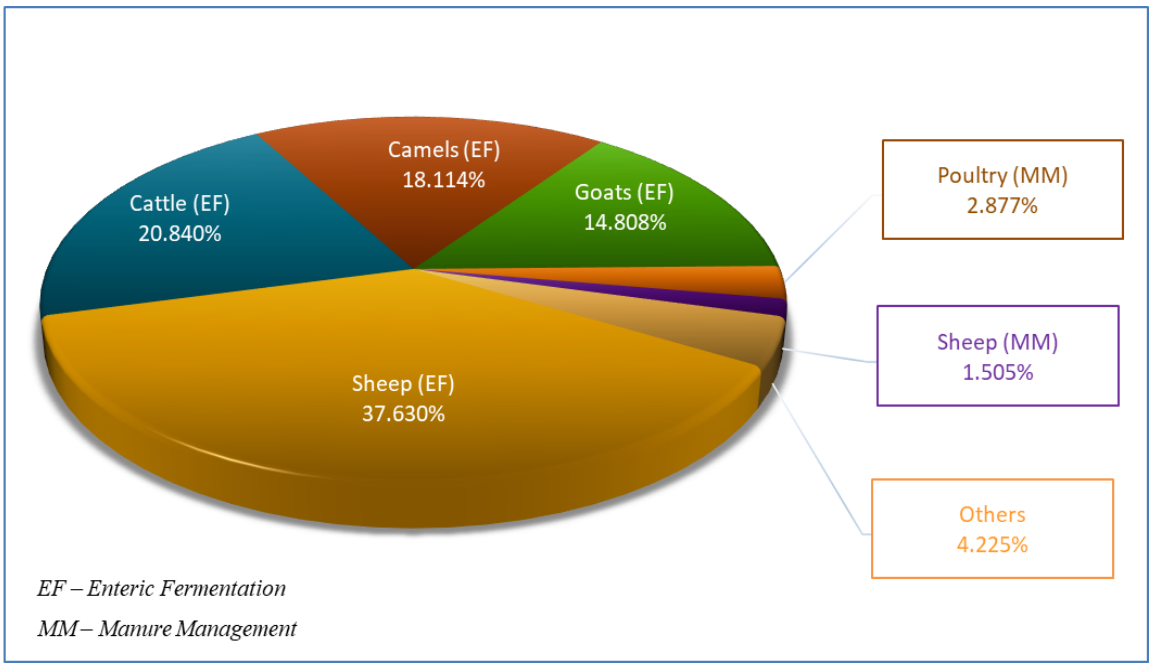

Figure 3.11. Relative contributions of major activities to 2019 CH_4 emissions from agriculture sub-sector.

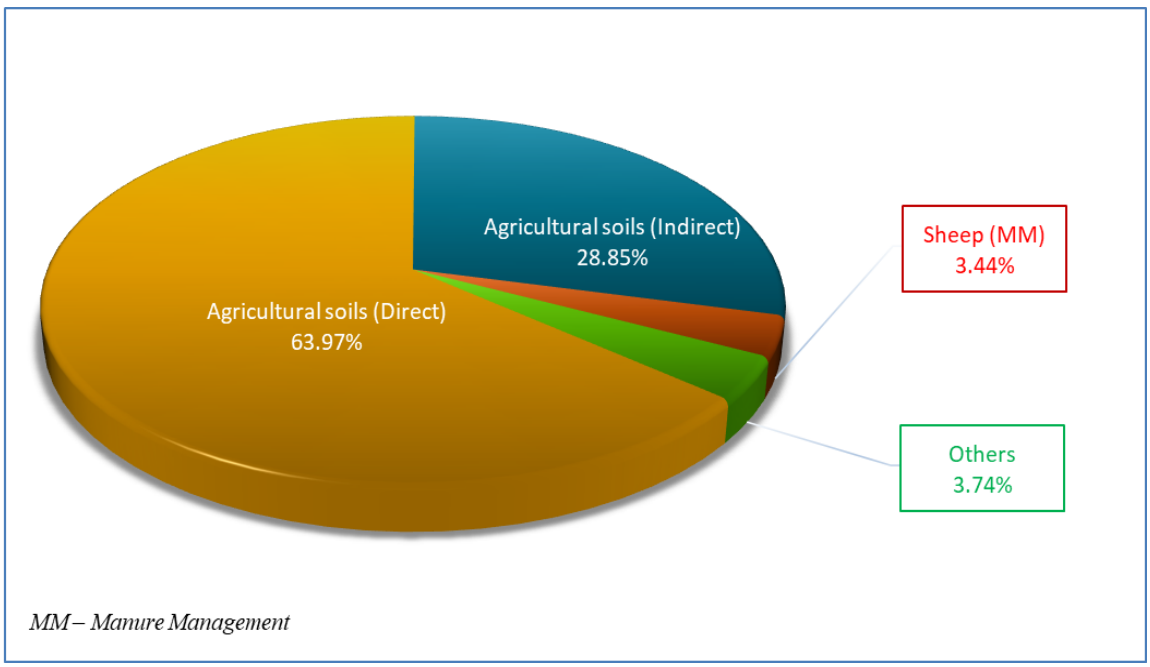

Figure 3.12. Relative contributions of major activities to 2019 N_2O emissions from agriculture sub-sector.

3.6.3.2 Forestry and Other Land-Use Sub-Sector

Calculations of emissions from forestry and other land-use focus upon three activities (Figure 3.13) that are sources or sinks of CO_2. Activities considered in this section include forest land remaining forest land, land converted to forest land, and changes in carbon stock in mineral soils. The estimated greenhouse gas emissions from this sector are presented in Table 3.2.

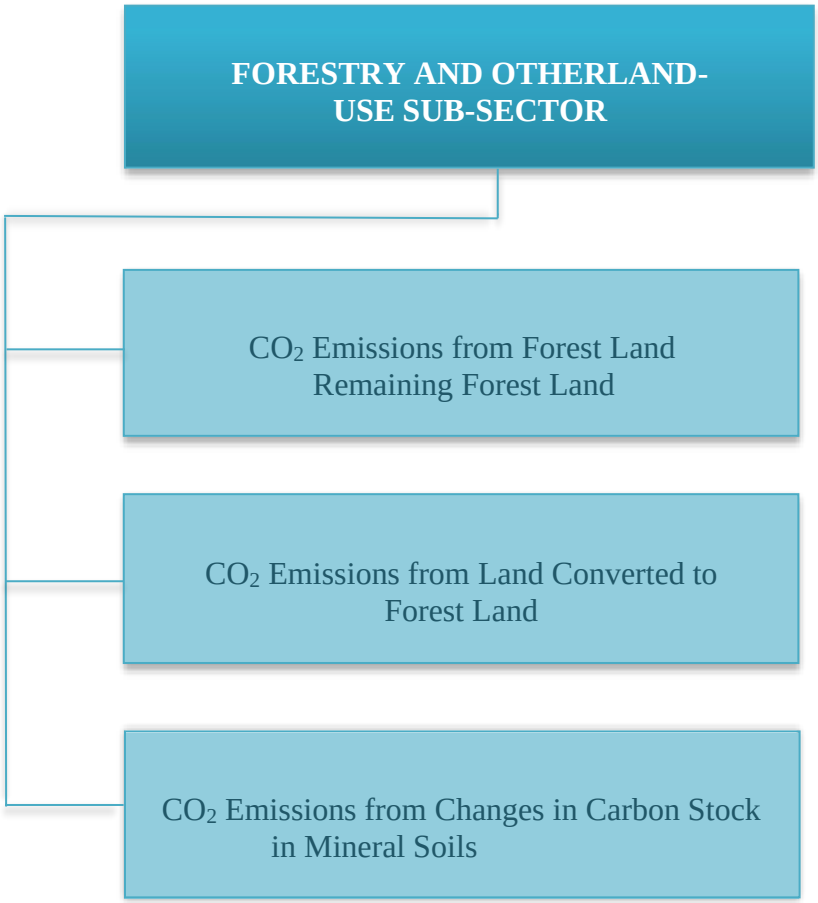

Figure 3.13. Activities considered in the forestry and other land-use sub-sectors.

Sinks

- A total of 7,519.7 Gg of CO_2 sink was estimated from various activities related to this sector.
- Forest land remaining forest land provided a sink for 2,428.9 Gg of CO_2.
- Land converted to forest land captured 4,014.5 Gg of atmospheric CO_2 to plant material (acting as a sink for CO_2).
- Soil Organic Carbon changes in mineral soils CO_2 emissions and removals resulting from C stock changes in mineral soil for 1,076.4 Gg of atmospheric CO_2.
- 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.

- 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.

Emissions

- No significant emissions of CO_2 from the forestry and other land-use sub-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 forestry and other land- use sub-sector are presented in Figure 3.14.

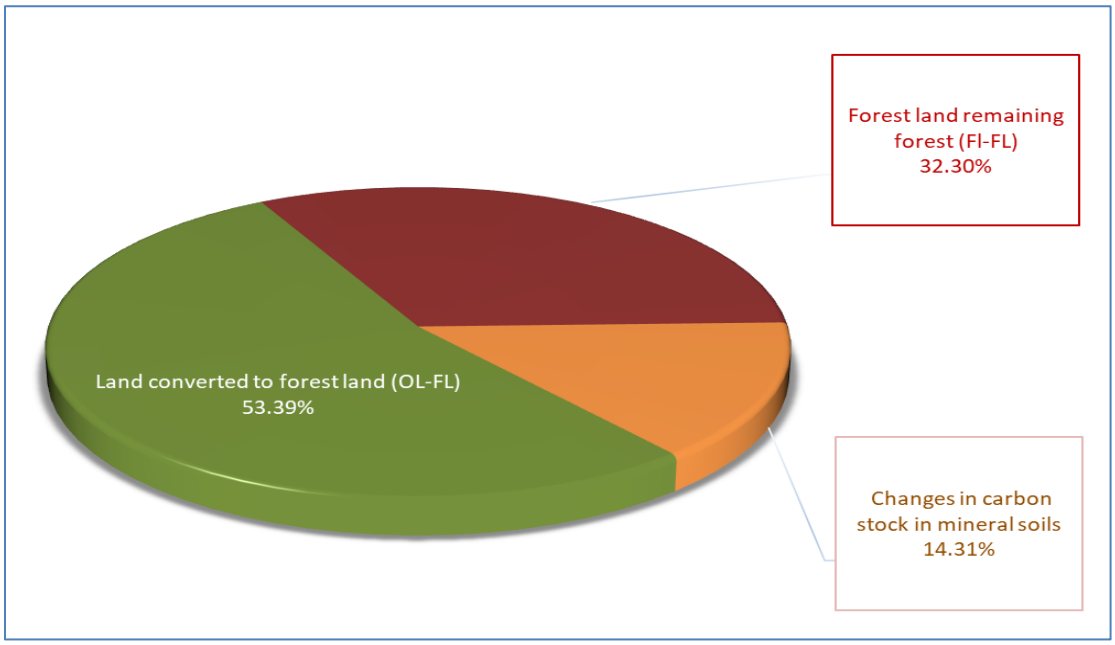

Figure 3.14. Relative contributions of the major sinks to 2019 CO_2 emission from forestry and other land-use sub-sector.

3.6.4 Waste Sector

The 2006 IPCC Guidelines recommend consideration of greenhouse gas emissions from landfilling of solid wastes, treatment of liquid wastes (wastewater), and waste incineration activities. Solid waste and wastewater disposal practices are considered in this section. The activities considered in the waste sector are shown in Figure 3.15. The emission estimations are summarized in Table 3.2.

The total CH_4 and N_2O emissions from various activities of this sector were 1,374.66 Gg and 4.44 Gg, respectively. Solid waste disposal on land emitted 609.51Gg of CH_4. Industrial and municipal wastewater handling emitted 670.6 and 92.75 Gg of CH_4, respectively. N_2O emissions from human sewage and solid waste and solid waste composting were estimated to be 4.34 Gg and 0.11 Gg, respectively. Industrial wastewater handling contributed 48.78 % of total CH_4 in the waste sector followed by solid waste disposal (44.34%), municipal wastewater handling (6.75%) and solid waste composting (0.13%).

The relative contributions of various activities to CH_4 emission in the waste sector are presented in Figure 3.16.

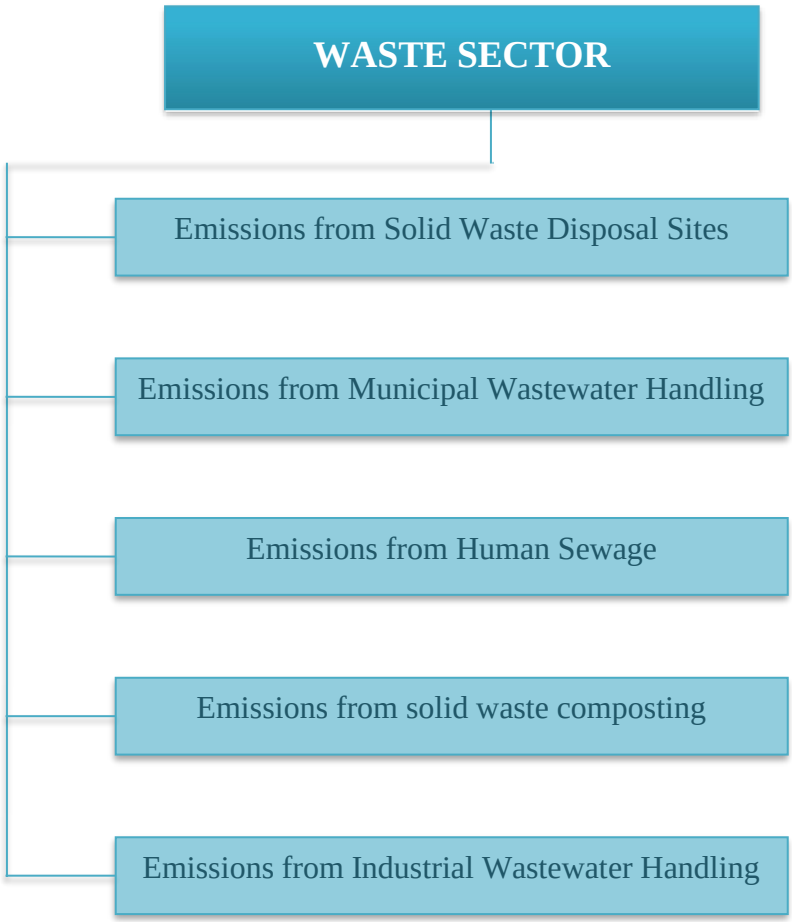

Figure 3.15. Activities considered in the waste sector.

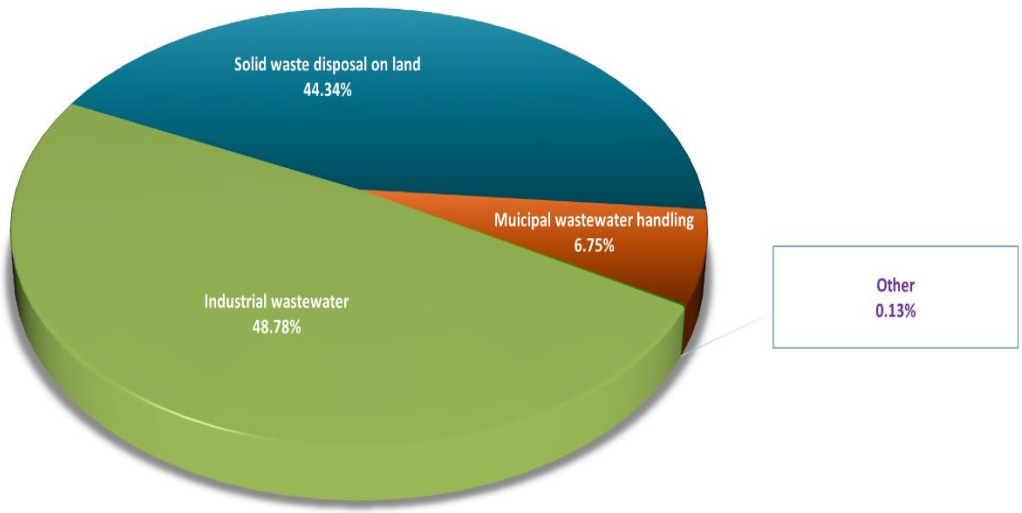

Figure 3.16. Relative contributions of various activities to 2019 CH_4 emissions from the waste sector.

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SECTION - 4

Impact of Climate Change Response Measures – Role of Economic Diversification as a Tool

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SECTION 4: Impact of Climate Change Response Measures – Role of Economic Diversification as a Tool

4.1 INTRODUCTION

The Kingdom of Saudi Arabia recognizes the need of a comprehensive and integrated approach to mitigate the adverse impacts of climate change response measures. Economic diversification, particularly in the context of resource-dependent countries, offers a pathway to reduce vulnerability to climate variability and market fluctuations. This section provides an update of the Fourth National Communication Report (NC4) particularly focusing on the sections related to climate change response measures.

Reminding of the importance of shifting economic paradigms, the First Biennial Update Report (BUR1) provided an in-depth analysis of economic diversification, particularly in the context of Saudi Arabia's climate change initiatives. It begins with defining economic diversification as a multifaceted process that involves moving away from a reliance on primary sectors to a more varied industrial and service-oriented economic structure. It discusses various theories that support economic diversification, highlights the drivers such as economic reforms and macroeconomic variables, and analyzes different dimensions like vertical and spatial diversification. It also outlines Saudi Arabia's specific challenges and responses, including its Nationally Determined Contribution (NDC), which integrates economic diversification to combat climate change, aligning with its Vision 2030.

Recalling the complexities of global climate change mitigation efforts, the NC4 analyzed the socioeconomic impacts of response measures. It acknowledges that while Greenhouse Gas (GHG) emission reductions carry a global benefit, they also impose economic costs that can hinder the ambitions of developing countries to pursue sustainable development, as per the principles of the UNFCCC. It emphasizes Saudi Arabia's stance on ensuring that international climate actions support the economic and social development of developing countries, highlighting the intricate balance between achieving the objectives of the Paris Agreement and Sustainable Development Goals (SDGs). It also stresses the importance of a multilateral approach to climate change, recognizing the need to understand and mitigate the adverse social and economic impacts that response measures may have. It identified several potential risks of increasing international inequality if the negative impacts are not carefully considered and addressed, advocating for a conscientious and well-planned engagement at all policy-making stages to mitigate these impacts.

4.2 APPROACH

The Kingdom’s approach to mitigating the adverse impacts of climate change and climate change response measures is multifaceted, integrating policy development, economic diversification, and various strategic initiatives. Central to this approach is the Saudi Vision 2030, a comprehensive plan focusing on economic diversification and reducing dependence on single resource. This vision is complemented by the Saudi Green Initiative and the Middle East Green Initiative.

Key elements of policy development include the Nationally Determined Contributions (NDC). The Circular Carbon Economy (CCE) approach, another significant initiative, promotes the efficient use of resources and the reduction of carbon emissions. Economic diversification initiatives are outlined, focusing on energy efficiency, renewable energy including green

hydrogen, Carbon Capture, Utilization, and Storage (CCUS) including blue hydrogen, methane management, and utilization of gas. Climate change adaptation initiatives include water and wastewater management, marine protection, and efforts to combat desertification and support afforestation. Urban planning initiatives like the NEOM Smart City project emphasize a commitment to sustainable development and enhance climate change adaptation and resilience. These comprehensive measures demonstrate Saudi Arabia's proactive stance in addressing climate change while pursuing economic growth and sustainability.

4.3 POLICY INITIATIVES

4.3.1 Saudi Vision 2030

In April 2016, the Kingdom of Saudi Arabia launched "Saudi Vision 2030" aimed at diversifying Saudi Arabia's economic structure to lessen the reliance on single resource, thereby supporting its resilience and sustainability (Guendouz and Ouassaf, 2020; Vision 2030 Kingdom of Saudi Arabia). This vision serves as a blueprint for sustainable development, boosted by a suite of social and economic reforms. It is articulated through 96 strategic targets derived from three pivotal principles of Saudi Vision 2030: fostering a Vibrant Society, cultivating a Thriving Economy, and building an Ambitious Nation. The vision's strategic plan prioritizes supporting service sectors such as healthcare, education, infrastructure, and tourism, which in turn is expected to increase employment and diversify the economic landscape. A critical objective under this vision is to increase the proportion of non-oil exports in the non-oil GDP from 16% to 50% (Vision 2030, KSA). Despite the significant disruptions caused by the COVID-19 pandemic, the Kingdom maintains a steadfast commitment to its economic diversification and sustainable development efforts. Saudi Arabia has initiated several large-scale projects including NEOM, AMAALA, AL-ULA, Qiddiya, the Red Sea Project, and the Prince Mohammad bin Salman Nature Reserve to further this agenda (Tricaud, 2020).

The Smart Government Strategy (2020-2024) of the Kingdom of Saudi Arabia presents a comprehensive framework for the digital transformation of the government, in accordance with the United Nations Sustainable Development Goals (SDGs) and the Saudi Vision 2030. The proposed strategy endeavors to transform the government into an agile, capable, and innovative entity by the year 2024, with a focus on providing seamless experiences that prioritize the requirements of beneficiaries. The objectives encompass the provision of a cohesive and exceptional smart service encounter on a global scale, equipping public officials with state-of-the-art competencies, enabling leaders to effectively tackle forthcoming obstacles, cultivating a digitally proficient workforce, expediting digital endeavors through collaborative alliances, and maximizing the efficient allocation of resources. The plan demonstrates a dedication to constructing a cohesive Smart Government that addresses the varied requirements of individuals, inhabitants, visitors, and enterprises.

The National Transformation Program, spanning 2016-2025, aims to facilitate Vision 2030 by enhancing infrastructure, achieving governmental excellence, fostering digital transformation, supporting the private sector, and promoting social development (National Transformation Program Delivery Plan 2021-2025). The first phase (2016-2020) saw significant accomplishments, and the current phase (2021-2025) focuses on sustaining vital resources, improving the labor market, and furthering the goals of Vision 2030 through public-private collaboration (Smart Government Strategy, 2020-2024).

4.3.2 Saudi Green Initiative

The SGI, inaugurated under the auspices of HRH Prince Mohammed bin Salman bin

Abdulaziz, Crown Prince, and Prime Minister, was unveiled in Riyadh during the Saudi Green Initiative Forum in October 2021. This initiative represents a comprehensive national effort to consolidate sustainability activities across the Kingdom, enhance the use of clean energy, address climate change, and fulfill the nation's climate goals. The initial batch of over sixty initiatives launched at the Forum under the SGI is set to boost the green economy. Among the key measures of the SGI are:

(i) **Updated Nationally Determined Contribution (NDC):** In 2021, Saudi Arabia updated its NDC, to remove, avoid, and reduce GHG emissions by 278 million tons of CO_2eq by 2030, which marks a substantial escalation from its former NDC presented in November 2015. The revised NDC relies on dynamic baseline indicating ongoing progression and ambition.

(ii) **Adjusting the Energy Mix:** Saudi Arabia intends to adjust its power sector's energy composition to a balance of 50% from renewable sources and 50% from thermal power stations utilizing gas by 2030. A strategy is in place to substitute 95% of liquid fuels with gas wherever feasible by 2030 in utilities, industries, and agriculture, leading to savings of roughly one million barrels of oil equivalent daily, with benefits for the climate, environment, and economy.

(iii) **Global Methane Pledge**: The Kingdom engaged to the Global Methane Pledge, aiming to reduce global methane emissions by 30% by 2030 compared to the levels in 2020, positioning Saudi Arabia as a leader in climate initiatives (GMI-2023).

(iv) **Clean Hydrogen Production:** Saudi Arabia plans to become the largest producer and exporter of Clean Hydrogen globally by producing 4 MTPA of clean Hydrogen. This will contribute to achieve the NDC ambitions and the Net-Zero Pledge by 2060.

(v) **Carbon Capture Utilization & Storage (CCUS):** The Kingdom is building a CCUS hub for capturing 9 million tons per annum of CO_2 and converting this CO_2 into useful products or stored deep underground starting 2027 (Aramco, 2024).

(vi) **Waste Management:** As a part of the SGI, the Kingdom declared an impressive 94% rerouting of Riyadh's domestic waste away from landfills towards recycling and composting, which is anticipated to lessen GHG emissions and produce electricity. This strategy may be extended throughout the Kingdom in the future. An integrated technical and economic plan will be developed for the Kingdom to divert 90% of waste from landfills by 2040, and effectively implement the principles of circular economy. The plan encompasses various waste types, including municipal solid waste, construction and demolition waste, healthcare waste, marine waste, agricultural waste, green waste, industrial waste, and sludge waste.

(vii) **Reforestation Efforts:** The ambition is to plant 450 million trees across Saudi Arabia by the year 2030.

(viii) **Conservation of Natural Habitats:** The SGI also includes a plan to augment the marine and terrestrial protected regions within the Kingdom to more than 20% by 2030, aiming to support biodiversity and safeguard natural landscapes and marine environments.

These initiatives will be implemented through a circular carbon economy (CCE) model,

proactive international collaboration, and early advances in technology and low-carbon fuel solutions.

4.3.3 Nationally Determined Contribution (NDC)

The Kingdom of Saudi Arabia submitted its Updated Nationally Determined Contribution (NDC) to the UNFCCC Secretariat in October 2021. This updated NDC aims to remove, avoid, and reduce greenhouse gas (GHG) emissions by 278 million tons of CO_2 equivalent by 2030, more than doubling the commitment from the Kingdom's previous NDC submitted in November 2015. The foundation of these NDCs lies in international decisions and principles, including Decisions 1/CP.19 through 1/CP.24, Article 3 of the UNFCCC, the Economic Diversification Initiative adopted as the Conference of Parties Decision 24/CP.18 in 2012 in Doha, and Articles 4.1, 4.7, and 4.15 of the Paris Agreement. The NDCs employ a 'Dynamic Baseline' approach that is aligned with the Paris Agreement and reflects Saudi Arabia's unique national circumstances. This approach includes two scenarios for 2020-2030. The first scenario projects an economy diversified by investments from hydrocarbon export revenues into sectors like financial and medical services, tourism, education, renewable energy, and energy efficiency technologies. The second scenario focuses on enhanced domestic industrialization with sustainable use of nationally produced hydrocarbons, impacting the petrochemical, cement, mining, and metal manufacturing sectors. The two baseline scenarios mainly differ in the allocation of hydrocarbons produced either for domestic consumption or export. While the domestic consumption of hydrocarbons will contribute to Saudi Arabia's GHG emissions, the export of these hydrocarbons will not add to the Saudi Arabia's GHG emissions.

The NDC's realization will come through actions, plans, and projects that promote economic diversification and climate change adaptation. Key actions include enhancing energy efficiency, renewable energy development in the power sector, hydrogen production, and carbon capture, utilization, and storage (CCUS) initiatives, particularly in the industrial cities of Jubail and Yanbu. Adaptation measures include water and wastewater management, marine protection, desertification reduction through tree planting, and urban planning. The Saudi Energy Efficiency Program (SEEP) aims to establish the country as a leader in energy efficiency, with 100 initiatives targeting both demand-side and supply-side management across various sectors. Renewable energy is set to constitute 50% of the energy mix by 2030, fostering economic growth and employment through the local renewable energy supply chain.

Furthermore, the Kingdom is focusing on hydrogen production and utilization as a source of energy positioning itself as a potential global leader in the growing hydrogen industry and developing CCUS technologies. Utilizing its abundant solar and wind resources, the Kingdom is well-placed to lead in green hydrogen production on a global scale. Beyond green hydrogen, the Kingdom's wealth of natural resources, underground carbon storage capabilities, and CCUS technology know-how position it as a potential leading producer of blue hydrogen globally.

4.3.4 GHG Crediting & Offsetting Mechanism (GCOM)

The establishment of the GCOM in Saudi Arabia is designed to achieve specific national emission reduction and/or removal levels, aligned with the Kingdom’s ambitious climate goals, in the most cost-effective manner. The GCOM aims to increase cooperation among national entities seeking to fulfil their climate ambitions by helping to mobilize finance in all sectors for a variety of projects and activities. It also aims to drive positive social, environmental, and economic impacts beyond emission reductions or removals. The ultimate objective of the

GCOM is to drive progress towards a path to net zero emissions by allowing interested companies and entities to offset their GHG emissions by purchasing credits and/or certificates from project proponents that voluntarily reduce or remove GHG emissions. The Mechanism is also meant to promote and ensure high-quality credits and/or certificates by providing guidance, transparent infrastructure, and best practices, including for project-level accounting.

The main features of GCOM include (i) voluntary project-based participation, (ii) scope covers GHG and non-GHG metrics across all sectors, (iii) eligible Participants include all entities from all sectors can participate and subsidiaries of international companies active in the Kingdom are also entitled to participate, (iv) open to a variety of methodologies (i.e., DNA prepared and DNA approved), and (v) robust additionality requirements. The Mechanism will adapt to future changes and developments at both the national and international level. The Saudi Designated National Authority (DNA) will be acting as the regulator of the GCOM.

The Mechanism considers, in its core, the inclusivity and integration of clean hydrocarbon technologies to support the Circular Carbon Economy (CCE) approach, as well as to create the financial incentives to scale up such technologies. It encourages sustainable development projects as defined by and measured against the United Nations Sustainable Development Goals (UNSDGs).

The GCOM is a significant stride towards addressing climate change, supporting the Kingdom's ambitious net zero emissions goal by 2060 and its NDC. Its role in achieving net zero emissions is multifaceted. By allowing for the crediting of emissions reductions and the sequestration of carbon, GCOM incentivizes both the public and private sectors to invest in carbon reduction projects. This not only aids in offsetting emissions from sectors where reduction is more challenging but also fosters the development and adoption of low-carbon technologies. Moreover, GCOM's establishment enhances Saudi Arabia's commitment to its NDC. The mechanism supports these commitments by quantifying and crediting the emissions reductions achieved through various initiatives, such as enhancing energy efficiency, increasing the share of renewable energy, and deploying clean hydrocarbon technologies. This quantification and crediting process is essential for monitoring progress towards the NDC achievement, ensuring transparency, and building international trust.

4.3.5 Circular Carbon Economy Approach

Saudi Arabia has adopted the Circular Carbon Economy (CCE) as a strategic framework for its climate goals, which was endorsed by the G20 leaders in 2020. The CCE, with its four Rs viz. reduce, reuse, recycle, and remove, aims to manage greenhouse gas emissions across all sectors while fostering economic growth and stability. It emphasizes a technology-neutral stance, valuing all potential solutions from carbon capture and storage (CCUS) to nature-based solutions like reforestation. The framework also includes the categorization of carbon into 'Living', 'Durable', and 'Fugitive', each addressed by different strategies within the CCE to minimize emissions. Saudi Arabia has been implementing this framework through various programs like the Saudi Energy Efficiency Program and the National Renewable Energy Program, as well as projects like the Uthmaniyah CO_2 Sequestration Project. The establishment of the Carbon Capture, Utilization and Storage Technology Research Centre (CCUSTRC) in 2020 further demonstrates the Kingdom's commitment to innovation and technology transfer in reducing emissions and enhancing its NDC.

4.3.6 Middle East Green Initiative (MGI)

Saudi Arabia launched the Middle East Green Initiative (MGI), a regional program designed

to support regional actions toward meeting international climate objectives. This initiative emphasizes collaborative efforts and strategic measures to fulfill climate-related objectives. The initiatives include:

(i) Advancing circular carbon economy endeavors across the GCC and Middle Eastern nations, enhancing clean energy adoption and reducing regional greenhouse gas emissions.

(ii) Creating a specialized center dedicated to Carbon Capture, Utilization, and Storage (CCUS).

(iii) Enhancing access to clean energy sources for cooking purposes in the Middle East, aimed at improving the health and life expectancy of individuals, especially women and children, while also reducing greenhouse gas emissions.

(iv) Launching the Clean Oceans and Rivers Initiative, which aims to get rid of the regional waters of plastic pollution.

By increasing regional cooperation and creating the infrastructure needed to reduce emissions and protect the environment, MGI can support global efforts against climate change, whilst creating far-reaching economic opportunities for the region. To accelerate the implementation of initiatives to achieve the MGI goals, HRH the Crown Prince and the Prime Minister announced in November 2022 that Saudi Arabia will establish and host a dedicated MGI Secretariat and will allocate US $2.5 billion to support MGI projects and governance.

The MGI aims to unite regional stakeholders to collectively cut emissions from regional hydrocarbon production by over 60%. The initiative's goal of reducing GHG emissions by 670 million tons of CO_2e aligns with the nationally determined contributions (NDCs) from all participating regional countries. At its announcement in 2021, this goal accounted for 10% of the global contributions. MGI plans to drive this ambitious target by fostering high-level governmental collaboration, thus enabling businesses and civil society to enhance carbon capture, invest in green economic strategies, and stimulate innovation and expansion in renewable energy sectors.

The initiative to plant 50 billion trees throughout the Middle East equates to the rehabilitation of 200 million hectares of degraded land. Of these, 10 billion trees, which is one-fifth of the total, are allocated for planting within the territory of Saudi Arabia. The remaining 40 billion trees are planned for planting in various parts of the region over the coming years. This ambitious goal is set to open new job opportunities and enhance the resilience of isolated communities. Additionally, these trees will offer multiple advantages, such as soil stabilization, protection from floods and dust storms, and contributing to a reduction in CO_2 emissions by as much as 2.5% of the worldwide total.

Saudi Arabia is at the forefront of initiating centers and programs vital for achieving the MGI objectives. These centers and programs are instrumental in building the necessary infrastructure and enhancing knowledge sharing, which are essential for environmental protection, emission reduction, and enhancing regional cooperation. Moreover, they are pivotal in drawing investments towards crucial areas like the circular carbon economy and tree planting efforts. The cross-border innovation and collaboration include (i) a cooperative platform to accelerate implementation of the CCE, (ii) a regional hub for climate change, (iii) a regional cloud seeding program, (iv) a regional early warning center, (v) a regional center

for carbon extraction, use and storage, (vi) a regional center for sustainable development of fisheries, (vii) a 'clean fuel solutions for cooking' initiative, (viii) a regional investment fund for Circular Carbon Economy technology solutions, (ix) establishment of the Green Initiative Foundation, an Independent non-profit body, and (x) regional drive to clean plastics from oceans (Saudi & Middle East Green Initiatives, 2023).

4.4 ECONOMIC DIVERSIFICATION INITIATIVES

Economic diversification is a shift from an economy primarily dependent on one source of income to a more varied one, drawing from a broader array of sectors and markets. This transition is aimed at fostering economic growth (Alhowais and Al-Shihri, 2010; Mobarak and Karshenasan, 2012). Historically linked to job creation and economic expansion, economic diversification now also emphasizes the shift to sectors that are both low in emissions and resilient to climate change, thereby ensuring sustainable development (UNFCCC, 2020). For the advancement of resilient economic progress, especially in developing nations, economic diversification plays a pivotal role (UNDESA, 2017). It is a recognized strategy within the global 2030 Agenda for Sustainable Development (UNDESA, 2015). There is a broad consensus in scholarly work that a lack of diversification can lead to increased economic vulnerability (UN-ECLAC, 2017). Furthermore, countries reliant on hydrocarbon resources face increased risks from the volatility of oil prices and the effects of climate change, making diversification an essential strategy (Al-Iriani, 2006; Soytas and Sari, 2003). These countries are more vulnerable to global oil price fluctuations and climate change impacts response measures, therefore necessitating economic diversification. The attainment of sustainable development for a nation is contingent upon the implementation of economic diversification strategies, particularly in cases where income is derived from non-renewable resources. The Gulf Cooperation Council (GCC) nations including Saudi Arabia are currently prioritizing diversification efforts, with particular emphasis on human capital development, education, and non-oil industries (Al Naimi, 2022).

The Kingdom of Saudi Arabia's efforts to reshape its economy has been evident since 1970 through its series of five-year Development Plans. These plans aimed to evolve the nation into a progressive and developed society, focusing on economic diversification despite the critical role of oil in economic growth. Oil price volatility has significantly influenced Saudi Arabia's economy, making diversification efforts imperative. The First Development Plan kicked off the strategy in 1970-75. In 2005, the Eight Development Plan introduced a long-term strategy to improve employment and living standards through 2024. The Ninth and Tenth Development Plans, covering 2010-2014 and 2015-2019 respectively, sought to reduce unemployment, balance regional development, and enhance international competitiveness by boosting non-oil revenue sectors. Since the 1990s, the Mining and Quarrying sector's GDP contribution has waned, while Services, Manufacturing, and Transport sectors have grown.

Economic diversification is particularly critical for Saudi Arabia, where oil comprises a significant share of the GDP. A research study by Sweidan and Elbargathi (2023) highlighted the short-term adverse effects of oil prices and geopolitical threats on diversification efforts, with long-term consequences from oil price instabilities. However, the government spending has had a positive impact, indicating the government's pivotal role in diversification and the necessity for a strong institutional framework to support this transition.

The Economic Diversification initiatives include (i) Energy Efficiency, (ii) Renewable Energy (iii) Carbon Capture, Utilization and Storage (CCUS) (iv) Utilization of Gas and (v) Methane Management.

4.4.1 Energy Efficiency

The Saudi Energy Efficiency Center (SEEC) has initiated the Saudi Energy Efficiency Program (SEEP) with the mission to improve the Kingdom's energy efficiency by crafting and executing various energy efficiency initiatives and their supporting mechanisms. It includes demand-side energy management, particularly in the building, transportation, and industrial sectors — collectively accountable for over 90% of Saudi Arabia's energy consumption. The program's committee also integrates five enabling elements into its work: regulatory frameworks, energy service companies, financing, governance structures, and public awareness campaigns.

By 2018, SEEC's responsibilities were broadened under a new mandate to include three additional areas on the supply side. These areas encompass power generation, inclusive of electricity transmission and distribution; water desalination; and broadening the industrial sector's scope to include the energy efficiency of industrial feedstock utilization.

The program developed several key initiatives, which are briefly described in the following sub-sections.

4.4.1.1 Demand-side Initiatives and Achievements

The demand-side initiatives included building, land transport and industrial sectors.

Building Sector

The building sector accounts for approximately 29% of Saudi Arabia's total energy use, with a notable 70% of that energy being attributed to cooling needs due to the country's climatic conditions (SEEP, 2017). In response, a suite of programs has been rolled out, including the revision of standard specifications for air conditioners, lighting, and household appliances, aiming to cut down on electricity usage within buildings. This has resulted in the establishment of 27 energy efficiency standards and regulations, which incorporate eight mandatory labeling requirements for products like insulation materials, air conditioners, white goods, and lighting products. Efforts are underway to develop and implement an Energy Use Intensity (EUI) ecosystem to bolster overall building efficiency.

The consumption of electrical energy by air conditioners is particularly high, presenting a significant opportunity for energy conservation. The first stage of the high-efficiency air-conditioner initiative began in 2018, with objectives to endorse the local manufacturing of high-efficiency air conditioners and to boost sales through incentives. This initiative was fully deployed in 2019, extended to all regions for a period of 24 months. It resulted in a 57% increase in the Energy Efficiency Rating (EER) requirements for split AC units in 2019 compared to 2012 (SEEP, 2019). Stringent regulations have been enacted to achieve a marked decrease in energy use within buildings. The implementation of energy efficiency standards yielded notable reductions in energy consumption: 22% for refrigerators, 60% for washing machines, and 80% for home and street lighting.

The SEEP has developed a set of energy efficiency standards and regulations (seven with mandatory labels) including (i) 14 insulation standards, (ii) small AC EE standard, (iii) large AC EE standard, (iv) refrigerators and freezers EE standard, (v) washing machines EE standard, (vi) water heaters EE standard, (vi) clothes dryers EE standard, (vii) 2 lighting products EE standards, and (viii) 2 Saudi Building Code regulations governing high-rise and low-rise buildings. The program has developed a number of guidelines to rationalize energy consumption in buildings focusing on air conditioning, thermal insulation, domestic washing

machines, refrigerators and freezers, lighting and heaters (SEEC, 2020b).

Land Transportation Sector

The transport sector accounts for approximately 21% of Saudi Arabia's total energy usage (SEEP, 2019). Specifically, land transportation, which includes light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs), consumes over 90% of the energy within the transport sector (SEEP, 2017). The Saudi Energy Efficiency Program initially prioritized LDVs to improve their fuel efficiency and to reduce the fuel consumption of vehicles already on the roads. The following measures were undertaken to enhance the fuel economy of imported LDVs:

- The introduction of the vehicle energy efficiency card (VEEC) in 2013, with its inaugural phase launched in 2014 and the subsequent phase in 2018.
- The establishment of a standard specification in 2014 addressing anti-rotation and wet surface adhesion for tires, with the first phase commencing in 2015 and the next in 2019.
- The creation and application of "The Saudi Arabia Corporate Average Fuel Economy (CAFE) standards for Light Vehicles" in 2014, with the initial phase beginning in 2016 and the following phase in 2021, which resulted in an 18.4% improvement in the new fleet's fuel economy.

The standards set for LDVs are projected to enhance the vehicle fuel economy in the Kingdom by roughly 3.5% each year. The goal is to increase the fuel economy from 12.5 kilometers per liter in 2015 to more than 19 kilometers per liter by 2025, as per the Saudi Corporate Average Fuel Economy (CAFE) standard for Light Vehicles. There are also various initiatives for HDVs under consideration, including anti-idling regulations, aerodynamic enhancements, and scrappage schemes for older vehicles. Both LDVs and HDVs have been subjected to rolling resistance and wet grip standards since 2015 and 2016, respectively.

Technical Regulations for Electric Vehicles were approved on March 28, 2023, at the meeting of the SASO Board of Directors. This regulation is designed to outline the fundamental criteria for electric vehicles covered by its scope. It specifies the conformity assessment procedures that suppliers must adhere to, ensuring that these products meet essential requirements that prioritize environmental preservation, consumer health and safety, and facilitate market surveillance procedures.

Industrial Sector

The industrial sector in Saudi Arabia consumes approximately 44% of the nation's total energy output (Al Schneiber, 2018). The Saudi Energy Efficiency Program (SEEP) targets key industries for energy conservation measures, including petrochemicals, cement, and steel, which combined account for about 70% of the sector's energy usage (SEEP, 2019). SEEP has established and is executing an energy efficiency protocol for industrial facilities in a three-staged approach, addressing 70% of total energy consumption in the first phase, 5% in the second phase, and 13% in the third phase. This framework is applied to both new and existing plants. Through the program's initiatives, significant enhancements in energy intensity (EI) from 2011 to 2019 have been noted across major industrial processes. Steel plants utilizing electric arc furnaces observed a 2% EI improvement, cement plants saw a 2.8% enhancement, clinker plants achieved a 4.2% increment, and the petrochemical industry reported a 2.8% improvement in energy intensity. In 2021, the industrial sector exhibited a decline of 4.79% in energy consumption intensity compared to the previous year (General Authority for Statistics, 2021).

4.4.1.2 Supply-side Initiatives and Achievements

Energy Utilities Sector

Several initiatives were undertaken in the Utilities Sector which included power plants and electricity cogeneration, water desalination plants, and electricity transmission and distribution. This sector consumes about 38% of the Kingdom's total primary energy (SEEC Annual Report, 2019). Therefore, the objectives in this sector are to (i) reduce electricity loss during electricity transmission and distribution, (ii) rationalize fuel consumption and raising electricity generation efficiency, (iii) comply with highest internationally recognized standards for efficiency within the these sectors, (iv) disseminate successful practices by way of spreading awareness among all relevant stakeholders, (v) establish institutions aiming to rationalize fuel consumption and (vi) contribute to overcome the technical challenges during this initiative (SEEC annual report, 2019). The following paragraphs discuss (i) power generation, transmission, and distribution, and (ii) desalination sector.

The Kingdom of Saudi Arabia has been actively updating and advancing its power sector to boost energy efficiency. This comprehensive upgrade includes the replacement of outdated power plants, enhancement of distribution networks, adoption of smart grid technologies, installation of smart meters, and the advancement of regional and international electrical grid connections (Export, 2017). In addition to establishing a national electricity market, Saudi Arabia has been leading a GCC initiative to interconnect the power grids of member states, allowing for electricity trade and more effective management of peak load demands.

From 2010 to 2019, the Saudi Electricity Company (SEC) increased the electricity output from energy-efficient combined-cycle power plants from 8.3% to 31.0%, while simultaneously reducing reliance on energy-demanding single-cycle power plants from 50% to 22%. The total electricity generated by combined cycles reached 59,258 MWh. Fuel consumption reduction has been realized by transforming less efficient single-cycle gas turbines into more efficient combined-cycle plants and by installing new combined-cycle facilities (Matar, Murphy, Pierru, Rioux, & Wogan, 2017). The number of combined-cycle electric generation units in the Kingdom escalated from 35 in 2007 to 121 in 2018, boosting the generation capacity from 3.1 GW to 17.1 GW (ECRA, 2015, 2019).

Saudi Arabia has strategically diversified its electricity generation mix and fuel sources to enhance efficiency. This involves integrating solar power with combined cycle capacity investments. Saudi Arabia aims to further reducing its environmental impact by transitioning to cleaner fuel mixes, emphasizing gas feedstocks, and aiming to displace liquid fuel entirely by 2030.

As a part of its initiative to enhance consumer energy efficiency through digital transformation, Saudi Arabia installed 10 million smart meters nationwide. This project unfolded in three stages: first, replacing old mechanical meters with smart versions; second, connecting the meters to the telecommunications grid; and third, integrating the meters into the electricity billing system, which also included the launch of smartphone applications (Saudi Electricity Company, 2020).

The Kingdom has 30 desalination plants and 139 purification stations with production capacity 7.5 and 4 million m3/day of desalinated water respectively (SWCC, 2022a). Saline Water Conversion Corporation (SWCC) produced 55.9%, Marafiq 6.3%, Shoaiba Water and Electricity Company produced 11.4%, Jubail Water and Power Company 10.4% while the remaining 16.0% is produced by 17 other licensees (ECRA, 2019). Several projects aim to enhance production plants in the Kingdom and increase water supplies across all regions,

focusing on improving environmental impact by replacing thermal technologies with eco-friendly reverse osmosis technologies. This shift is expected to contribute to cost reduction, heightened production efficiency and emission reduction (Figure 4.1). Key achievements include the establishment of the Al-Khobar plant, phase 2, utilizing reverse osmosis with a design capacity of 630,000 cubic meters per day. Additionally, operations have commenced at the world's largest floating desalination plant with a production capacity of 50,000 cubic meters per day (SWCC, 2022b). Furthermore, the Al-Jubail plant, phase 2, has been established, employing reverse osmosis with a capacity of 400,000 cubic meters per day.

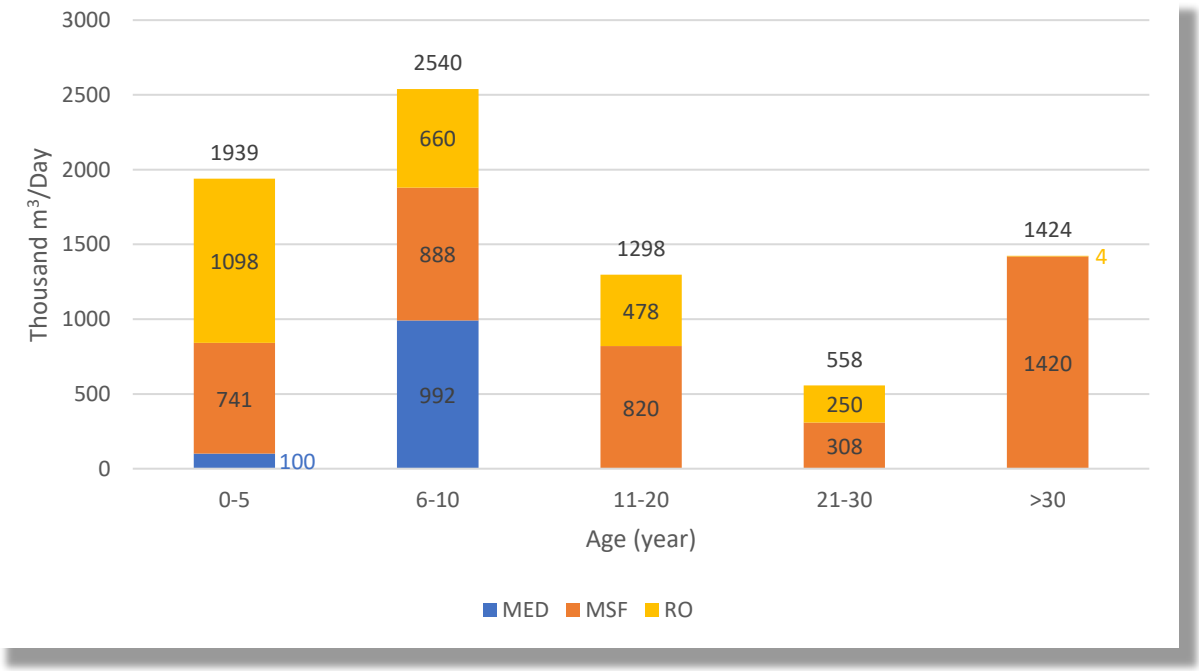

Figure 4.1: Share of Desalination Technologies with Time (ECRA Annual Report, 2019)

The desalination plants generally use three technologies including multistage flash (MSF), multi-effect desalination (MED) and reverse osmosis (RO). RO is the most energy efficient among the three technologies (Napoli and Rioux, 2015, UNESCWA, 2009). The share of energy efficient RO technology has been steadily increasing (Figure 4.2).

In the last 5 years, a total of 1.098 million m^3 per day production capacity by RO was added out of a total capacity addition of 1.939 million m^3 per day (ECRA Annual Report, 2019). The Kingdom produced 59% desalinated water by MSF, 14% by MED and 27% by RO in 2018 (Figure 4.2).

The integration of solar power, membrane desalination and energy and water storage systems are being tested in Saudi Arabia. For example, a pilot solar desalination plant is being constructed in the town of Al-Khafji in the northeast of Saudi Arabia, designed to provide 60,000 cubic meter per day of desalinated water using reverse osmosis, with a solar photovoltaic plant capable of supplying the power for the desalination process (AWT, 2021).

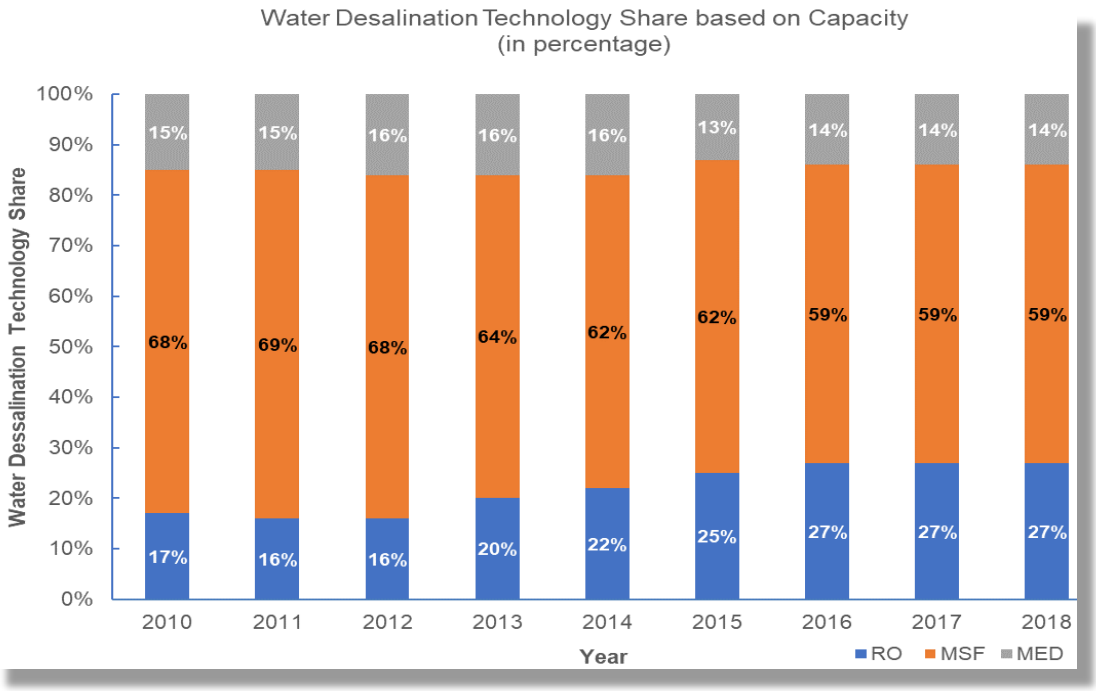

Figure 4.2: Water Desalination Technology Share in the Kingdom. (ECRA, 2020b)

4.4.1.3 Regulatory Framework for Energy Sources

In 2013, the Electricity and Cogeneration Regulatory Authority (ECRA) formulated a national plan for the adoption of smart meters and intelligent grid systems. Since 2008, the Electricity Distribution Code has set forth the standards and directives for energy distribution, playing a pivotal role in the management of electricity demand. ECRA has been proactive in formulating regulatory frameworks to encourage the use of sustainable and renewable energy sources for electricity production. It works with various relevant organizations to create suitable regulatory environments for the operations of electricity production, cogeneration, and water desalination, utilizing nuclear and renewable energies. The industry's current structure is a vertically integrated model where the Saudi Electricity Company (SEC) monopolizes the transmission and distribution network, serving electricity to consumers. While SEC produces most of the electricity and purchases additional supply from other producers like MARAFIQ, SWCC, and various Independent Power Producers (IPPs).

The Seawater Desalination Code established by ECRA (currently WERA) lays out explicit operational guidelines to ensure high efficiency, which all involved entities are mandated to follow (ECRA, 2020a). Furthermore, there are plans in the Kingdom to launch a national program dedicated to optimizing water and energy use.

4.4.1.4 Power Sector Key Initiatives

There are several key initiatives launched in Saudi Arabia under the power sector integration (PSI) which promotes collaboration between the power sector teams and integration between multiple programs and initiatives. These programs and initiatives are:

<u>Power Sector Energy Mix Program</u>

The Kingdom is transitioning its power sector energy mix to a more balanced and sustainable blend by 2030. The future mix aims to comprise 45% to 50% renewable energy and 50% to 55% gas-fired thermal power plants. The renewable segment will feature a diverse array of

sources, including photovoltaic (PV) systems, wind energy, and concentrated solar power (CSP). Meanwhile, the thermal power plants will primarily consist of efficient, gas-fired combined cycle systems, which will rely on the domestic gas supply. This strategic shift also includes a significant reduction, and eventual phase-out, of liquid fuel usage in the power sector wherever feasible.

Liquid Fuel Displacement Program

The Kingdom has set a goal to shift from liquid fuels to gas in utilities, industry, and agriculture by 2030. This shift aims to improve gas utilization, reduce greenhouse gas emissions, and increase thermal efficiency. The strategy is projected to save around one million barrels of oil equivalent per day, which can then be exported. The plan includes several key steps: (a) transitioning power and desalination plants from liquid to gas firing, (b) establishing new, highly efficient thermal gas-fired power plants, (c) decommissioning outdated liquid fuel power plants, (d) switching industrial facilities to gas, and (e) integrating agricultural farms and industries into the electrical grid.

Smart Meter Project

The Kingdom successfully achieved its goal of installing more than 10 million smart electricity meters across all customer segments, completing the project swiftly as scheduled. The deployment of these smart meters brings several advantages for both the electricity consumers and the provider. Key benefits include a reduction in energy losses, improved accuracy in load forecasting, fewer power outages, and quicker restoration of power services. Additionally, these smart meters enhance customer experience by empowering them with real-time consumption data and more control over their electricity usage. This project also significantly contributed to maximizing local content, creating job opportunities, and boosting overall energy efficiency in the Kingdom (Saudi Electricity Company, 2020).

4.4.1.5 Energy Services Company (ESCO) Initiative

The Program has been setting the stage for a robust market environment for energy service providers and consumers. It ensures the proficiency of energy service companies through a licensing system and authorizes investors interested in the sector once they fulfill the licensing criteria. Such licenses enable companies to engage in commercial activities identified in the national directory, seize investment opportunities in energy audits, enhance energy efficiency in commercial and private buildings, as well as in industrial settings, offering three distinct license types (SEEC, 2020a).

The Program also engages in educational initiatives, routinely organizing workshops to guide potential clients seeking energy efficiency services for their facilities, whether in the building or industrial sector. Additionally, the Program has approved the KSA Measurement & Verification (M&V) user guide, which serves as a technical benchmark for energy efficiency projects in the Kingdom by defining the standards for measuring and verifying energy savings, thus safeguarding the interests of all project stakeholders, from service providers to clients. The initiative also accelerates the entrance of new markets or sectors by fostering the development of super energy service companies that act as industry stimulants. This strategy is expected to foster a market for energy-efficient refurbishments in government and commercial buildings, generate numerous jobs in engineering and project management, and promote the localization of the supply chain (SEEP, 2019).

National Energy Services Company (*Tarshid*)

Saudi Arabia initiated Tarshid, known as the National Energy Services Company, tasked with establishing, financing, and overseeing influential energy efficiency projects within the governmental and commercial sectors, targeting considerable energy conservation.

The responsibilities and aims of Tarshid encompass:

(i) Curtailing the Kingdom's energy usage through energy-efficient refurbishments.

(ii) Driving the growth of the ESCO industry within the Kingdom.

(iii) Fostering domestic energy efficiency expertise and promoting the rise of national leaders in the sector.

Tarshid's role is to identify opportunities for energy efficiency, oversee the comprehensive execution of energy efficiency projects, and offer innovative financing options. It is responsible for the administration and financial backing of energy efficiency initiatives in government and commercial edifices, as well as street lighting systems. Since its inception in 2018, Tarshid has been implementing its retrofitting programs across a variety of buildings, including offices, educational institutions, places of worship, universities, medical facilities, and has also been upgrading street lighting across the central, eastern, western, northern, and southern regions of the Kingdom, leading to significant power savings and reductions in greenhouse gas emissions.

4.4.1.6 Support for Economic Diversification and Job Creation

The energy efficiency measures such as standards, regulations, product testing and control, incentives, energy service companies (ESCOs), district cooling, and others, under the Saudi Energy Efficiency Program (SEEP), have been promoting economic diversification. These measures generate increased demand and business prospects in current markets, particularly through the replacement or modernization of capital assets like inefficient equipment, buildings, and industrial plants. This burgeoning demand is driven by regulatory frameworks. Moreover, these initiatives are instrumental in fostering new sectors and/or industries as well as in providing new job opportunities.

4.4.2 Renewable Energy

The Kingdom of Saudi Arabia launched more than a dozen realization programs to achieve the objectives of the Saudi Vision 2030 (Saudi Vision 2030, 2016) where most of them considered the ambitious renewable energy goals in their major activities. The programs which proposed relevant guidelines and frameworks to achieve the national renewable energy plan include (i) quality of life program, (ii) national transformation program, (iii) public investment fund program, (iv) privatization program, (v) national companies' promotion program, (vi) national industrial development & logistics program, and (vii) human capital development program.

4.4.2.1 National Renewable Energy Initiative: National Renewable Energy Program (NREP)

Since the initiation of the National Renewable Energy Program (NREP) in 2017, Saudi Arabia has been strategically integrating renewable energy into its energy portfolio. The Kingdom is predominantly focusing on solar and wind power to enhance the share of renewable energy. Additionally, it is pursuing job creation in the renewable sector by ensuring that a substantial part of the production and research & development within the renewable energy supply chain

is localized within its economy. The NREP, established by the Ministry of Energy (MoE) aligns with the National Transformation Program (NTP) and the broader Saudi Vision 2030. Its aim is to cultivate a thriving renewable energy market, promoting collaboration between public and private entities and enabling private sector investments to foster industry growth.

Renewable Energy Resources (RER) Initiative

The NREP has set out a systematic and targeted roadmap to rapidly diversify the Kingdom's domestic power supply (KSA-Climate, 2019; National Renewable Energy Program, 2019; Power Saudi Arabia, 2020). In 2020, Saudi Arabia's Ministry of Energy initiated round three of its NREP, featuring four solar PV projects totaling 1,200 MW. The projects are categorized into "Category A" for smaller companies and "Category B" for larger ventures, with a minimum requirement of 17% local content to boost the national economy (NREP, 2020). The renewable energy projects will be deployed in 35 plus parks by 2030 spread all over the Kingdom to promote regional development.

4.4.2.2 King Abdullah City for Atomic and Renewable Energy (K.A.CARE)

In 2010, Saudi Arabia established King Abdullah City for Atomic and Renewable Energy (K.A.CARE), aiming to cultivate significant capabilities in both atomic and renewable energy, supported by domestic industrial support. K.A.CARE is tasked with advancing scientific research, localizing technology, orchestrating the efforts of research institutions and centers, and setting strategic priorities and policies (K.A.CARE, 2016). By 2017, K.A.CARE had outlined its strategy for the atomic energy sector to serve as a reliable energy source and to meet the developmental needs of the nation (K.A.CARE, 2017). Incorporating atomic energy into the national energy framework is a key step towards achieving Saudi Arabia's aspiration to be an energy-efficient leader as envisioned in Saudi Vision 2030. The project's primary advantages are (i) diversifying the nation's energy portfolio, (ii) conserving oil reserves, (iii) utilizing atomic energy for seawater desalination, and (iii) generating new educational, training, and employment opportunities.

4.4.2.3 National Renewable Energy Data Center Initiative

The initiative aims to establish a center to provide information of renewable energy in the Kingdom which will provide a number of promising locations of renewable energy projects, specialized models and tools. It will also depict the status of the renewable energy sector. The K·A·CARE launched its online Renewable Resource Atlas (K.A.CARE, 2020c).

4.4.2.4 Renewable Energy Technology Localization Initiative

The K.A.CARE collaborates with both international and domestic organizations and corporations to advance and possess renewable energy technologies. This includes innovations in solar and wind power, geothermal energy, energy derived from waste, as well as desalination, energy storage, subsurface technologies, and concentrated solar power (K.A.CARE, 2016). In 2019, K.A.CARE initiated the second phase of its Technology Localization and Commercialization (TLC) initiative. This phase is designed to mitigate risks associated with the domestication of renewable energy technologies and aims to boost private sector involvement in these technology localization efforts (K.A.CARE, 2019).

4.4.2.5 Human Capacity Building Initiative

The K.A. CARE in cooperation with various local and international business partners has been exerting efforts to develop and stimulate human capital to meet the job market needs. This

initiative will support the development of the educational system, technology localization and knowledge transfer.

4.4.2.6 Green Hydrogen

NEOM, the Kingdom's major giga-project, aims to establish one of the largest green hydrogen production facilities worldwide. The facility is planned to operate on more than four gigawatts of renewable solar and wind energy. Scheduled to be operational by 2025, the plant is projected to yield 650 tons of green hydrogen daily via electrolysis, along with an annual production of 1.2 million tons of green ammonia.

4.4.2.7 Other Renewable Energy Initiatives

Renewable Energy and Water Management

The private companies are focusing on developing, investing in, and operating power generation and desalination plants, and have emerged as a key player in Saudi Arabia's transition to a more sustainable and eco-friendly energy approach. SABIC, with a commitment to using renewable energy for its operations, is aiming to acquire up to 4 gigawatts (GW) of renewable energy in the next three years, including 3.5 GW from sources like solar, wind, hydroelectric, and biomass in Saudi Arabia. Meanwhile, ENOWA is collaborating with ITOCHU and Veolia to construct an innovative desalination plant in Oxagon, NEOM's hub for advanced manufacturing and innovation, which will be entirely powered by renewable energy. This facility is planning to achieve complete Zero Liquid Discharge in its subsequent brine processing industries (Ministry of Economy and Planning, 2023).

Geothermal Energy

Geothermal energy, derived from the inherent heat beneath the earth's surface, involves evaluating an array of subterranean data parameters to assess its potential (K·A·CARE, 2020a). Saudi Arabia, recognized as one of the most geothermally active nations in the Middle East, has been surveying its geothermal resources since the 1980s. The Ministry of Energy in Saudi Arabia is now investigating the potential of geothermal energy Many regions within Saudi Arabia, show promising geothermal prospects specifically, the Jazan province, known for its high heat flow and geothermal gradient, contains multiple thermal springs and is projected to produce approximately 134 × 106 KWh of electricity (Chandrasekharam et al., 2015). . By 2032, Saudi Arabia aims to have an installed geothermal capacity of 1GW (K·A·CARE, 2020a), and has already developed facilities like refreshment and swimming pools in the Jazan region, harnessing geothermal energy (Demirbas et al., 2016).

Waste to Energy Initiative

In Saudi Arabia, substantial quantities of municipal solid waste (MSW), by-products from wastewater treatment plants (WWTP), and organic waste from industrial and agricultural sources present a viable opportunity for renewable energy production (K·A·CARE, 2020d). The country produced 15.3 million tons of MSW in 2014, with expectations to double by 2033, alongside significant industrial and agricultural waste. Traditional waste management involving collection and landfilling, currently practiced in Saudi Arabia, poses environmental and health risks (Ouda et al., 2016). Waste-to-energy (WTE) initiatives could simultaneously mitigate waste and generate eco-friendly energy.

Saudi Arabia's ample MSW, characterized by high quality, is an excellent candidate for WTE conversion using state-of-the-art technologies like RDF incineration, gasification, pyrolysis, and anaerobic digestion. These technologies can convert waste into electricity, hydrogen, and

water (Zafar, 2020a; Hadidi, Ghaithan, Mohammed, & Al-Ofi, 2020; Miandad et al., 2016, Agboola & Saleh, 2016), positioning solid waste as a renewable energy source to partly meet the nation's electricity needs (Ouda, Raza, Al-Waked, Al-Asad, & Nizami, 2017).

As a part of the SGI, the Kingdom declared an impressive 94% rerouting of Riyadh's domestic waste away from landfills towards recycling and composting, which is anticipated to lessen GHG emissions and produce electricity (SGI, 2021). A Saudi facility has been established to convert waste into energy, processing around 180 tons of waste daily into distilled water and generating about 6 MW of electricity and 950 cubic meters of water (Amran et al., 2020).

Hydro Energy

Saudi Arabia is at the forefront globally in both the production and use of desalinated water, having produced 2,558 million cubic meters in 2019 (ECRA, 2020b). The Kingdom leverages the output of its desalination facilities, a significant source of renewable energy, for generating electricity. The cumulative hydroelectricity produced by all authorized entities, including the Saline Water Conversion Corporation (SWCC), in 2017 was about 151 thousand gigawatt-hours (TGWh) (Figure 4.3). (GASTAT 2018).

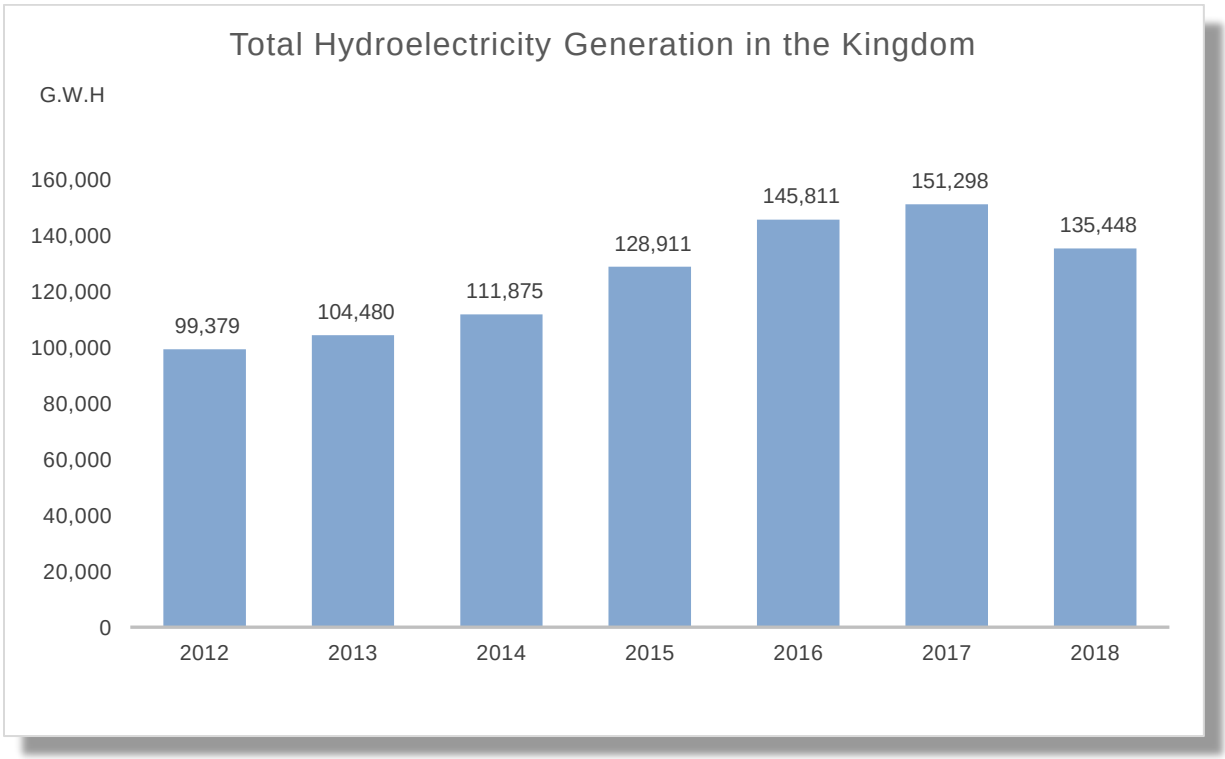

Figure 4.3: Total Generated Hydroelectricity in the Kingdom (GASTAT, 2018).

4.4.3 Carbon Capture, Utilization and Storage (CCUS)

4.4.3.1 Major Initiatives

The Kingdom of Saudi Arabia considers Carbon Capture, Utilization, and Storage (CCUS) vital for both economic diversification and as a strategy to meet its Nationally Determined Contributions (NDCs). With global advancements in CCUS and Carbon Capture and Storage (CCS), studies suggest these technologies could contribute a 14% cumulative reduction in CO_2 emissions by 2050 (GCCSI, 2017b). The IPCC's Fifth Assessment Report highlights that without CCS, mitigation costs could surge by 138%, making the CO_2-equivalent concentration

target of 450 ppm unattainable (IPCC, 2014).

CCS and CCUS technologies in energy and industrial sectors can greatly curb CO_2 emissions, potentially raising the proportion of low-carbon electricity from about 30% today to over 80% by 2050, leading to a near elimination of fossil fuel power generation without CCS by 2100 (IPCC, 2014). The Carbon Sequestration Leadership Forum (CSLF) also noted the critical role of CCUS, projected to account for 12-14% of CO_2 emissions avoidance by 2050. Moreover, CCUS not only diminishes environmental impacts but also enhances energy security, preserves existing infrastructure investments, and can reduce emissions in hard-to-abate industrial sectors. CCUS investment can foster job creation and economic growth, particularly in regions dependent on heavy industries (GCCSI, 2017b).

The Kingdom has reported progress on two key projects: enhanced oil recovery (EOR) and CO_2 to methanol and urea projects in its TNC and BUR1 reports. Jubail City is set to host one of the largest Carbon Capture and Storage (CCS) hubs globally, with an objective to capture 44 million tons of CO_2 annually by 2035. This ambitious project involves a collaborative effort between Saudi Aramco, SLB, and Linde, and is expected to sequester up to 9 million tons of CO_2 each year starting in 2027 (Ministry of Economy and Planning, 2023). Recognizing the broad benefits of CCUS, the Kingdom focused on:

- Cutting national emissions through cost-effective carbon capture deployment.
- Lowering carbon capture costs by focusing on the highest emitting sectors, such as power plants.
- Creating economic value from low carbon products, like blue hydrogen.
- Exploiting its considerable potential for geological CO_2 storage.

4.4.3.2 Blue Hydrogen

A National Hydrogen Strategy is being formulated by the Kingdom to outline approaches for achieving global leadership in the hydrogen production sector. Blue hydrogen, with its carbon emissions captured, utilized, or stored in geological formations, can be employed across different industrial sectors at national level. Efforts will focus on prioritizing pilots, research, and demonstrations to enhance technology readiness and reduce costs, particularly in the aviation, shipping, petrochemicals, and steel industries.

4.4.4 Utilization of Gas

The Kingdom is actively working to enhance the contribution of natural gas within its domestic energy mix, leveraging its higher energy content and lower carbon dioxide emissions per unit of energy produced. Aligned with the goals set forth in Saudi Vision 2030, there is a concerted effort to augment natural gas production and establish a comprehensive distribution network throughout the country. Over the decade from 2008 to 2018, there has been a notable uptick in natural gas utilization across the Kingdom's sectors of power generation and water desalination (Rami Shabaneh, 2020).

4.4.4.1 Increase of Gas in the Domestic Energy Mix of Electricity Generation Initiative

The Kingdom intends to increase the share of gas in the electricity generation to 50% – 55% by 2030.

4.4.5 Methane Management

Saudi Arabia's Master Gas System (MGS), the largest gas collection system in the world, was established in 1982 primarily to gather associated gas to minimize flaring and venting. It comprises an extensive network of pipelines and facilities to capture, process, and harness gas for fuel and as a feedstock for petrochemical industries located in Jubail and Yanbu. This system has played a crucial role in reducing gas flaring in the Kingdom from 2.26% in 2009 to just 0.5% in 2017 while significantly boosting the production of raw gas to around 13,000 MMSCF/day.

4.4.5.1 Zero Routine Flaring Initiative

In December 2018, the Kingdom of Saudi Arabia took a significant step towards reducing gas flaring by joining the World Bank's "Zero Routine Flaring by 2030 Initiative" (World Bank, 2015). This move is a clear indication of the Kingdom's commitment to eliminating routine gas flaring in its operations. It underscores a dedicated approach towards addressing the challenges of climate change and promoting sustainable economic development within the Kingdom.

4.4.5.2 Global Methane Initiative

Launched in 2004, the Global Methane Initiative (GMI) is a collaborative international public-private endeavor that targets cost-effective, near-term reduction, recovery, and utilization of methane as a valuable energy source. The GMI's work spans three key sectors: biogas (inclusive of agriculture, municipal solid waste, and wastewater), coal mines, and oil and gas systems. This initiative emphasizes the mitigation of methane emissions as a strategic means to decrease greenhouse gas (GHG) emissions, thereby bolstering energy security, economic growth, air quality, and worker safety. The GMI aids countries in achieving methane reductions by capturing and converting it into usable energy by providing technical support, acting as an informational resource, promote peer exchange on best practices and experiences, and working in conjunction with other international organizations to foster international collaboration.

Saudi Arabia is a member of the GMI since 2014. In the biogas sector, methane emissions are expected to reach 45.149 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) by 2050. The oil and gas sector forecasts 18.216 $MMTCO_2e$. Emissions from other non-GMI sectors are expected to change from 3.936 $MMTCO_2e$ in 2020 to 5.369 $MMTCO_2e$ by 2050 (Methane-KSA report).

4.4.5.3 Global Methane Pledge

The Global Methane Pledge, initiated at COP26 in November 2021, is an international commitment spearheaded by the United States and the European Union to propel significant reductions in methane emissions, a potent greenhouse gas. With 111 countries partaking, which collectively contribute to 45% of global anthropogenic methane emissions, the Pledge seeks a collective action to diminish these emissions by at least 30% from 2020 levels by the year 2030. This ambition has profound implications for the climate. Achieving the Pledge could equate to the global transport sector moving to net-zero emissions, offering a substantial cooling effect in the short term. While the Pledge is a step towards coordinated international climate action, its success hinges on effective implementation. The Pledge operates on a non-binding basis, without specific targets for individual countries, focusing instead on a shared goal. To drive progress, annual ministerial meetings are planned for a review.

Saudi Arabia has announced joining the Global Methane Pledge to cut global methane emissions by 30% by 2030 relative to 2020 levels. The Kingdom has been developing its institutional and technical capacities through participation in the Global Methane Pledge and international forums. It has taken steps to develop domestic markets, internal pricing, and voluntary efforts to promote emission reductions.

4.5 CLIMATE CHANGE ADAPTATION INITIATIVES

The adaptation initiatives primarily include (i) water and wastewater management, (ii) marine protection (iii) Reduced desertification/tree planting and (iv) urban planning.

4.5.1 Water and Wastewater Management

4.5.1.1 Initiatives of Ministry of Environment, Water and Agriculture (MEWA)

The Ministry of Environment, Water, and Agriculture (MEWA) in Saudi Arabia is actively working towards enhancing water efficiency and management through the establishment of the National Center for Water Efficiency and Rationalization. The goal of this center is to improve the efficiency of water production, transportation, and distribution, encourage rational use of water, and coordinate efforts among various governmental and non-governmental entities. Additionally, MEWA has initiated programs to support and guide companies and institutions in auditing and rationalizing water consumption, including the detection of leaks. These programs involve training and workshops to build capacity in water auditing and rational usage (National Water Efficiency & Conservation Center, 2023).

Furthermore, MEWA has developed the National Water Strategy 2030, which spans from 2018 to 2030. This strategy is aimed at creating a sustainable water sector that protects natural resources and the environment of the Kingdom while ensuring the provision of cost-effective and high-quality water services. The strategy's major objectives are to enhance water demand management, safeguard and optimize water resource usage, and foster water sector competitiveness. This involves promoting effective governance, encouraging private sector participation, and localizing capabilities and innovation, all contributing positively to the national economy. The expected main key outputs of this strategy are provided below.

i. Demand Management

Saudi Arabia is implementing a strategic plan to substantially reduce its water demand from 24.8 billion cubic meters per year to 12.5 billion cubic meters by the year 2030. A significant focus of this reduction is on the agricultural sector, which currently accounts for a considerable portion of water usage. In 2016, the agricultural sector's water consumption was 21.2 billion cubic meters, and the goal is to decrease this to 11.4 billion cubic meters by 2030. This plan is part of a broader effort to achieve sustainable water resource management in the Kingdom.

ii. Preservation of Non-Renewable Water Resources

Saudi Arabia's initiatives for water resource management are focused on enhancing the efficiency and capabilities of Integrated Water Management systems. These efforts are crucial in significantly reducing the dependency on non-renewable groundwater sources. As part of these initiatives, the decrease in consumption is estimated to come down from 20.6 billion cubic meters in 2016 to 8.8 billion cubic meters in the year 2030. This substantial reduction reflects the Kingdom's commitment to sustainable water resource management and conservation. Agriculture holds a significant share of total water consumption, with an annual growth rate of 7%. It relies heavily on non-renewable groundwater, approximately 80%. Goals

are set to increase on-farm irrigation efficiency to 75% by 2030 and ambitiously reduce the usage of non-renewable groundwater by the same year (Ministry of Economy and Planning, 2023).

The Kingdom has been utilizing treated wastewater in agriculture and other non-drinking applications to preserve water resources and lessen the reliance on freshwater sources. In line with this, there is a goal to increase the reuse of treated wastewater from 14.4% in 2016 to 80% of the total volume produced by 2030 (Ministry of Economy and Planning, 2023).

iii. Employment Opportunities

It is anticipated that an additional 70,000 jobs will be created both directly and indirectly, by the year 2030. This initiative aligns with the Kingdom's broader strategy to diversify its economy and create new employment opportunities across various sectors.

iv. Pollution Reduction

The national water strategy includes the development of environmental compliance regulations to monitor and reduce both water and air pollution. This strategy emphasizes the use of membrane-based desalination technologies, which are recognized for their energy efficiency compared to conventional Multi-Stage Flash (MSF) and Multi-Effect Distillation (MED) technologies. These membrane-based technologies, such as reverse osmosis, are more energy-efficient in separating dissolved salts and thus offer a sustainable approach to desalination.

The Kingdom of Saudi Arabia has been enhancing wastewater treatment infrastructure and better management of wastewater to minimize its effects on public health and the environment. This effort will provide substantial amounts of tertiary treated wastewater suitable for various uses, including agriculture, industrial, and urban activities, adhering to established standards and guidelines. By 2030, it is projected that the total treatment capacity will reach approximately 10.3 million cubic meters per day (Ministry of Economy and Planning, 2023).

4.5.2 Marine Protection

Saudi Arabia's Vision 2030 program is strongly focused on environmental protection and the preservation of natural resources. The country is dedicated to the protection and rehabilitation of its beaches, natural reserves, and islands. This commitment is reflected in several measures aimed at conserving biodiversity, maintaining wildlife habitats, and developing these areas for future generations. To support these efforts, Saudi Arabia has implemented various national regulations and strategies. These include the (i) General Environmental Law, (ii) Wildlife Protected Areas Regulation, (iii) Wildlife Animal and Bird Hunting Regulation, and (iv) Regulation on Trafficking of Endangered Wildlife Species and their Products. Additionally, the Kingdom has ratified international agreements such as the United Nations Convention on Biological Diversity, showcasing its commitment to global environmental conservation efforts (Unified National Platform, 2020a).

4.5.2.1 Blue Carbon Initiatives

Saudi Arabia has recognized the blue carbon sink as a key adaptive action. The Kingdom emphasizes the importance of implementing coastal management strategies to achieve this goal (Herr and Landis, 2016). Studies conducted in Saudi Arabia across 25 locations along the Western Arabian Gulf coast have underscored the significance of mangrove, saltmarsh, and seagrass habitats as effective carbon sinks (Cusack et al., 2018). In the Red Sea region of Saudi Arabia, mangrove areas have expanded by approximately 30 percent. This growth is attributed

to the nation's concerted conservation and restoration initiatives.

4.5.2.2 Biodiversity and Marine Ecosystem Initiatives

Saudi Arabia, characterized by diverse climates and habitats ranging from marine and coastal to desert, valley, and mountain ecosystems, is actively engaged in biodiversity conservation across its territories. The nation's coastal areas, particularly along the Red Sea and Arabian Gulf, are home to rich coral reefs, crucial for marine life habitats. Efforts are ongoing to enhance these marine ecosystems, which are vital for the country's development and food security. The Kingdom is also focused on addressing challenges faced by marine ecosystems and implementing solutions for sustainable development. The National Strategy for Conservation of the Kingdom's Biodiversity encompasses plans for biodiversity research and promotes the optimal and sustainable use of both biodiversity and marine resources. By 2016, Saudi Arabia had expanded its terrestrial protected areas, forest coverage, and protected marine reserves to 85,393, 27,000, and 7,823 square kilometers, respectively (Kingdom of Saudi Arabia, 2018). Additionally, the Ministry of Environment, Water and Agriculture (MEWA) enforces a six-month yearly ban on shrimp fishing along the Arabian Gulf coast to support shrimp reproduction and manage shrimp populations sustainably.

Saudi Arabia has also been undertaking various initiatives for biodiversity protection. The establishment of the Shaybah Wildlife Sanctuary, covering 637 square kilometers, supports numerous native plant and animal species. The deployment of around 1,000 tons of artificial reefs in the Arabian Gulf, with more than 2,700 reefs already in place, aims to restore marine ecosystems and support the fisheries industry. Plans include further reef deployments in the southern Red Sea.

4.5.2.3 Terrestrial and Marine Protected Areas

The Kingdom plans to increase the marine and terrestrial protected areas in the Kingdom to over 20% by 2030 to enhance biodiversity and to protect land and sea areas.

4.5.3 Reduced Desertification and Afforestation

The Kingdom has been undertaking measures to combat desertification. by supporting actions that will promote the stabilization of sand movements around cities and roads, while increasing sinks for capacity through using green belts as barriers. The Kingdom 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 management, pasture, and wildlife resources through a system of protected areas and reserves.

As a part of the SGI, the Kingdom will plant 450 million trees across Saudi Arabia by the year 2030 and rehabilitate 40 million hectares of land. According to MGI, the Kingdom has planned to plant 10 billion trees. Ma’aden has launched the Afforestation Initiative, aiming to plant 20 million trees by 2040, and invest in CO_2 capturing and utilization technologies (Ministry of Economy and Planning, 2023). Saudi Aramco's "Environmental Initiative for Planting One Million Trees" is a continuation of its earlier achievement in planting two million mangrove trees on the Arabian Gulf coast, completed in 2017. In 2020, SWCC launched an initiative to plant 5 million trees on 12 million square meters. SWCC planted 360,000 trees by 2022(SWCC, 2022a).

The National Center for Vegetation Cover and Combating Desertification (NCVC) is tasked with the sustainable administration of forests, rangelands, and national parks, along with the

preservation of vegetation across various landscapes and the fight against desertification. Within the NCVC, there is a specialized directorate of forests responsible for devising reforms in the forest sector (NCVC, 2023).

4.5.4 Urban Planning

4.5.4.1 Transportation Related Initiatives

The use of fuel in the transport sector results in GHG emissions. To reduce the use of private automobiles and meet the transportation demands of Saudi population, nine mega integrated public transport projects were initiated. Some have been completed and others are in various stages of completion.

i. Haramain High Speed Rail (HHR)

It links Mecca and Madinah and passes through three stations: The project was opened to the public in 2018. HHR has a capacity of 60 million passengers a year ("Haramain High Speed Rail," 2018).

ii. Riyadh Public Transit Network Project

The MEDSTAR 2030 strategy isa key element of Saudi Vision 2030. The 176-kilometer metro network is designed to accommodate 1.16 million passengers daily in its initial phase. Eventually, it is projected to handle a peak capacity of 3.6 million passengers per day. The Riyadh Metro, once operational, will be complemented by an extensive bus network, forming a cohesive and integrated urban transportation system ("Riyadh City review report : Future of Saudi Cities," 2017).

iii. Makkah Monorail Project

The Makkah monorail project, which extends over 18.1 kilometers has the capacity to transport up to 72,000 passengers per hour in each direction, significantly easing the movement and accessibility.

iv. Jeddah Public Transport Program (JPTP)

The JPTP consists of an automated metro (MRT), light rail transportation (LRT), a corniche tram, bus rapid transit (BRT), one commuter rail line, one waterbus network and 11 park and ride facilities. The MRT network consists of 161.1 km of route. The LRT provides a hop-on/hop-off service and runs in an east-west direction. The commuter rail line serves along the eastern periphery of Jeddah and the waterbus network serves along the coastline (Metro Jeddah Company, n.d.).

v. Saudi Arabian Railway (SAR)

The northern line is fully operational since 2017 (Saudi Arabian Railway, 2018). The length of northern line is approximately 2,750 km and it connects Riyadh, Majmaah, Qassim, Hail, Al-Jouf, and Qurayyat (Saudi Arabian Railway, 2023). SAR has planned to expand the project and connect with the industrial city of Jubail and Ras Al-Khair industrial City. The company will also provide Jubail and Dammam with a 107 km long railway and build a railway network within the Industrial City of Jubail (Saudi Arabian Railway, 2018).

4.5.4.2 Solid Waste Management Initiatives

Saudi Arabia's Vision 2030 aims at 100% diversion of municipal solid waste and an 85% diversion of industrial waste from landfills. The Ministry of Environment, Water and Agriculture (MEWA) of Saudi Arabia has established the National Waste Management Center

(NWMC) to oversee and regulate the country's waste management practices. The NWMC aims to enhance environmental protection and public health through these activities.

The Saudi Investment Recycling Company (SIRC), established in 2017, aims to advance waste management practices, promote recycling initiatives, conserve natural resources, and transition to a circular carbon economy in alignment with the Kingdom's Vision 2030. The company is committed to generating value from waste utilization, protecting the environment, and enhancing citizens' quality of life. It seeks to establish partnerships, attract foreign investments, and leverage technologies to maximize waste recycling and minimize disposal, contributing to environmental and sustainability goals.

In Saudi Arabia, several initiatives have been undertaken to minimize GHG emissions in solid waste management. These include the development of landfill gas collection and flaring systems, as well as the conversion of waste materials into organic fuels. Notably, the Madinah Landfill Gas Capture Project has been instrumental in gathering and diverting landfill gas to a flaring system, thereby preventing its release into the atmosphere. Similarly, the Jeddah Old Landfill (JOLF) and Jeddah New Landfill (JNLF) have implemented Landfill Gas Recovery Bundled Projects (Clean Development Mechanism, 2023). These projects have successfully installed landfill gas recovery and flaring systems, contributing to an annual reduction of approximately 362,668 tons of CO_2 equivalent from 2012 to 2021. The Kingdom also boasts over forty waste recycling companies, each operating at various levels and handling diverse types of waste. Major cities like Jeddah are adopting strategic plans focused on waste minimization. These plans include waste management programs aimed at decreasing landfill dependency through technologies such as composting. The Ministry of Environment, Water and Agriculture (MEWA) in Saudi Arabia is dedicated to organizing an integrated waste management process. This process encompasses reducing waste production, sorting, storing, collecting, transporting, and recycling. The goal is to achieve environmental sustainability while maintaining public health and human well-being.

4.6 CONCLUSIONS

The Kingdom of Saudi Arabia has taken a comprehensive approach to address climate change. This includes various initiatives aimed at efficient energy use, developing renewable energy, managing energy resources, supporting research and development, establishing institutional frameworks and business models, adopting a circular carbon economy, and promoting energy-efficient behaviors among the public. Relevant ministries are collaborating to ensure the success of these initiatives. The Kingdom announced the SGI and the MGI. Under the SGI, headed by HRH the Crown Prince and Prime Minister, Saudi Arabia has significantly enhanced its NDC ambition to reduce GHG emissions by 278 million tons CO_2eq annually. Saudi Arabia has embraced a circular carbon economy framework to create a new balance by enhancing energy efficiency, utilizing renewable energy, reusing emissions for value products, and reducing carbon emissions. This framework aims to develop a comprehensive technology roadmap for CO_2 capture, sequestration, and utilization. The Kingdom is also using advanced technologies to control flaring activities and reduce methane emissions, particularly from oil and gas operations. Efforts are being made to lower GHG emissions in solid waste management, including methane gas collection and flaring systems. As part of the SGI, Saudi Arabia plans to divert 94% of its solid waste in Riyadh from landfills by 2030. Finally, the GHG Crediting and Offsetting Mechanism (GCOM) was launched to facilitate the country's ambitious climate objectives efficiently, promoting collaboration among local stakeholders and providing financial assistance for diverse projects.

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