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Potential Employment Generation Capacity of Renewable Energy in MENA

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Summary

The Middle East and North Africa (MENA) region, globally renowned for its vast reserves of fossil fuels, is undergoing a significant paradigm shift towards embracing renewable and green energy sources. This transition is not only driven by environmental objectives but also by the recognition of the substantial employment and economic diversification opportunities inherent to renewable energy solutions. The MENA region, with its abundant solar radiation and wind resources, is poised to leverage these natural assets to propel its economy into a greener and more sustainable future.

This study provides a comprehensive analysis of the employment impacts, societal challenges, and economic opportunities associated with the adoption of renewable energy technologies. The study particularly focuses on the variety of benefits, barriers and the complexities inherent to the transition to renewable energy in the six target countries—Egypt, Jordan, Lebanon, Morocco, Sudan, and Tunisia.

The adoption of renewable energy technologies, such as solar power, wind energy, biomass, green hydrogen, and hydro-power, catalyzes the emergence of new industries and job opportunities across the MENA region. With its abundant solar and wind resources, the region is primed to capitalize on renewable energy projects, thereby fostering employment growth in sectors ranging from engineering, manufacturing, construction, to project management. The construction, installation, and maintenance of renewable energy infrastructure requires a skilled workforce, offering added direct employment opportunities and stimulating ancillary industries.

Investments in green energy initiatives have historically stimulated research and development (R&D) activities, driving innovation and technological advancements. The MENA region is witnessing a similar trend, with governments and private entities increasingly investing in clean energy R&D. This influx of investment not only creates job opportunities for scientists, engineers, and technicians but also promotes knowledge transfer and enhances the region's technical expertise, positioning it as a hub for renewable energy innovation.

The production and installation of renewable energy equipment, such as solar panels and wind turbines, also necessitates the development of a robust local supply chain and manufacturing capabilities. By supporting the production of renewable energy components within the region, MENA countries can reduce dependence on imports and gain a competitive advantage in the global green energy equipment market. This, in turn, will lead to job creation in manufacturing, assembly, logistics, and related support services. Moreover, the rapid expansion potential of Electric Vehicles (EVs) manufacturing presents additional employment opportunities, with several MENA countries already making progress in this direction.

Transitioning to renewable energy is complemented by promoting energy efficiency measures and retrofitting existing infrastructure for improved energy performance. This too can generate employment opportunities in the MENA region. As countries seek to optimize energy consumption and mitigate greenhouse gas emissions, the demand for professionals specializing in energy-efficient solutions such as, energy audits, building

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retrofits, and energy management can be expected to rise. This creates opportunities in several new industries involved in the production and installation of energy-efficient equipment, fostering job growth and sustainability.

Governments, MSMEs and educational institutions in the MENA region can and should play a pivotal role in providing training programs and vocational courses focused on renewable energy technologies. By equipping individuals with the necessary skills, the region can enhance its human capital, fostering employment opportunities and sustainable development in the green and renewable energy sector.

An added opportunity that is unique to renewable energy given that it is less transportable than fossil fuels, is the opportunity to attract energy intensive industries to agglomerate near the sources of renewable energy. This agglomeration effect augurs well for creating manufacturing hubs that generate substantial employment. This clustering effect promotes economic diversification, job creation, and industrial growth, laying the foundation for a sustainable, diversified and resilient economy.

The structure of the report is designed to provide a comprehensive understanding of the potential employment impacts of renewable energy in the MENA region. It begins with an introductory section, setting out the overarching objectives and scope of the study. Then the report transitions into an in-depth analysis of the energy supply and demand dynamics in the MENA region, with a particular focus on the six selected countries. Each country-specific section provides an exploration of its energy landscape, highlighting past trends, present dynamics, and future projections. The report ventures into a broader discourse on the transition to green and renewable energy, delineating the importance for MENA economies to capitalize on the green transition. It presents the complex relationship between renewable energy adoption, job creation, job quality, and job distribution, underscoring the transformative potential of renewable energy for economic rebasing and social transformation. Through a synthesis of theoretical frameworks and analytical models, the report navigates the complexities of estimating the employment impacts of renewable energy, offering insights into alternative approaches and methodological considerations. Moreover, the report embarks on an exploration of emerging paradigms in renewable energy, such as the economic potential and impacts of EVs and green hydrogen.

The conclusion is devoted to provide a synthesis of key findings and recommendations. emphasizing its role in economic diversification, job creation, reduced carbon footprint and inclusive growth.

Transitioning to renewable energy aligns with global trends and offers possible solutions challenging regional problems such as the high regional unemployment rates, particularly among youth and women. By strategically investing in renewable energy infrastructure, fostering innovation, and promoting skills development, the MENA region can unlock the potential promoting prosperity, sustainability, resilience and inclusivity. The transition to renewable energy represents not only an opportunity to mitigate climate risks but also a pathway towards a more equitable and prosperous future for the peoples of the region.

1. Introduction

The Middle East and North Africa region (MENA), renowned for its vast reserves of fossil fuels, is increasingly recognizing the importance of transitioning to renewable and green energy sources. There is a growing consensus that this shift toward sustainable energy solutions not only addresses environmental concerns but also presents significant employment and income opportunities and the opportunity to diversify economies.

This study examines the potential employment impacts of green energy in the MENA region with a special focus on six target countries (Egypt, Jordan, Lebanon, Morocco, Sudan, and Tunisia), highlighting the potential benefits for the region's workforce, societal challenges, and economy. It also presents quantitative estimates of the potential employment impacts of green and renewable energy using input-output (IO) models and comparative estimates derived from econometric studies conducted by the International Monetary Fund (IMF), studies from Chile, and studies collected from the general economic literature.

As an introduction to the in-depth analysis that will be undertaken in subsequent sections, we begin with a general summary of the employment impacts and general benefits associated with renewable and green energy that could be realized by the region.

The identified benefits are many and involve several aspects and domains, which include, but are not restricted to, the following:

1.1. Job creation in the renewable energy sector

The adoption of green energy technologies, such as solar power, wind energy, biomass, and hydropower, necessitates the establishment of new supporting and downstream industries, leading to job creation across various sectors. The MENA region, with its abundant solar irradiation and wind resources, has immense potential for renewable energy projects. As a result, the construction, installation, and maintenance of the renewable energy infrastructure will require a skilled workforce, contributing to direct job opportunities in engineering, manufacturing, construction, and project management.

1.2. Research, development, and innovation

Investments in green energy initiatives in several developed and developing countries have stimulated research and development (R&D) activities, fostering innovation and technological advancements. Their experience suggests that this could be expected in the MENA region. Governments and private entities in the MENA region are increasingly investing in clean energy R&D, aiming to develop efficient and cost-effective renewable energy systems. This will create employment opportunities for scientists, engineers, and technicians specializing in renewable energy research and development. The growth of R&D centers and innovation hubs promotes knowledge transfer and enhances the region's technical expertise.

1.3. Supply chain and manufacturing

Green energy projects are expected to entail the production and installation of renewable energy equipment, such as solar panels, wind turbines, and energy storage systems. Establishing a robust local supply chain and manufacturing capabilities can significantly contribute to job creation. By supporting the production of renewable energy components within the region, a few examples are already being established; MENA countries can reduce their dependence on imports and develop a competitive advantage in the global green energy market. This would lead to employment opportunities in manufacturing, assembly, logistics, and related support services. This is in addition to the expanding potential of moving downstream and off-stream to the manufacturing of Electric Vehicles (EVs), a prospect that is already being rooted in several MENA countries, including Morocco, Egypt, Algeria, the United Arab Emirates (UAE), and Saudi Arabia.

1.4. Energy efficiency and retrofitting

Promoting energy efficiency measures and retrofitting existing infrastructure for improved energy performance can also generate employment opportunities. As the countries of the region seek to optimize energy consumption and reduce greenhouse gas (GHG) emissions, there will be a demand for professionals specializing in energy audits, building retrofits, and energy management. Industries involved in the production and installation of energy-efficient equipment, such as lighting systems and HVAC (heating, ventilation, and air conditioning) solutions, will witness growth and create additional jobs.

1.5. Skills development and training

The transition to green energy necessitates a skilled workforce capable of meeting the demands of the evolving energy landscape. Governments and educational institutions in the MENA region can play a vital role by providing training programs and vocational courses focused on renewable energy technologies and energy-efficient systems and products. By equipping individuals with the necessary skills, the region can enhance its human capital, fostering employment opportunities and sustainable development in the green and renewable energy sector.

1.6. Energy-intensive industries agglomeration potential

Unlike fossil fuels, green energy is not easily transportable. Energy-intensive industries can no longer be separated easily and cheaply from the sources of energy. This could give the region a comparative cost advantage to attract these energy-intensive industries in heavy metals, chemicals, and energy to locate in the region, thereby creating manufacturing hubs that generate substantial jobs for all types of skills and occupations.

A summary of the findings shows that the potential employment impacts of green and renewable energy in the MENA region are multifaceted and promising. Embracing renewable energy technologies presents an opportunity for the region to diversify its economy, mitigate the possible negative impacts of digitalization and AI on existing jobs, reduce its carbon footprint, and create significant levels of employment across various sectors. By investing in renewable and green energy infrastructure, research and development, local manufacturing, energy-intensive manufacturing, energy efficiency measures, and skills development, the MENA region can unlock the full potential of the green energy sector, leading to a greener future and a more sustainable, efficient, diversified, and well-paid workforce.

The region's stakes in limiting emissions at home and abroad, managing its energy use efficiently, creating sufficient jobs for its growing population, dealing with its high unemployment rates of youth and women, and improving and expanding its resiliency to deal with natural disasters and the expected high economic costs of climate change are leaving the region with no option but to expedite its transition to renewable energy.

Factoring in the increased likelihood of fossil fuels becoming stranded assets as countries and industries abandon fossil fuels, the MENA region is at the threshold of a major economic crisis if it delays its transition away from its heavy dependence on fossil fuels. The region remains home to the highest world levels of unemployment, particularly youth unemployment. It is also a region where the low participation of women in the labor force and their underrepresentation in leadership and high-paying positions are defining characteristics.

The transition to renewable energy can be conceived as a social project to capitalize on the net socioeconomic and environmental benefits of a speedy, careful, and "just" transition plan to renewable and green energy. This is increasingly becoming possible due to international and regional funding opportunities for more environmentally friendly development that is capable of sustaining credible alternative income dividend streams, creating new exports, generating sufficient jobs for the growing populations, and expanding labor supplies. The transition to renewable energy also promises to ensure energy sufficiency and potentially meet the social objectives of inclusiveness and equity.

In general, the MENA region comprises three sub-regions: North Africa, the Arabian Peninsula, and the Levant (Middle East). The choice to target six countries in the region for an in-depth consideration and analysis is motivated by the realization that the chosen countries represent a rich mix of constraints and opportunities that allows us to focus on the potential realization of the inherent benefits that the transition to renewable and green energy could afford for the people of the region – particularly those that are less fortunate than their neighbors in the rich economies of the Gulf.

This report is meticulously structured to provide a comprehensive understanding of the potential employment impacts of renewable energy in the MENA region. It begins with this introductory section, delineating the overarching objectives and scope of the study. Subsequently, the report delves into the employment prospects within the renewable energy sector, examining facets such as job creation, research, development, innovation, supply chains, manufacturing, energy efficiency, retrofitting, skills development, training, inclusive development and women and youth empowerment. Each subsection within the introduction elucidates specific dimensions of the employment landscape, offering insights into the diverse avenues for job growth associated with renewable energy adoption., Subsequent sections are structured as follows: Section 2 discusses the current supply and demand for primary energy and electricity generation in the MENA region, specifically in the six targeted countries in the region. Each country-specific section presents the case for transitioning to green and renewable energy and how each country in the MENA region can rebase the growth of their economies and capitalize on renewable energy potential for diversifying their economies, creating jobs for their growing populations and cleaning their environments. Furthermore, the report ventures into a broader discourse on the transition to green and renewable energy, delineating the importance for

MENA economies to capitalize on the green transition. It presents the complex relationship between renewable energy adoption, job creation, job quality, and job distribution, underscoring the transformative potential of renewable energy for economic rebasing and social transformation. In tandem with the discussion on renewable energy's macroeconomic implications, the report delves into the complexities of an Integrated Energy System Plan (IESP) that treats renewable energy within the broader contexts of energy security, sufficiency, and efficiency. Through a synthesis of theoretical frameworks and analytical models, the report describes alternative approaches to estimating the employment creation potential of renewable energy applied by international organizations and different countries.

Moreover, the report embarks on an exploration of emerging paradigms in renewable energy, such as the economic potential and impacts of Electric Vehicles (EVs) and green hydrogen. By unpacking the gross and net employment impacts of EVs and delineating the transformative potential of green hydrogen, the report illuminates novel pathways for sustainable energy leadership in the MENA region. Concluding with a synthesis of key findings and recommendations, the report offers a roadmap for policymakers, industry stakeholders, and civil society actors to navigate the transition to renewable energy. It underscores the importance for proactive measures to harness the employment potential of renewable energy, foster inclusive growth, and catalyze sustainable development across the MENA region.

2. Energy supply and demand in the MENA region with special emphasis on the six selected countries: past, present, and future trends[1]

The MENA region is home to significant oil and gas reserves, with estimates varying between 48.3 percent and 58 percent of the world's oil reserves and over 43 percent of its gas reserves as of 2021.[2] The region has immensely benefited from substantial oil and gas export revenues, which have contributed to major socioeconomic advancements in the entire MENA region, particularly in the Gulf Cooperation Countries (GCC). These benefits, however, came at a cost manifested in a lack of economic diversification and lopsided economic structures, as well as a few sociopolitical anomalies such as a slow transition to democracy and a limited role for the private sector.[3]

Capturing, allocating, and distributing the wealth generated from hydrocarbon exports has been the dominant role of the state in the GCC countries. This exclusive capture of the oil wealth by the state reduced, if not eliminated, the need for citizens' taxation. Oil revenues, in one sense or another, have reversed the normal relationship between the rulers and the ruled, which led to limited political representation.[4] Despite variations in resource abundance, the entire MENA region has developed a rentier structure. This occurs either directly or indirectly through the citizens of MENA non-oil producers sending large remittances back to their countries on incomes generated in the GCC countries, through non-oil Arab countries directing their main exports to GCC countries or receiving generous aid from them, or through large streams of investments. This deep interplay between oil, economics, and politics within the MENA countries has become a defining characteristic of the region.

In 2021, the total MENA primary energy supply exceeded 32,229,297 TJ (Table 1); oil and natural gas accounted for 96.7 percent of this total while renewable energy (solar, wind, hydro, and biofuels) supplied less than 0.56 percent. The projected annual increase in energy demand in the MENA region is put at 1.9 percent, based on two factors: the high population growth and the rapid urbanization that has accompanied economic growth.

At present, the installed renewable energy capacity (electricity generation) in the MENA region is approximately 28 GW, primarily dominated by

[1] This section benefited from the study prepared by Sara Ragab and Esraa Medhat (July 2023). Powering the Future of MENA: Energy Transition, Country Profiles, and Review of Data and Literature.

[2] https://www.statista.com/statistics/237065/share-of-oil-reserves-of-the-leading-ten-countries/ puts these reserves at 48.3 percent of global reserves while OPEC puts this share at 58 percent.

https://www.opec.org/opec_web/en/2211.htm#:~:text=OPEC%20Member%20Countries%20in%20MENA,metres%20of%20proven%20gas%20reserves.

[3] IEA (2020). The case for energy transitions in major oil- and gas-producing countries.

[4] Giacomo Luciani and Hazem Beblawi (eds.) (1987). The Rentier State, London: Croom Helm.

Table 1. Primary supply in the MENA region, 2021

	TJ	Share (%)
Coal	147,121	0.46%
Natural Gas	18,297,711	56.77%
Nuclear	63,164	0.20%
Hydro	81,470	0.25%
Wind and Solar	56,669	0.18%
Biofuels and Waste	42,322	0.13%
Oil	13,540,840	42.01%
Total	32,229,297	100.00%

Source: iea.org/regions/middle-east

hydropower. Existing non-hydro renewable energy sources account for approximately seven percent of total energy generation, with four countries contributing 80 percent of this share.[5]

In 2021, solar photovoltaic (PV) and wind energy emerged as the most cost-effective and competitive resources in the region. There is a lot of room to expand renewable energy generation in the region given its large and rich endowments of solar radiation and wind, so much so that a few credible projections have suggested that the region, with sufficient investments, could contribute up to 45 percent of the world's potential renewable energy generation.[6]

Below, we review the current primary energy supply as well as the share of renewable resources in this supply and in the electricity generation in order to set the stage for estimating the potential supply shares of renewable energy in the supply mix in the six target countries of this study in 2030 and 2050. The main focus will be on the expected shares of solar, wind, hydro, geothermal, and waste in each of these countries, which will help us determine the potential employment generation capacity of renewable energy in each country in 2030 as declared in their NDC submissions and in the zero net emission scenario in 2050.

The current demand for and supply of primary energy and the electricity generation capacity in each of the six countries are presented sequentially below in order to benchmark the starting points for future renewable energy demands.

2.1. Egypt

Egypt relies heavily on energy imports, particularly those of oil and natural gas, to meet its growing energy demand. The substantial increase in Egypt's population in the past few decades has led to a surge in energy demand, resulting in significant strains on domestic energy resources as they fell short of supplying the increased demand.

Natural gas and oil accounted for over 92 percent of the total primary energy supply in 2020 (Table 2), while oil alone contributed 34.1 percent of the total primary energy supply in the same year. Hydropower, coal, wind, and solar power made up a smaller share. Although Egypt possessed a significant surplus of available power generation capacity, reaching 21 GW in 2022, the majority of this capacity was derived from thermal plants, representing 90 percent of the installed capacity. The current surplus of power generation capacity, predominantly based on gas, along with the existing lifespan of gas-based power plants, restricts the immediate and near-term integration of renewable energy into the generation mix, unless the excess energy generated can be exported.[7]

The government recently formulated an energy diversification strategy known as the Integrated Sustainable Energy Strategy (ISES), which is set to be achieved by 2035. The primary objective of this strategy is to ensure a reliable energy supply that can effectively meet the needs of the growing population and economy. By accomplishing this, Egypt can enhance the development of renewable energy sources and promote efficient energy utilization, contributing to sustainable development in the country.[8]

The heavy dependence on fossil fuels has its roots as far back as the 1990s as shown in Table 2. Renewable energy sources have increased since the year 2000, but their growth rate has lagged behind the growth of non-renewable energy sources.

The renewable and non-renewable energy supply in 2014 and 2019 is presented in Table 3 and Figures 1 and 2. The current situation suggests that energy supply is still heavily dependent on fossil fuels, with renewable sources remaining limited at only seven percent of the total energy supply in 2019 (Figure 1).

[5] "Renewable Energy in the MENA Region: Key Challenges and Lessons Learned." 2021.

[6] "Renewable Energy in the MENA Region: Key Challenges and Lessons Learned." 2021.

[7] World Bank (April 2023). Egypt Economic Update: Restoring Growth, Reducing Poverty, and Protecting the Vulnerable.

[8] Salman, Gomaa I., and Ahmed M. Hosny (2021). The Nexus between Egyptian Renewable Energy Resources and Economic Growth for Achieving Sustainable Development Goals.

Table 2. Total energy supply, Egypt, 1990-2020 (TJ)

	Coal	Natural gas	Hydro	Biofuels and waste	Oil	Wind, solar, etc.	Total
1990	31,782	281,876	35,755	100,938	956,677	-	1,407,028
1995	26,999	430,715	41,087	111,850	922,205	-	1,532,856
2000	34,780	604,417	49,309	118,560	936,392	493	1,743,951
2005	33,842	1,255,451	45,518	125,762	1,184,051	1,987	2,646,611
2010	24,344	1,499,297	46,966	132,620	1,425,226	6,134	3,134,587
2015	14,659	1,539,581	48,762	137,187	1,629,825	8,014	3,378,028
2020	59,674	2,133,784	54,137	142,276	1,252,730	31,460	3,674,061
				Shares			
1990	2.26%	20.03%	2.54%	7.17%	67.99%	0.00%	100.00%
1995	1.76%	28.10%	2.68%	7.30%	60.16%	0.00%	100.00%
2000	1.99%	34.66%	2.83%	6.80%	53.69%	0.03%	100.00%
2005	1.28%	47.44%	1.72%	4.75%	44.74%	0.08%	100.00%
2010	0.78%	47.83%	1.50%	4.23%	45.47%	0.20%	100.00%
2015	0.43%	45.58%	1.44%	4.06%	48.25%	0.24%	100.00%
2020	1.62%	58.08%	1.47%	3.87%	34.10%	0.86%	100.00%

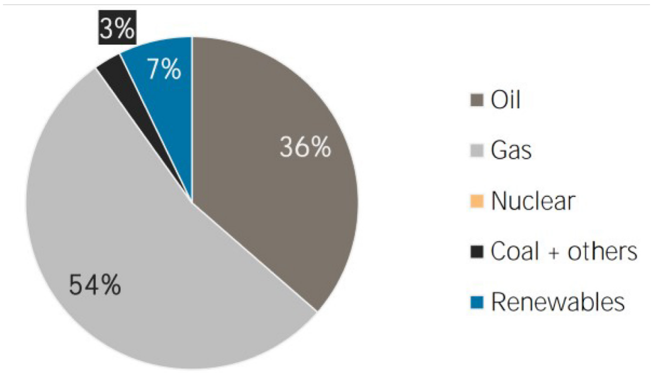
Source: IEA World Energy Balances 2022. Https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances

Table 3. Total energy supply, Egypt, 2014 and 2019

Total Energy Supply (TES)	**2014**	**2019**
Non-renewable (TJ)	3 217 682	3 809 359
Renewable (TJ)	274 135	294 596
Total (TJ)	3491817	4103955
Renewable share (%)	8	7
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+18.4	+6.7
Renewable (%)	+7.5	-0.4
Total (%)	+17.5	+6.2
Primary energy trade	**2014**	**2019**
Imports (TJ)	901 347	795 743
Exports (TJ)	603 143	658 926
Net trade (TJ)	- 298 204	136 817
Imports (% of supply)	26	19
Exports (% of production)	19	16
Energy self-sufficiency (%)	93	98

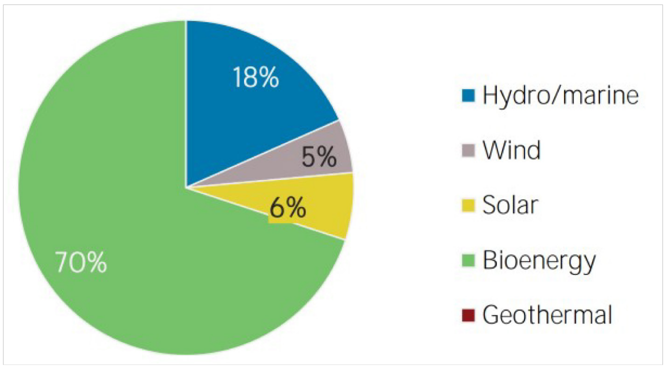
Source: IRENA, Energy Profile Egypt.

Figure 1. Total energy supply, Egypt, 2019



Source: IRENA, Energy Profile Egypt.

Figure 2. Renewable energy supply, Egypt, 2019



Source: IRENA, Energy Profile Egypt.

2.1.1. Renewable energy market

The renewable energy sector in Egypt has registered some growth over the past decade, particularly in hydropower, solar power, and wind power. The country's rich renewable resources present a significant potential for further development and utilization, contributing to a diversified and sustainable energy portfolio. The differential performance of the various subcomponents of this sector is detailed below.

2.1.2. Hydroelectric energy

The primary source of hydropower in Egypt is the River Nile, particularly in the Aswan region, where multiple power stations have been established with a total capacity of 2,800 megawatts (MW). These power stations contribute significantly to the annual electricity generation, totaling 13,545 gigawatt-hours (GWh). In the 1960s and 1970s, approximately 50 percent of Egypt's electricity was generated from hydropower. The expansion of thermal power stations led to a substantial decrease in the share of hydropower such that by 2015/16, hydropower's share had diminished to only 7.2 percent. Egypt currently operates five main hydroelectric stations, with four additional power stations in Assiut added in 2018. Furthermore, there are plans to construct a 2,400 MW pumped storage hydroelectric plant in Attaqa by the end of 2022, which will further expand the hydroelectric capacity of the country.[9]

2.1.3. Wind energy

Egypt has abundant wind resources to tap into, particularly in the Gulf of Suez region, making it one of the best locations globally for wind energy generation. The availability of high and stable wind speeds, averaging eight to 10 meters per second at a height of 100 meters, contributes to this advantage. Additionally, new wind-rich areas have been identified east and west of the Nile River, including Beni Sueif, Menya, and El Kharga Oasis. These regions exhibit average wind speeds ranging from five to eight meters per second, providing relatively suitable conditions for electricity generation and water pumping.[10]

2.1.4. Solar energy

Solar energy in Egypt can be divided into two types: latent solar energy, which involves direct utilization of solar energy, and dynamic solar energy, which converts the sun's electromagnetic radiation into electrical energy. Egypt's favorable solar radiation levels enable efficient electricity generation and the utilization of solar energy for thermal heating applications. The largest solar PV project in the world is currently under construction in Benban, Aswan. This project, with an estimated cost of USD 4 billion, aims to produce over 1.8 gigawatts (GW) of power. Solar PV projects in Egypt play essential roles in various applications such as water pumping, lighting, advertising, and desalination. Since 2014, following electricity shortages and a decline in PV panel costs, Egypt has prioritized efforts to promote PV applications. Two additional major solar PV plants were completed by late 2019 in Hurghada and Kom Ombo, financed by Japan and France, respectively. These plants are expected to reduce CO_2 emissions by 40,000 tons and generate an annual output of approximately 32 to 42 GWh.[11]

2.1.5. Solar water heaters

During the period extending from 2010 to 2017, the average annual growth rate of direct jobs created by solar water heaters (SWH) technology was 24.8 percent. In 2010, SWH technology generated 607 direct jobs, which increased to 2,812 in 2017. In 2018, there was a growth rate of 35 percent, resulting in 2,696 direct jobs. From 2019 to 2030, SWH technology is expected to maintain an average share of 8.9 percent of the total number of direct jobs created by renewable energy. In terms of indirect jobs, SWH technology has represented a small portion of the total number of jobs created over the years. Between 2010 and 2013, its average share was 3.75 percent, while it increased to 6.9 percent between 2014 and 2017. In 2010, 72 indirect jobs were created, which rose to 345 in 2017. In 2018 and 2019, 346 and 333 indirect jobs were created, respectively.[12] These are modest estimates and could easily underestimate the number of these indirect jobs given the extensive connections solar water heaters have with other sectors feeding inputs into their making. It is also worthwhile to note the induced jobs that are typically created by workers and firms spending the incomes they

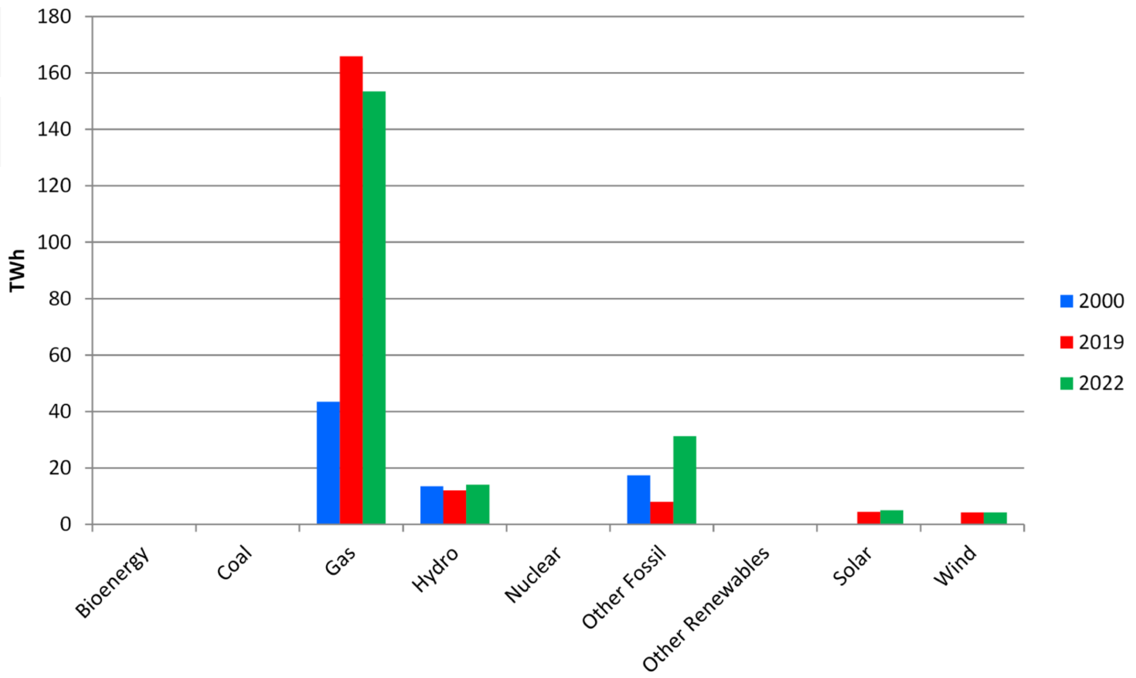
[9] Salman, Gomaa I., and Ahmed M. Hosny (2021). The Nexus between Egyptian Renewable Energy Resources and Economic Growth for Achieving Sustainable Development Goals.

[10] Salman, Gomaa I., and Ahmed M. Hosny (2021). The Nexus between Egyptian Renewable Energy Resources and Economic Growth for Achieving Sustainable Development Goals.

[11] Salman, Gomaa I., and Ahmed M. Hosny (2021). The Nexus between Egyptian Renewable Energy Resources and Economic Growth for Achieving Sustainable Development Goals.

[12] Elguindy, R., M. Bououd and M. Elsharief (2020). Mapping EE and RES Market Potential Areas with Higher Impact on Local Economy and Job Creation. MEDENER and RCREEE. Available at: https://rcreee.org/wp-content/uploads/2020/04/v3_15_a32_impact-map-eco-and-job_final.pdf

Figure 3. Sources of fuel for electrivity generation: Egypt 2000, 2019 and 2022



derive from expanded activities connected to water heaters and their suppliers.

2.1.6. Biomass

Biomass energy production derived from agricultural sources represents a significant opportunity for clean energy generation. Biomass is formed when organic matter converts into energy, and this process is both environmentally friendly and economically viable. Egypt in particular has abundant resources that can be harnessed for biomass production given its vibrant agriculture sector and large urban population. These resources encompass agricultural waste, urban solid waste, and animal fertilizers. Agricultural waste alone amounts to approximately 35 million tons per year, with nearly 60 percent of this waste being utilized for energy purposes. Urban solid waste in Cairo alone reaches 10,000 tons per day. In recent years, there have been notable advancements and innovations in biomass technologies, particularly in the production of biogas from animal waste, especially in rural areas. These technologies have not only created numerous job opportunities in rural regions but may have also contributed to a decline in the rate of migration of young individuals from rural to urban areas.[13]

Bioenergy makes up the largest share of renewable energy sources in Egypt. In 2019, it contributed over 70 percent of the total supply of renewable energy, followed by hydro with a share of 18 percent (Figure 2). Wind and solar show a share of 11 percent almost equally divided between solar and wind (Figure 2).

Egypt would have a significant competitive edge in renewable energy once it decides to exploit its endowments and substantial potential for harnessing wind and solar power generation. The country has already committed to expediting the integration of renewable energy in alignment with its National Climate Change Strategy (NCCS) and the updated Nationally Determined Contributions (NDCs). However, this will require substantial upfront investment in additional infrastructure, including storage systems in order to accommodate and stabilize the power grid, as well as a different electricity tariff and feed-in strategy and substantial training of the requisite labor force. As of 2021, renewable electricity generation accounted for 11.4 percent of the total power produced (Table 4), with installed capacity reaching 18.9 percent, in line with the interim target set by Egypt's Integrated Sustainable Energy Strategy (ISES) 2035. The record, however, shows that the contribution of non-hydro renewable energy to the overall energy mix was only 4.5 percent in 2021, suggesting that a large untapped potential remains unexploited.[14]

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[13] Salman, D., Hosny, N.A. The nexus between Egyptian renewable energy resources and economic growth for achieving sustainable development goals. Futur Bus J 7, 47 (2021). https://doi.org/10.1186/s43093-021-00091-8

[14] World Bank (April 2023). Egypt Economic Update: Restoring Growth, Reducing Poverty, and Protecting the Vulnerable.

Table 4. Sources of fuel for electricity generation, Egypt, 2000-2022

	TWh										Share (%)									
Year	**Bioen-ergy**	**Coal**	**Gas**	**Hydro**	**Nucle-ar**	**Other Fossil**	**Other Re-new-ables**	**Solar**	**Wind**	**Total**	**Bioen-ergy**	**Coal**	**Gas**	**Hydro**	**Nucle-ar**	**Other Fossil**	**Other Re-new-ables**	**Solar**	**Wind**	**Total**
2000	0	0	43	13.56	0	17.36	0	0	0.14	74.47	0.00	0.00	58.29	18.21	0.00	23.31	0.00	0.00	0.19	1,407,028
2001	0	0	47	14.98	0	17.13	0	0	0.22	79.37	0.00	0.00	59.27	18.87	0.00	21.58	0.00	0.00	0.28	1,532,856
2002	0	0	57	12.73	0	14.55	0	0	0.2	84.81	0.00	0.00	67.60	15.01	0.00	17.16	0.00	0.00	0.24	1,743,951
2003	0	0	63	12.89	0	14.61	0	0	0.37	90.48	0.00	0.00	69.20	14.25	0.00	16.15	0.00	0.00	0.41	2,646,611
2004	0	0	73	12.52	0	10.25	0	0	0.52	96.21	0.00	0.00	75.79	13.01	0.00	10.65	0.00	0.00	0.54	3,134,587
2005	0	0	75	12.52	0	14.72	0	0	0.55	103.2	0.00	0.00	73.06	12.14	0.00	14.27	0.00	0.00	0.53	3,378,028
2006	0	0	81	12.8	0	14.87	0	0	0.62	109.5	0.00	0.00	74.16	11.69	0.00	13.58	0.00	0.00	0.57	100.00%
2007	0	0	87	15.35	0	15.42	0	0	0.83	118.8	0.00	0.00	73.40	12.92	0.00	12.98	0.00	0.00	0.70	
2008	0	0	92	14.53	0	17.29	0	0	0.91	124.3	0.00	0.00	73.67	11.69	0.00	13.91	0.00	0.00	0.73	
2009	0	0	97	12.73	0	20.43	0	0	1.13	131.7	0.00	0.00	73.96	9.67	0.00	15.52	0.00	0.00	0.86	
2010	0	0	123	12.92	0	22.34	0	0.21	1.5	160.3	0.00	0.00	76.94	8.06	0.00	13.94	0.00	0.13	0.94	
2011	0	0	124	12.81	0	18.37	0	0.22	1.52	157.1	0.00	0.00	79.04	8.16	0.00	11.69	0.00	0.14	0.97	
2012	0	0	128	12.99	0	21.71	0	0.24	1.12	164.4	0.00	0.00	78.07	7.90	0.00	13.21	0.00	0.15	0.68	
2013	0	0	126	13.22	0	27.66	0	0.11	1.33	168.2	0.00	0.00	74.84	7.86	0.00	16.44	0.00	0.07	0.79	
2014	0	0	127	13.68	0	32.54	0	0.24	1.44	175.3	0.00	0.00	72.67	7.80	0.00	18.56	0.00	0.14	0.82	
2015	0	0	133	13.41	0	37.39	0	0.17	2.06	186.3	0.00	0.00	71.54	7.20	0.00	20.07	0.00	0.09	1.11	
2016	0	0	140	12.72	0	34.23	0	0.58	2.2	189.6	0.00	0.00	73.77	6.71	0.00	18.06	0.00	0.31	1.16	
2017	0	0	155	12.6	0	26.3	0	0.6	2.33	196.8	0.00	0.00	78.75	6.40	0.00	13.36	0.00	0.30	1.18	
2018	0	0	167	12.77	0	15.7	0	1.52	3.02	199.6	0.00	0.00	83.46	6.40	0.00	7.86	0.00	0.76	1.51	
2019	0	0	166	12.09	0	8	0	4.43	4.23	194.6	0.00	0.00	85.23	6.21	0.00	4.11	0.00	2.28	2.17	100.00%
2020	0	0	162	12.09	0	6.81	0	4.51	4.23	189.3	0.00	0.00	85.40	6.39	0.00	3.60	0.00	2.38	2.23	100.00%
2021	0	0	169	14	0	10.58	0	4.8	4.23	202.3	0.00	0.00	83.38	6.92	0.00	5.23	0.00	2.37	2.09	100.00%
2022	0	0	153	14.07	0	31.29	0	5.05	4.23	208.1	0.00	0.00	73.74	6.76	0.00	15.04	0.00	2.43	2.03	100.00%

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

The Government of Egypt has actively encouraged investments in renewable energy through various policy measures regulated under the Renewable Energy Law (Decree No. 203/2014) and supporting legislation. The installed capacity of wind and solar power plants reached 3,016 MW in FY 2019/20, indicating a remarkable 340 percent increase compared to FY 2015/16 (887 MW). The total capacity of renewable energy, including hydropower, in FY 2019/20 exceeded 5,848 MW. Notable achievements in the power sector include the establishment of the Benban Solar Park, with a total capacity of 1,465 MW, as well as the Assiut hydropower plant (32 MW), Kom Ombo Solar PV Plant (26 MW), and Gabal El-Zeit Wind Power Plant (580 MW).[15]

2.2. Jordan

Jordan's energy demand in 2020 reached a total of 8.47 million tons of oil equivalent.[16] The majority of Jordan's energy demand is met by imported oil and natural gas.[17] The demand for electricity is experiencing rapid growth and is projected to reach 52 terawatt-hours (TWh) by 2030.[18] Jordan relies heavily on imported energy sources, as its domestic energy production is limited and fulfills only approximately 40 percent of the nation's energy requirements.[19] Oil, natural gas, and renewable energy are the main sources of energy production in Jordan.[20] The production of oil in Jordan has experienced a downward trend in recent years and is projected to stabilize by 2025.[21] Jordan has limited natural gas production and relies on imports to meet its energy needs in this regard.[22] Renewable energy is experiencing significant growth in Jordan and is becoming an increasingly important source of energy. The government has established an ambitious goal of achieving 31 percent renewable energy in the country's power mix by 2030.[23]

Between 2010 and 2017, the Total Primary Energy Supply (TPES) experienced a steady growth rate of three percent annually, reaching 10 million tons of oil equivalent (mtoe) in 2017. However, in 2018, it witnessed a three percent decline, reaching 9.7 mtoe. This decrease was attributed to stagnant consumption in certain sectors. The dominant sources of energy in 2018 were oil, natural gas, and electricity, with oil accounting for more than half of the total energy supply. The transportation sector heavily relies on crude oil and its derivatives, driven by population growth, urbanization, and economic activity.

Over the past decade, the share of natural gas in TPES has exhibited significant fluctuations. It decreased from 40 percent in 2009 to four percent in 2014 but then rose to 35 percent in 2018, according to the Ministry of Energy and Mineral Resources (MEMR, 2019). These fluctuations were primarily caused by disruptions in imported natural gas supply in 2011. The decline in natural gas share was compensated by the increased use of oil products, such as heavy fuel oil and diesel, particularly in the power sector. However, relying on costly oil product imports to meet the energy demand has had adverse financial implications for the National Electric Power Company (NEPCO). Consequently, there is a compelling case for pursuing diversification through the utilization of domestic energy resources.

The dependency on energy imports has remained high in the TPES over the past decade, reaching its peak in 2014 at 99.9 percent and standing at 92 percent in 2018. To address this issue, the Master Strategy of the Energy Sector 2020-2030 aims to increase the contribution of domestic energy resources to the primary energy mix, targeting a share of 48.5 percent. This objective will be achieved primarily through the utilization of renewable energy sources and optimizing the oil sector.[24]

Jordan possesses considerable potential for renewable energy, benefiting from ample solar and wind resources. Once this potential is exploited, it will play a vital role in enhancing energy security, lowering energy costs, promoting environmental conservation, and facilitating the country's post-COVID-19 recovery.[25]

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[15] Arab Republic of Egypt. (2022). Egypt's first updated nationally determined contribution. https://unfccc.int/sites/default/files/NDC/2022-07/Egypt%20Updated%20NDC.pdf.pdf

[16] Jordan Energy Profile, https://ourworldindata.org/energy/country/jordan

[17] Jordan Energy Report, https://www.enerdata.net/estore/country-profiles/jordan.html

[18] Jordan Energy Profile, https://ourworldindata.org/energy/country/jordan

[19] Jordan Energy Report, https://www.enerdata.net/estore/country-profiles/jordan.html

[20] Energy in Jordan, https://en.wikipedia.org/wiki/Energy_in_Jordan

[21] Jordan Energy Report, https://www.enerdata.net/estore/country-profiles/jordan.html

[22] Jordan Energy Report, https://www.enerdata.net/estore/country-profiles/jordan.html

[23] Jordan Energy Report, https://www.enerdata.net/estore/country-profiles/jordan.html

[24] International Renewable Energy Agency (IRENA) (2021). Jordan Renewable Readiness Assessment. IRENA, February.

[25] IRENA (2021). Renewables Readiness Assessment: The Hashemite Kingdom of Jordan.

Reviewing the current and expected situation in terms of the detailed components of renewable energy suggests that there is rich and promising potential to be exploited. The following discussion is directed toward revealing this potential and what it would take to realize it.

2.2.1. Solar energy

Jordan benefits from abundant solar resources, receiving an average daily solar radiation ranging between 5 and 7 kWh/m2. Recognizing the potential of solar power, the Government of Jordan has set an ambitious target of incorporating 20 percent of renewable energy into the power mix by 2025. Solar energy is poised to play a pivotal role in attaining this goal, showcasing its significant contribution to the country's renewable energy transition.[26]

2.2.2. Wind

Jordan also possesses favorable wind resources, characterized by an average wind speed ranging from six to eight meters per second in certain regions. Wind power is anticipated to emerge as an increasingly significant source of renewable energy in Jordan, contributing to the nation's sustainable energy transition.[27] The government has already started granting licenses for numerous wind projects and there is a commitment to make wind a major source of energy in the coming few years.

2.2.3. Geothermal

Jordan possesses a few geothermal resources, but their exploitation is still in its nascent stages. The government is actively engaged in evaluating the potential of geothermal energy within the country with the aim of becoming a substantial source of renewable energy in the foreseeable future. With ongoing efforts and exploration, geothermal energy holds promising prospects for contributing to Jordan's renewable energy mix and bolstering its sustainable energy landscape.[28]

2.2.4. Hydropower

Hydropower resources in Jordan are limited but the potential for the development of small-scale hydropower projects still exists. The government is actively exploring alternative solutions, including the prospect of importing hydroelectricity from neighboring countries. Jordan is actively aiming to leverage the benefits of hydropower and diversify its renewable energy portfolio, contributing to a more sustainable and resilient energy future.[29]

Table 5. Total energy supply, Jordan, 2014 and 2019

Total Energy Supply (TES)	**2014**	**2019**
Non-renewable (TJ)	348 284	384 307
Renewable (TJ)	4107	15 266
Total (TJ)	352 392	399 573
Renewable share (%)	1	4
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+10.3	+3.8
Renewable (%)	+271.7	+26.1
Total (%)	+13.4	+4.5
Primary energy trade	**2014**	**2019**
Imports (TJ)	355 457	395 259
Exports (TJ)	233	10 797
Net trade (TJ)	- 355 224	384 462
Imports (% of supply)	101	99
Exports (% of production)	3	61
Energy self-sufficiency (%)	2	4

Source: IRENA, Energy Profile Jordan.

As of the end of 2018, Jordan's total installed power capacity had increased to 5.2 GW, compared to 3.9 GW in 2014, showcasing significant growth. Among the various power generation technologies, combined cycle power plants held the largest portion of installed capacity, surpassing 50 percent. Notably, diesel accounted for a significant share of the total installed capacity, amounting to 16 percent in 2018. On the other hand, the share of renewable power capacity experienced substantial growth, rising from less than one percent in 2014 to over 20 percent in 2018. Projections indicate that it is expected to reach 31 percent by 2030, as stated by the Ministry of Energy and Mineral Resources. The increase in the proportion of renewable power capacity within the total installed capacity is primarily driven by the addition of wind and solar PV (utility-scale and distributed) capacity. Over the past decade, Jordan's power sector has demonstrated consistent growth in total generation, increasing from approximately 15 terawatt-hours (TWh) in 2010 to nearly 21 TWh in 2018. This growth has been accompanied by significant changes in the fuel mix utilized for domestic electricity generation, largely influenced by evolving regional geopolitical conditions and their impact on fuel supply dynamics.[30]

[26] Jordan Energy Report (2023).

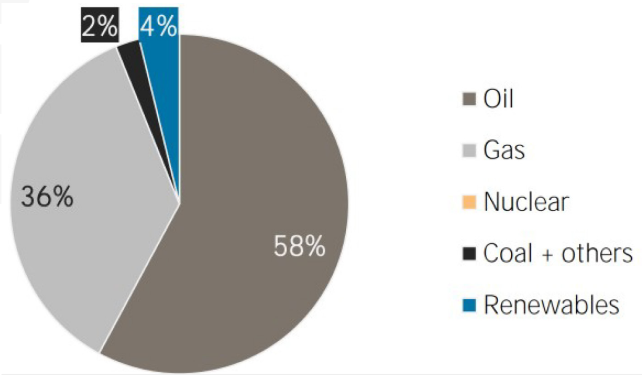
[27] Jordan Energy Report (2023).

[28] Jordan Energy Report (2023).

[29] Jordan Energy Report (2023).

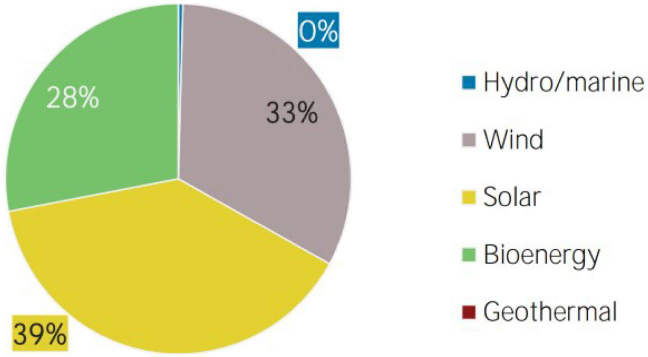
[30] IRENA (2021). Jordan Renewable Readiness Assessment. IRENA, February.

Figure 4. Total energy supply, Jordan, 2019



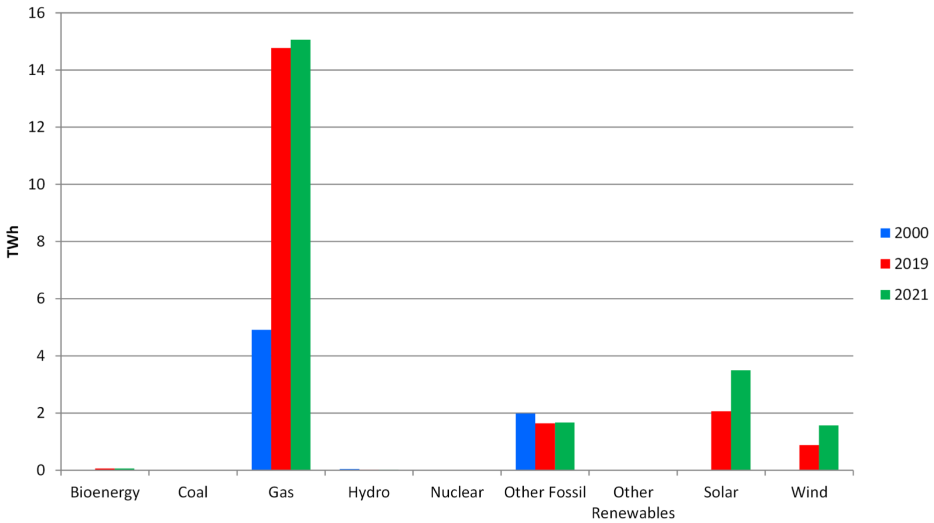
Source: IRENA, Energy Profile Jordan.

Figure 5. Renewable energy supply, Jordan, 2019



Source: IRENA, Energy Profile Jordan.

Figure 6. Sources of fuel for electrivity generation: Jordan 2000, 2019 and 2022



As of 2014, the majority of the electricity mix in Jordan comprised diesel and heavy fuel oil, making up more than 90 percent of the total. Conversely, the share of natural gas had declined to slightly over seven percent. This situation was reversed with the introduction of liquefied natural gas (LNG) imports through the port of Al-Sheikh in Aqaba in mid-2014. The utilization of natural gas for electricity generation increased substantially, reaching over 80 percent by 2018. Additionally, in January 2020, the Leviathan Gas Field in Israel initiated trial operations for supplying natural gas through pipelines as part of a 15-year agreement with Noble Energy, supplying Jordan with the largest share of its natural gas needs.[31]

The Attarat Power Company project consists of two power-generating units, each capable of producing approximately 235 MW of electricity by directly burning shale oil. Jordan has developed several grid interconnections with neighboring countries and the wider region in an attempt to export energy but has not been successful, running headfirst into US Cesar Sanctions and Israeli obstructionism. Jordan is still importing energy; in 2018, electricity imports reached over 188 GWh, a substantial increase from the previous year's 51 GWh but a significant decrease from 604 GWh in 2015. Given the limited growth in domestic electricity consumption and the upcoming launch of several power projects in the next two to three years, cross-border electricity exports could play a crucial role in stimulating demand. To enhance export capabilities, the National Electricity Company of Jordan entered an agreement in October 2019 with the Jerusalem local electricity company to boost its electricity export capacity from 30 MW to 100 MW. In 2019, the volume of exported electricity grew by 4.7 percent, reaching approximately 98 GWh.[32]

[31] IRENA (2021). Ibid.

[32] IRENA (2021). Jordan Renewable Readiness Assessment. IRENA, February.

Table 6. Sources of fuel for electricity generation, Jordan, 2000-2021

	TWh										Share (%)								
Year	Bioen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind	Total	Bioen-erg	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind
2000	0.01	0	4.91	0.04	0	1.98	0	o	0	6.94	0.14%	0.00%	70.75%	0.58%	0.00%	28.53%	0.00%	0.00%	0.00%
2001	0.01	0	5.02	0.04	0	2.02	0	0	0	7.09	0.14%	0.00%	70.80%	0.56%	0.00%	28.49%	0.00%	0.00%	0.00%
2002	0.01	0	5.41	0.05	0	2.18	0	0	0	7.83	0.13%	0.00%	70.72%	0.6396	0.00%	28.50%	0.00%	0.00%	0.00%
2003	0.01	0	5.32	0.04	0	2.15	0	0	0	7.52	0.13%	0.00%	70.74%	0.53%	0.00%	28.59%	0.00%	0.00%	0.00%
2004	0.01	0	5.96	0.05	0	2.41	0	0	0	8.43	0.12%	0.00%	70.70%	0.59%	0.00%	28.59%	0.00%	0.00%	0.00%
2005	0.01	0	6.42	0.06	0	2.59	0	0	0	9.08	0.11%	0.00%	70.70%	0.66%	0.00%	28.52%	0.00%	0.00%	0.00%
2006	0.02	0	7.95	0.05	0	2.43	0	0	0	10.45	0.19%	0.00%	76.08%	0.48%	0.00%	23.25%	0.00%	0.00%	0.00%
2007	0.03	0	9.29	0.06	0	2.85	0	0	0	12.23	0.25%	0.00%	75.96%	0.49%	0.00%	23.30%	0.00%	0.00%	0.00%
2008	0.03	0	9.89	0.06	0	3.03	0	0	0	13.01	0.23%	0.00%	76.02%	0.46%	0.00%	23.29%	0.00%	0.00%	0.00%
2009	0.02	0	10.82	0.06	0	2.51	0	0	0	13.41	0.15%	0.00%	80.69%	0.45%	0.00%	18.72%	0.00%	0.00%	0.00%
2010	0.02	0	11.54	0.06	0	2.27	0	0	0	13.89	0.14%	0.00%	83.08%	0.43%	0.00%	16.34%	0.00%	0.00%	0.00%
2011	0.02	0	11.45	0.05	0	2.25	0	0	0	13.77	0.15%	0.00%	83.15%	0.36%	0.00%	16.34%	0.00%	0.00%	0.00%
2012	0.02	0	13.33	0.06	0	2.19	0	0	0	15.6	0.13%	0.00%	85.45%	0.38%	0.00%	14.04%	0.00%	0.00%	0.00%
2013	0.02	0	13.87	0.05	0	2.28	0	0	0	16.22	0.12%	0.00%	85.51%	0.31%	0.00%	14.06%	0.00%	0.00%	0.00%
2014	0.02	0	14.68	0.06	0	2.42	0	0	0	17.18	0.12%	0.00%	85.45%	0.35%	0.00%	14.09%	0.00%	0.00%	0.00%
2013	0.07	0	15.48	0.05	0	2.15	0	0.05	0.12	17.92	0.39%	0.00%	86.38%	0.28%	0.00%	12.00%	0.00%	0.28%	0.67%
2016	0.07	0	15.46	0.04	0	2.15	0	0.43	0.39	18.54	0.38%	0.00%	83.20%	0.22%	0.00%	11.60%	0.00%	2.32%	2.10%
2017	0.08	0	15.99	0.04	0	2.21	0	0.91	0.45	19.58	0.41%	0.00%	21.15%	0.20%	0.00%	11.29%	0.00%	4.65%	2.30%
2018	0.06	0	15.34	0.02	0	1.7	0	1.43	0.71	19.26	0.31%	0.00%	79.65%	0.10%	0.00%	9.83%	0.00%	7.42%	3.69%
2019	0.06	0	14.77	0.02	0	1.64	0	2.06	0.89	19.43	0.31%	0.00%	76.02%	0.10%	0.00%	8.44%	0.00%	10.60%	4.53%
2020	0.05	0	14.15	0.02	0	1.57	0	2.87	1.38	20.04	0.25%	0.00%	70.61%	0.10%	0.00%	7.83%	0.00%	14,32%	6.89%
2021	0.06	0	15.06	0.02	0	1.67	0	3.5	1.57	21.98	0.27%	0.00%	68.81%	0.09%	0.00%	7.63%	0.00%	16,00%	7.18%

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

2.3. Lebanon

Lebanon's energy sector is currently undergoing an unplanned transition toward renewable energy sources while grappling with the need to ensure reliable and sustainable electricity access. The nation's heavy reliance on thermal sources for energy generation has resulted in significant pollution and GHG emissions. To mitigate these environmental impacts, efforts have been made to reform the electricity sector, including introducing greater private-sector participation and establishing an independent regulatory body. Unfortunately, previous attempts at regulation and enforcement have encountered limited success. Lebanon has initiated initiatives to diversify its energy sources, including the development of wind farms and solar power plants. The Ministry of Industry has also implemented strategies to promote sustainable consumption and production practices in the industrial sector. The energy sector is regulated by the state-controlled Électricité du Liban (EDL), while the full implementation of the Electricity Regulatory Authority (ERA) is still pending. Financial challenges, inadequate cost-recovery mechanisms, and reliance on expensive fuel imports further exacerbate the sector's financial viability issues. Although the government provided large subsidies on energy prices, these were withdrawn in 2021 as government finance almost withered away under the weight of a major economic crisis starting in 2019 that saw a depreciation of more than 90 percent of the national currency and left government finance near bankruptcy levels. The low cost-recovery rate, technical losses, electricity theft, and intense competition from politically supported generator electricity suppliers continue to strain the sector's finances.

Household income is closely correlated with the duration of electricity outages, with the poorest quintile experiencing longer periods without electricity compared to the wealthiest quintile. Financially vulnerable households and those unable to afford generators or alternative energy sources face the greatest challenges, enduring up to 16 hours without electricity daily. The reliance on private generators perpetuates societal inequality, transforming electricity provision into a privilege reserved for affluent and politically connected groups. Moreover, the reliance on fuel oil-powered plants and diesel generators continues to pollute the air, impacting both the environment and public health. Greenpeace research revealed that Lebanon had the highest number of premature deaths in the MENA region caused by air pollution, with associated costs reaching USD 1.4 billion in 2018. Limited access to state-provided electricity and the high costs of alternative sources both exacerbate the challenges faced by low-income households, highlighting the disparities in electricity access across income levels in Lebanon.[33] Furthermore, the removal of fuel subsidies in 2021 exacerbated the financial burden on low- and middle-income households.

2.3.1. The Demand and Supply of Primary Energy

According to IRENA's country profile report for Lebanon, the country's total primary energy supply is mostly dependent on oil, representing 95 percent of its energy supply in 2019 (Figure 7). With regards to the composition of the country's renewable energy supply in 2019, as shown in Figure 8, bioenergy, followed by solar energy, constitutes the highest portion of the country's renewable energy mix. In recent years, there has been a consistent increase in energy demand in Lebanon, and this upward trend is projected to persist in the coming years.[34] Lebanon's primary energy demand in 2020 amounted to 7.4 million tons of oil equivalent (Mtoe).[35] In 2020, Lebanon had a per capita energy consumption of 1.1 Mtoe/cap, and a per capita electricity consumption of 2,300 kWh. The total energy consumption in the country decreased by 14 percent to 7.4 Mtoe in 2020, following a six percent decline in 2018 and stabilized in 2019. Prior to this, there was a significant increase in energy consumption between 2011 and 2017, with an average annual growth rate of approximately six percent.

Oil accounted for 95 percent of Lebanon's overall energy consumption, while biomass, coal, and primary electricity each contributed two percent to the energy mix.[36] Oil dominates as the primary source of energy in Lebanon, representing approximately 54 percent of the country's total energy demand.[37] This heavy reliance on oil, most of which is imported, makes the country susceptible to price volatility and supply interruptions.[38] Natural gas also plays a significant role in Lebanon's energy sector, representing approximately 24 percent of the country's energy demand. While Lebanon imports a portion of its natural gas, it also has domestic production capabilities in this resource.[39]

Lebanese laws grant the exclusive right to generate and sell electricity to EDL and a few licensed independent power producers, making the commercial generator sector

[33] Cut Off From Life Itself: Lebanon. 2023.

[34] Energy Information Administration (2023).

[35] Our World in Data (2023).

[36] Enerdata (2023).

[37] Our World in Data (2023).

[38] Lebanese Center for Energy Conservation (2023).

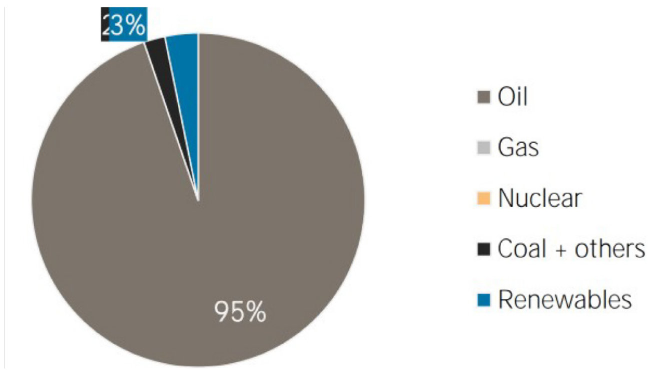
[39] Lebanese Center for Energy Conservation (2023).

Table 7. Total energy supply, Lebanon, 2014 and 2019

Total Energy Supply (TES)	2014	2019
Non-renewable (TJ)	299 551	339 221
Renewable (TJ)	8 581	11 221
Total (TJ)	308 132	350 442
Renewable share (%)	3	3
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+13.2	+0.2
Renewable (%)	+30.8	-2.2
Total (%)	+13.7	+0.1
Primary energy trade	**2014**	**2019**
Imports (TJ)	311 698	353 046
Exports (TJ)	0	0
Net trade (TJ)	311 698	353 046
Imports (% of supply)	101	101
Exports (% of production)	0	0
Energy self-sufficiency (%)	3	3

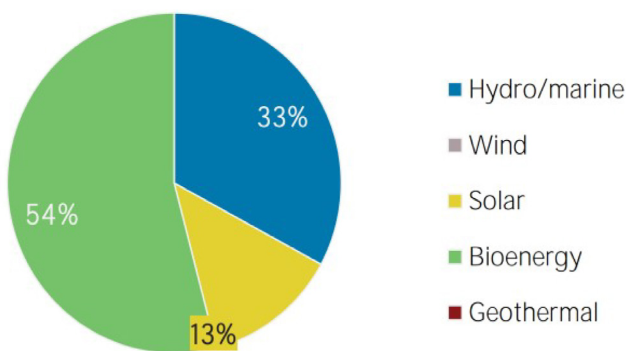
Source: IRENA, Energy Profile Lebanon.

Figure 7. Total energy supply, Lebanon, 2019



Source: IRENA, Energy Profile Lebanon.

Figure 8. Renewable energy supply, Lebanon, 2019



Source: IRENA, Energy Profile Lebanon.

largely informal and resistant to regulation. Although fuel imports for generators are known to generate income through customs and taxes, generator operators, often backed by powerful but corrupt politicians, often do not declare their revenues or pay taxes, resulting in significant revenue losses for the state. Despite this, successive governments have overlooked these revenue shortfalls due to their inability to address EDL's shortages and concerns about reprisals from the political backers of the generator operators.[40]

2.3.2. Renewable energy

Renewable energy currently represents a relatively small share of Lebanon's energy demand (three percent in 2019, Figure 7). There are plans and commitments to expanding this share. Recognizing the importance of transitioning toward more sustainable energy sources, Lebanon aims to increase the contribution of renewable energy in its energy mix. This commitment signifies a proactive approach toward reducing reliance on conventional energy and embracing cleaner and more environmentally friendly alternatives.[41] In line with its updated NDCs released in March 2021, the Lebanese government has established ambitious targets for renewable energy adoption. These targets include generating 18 percent of the country's power demand and 11 percent of its heat demand from renewable sources by 2030. With the potential of international support, these targets could be further increased to 30 percent for power demand and 16.5 percent for heat demand. It is worth noting that the target of installing one million square meters of solar water heaters by 2020 was not achieved, with only 735,000 square meters installed during that year. These targets serve as a clear indication of Lebanon's commitment to advancing renewable energy and reducing reliance on conventional energy sources.[42]

2.3.3. Solar energy

Solar energy requires high upfront costs but has low and predictable operating and maintenance costs. Similar to wind power, it has minimal emissions and pollution. Utility-scale solar projects can make a significant contribution to Lebanon's energy mix, while household solar systems can enhance household energy security. The recent growth in renewable energy in Lebanon has mainly been driven by the installation of solar PV systems. From 2010 to 2020, the cumulative installed solar PV capacity experienced a remarkable increase of 27,200 percent, rising from 330 kWp in 2010 to 89.84 MWp in 2020.

[40] Human Rights Watch (2023).

[41] Enerdata (2023).

[42] Enerdata (2023).

EDL continues to count on these systems to reduce the need for costly grid upgrades and expensive peaking capacity. For consumers, substantial cost savings are possible, although the extent of these savings depends on a number of project parameters. Additionally, distributed solar PV can enhance energy resilience, expedite the scaling up of renewable energy, reduce emissions, and foster a positive cultural change.[43] Currently, on-grid solar PV systems appear to be the most cost-effective deployment option, with a levelized cost of electricity (LCOE) of 8 US cents/kWh. Dual-mode solar PV systems with storage have an electricity cost of around 37 US cents/kWh. As storage costs are projected to decrease, the economics of off-grid systems are expected to improve in the coming years. The cost of electricity from diesel generators is highly influenced by diesel fuel prices, with a price of USD 0.63/liter resulting in an electricity cost of approximately 24 US cents/kWh.[44] However, due to the recent rise in diesel fuel prices and the difficulty of financing imports, reliance on solar power will expand.

At this time, it seems that the only feasible and cost-effective way to meet electricity demand is by integrating solar PV systems with the existing commercial diesel generator network. The financial benefits of incorporating solar PV systems are maximized when diesel prices are high, as the displaced fuel leads to greater savings. While future price changes are difficult to predict, including solar PV systems in the operations of commercial diesel generators can help mitigate price volatility risks. The economic value of these systems will also improve as technology costs decrease and knowledge advances.[45]

Following the economic crisis, the removal of diesel subsidies, and the significant decline in national electricity generation, Lebanon has seen a surge in residential solar power systems. The Lebanese Center for Energy Conservation (LCEC) reported a significant increase in inquiries about solar PV installations, from approximately one call per week in 2018 to an average of five calls per day in 2021. Moreover, the Lebanese Solar Energy Society noted that nearly 100 new companies entered the market since the crisis began in 2019, almost matching the number of companies that entered the market in the previous 10 years.[46] Many experts, however, have expressed concerns about the unregulated nature of the solar PV market. Despite initiating discussions on standardization and technical supervision of solar PV systems with the Order of Engineers, no regulations have been issued thus far, according to the head of LCEC.

The industrial and commercial sectors have several advantages over the residential sector when it comes to using solar PV systems. They have available space on factory and warehouse rooftops to accommodate higher capacities of solar PV modules. Additionally, their higher consumption levels provide greater ability to finance such projects, especially with supportive mechanisms like NEEREA. Industrial and commercial users are typically more conscious of the impact of energy consumption on costs and overall profitability, enabling better assessment of the value of investing in solar PV systems.[47]

Distributed solar PV systems are not without a few technical challenges that vary based on penetration level, capacity, and connection points with the electricity grid. In the short term, the main challenge related to Lebanon's power sector is the "islanding" effect, which requires on-grid renewable sources to disconnect immediately from the grid during disruptions. Lebanon's frequent power outages exacerbate the islanding effect, leading to energy waste in the absence of storage. However, this challenge can be addressed as grid supply improves, storage costs decline, and capacity expands.[48]

Incorporating storage, particularly for on-grid dual-mode systems, can minimize power waste due to the islanding effect prevalent in Lebanon. Nonetheless, energy storage remains expensive, despite recent cost reductions. In the short term, a smart rationing system could be implemented by EDL, prioritizing supply hours to areas with solar generation above a certain threshold that significantly impacts operations.[49]

2.3.4. Hydropower

In the past, hydropower played a significant role in Lebanon's energy mix, accounting for 70 to 75 percent of Lebanon's electricity production in the 1970s. However, as of 2019, renewable energy constituted only 7.83 percent

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[43] ESMAP (May 2020). Distributed Power Generation for Lebanon: Market Assessment and Policy Pathways. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO.

[44] ESMAP (May 2020).

[45] ESMAP (May 2020).

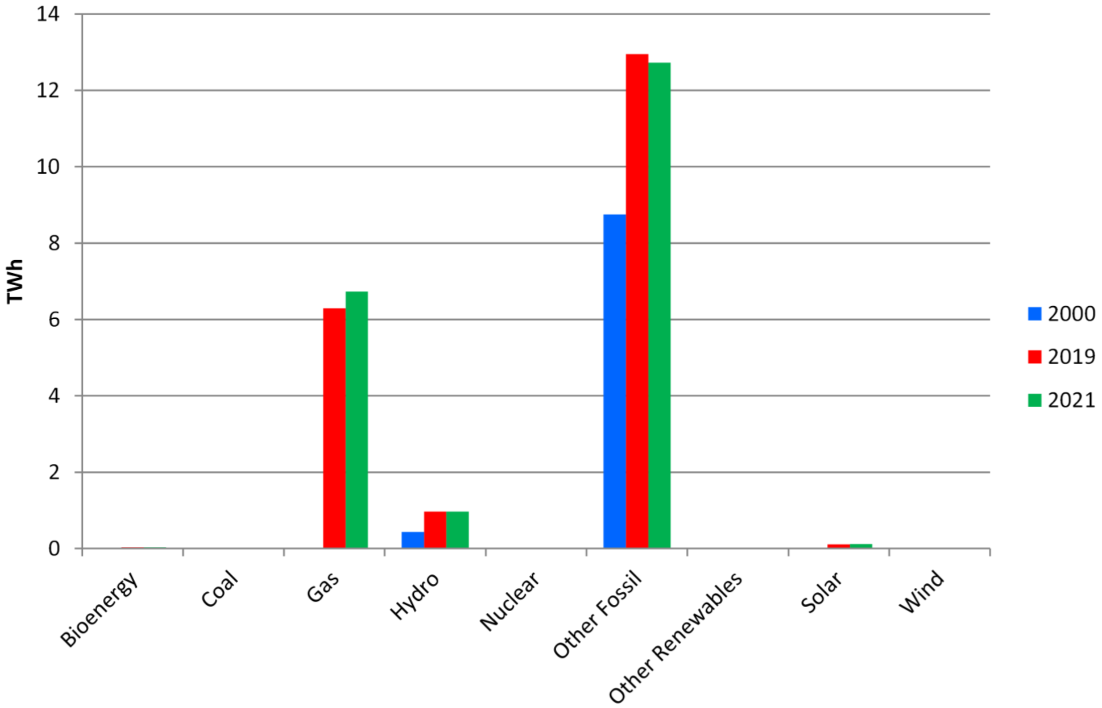
[46] Human Rights Watch (2023).

[47] ESMAP (May 2020).

[48] ESMAP (May 2020).

[49] ESMAP (May 2020).

Figure 9. Sources of fuel for electrivity generation: Lebanon 2000, 2019 and 2021



of the total electricity generation, with solar power contributing just 0.73 percent and hydropower 1.82 percent. Lebanon's hydroelectric power stations, which have an installed capacity of 286 MW, suffer from an aging infrastructure and outdated tariff rates (USD 0.1 per kWh), resulting in financial losses and inadequate maintenance. Consequently, production losses of approximately 30-40 percent have been observed, leading the LCEC to estimate the actual generation capacity of these stations to be around only 190 MW. The LCEC suggests that rehabilitating these hydroelectric power stations could increase their production capabilities by 25 percent.[50]

2.3.5. Wind energy

While wind energy requires substantial initial investment, it has low and predictable operating costs. It is a clean energy source with no direct emissions or pollution, but its intermittent nature means it only generates power when the wind is blowing. While setting wind power projects appropriately is a challenge, they generally pose fewer human rights risks. Incorporating wind power can play a significant role in Lebanon's energy mix. However, despite the substantial percentage increase, solar energy still accounts for less than one percent of Lebanon's overall energy mix.[51] Despite its significant potential, wind energy currently contributes negligibly to Lebanon's electricity generation. In 2018, the Energy Ministry signed a power purchase agreement for three utility-scale wind power projects in Akkar with a total capacity of 226 MW. However, these projects were put on hold due to the economic crisis. The LCEC and Lebanese Foundation for Renewable Energy estimate that wind speeds in Lebanon and the availability of public lands could support the generation of approximately 5,000 MW of electricity annually, enough to power the entire country.[52] Naturally, storage poses a challenge, as it is not guaranteed that there will be wind when power is needed. There are credible suggestions that the storage challenge will be resolved favorably soon as R&D initiatives are heavily focused on expanding the storage capacity of renewable energy alternatives.

2.4. Morocco

Morocco continues to grapple with three major challenges in the energy domain. First, it does not have sufficient

[50] Human Rights Watch (2023).

[51] Human Rights Watch (2023).

[52] Human Rights Watch (2023).

Table 8. Sources of fuel for electricity generation, Lebanon, 2000-2021

	TWh										Share (%)								
Year	**Bioen-ergy**	**Coal**	**Gas**	**Hydro**	**Nucle-ar**	**Other Fossil**	**Other Renew-ables**	**Solar**	**Wind**	**Total**	**Bioen-ergy**	**Coal**	**Gas**	**Hydro**	**Nucle-ar**	**Other Fossil**	**Other Renew-ables**	**Solar**	**Wind**
2000	0	0	0	0.44	0	8.75	0	0	0	9.19	0.00	0.00	0.00	4.79	0.00	95.21	0.00	0.00	0.00
2001	0	0	1.38	0.33	0	7.86	0	0	0	9.57	0.00	0.00	14.42	3.45	0.00	82.13	0.00	0.00	0.00
2002	0	0	2.7	0.67	0	7.68	0	0	0	11.1	0.00	0.00	24.43	6.06	0.00	69.50	0.00	0.00	0.00
2003	0	0	2.68	1.35	0	7.96	0	0	0	12	0.00	0.00	22.35	11.26	0.00	66.39	0.00	0.00	0.00
2004	0	0	2.69	1.11	0	7.99	0	0	0	11.8	0.00	0.00	22.82	9.41	0.00	67.77	0.00	0.00	0.00
2005	0	0	2.95	1.04	0	7.75	0	0	0	11.7	0.00	0.00	25.13	8.86	0.00	66.01	0.00	0.00	0.00
2006	0	0	2.75	0.69	0	7.51	0	0	0	11	0.00	0.00	25.11	6.30	0.00	68.58	0.00	0.00	0.00
2007	0	0	2.9	0.58	0	7.9	0	0	0	11.4	0.00	0.00	25.48	5.10	0.00	69.42	0.00	0.00	0.00
2008	0	0	3.23	0.37	0	8.97	0	0	0	12.6	0.00	0.00	25.70	2.94	0.00	71.36	0.00	0.00	0.00
2009	0	0	3.23	0.62	0	9.13	0	0	0	13	0.00	0.00	24.88	4.78	0.00	70.34	0.00	0.00	0.00
2010	0	0	3.36	0.83	0	10.62	0	0	0	14.8	0.00	0.00	22.69	5.60	0.00	71.71	0.00	0.00	0.00
2011	0	0	3.46	0.8	0	11.11	0	0	0	15.4	0.00	0.00	22.51	5.20	0.00	72.28	0.00	0.00	0.00
2012	0.01	0	3.45	1	0	11.09	0	0	0	15.6	0.06	0.00	22.19	6.43	0.00	71.32	0.00	0.00	0.00
2013	0.01	0	4.79	1.26	0	11.7	0	0	0	17.8	0.06	0.00	26.97	7.09	0.00	65.88	0.00	0.00	0.00
2014	0.01	0	4.85	0.19	0	11.85	0	0.01	0.01	16.9	0.06	0.00	28.66	1.12	0.00	70.04	0.00	0.06	0.06
2015	0.01	0	4.85	0.47	0	12.21	0	0.02	0.01	17.6	0.06	0.00	27.60	2.68	0.00	69.49	0.00	0.11	0.06
2016	0.03	0	5.07	0.38	0	12.75	0	0.04	0.01	18.3	0.16	0.00	27.74	2.08	0.00	69.75	0.00	0.22	0.05
2017	0.04	0	6.25	0.41	0	13.27	0	0.06	0.01	20	0.20	0.00	31.19	2.05	0.00	66.22	0.00	0.30	0.05
2018	0.03	0	6.27	0.34	0	13.3	0	0.09	0.01	20	0.15	0.00	31.29	1.70	0.00	66.37	0.00	0.45	0.05
2019	0.03	0	6.29	0.97	0	12.95	0	0.11	0.01	20.4	0.15	0.00	30.89	4.76	0.00	63.61	0.00	0.54	0.05
2020	0.03	0	5.86	1.05	0	12.42	0	0.12	0.01	19.5	0.15	0.00	30.07	5.39	0.00	63.72	0.00	0.62	0.05
2021	0.03	0	6.73	0.97	0	12.72	0	0.12	0.01	20.6	0.15	0.00	32.70	4.71	0.00	61.81	0.00	0.58	0.05

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

local energy resources to meet its current energy needs. Second, it relies heavily on energy imports, particularly imports of oil and gas from neighboring countries. Third, coal constitutes a large share of its primary energy supplies. In this context, the country has recently made strides into renewable energy production that could change this situation. The country's electricity production continues to be predominantly fossil fuel-based, where coal accounted for 40 percent, oil 10.6 percent, and natural gas 11.8 percent; both oil and gas are primarily imported at high costs from neighboring countries (Algeria and Nigeria) (Table 11). Wind, solar, and hydropower collectively contributed only 20 percent to the country's electricity generation and four percent to its total energy consumption in 2021. In contrast, oil accounted for 55.2 percent, coal for 32 percent, biofuels and waste for six percent, and natural gas for 3.3 percent of the total primary energy supply in 2020 (Table 9).

Despite significant recent efforts to harness Morocco's considerable renewable energy potential, the commissioning of three new coal power plants during the 2010s expanded the total coal-fired power capacity to over 4 GW in 2021. Consequently, the carbon intensity of the power sector has continued to rise, making Morocco's power sector one of the most carbon-intensive globally, emitting approximately 600 tons of CO2 per GWh in 2020. The significant reliance on coal for power generation, which is atypical in the MENA region, is driven primarily by Morocco's limited domestic natural gas resources and a cautious approach toward depending on gas imports from neighboring countries.[53]

The heavy reliance on fossil fuels to meet Morocco's current energy needs carries significant macroeconomic implications for Morocco. Between 2010 and 2020, energy accounted for 19.4 percent of total imports. Furthermore, despite the partial liberalization of hydrocarbon prices in 2012-15, explicit subsidies for liquid petroleum gas (LPG) still account for nearly 2.4 percent of government expenditure, equivalent to almost one percent of GDP annually.[54]

Fossil fuels will continue to play a prominent role in Morocco's energy supply for the foreseeable future, given that they represented 90 percent of the total primary energy supply in 2021. In 2014, fossil fuels represented 92.5 percent but declined to 89.8 percent in 2019 (Table 10). The primary fossil fuels utilized in the country include coal, oil, and natural gas. Among these fossil fuels, coal makes a significant contribution of 30 percent to the country's overall primary energy supply (Figure 11). Morocco's major coal-fired power plants are situated in Jorf Lasfar and Safi. Oil supplies the largest share of primary energy at 52 percent of the total primary energy supply (Figure 11). The country primarily relies on imports from Algeria and Saudi Arabia to meet its oil demands. Natural gas supplies only four percent of the total primary energy supply in Morocco (Figure 11). The main sources of natural gas are imports from Algeria and Nigeria.[55]

2.4.1. Renewable Energy

Renewable energy sources contributed 10.2 percent to the overall primary energy supply in Morocco in 2019 (Table 10). Morocco has made a dedicated commitment to augmenting the proportion of renewable energy within its energy portfolio. With a clear vision in mind, the government has established a goal to achieve 52 percent of its electricity generation from renewable sources by the year 2030. This ambitious target showcases Morocco's determination to embrace sustainable and environmentally friendly energy solutions.

2.4.2. Bioenergy

Bioenergy constituted the largest component of renewable energy in 2019, contributing about 65 percent of total renewable energy in 2019 (Figure 12). Morocco has a large and vibrant agricultural sector, which feeds the major share of this component of renewable energy.

2.4.3. Hydropower

Hydropower represents a limited share of renewable energy; it accounted for just three percent of the total renewable energy supply in 2019 (Figure 12). The major hydropower plants in Morocco are strategically located in the High Atlas Mountains.

2.4.4. Solar energy

Solar energy in 2019 accounted for 14 percent (Figure 12) of the country's total renewable energy, but this share is likely to rise with the new investments in this sector. With Morocco's substantial solar potential, the government is actively expanding this sector with major solar power projects. Morocco has built the Noor-Ouarzazate complex, which is the world's largest concentrated solar power plant. It is an enormous array of curved mirrors spread over 3,000 hectares (11.6 sq. miles) that concentrate the sun's rays toward tubes of fluid, with the hot liquid then used to

[53] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report.

[54] World Bank Group (2022). Ibid.

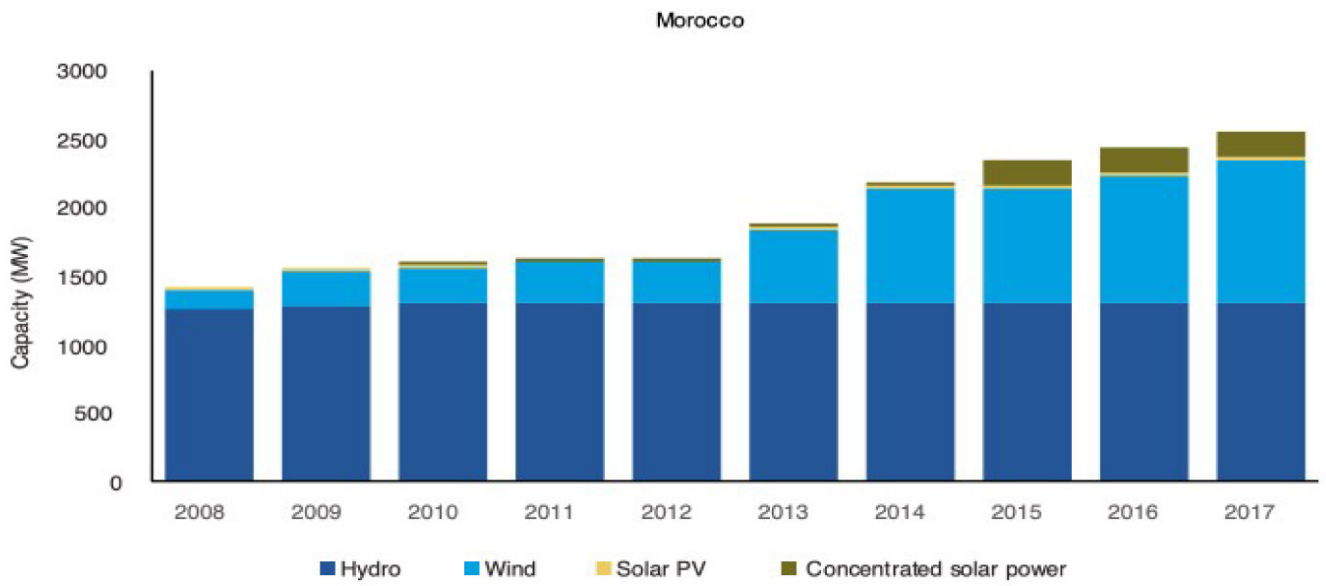
[55] International Energy Agency (2022).

Table 9. Total energy supply, Morocco, 1990-2020 (TJ)

	Coal	Natural gas	Hydro	Biofuels and waste	Oil	Wind, solar, etc.	Total
1990	47,464	1,813	4,392	41,540	223,399		318,608
1995	70,832	461	2,200	47,733	268,885		390,111
2000	110,899	1,591	2,585	50,954	286,706	230	452,965
2005	131,539	15,677	3,524	90,111	376,255	742	617,848
2010	116,888	23,855	12,485	63,189	482,133	2,372	700,922
2015	186,081	42,526	6,786	57,288	496,319	9,119	798,119
2020	280,079	28,500	3,123	52,416	485,868	30,263	880,249
				Shares			
1990	14.90%	0.57%	1.38%	13.04%	70.12%	0.00%	100.00%
1995	18.16%	0.12%	0.56%	12.24%	68.93%	0.00%	100.00%
2000	24.48%	0.35%	0.57%	11.25%	63.30%	0.05%	100.00%
2005	21.29%	2.54%	0.57%	14.58%	60.90%	0.12%	100.00%
2010	16.68%	3.40%	1.78%	9.02%	68.79%	0.34%	100.00%
2015	23.31%	5.33%	0.85%	7.18%	62.19%	1.14%	100.00%
2020	31.82%	3.24%	0.35%	5.95%	55.20%	3.44%	100.00%

Source: IEA World Energy Balances 2022. Https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances

Figure 10. Morocco's renewable energy growth 2006-17



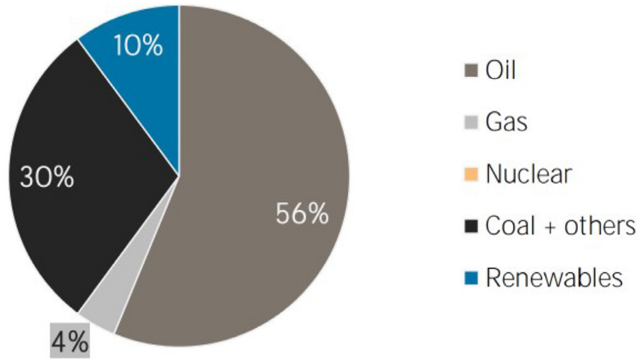
Source: IRENA (2018a).

Table 10. Total energy supply, Morocco, 2014 and 2019

Total Energy Supply (TES)	2014	2019
Non-renewable (TJ)	724 568	845 312
Renewable (TJ)	58 849	95 772
Total (TJ)	783 417	941 084
Renewable share (%)	8	10
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+16.7	+7.8
Renewable (%)	+62.7	-5.4
Total (%)	+20.1	+6.3
Primary energy trade	**2014**	**2019**
Imports (TJ)	867 941	866 642
Exports (TJ)	50 514	5 232
Net trade (TJ)	- 817 427	861 410
Imports (% of supply)	111	92
Exports (% of production)	81	5
Energy self-sufficiency (%)	8	11

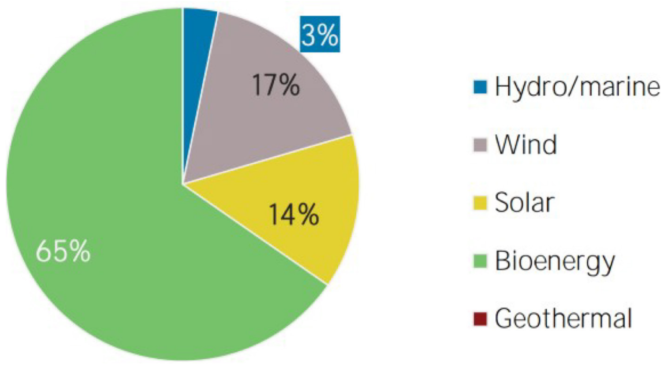
Source: IRENA, Energy Profile Morocco.

Figure 11. Total energy supply, Morocco, 2019



Source: IRENA, Energy Profile Morocco.

Figure 12. Renewable energy supply, Morocco, 2019



Source: IRENA, Energy Profile Morocco.

produce power. This allows electricity to be produced at night when demand is high.

China's CNGR Advanced Material will build a cathode materials plant in Morocco to supply the US and European battery markets, as the North African country emerged as an unlikely winner from US-China tensions. The USD 2 billion investment in Morocco will enable Morocco to emerge as a major producer of batteries to support its solar power transition and its plans to become a major producer of EVs.[56]

2.4.5. Wind energy

Wind energy in 2019 constituted a higher share of over 17 percent of the total renewable energy (Figure 12). Although Morocco possesses moderate wind potential, the government is still making a concerted effort to develop wind power projects.[57]

Morocco's rich endowments of wind and solar resources allow it to capitalize on the advantages that come with embracing a decarbonization agenda. Morocco was recently at the forefront of middle-income countries in pursuing an ambitious renewable energy program since the late 2000s, effectively doubling the contribution of renewable energy to its power generation capacity, which now stands at nearly 4 GW. Despite these achievements, Morocco has also witnessed a continued – and even accelerated – use of coal for power generation. The country is increasingly determined to fully tap into its vast and competitive renewable energy potential, while significantly reducing or eliminating the reliance on coal.[58]

Figure 14 highlights the potential for the distribution of solar energy and wind energy in relation to the world distribution of these two sources.

Morocco recently introduced a comprehensive plan known as the New Development Model (NDM), which aims to bring about profound socioeconomic changes in the country. The NDM centers around four key areas of transformation and sets ambitious goals, including the ambitious target of doubling per capita GDP by 2035.

[56] https://www.ft.com/content/9539f746-82bf-49db-ae87-237196a60c88

[57] Enerdata (2022).

[58] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

Table 11. Sources of fuel for electricity generation, Morocco, 2000-2021

	TWh										Share (%)								
Year	Bioen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind	Total	Been-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind
2000	0	7.93	0	0.71		3.43	0	0	0.06	12.1	0.00	65.38	0.00	5.85	0.00	28.28	0.00	0.00	0.49
2001	of	9.73	0	0.86		3.4	o		0.21	14.2	0.00	68.52	0.00	6.06	0.00	23.94	0.00	0.00	1.48
2002	o	10.4	0	0.84		3.76	o		0.19	15.2	0.00	68.40	0.00	5.54	0.00	24.80	0.00	0.00	1.25
2003	0	10.9	0	1.44		3.95	o		02	16.5	0.00	66.08	0.00	8.74	0.00	23.97	0.00	0.00	1.21
2004	0	115	0	1.59		4.18	o		02	17.5	0.00	65.89	0.00	9.09	0.00	23.89	0.00	0.00	1.14
2005	0	11.1	2.4	0.97		4.03	o		0.21	18.8	0.00	$9.24	13.00	5.17	0.00	21.47	0.00	0.00	1.12
2006	of	11.4	25	0.99		4.15	o		0.18	19.3	0.00	59.37	13.03	5.14	0.00	21.54	0.00	0.00	0.93
2007	0	11.5	2.5	0.91		4.16	0		0.28	19.3	0.00	59.31	13.03	4.71	0.00	21.51	0.00	0.00	1.45
2008	0	11.6	2.6	0.92		4.22	o		0.3	19.6	0.00	59.27	13.03	4.68	0.00	21.49	0.00	0.00	1.53
2009	o	10.4	2.3	2.54		4.43			0.39	20	0.00	51.85	11.39	1269	0.00	22.13	0.00	0.00	1.95
2010	0.01	10.	4.9	3.4)		4.38			0.66	23.4	0.04	43.40	20.73	14.51	0.00	18.53	0.00	0.00	2.79
2011	0.01	11.3	5.6	1.99		.			0.69	25	0.00	46.06	22.37	7.96	0.00	20.01	0.00	0.00	2.76
2012	0.01	13.1	6.3	162		5.6		0.06	0.73	27.	0.04	47.86	22.86	5.91	0.00	20.45	0.00	0.22	2.67
2013	0.01	11.5	5.7	2.76		5.06		0.06	1.36	26.	0.04	44.29	21.17	10.31	0.00	18.89	0.00	0.22	5.00
2014	0.01	14.6	s	162		4.5		0.06	1.92	27.	0.04	52.60	18.17	5.84	0.00	16.22	0.00	0.22	6.92
2015	0.03	15.2	5.2	1.87		4.68		0.00	2.52	29.5	0.10	51.35	17.74	6.33	0.00	15.84	0.00	0.10	8.53
2016	0.05	154	5.4	1.24		4.8		0.43	3.02	30.5	0.16	51.08	17.62	4.07	0.00	15.75	0.00	1.43	9.91
2017	0.04	17.1	5.2	117		4.62		0.44	3.04	31.6	0.13	54.10	16.39	3.71	0.00	14.64	0.00	1.39	9.64
2018	0.03	20	4.1	1.68		3.65		0.95	3.86	34.2	0.09	58.37	11.92	4.91	0.00	10.66	0.00	2.78	11.28
2019	0.04	23.4	48	1.26		4.26		1.58	4.72	40	0.10	58.40	11.93	3.15	0.00	10.66	0.00	3.95	11.81
2020	0.04	22.6	46	0.87		4.13		1.52	4.59	38.	0.10	58.91	12.04	2.27	0.00	10.76	0.00	3.96	11.96
2021	0.04		4.9	1.21		4.36		1.82	5.11	41	0.10	57.82	11.82	2.93	0.00	10.56	0.00	4.43	12.37

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

Figure 13. Sources of fuel for electrivity generation: Morocco 2000, 2019 and 2021

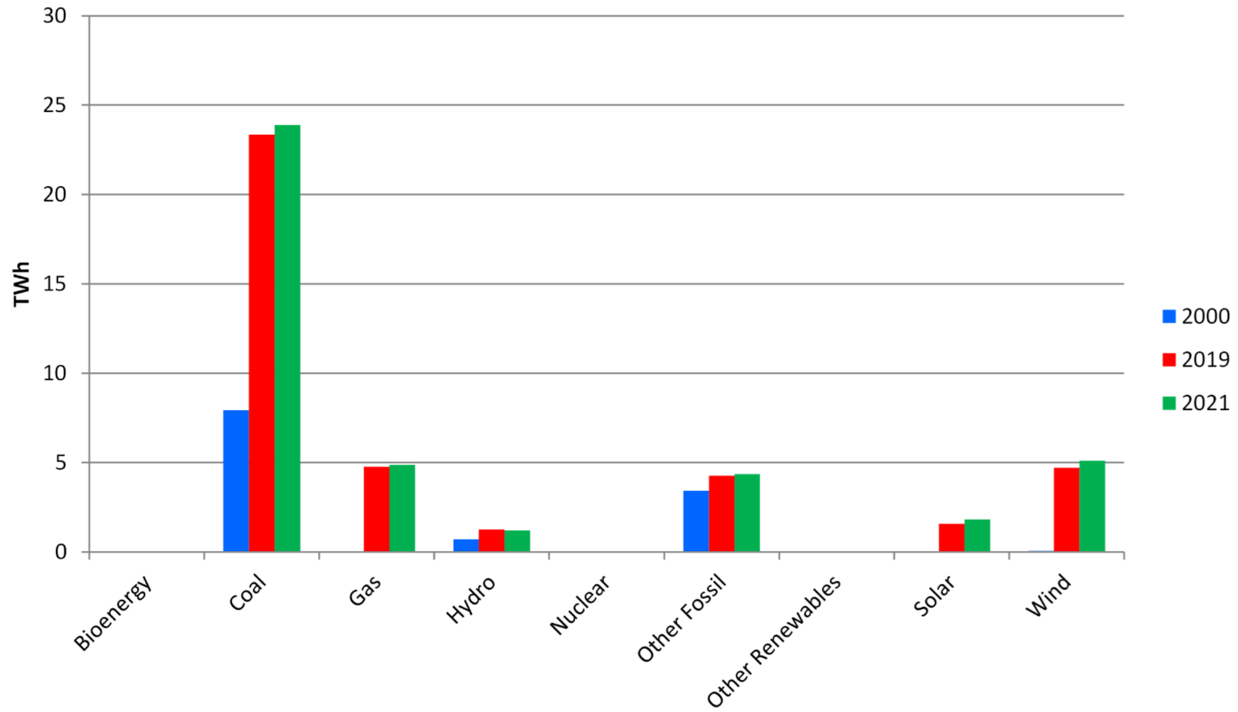
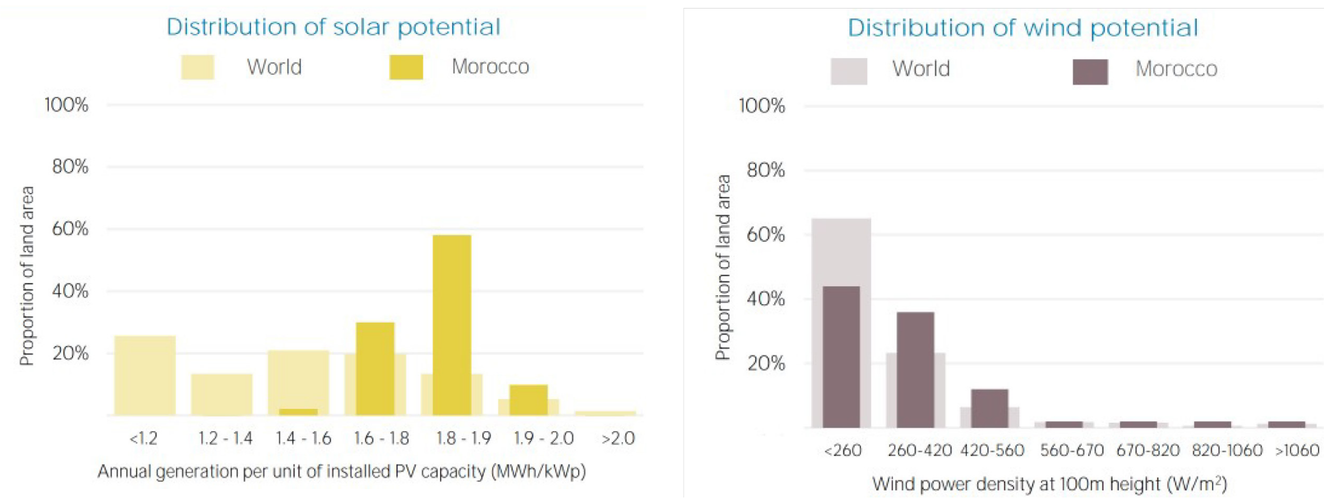


Figure 14. Distribution of solar and wind power in Morocco



Achieving such a feat requires a sustained average real annual growth rate of nearly seven percent over the next 12 years.[59]

What is particularly relevant to this study is the fact that the NDM has set a priority goal of positioning Morocco as a regional leader in green energy, building upon ongoing efforts to transform the energy mix. Recent simulations indicate that in order to maintain such a rate of growth, Morocco needs to prioritize actions that unlock a productivity-driven structural transformation that rebalances investments in favor of the private sector, addresses barriers preventing women and youth from participating in the labor force, and enhances human capital through improved education and healthcare services. While the NDM does not explicitly prioritize climate change, it recognizes the opportunities associated with decarbonization and acknowledges the challenge of water scarcity for the country's sustainable development. It is worth mentioning here that the NDM explicitly seeks to establish Morocco as a regional leader in green energy

[59] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

through its focus on transforming the country's energy mix.[60]

Morocco's National Sustainable Development Strategy is paving the path toward reaching its INDCs. Morocco's commitment to sustainability is enshrined in its 2011 Constitution, which recognizes sustainable development and environmental protection as fundamental rights alongside healthcare and social protection. The country has implemented the National Sustainable Development Strategy, guided by the National Charter for Environment. The strategy is built upon seven interconnected pillars, including transitioning to a green economy, fostering a culture of sustainable development, enhancing governance for sustainability, improving natural resource management, promoting human development and reducing social inequalities, prioritizing sensitive areas, and expediting the implementation of climate change policies.

As part of its Intended Nationally Determined Contributions (INDC) mandated under the Paris Climate Agreement, Morocco needs to enhance resilience to climate change and its transition toward a low-carbon economy. To achieve this vision, significant efforts will be focused on transforming the energy sector. The key objectives include reducing reliance on fossil fuels and energy imports while increasing the share of renewable energy in its energy mix. By June 2015, the government had outlined its energy-related INDC targets as follows:[61]

- Morocco's 2009 National Energy Strategy defined its strategic priorities to encompass several key areas, which include:[62] Achieving a well-diversified and optimized energy mix, enhancing energy supply security, supporting the growth of renewable energy and energy efficiency industries, promoting the development of domestic energy resources, and integrating with regional and international energy markets, with a focus on Africa and Europe.
- Energy efficiency is a key national policy priority, with an initial target of achieving 12 percent energy savings by 2020 and 15 percent by 2030. This target has been revised upwards to a more ambitious goal of 20 percent energy savings by 2030. Additionally, Morocco initially set a target of achieving 42 percent renewable energy in its total installed power capacity by 2020. However, in 2015, the target was revised to 52 percent by 2030, with a balanced distribution between solar, wind, and hydropower resources. It is estimated that achieving this 2030 renewable energy target will require significant investments totaling around USD 30 billion.[63]

2.5. Sudan

Sudan's government is currently grappling with significant economic stagnation and a challenging high unemployment situation. Moreover, the forces of globalization, rapid technological advancements, and political upheavals are exerting negative pressures and placing excessive demands on the pace of social and economic progress.[64] Despite all these pressures, Sudan recognizes the urgency of addressing climate change, which has become a crucial policy priority globally. As temperatures rise and electrification rates increase, the demand for air conditioning, refrigeration, and lighting is expected to escalate. Sudan, as a party to the Paris Agreement, is committed to achieving climate targets, including achieving net GHG neutrality by the mid-21st century. To accomplish this, Sudan is progressively raising its ambition and establishing specific sector goals within its NDCs, employing a ratcheting-up mechanism.

A study conducted by United for Efficiency (U4E), an initiative by the United Nations Environment Program, revealed that Sudan could achieve significant annual electricity savings of two TWh by 2030 through minimum ambitious energy efficiency policies in lighting, cooling, industrial motors, and distribution transformers. According to a World Bank report, Sudan's population is projected to grow at a rate of 2.4 percent per year, reaching 56 million by 2031 as compared to 40 million in 2019. While 2.2 million households currently have access to electricity, approximately 4.5 million households still lack access. This underscores the importance of implementing highly efficient technologies to curb the overall growth in energy demand while ensuring widespread access to energy for as many households as possible.[65]

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[60] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

[61] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

[62] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

[63] World Bank Group (2022). Morocco Country Climate Development Report. Washington, DC: World Bank. https://www.worldbank.org/en/country/morocco/publication/morocco-country-climate-and-development-report

[64] A/Rahman W., Ahmed, A., Ragab, M., and Alsaeed, M. (2022). Global Entrepreneurship Monitor: Sudan National Report 2021/2022.

[65] United for Efficiency (2021). National Energy Efficiency Strategy for Sudan.

Sudan, as is the case with other oil-importing MENA countries, relies heavily on energy imports and faces major challenges due to insufficient investments in the energy sector. Additionally, there is a significant electricity deficit in Sudan, particularly in rural areas where a large share of the population lacks access to the national grid. Recent data indicate that less than 50 percent of rural communities in the country have electricity. To address this issue, Sudan is actively working to expand its renewable energy market and meet its growing energy needs.[66] This is welcome news as Sudan has great potential in this area given its rich natural endowments of sun radiation, wind, hydropower, and bioenergy.

2.5.1. Sudan's energy supply and energy consumption

Based on IRENA's 2019 country profile data, the energy supply in Sudan in 2019 mainly relied on oil and renewables. While renewable energy contributed 51.3 percent of total energy in 2014, this share declined to 46.4 percent in 2019 (Table 12). The main sources of renewable energy in Sudan are bioenergy and hydro/marine, representing 84 percent and 16 percent of the country's total renewable energy mix, respectively (Figure 16). The domestic consumption of petroleum products in Sudan and South Sudan experienced rapid growth due to industrialization, increased car ownership, and improved access to electricity during the 2000s. The ongoing instability in both countries has, however, hindered consumption. The decline in domestic oil production since the 2000s has resulted in a greater reliance on imported petroleum products to fulfill the domestic demand, which was previously met by domestically refined crude oil. Collectively, Sudan and South Sudan had a peak total liquid fuel consumption of 152,000 barrels per day (b/d) in 2016, and this level has remained relatively stable since then. Motor gasoline and distillate fuel oil, such as diesel, constitute the majority of the liquid fuels utilized in both countries.[67]

2.5.2. Exploration and production

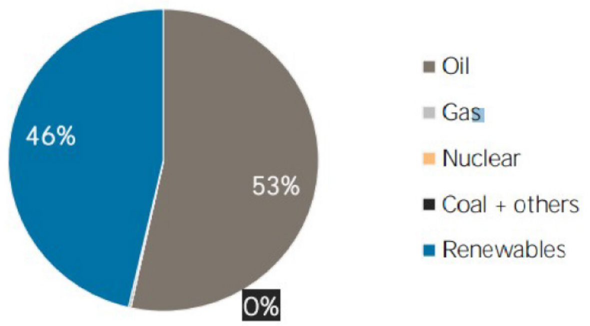
As of January 2022, Sudan and South Sudan collectively had proven oil reserves of 5 billion barrels, according to the Oil & Gas Journal (OGJ). The primary production of crude oil in both countries occurs in the Muglad Basin

Table 12. Total energy supply, Sudan, 2014 and 2019

Total Energy Supply (TES)	2014	2019
Non-renewable (TJ)	222 066	288 12
Renewable (TJ)	234 354	249 303
Total (TJ)	456 420	537 425
Renewable share (%)	51	46
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+29.7	+1.2
Renewable (%)	+6.4	+1.6
Total (%)	+17.7	+1.4
Primary energy trade	**2014**	**2019**
Imports (TJ)	72 758	137 465
Exports (TJ)	82 623	4 607
Net trade (TJ)	9865	132 858
Imports (% of supply)	16	26
Exports (% of production)	17	1
Energy self-sufficiency (%)	104	76

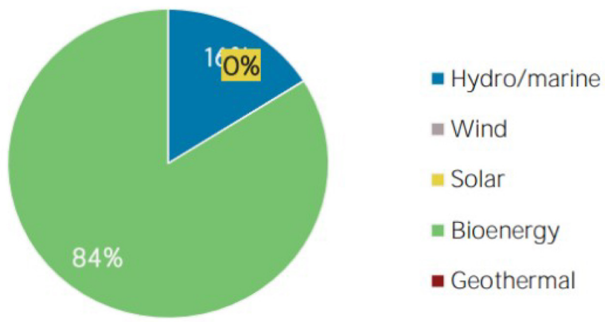
Source: IRENA, Energy Profile Sudan.

Figure 15. Total energy supply, Sudan, 2019



Source: IRENA, Energy Profile Sudan.

Figure 16. Renewable energy supply, Sudan, 2019



Source: IRENA, Energy Profile Sudan.

[66] U.S. Agency for International Development (2021). Sudan Energy Sector Assessment.

[67] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

and Melut Basin, with Sudan and South Sudan offering three distinct crude oil blends: Dar, Nile, and Fula. In an effort to revitalize upstream development, Sudan has made eight oil blocks available in its latest licensing round. The closing date for this licensing round was set for August 2022, with the announcement of awards planned for 2023. In 2021, South Sudan initiated its inaugural licensing round, offering five exploration licenses. The government aims to attract a diverse range of foreign investors to stimulate upstream investment and enhance crude oil production.[68]

2.5.3. Refining and refined oil products

Sudan possesses three oil refineries, but only two are currently operational, along with three topping plants, which are smaller and less complex refineries. The active refineries are the Khartoum (al-Jaili) refinery, situated around 45 miles north of Khartoum, and the El-Obeid topping plant. The al-Jaili refinery is the largest in the country. The Port Sudan refinery, the other full-conversion refinery, has suspended its operations. Among the three topping plants, only El-Obeid is currently functioning, while the Shajirah and Abu Gabra topping plants are inactive.

2.5.4. Natural gas

Despite having proven reserves of three trillion cubic feet, neither Sudan nor South Sudan currently produce natural gas for commercial or domestic use. The OGJ estimated these reserves in 2021. In Sudan, most of the natural gas is either flared or reinjected into associated oil fields rather than being utilized for consumption. As a result, the potential of natural gas as an energy resource in both countries remains largely untapped.

2.5.5. Solar, wind, and geothermal

With its vast geographical area, abundant sunshine, and regions characterized by high wind speeds, Sudan has significant potential for sustainable geothermal, solar, and wind renewable energy production. Recognizing this opportunity, the Ministry of Energy and Petroleum has expressed the government's interest in harnessing additional renewable energy resources to augment the existing hydropower capacity. New plans have been devised to address the expansion of renewable energy projects and overcome previous challenges.

[68] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

Combining fossil fuels with renewable energy resources is indeed a common approach for many countries to achieve energy security, address climate change concerns, and reduce dependence on oil. Clean energy technologies offer numerous advantages, including job creation, economic growth, and reduced vulnerability to fluctuating oil prices. It is crucial for the Sudanese government to adopt environmentally friendly regulations and policies that incentivize both local business leaders and foreign investors to embrace renewable energy and support the transition.

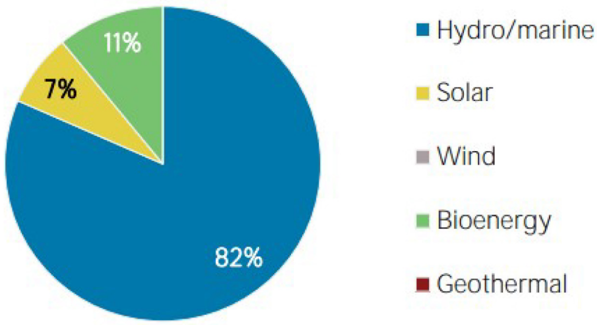
Advancements in technology have made solar and wind energy increasingly feasible and affordable. According to Figure 17, Sudan has mainly been relying on bioenergy as its main source of renewable energy, yet it has significant potential for the development of its other renewable energy resources, particularly solar and wind. While solar energy may have higher initial capital expenditures compared to wind energy, the cost of solar technologies has been decreasing rapidly, especially with the introduction of new crystalline silicon fixed-tilt panels. PV technologies, such as parabolic troughs and solar power towers, have already proven successful in electricity generation in many countries, including Sudan.[69]

Although hydroelectricity accounts currently for approximately half of Sudan's electricity generation, there are various challenges impeding its full utilization. These challenges include issues related to international boundaries, environmental degradation, and limited financial resources for investment. In 2010, a preliminary agreement was signed with Omene Company, based in Dubai, to construct a wind power facility along the Red Sea coast with a capacity of approximately 500 MW. This agreement has not been realized, and the utilization of wind power remains limited to applications such as irrigation and water pumps.[70] In June 2021, the Sudanese government, in collaboration with the United Nations Development Program (UNDP), received the first wind turbine. The project, facilitated by the Global Environment Facility (GEF), aimed to provide expertise and support to the Sudanese government in utilizing wind energy. The installation of the wind turbine in the Northern state not only demonstrated the country's potential in wind energy generation but also offered a few training opportunities for Sudanese engineers, enabling them to develop skills

[69] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

[70] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

Figure 17. Renewable capacity in 2021



Source: IRENA, Energy Profile Sudan.

for future wind projects. The turbine is expected to provide electricity to around 14,000 people and serve as a stepping-stone toward attracting more investment in renewable energy in Sudan.[71]

Sudan also has significant potential for geothermal energy production, which involves harnessing heat from underground to generate electricity by driving turbines with steam. Promising indications of geothermal heat have been identified in various regions, including the Tagbo and Beidob hills, Jebel Marra volcano in the Darfur region, and Bayud volcano in the Red Sea State. These geothermal resources have an estimated capacity to generate around 400 MW of electricity.[72]

Solar energy, while requiring substantial upfront investment costs, has low operating expenditures due to minimal maintenance requirements and the absence of fuel requirements for operation. The cost of wind energy installation depends on factors such as the elevation of the wind plant and the turbine technology. Solar energy holds the greatest potential for Sudan compared to other renewable energy sources. The country's annual radiation range exceeds the global average, ranging from 436 to 639 W/m2 per year. Sudan also benefits from a significant period of solar radiation, averaging between 8.5 and 11 hours per day. Moreover, Sudan has ample available land that can be utilized for renewable energy development. By capitalizing on these opportunities and implementing supportive policies, Sudan can accelerate the adoption of renewable energy, leverage its natural resources, and unlock the economic, environmental, and social benefits associated with the clean energy transition.[73]

To expand its solar energy capacity, the Sudanese government signed a Memorandum of Understanding (MoU) with the UAE to establish a solar power plant. The MoU allows a private company from the UAE to install a 500 MW solar power plant and operate it for a period of 20 years. While specific technical and financial details are not mentioned in the MoU, this agreement highlights Sudan's commitment to increase its solar energy share and attract foreign investment in the sector.

Despite the growth in power generation since independence, access to electricity remains limited in Sudan. As mentioned earlier, only around 55 percent of the population had access to electricity in 2020, with urban areas enjoying a higher access rate of 82 percent compared to rural areas where only 41 percent have access. Those without grid connectivity rely on biomass or diesel-fired generators for their energy needs. The transmission and distribution network in Sudan primarily serves major demand centers like Khartoum and it is mainly concentrated in the more populous eastern region. On the other hand, rural areas in western Sudan face significant limitations in electricity transmission and distribution infrastructure.[74]

Total electricity generation in 2021 exceeded 16.6 TWh, which is almost double the electricity generated in 2011 (Table 13). Hydroelectricity alone contributed around 60.3 percent, gas 5.9 percent, oil 30.5 percent, bioenergy 3.13 percent, and the remaining 0.18 percent came from solar energy (Table 13 and Figure 18).

Sudan developed and updated its NDCs in August of 2017. It continued updating its NDCs in May 2021, with a subsequent update in September 2022. The NDCs, although concise, are being continuously transformed from mere communication documents into a comprehensive action plan. The focus of mitigation efforts is on promoting low-emission, resilient, and sustainable development within the energy, forestry, land use, and water sectors.[75]

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[71] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

[72] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

[73] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

[74] Abdalla, H. and Qarmout, A. (2023). An Analysis of Sudan's Energy Sector and its Renewable Energy Potential in a Comparative African Perspective.

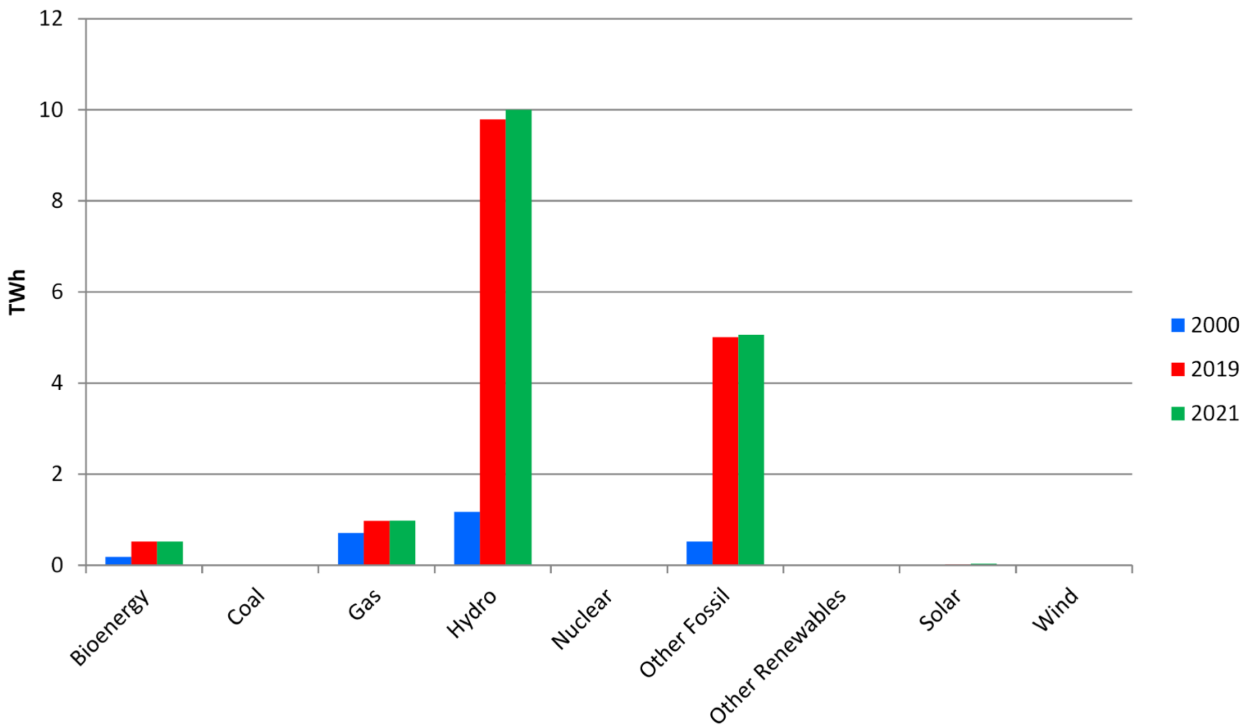
[75] Tutundjian, S. and Maroun, D. (2023). Climate Action in the Arab Region: White Paper on The Nationally Determined Contributions of Middle East and North Africa Countries. Thriving Solutions L.L.C.

Table 13. Sources of fuel for electricity generation, Sudan, 2000-2021

	TWh										Share (%)								
Year	Bioen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind	Total	Bioen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind
2000	0.18	0	0.71	1.17	0	0.52	0	0	of	2.58	6.98	0.00	27.57	45.35	0.00	20.16	0.00	0.00	0.00
2001	0.2	0	0.8	1.25	0	0.58	0	0	0	2.83	7.07	0.00	28.27	44.17	0.00	20.49	0.00	0.00	0.00
2002	0.23	0	0.89	1.27	0	0.7	0	o	0	3.09	7.44	0.00	28.80	41.10	0.00	22.65	0.00	0.00	0.00
2003	0.18	0	0.71	1.15	0	1.29	0	o	0	3.33	5.41	0.00	21.32	34.53	0.00	38.74	0.00	0.00	0.00
2004	0.16	0	0.61	1.1	0	1.59	0	o	0	3.46	4.62	0.00	17.63	31.79	0.00	45.95	0.00	0.00	0.00
2005	0.17	0	0.66	1.25	0	1.72	0	0	0	3.8	4.47	0.00	17.37	32.89	0.00	45.26	0.00	0.00	0.00
2006	0.2	0	0.78	1.36	0	2.12	0	0	0	4.46	4.48	0.00	17.49	30.49	0.00	47.53	0.00	0.00	0.00
2007	0.22	0	0.87	1.44	0	2.41	0	0	0	4.94	4.45	0.00	17.61	29.15	0.00	48.79	0.00	0.00	0.00
2008	0.19		0.74	1.45	0	3.02	0	o	of	5.4	3.52	0.00	13.70	26.85	0.00	55.93	0.00	0.00	0.00
2009	0.15	0	0.61	3.2	0	2.46	0	0	0	6.42	2.34	0.00	9.50	49.84	0.00	38.32	0.00	0.00	0.00
2010	0.06	0	0.23	6.14	0	1.07	0	o	0	7.5	0.80	0.00	3.07	81.87	0.00	14.27	0.00	0.00	0.00
2011	0.08		0.33	6.4	0	157	0	0	0	8.38	0.95	0.00	3.94	76.37	0.00	18.74	0.00	0.00	0.00
2012	0.24		0.44	6.55	0	2.09	0	0.01	0	9.33	2.57	0.00	4.77	70.20	0.00	22.40	0.00	0.11	0.00
2013	0.17		0.32	8.23	0	1.5	0	0.01	0	10.2	1.66	0.00	3.13	80.45	0.00	14.66	0.00	0.10	0.00
2014	0.21		0.39	8.82	0	1.84	0	0.01	0	11.3	1.86	0.00	3.46	78.26	0.00	16.33	0.00	0.09	0.00
2015	0.38		0.71	8.34	0	3.38	0	0.01	0	12.8	2.96	0.00	5.54	65.05	0.00	26.37	0.00	0.08	0.00
2016	0.51		0.96	7.97	0	464	0	0.02	0	14.1	3.62	0.00	6.81	56.52	0.00	32.91	0.00	0.14	0.00
2017	0.5		0.93	9.25	0	452	0	0.02	0	15.2	3.29	0.00	6.11	60.78	0.00	29.70	0.00	0.13	0.00
2018	0.5		0.94	9.56	0	4.88	0	0.02	0	15.9	3.14	0.00	5.91	60.13	0.00	30.69	0.00	0.13	0.00
2019	0.52		0.97	9.79	0	5.01	0	0.02	0	16.3	3.19	0.00	5.95	60.02	0.00	30.72	0.00	0.12	0.00
2020	0.49		0.92	10.27	0	4.76	0	0.03	0	16.5	2.98	0.00	5.59	62.36	0.00	28.90	0.00	0.18	0.00
2021	0.52		0.98	10	0	5.06	0	0.03	0	16.6	3.13	0.00	5.91	60.28	0.00	30.50	0.00	0.18	0.00

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

Figure 18. Sources of fuel for electrivity generation: Sudan 2000, 2019 and 2021



A key objective is the transition to renewable energy sources and the utilization of blended fuels to reduce biomass energy consumption. Within the transport sector, there is an emphasis on encouraging the shift of goods transportation from trucks to rail. The forestry sector plays a significant role in both adaptation and mitigation strategies, encompassing activities such as restoration, carbon removal, blue carbon mangrove restoration, and protection. In the water sector, mitigation measures include the implementation of waste management systems, composting, recycling, and other relevant approaches. In terms of adaptation, Sudan's predominant focus lies in ensuring food security and addressing vulnerabilities in water, agriculture, coastal zones, and health. By adopting this comprehensive approach, Sudan aims to effectively address climate change, promote sustainable development, and enhance resilience.[76]

Sudan has also demonstrated its commitment to various national and international regulations and agreements pertaining to specific sectors, as outlined and categorized into three policy areas below.[77]

In regards to climate policies, Sudan signed the Paris Agreement on 22 April 2016, and subsequently ratified it in August 2017. The Paris Agreement became operational on 4 November 2016 after reaching the required number of ratifications. In October 2015, Sudan's Ministry of Environment submitted its initial NDC in line with the agreement. Furthermore, Sudan participated in the amendment of the Montreal Protocol in 2016, known as the Kigali Amendment, which came into effect on 1 January 2019, following sufficient ratifications.[78]

Sudan's government has completed a draft Electricity Sector Strategy for the period 2020-35 that highlights the need for policies concerning quality control and energy efficiency regulations for imported electrical equipment. These policies were covered in an earlier section of this report.[79]

2.6. Tunisia

Tunisia is already facing a few challenges due to escalating temperatures, rising sea levels, diminished rainfall, and extreme weather events like floods and droughts. These factors have heightened Tunisia's exposure to climate risks, leading to negative socioeconomic and environmental consequences such as water scarcity,

[76] Tutundjian, S. and Maroun, D. (2023). Climate Action in the Arab Region: White Paper on The Nationally Determined Contributions of Middle East and North Africa Countries. Thriving Solutions L.L.C.

[77] United for Efficiency (n.d.). National Energy Efficiency Strategy for Sudan.

[78] United for Efficiency (n.d.). National Energy Efficiency Strategy for Sudan.

[79] United for Efficiency (n.d.). National Energy Efficiency Strategy for Sudan.

increased evapotranspiration, decreased agricultural land yields and productivity, land salinization, and coastal erosion.[80]

In its recently adopted 2014 Constitution, Tunisia expressed its commitment to global climate change efforts by pledging to "provide the necessary resources to ensure a healthy and balanced environment and contribute to climate integrity" (Tunisia 2019). As a demonstration of these strong commitments, Tunisia ratified the Paris Agreement in 2017 having ratified the UNFCCC in 1993, the United Nations Convention to Combat Desertification in 1995, and the Convention on Biological Diversity in 2003.[81]

In 2021, the population of Tunisia reached 12.26 million, with an annual growth rate of 1.1 percent. Around 69 percent of the population resides in urban areas. Tunisia benefits from unique climatic characteristics, making it an emerging economic center and attractive tourist destination. The climate varies significantly across the country, with a Mediterranean climate in the north and along the coast, semi-arid conditions in the interior, and arid conditions in the south.[82] Tunisia achieved an average annual Gross Domestic Product (GDP) real growth rate of 4.3 percent from 2000 to 2010, positioning it as the most competitive economy in Africa. Despite political instability, the country demonstrated a rapid recovery in GDP growth following a recession in 2011, reaching 4.0 percent in 2012. Sustaining this real rate of growth has been challenging in the face of political uncertainty and world economic difficulties, resulting in a decline in the growth rate to 2.6 percent in 2018.[83] Presently, Tunisia faces a few new economic challenges, including the devaluation of the Tunisian dinar, which has contributed to significant increases in public debt and the foreign trade deficit. As of September 2018, Tunisia's public debt amounted to 71.4 percent relative to GDP, while the foreign trade deficit expanded by 16.8 percent in 2017.[84]

The intersection of the energy situation with the economic conditions is varied and complex. Economic difficulties are often translated into larger energy deficits and limited flexibility to pursue desired policies.

2.6.1. Tunisia's energy outlook: trends, challenges, and future prospects

Over the past two decades, Tunisia has experienced a growing deficit in its energy balance, primarily due to its heavy reliance on fossil fuels such as oil and natural gas to meet the increasing energy demand. Declining domestic hydrocarbon resources have resulted in a heightened dependence on fossil fuel imports, reaching record levels in 2019, where the primary energy balance deficit stood at 5,672 thousand tons of ktoe, or a deficit of 273,636 TJ as depicted in Table 14 below. This indicates that 74 percent of the total energy supply in Tunisia is imported. In response, Tunisia has initiated efforts to tap into its renewable energy sources as a means to diversify its energy mix and reduce its reliance on expensive energy imports (Table 14). In 2014, renewable energy constituted 9.5 percent but increased to 9.9 percent in 2019 as non-renewable energy increased at an annual rate of 1.7 percent, whereas renewable energy sources increased at an annual rate of 1.8 percent between 2014 and 2019. This difference is small but augurs well for the future as the country is committed to reducing its dependence on imported fossil fuels. Additionally, the country has implemented a few energy efficiency programs aimed at addressing the energy balance deficit.[85]

On the other hand, Tunisia has made a remarkable achievement in expanding electricity generation in the past two decades and has succeeded in broadening access to it by the population; by 2019, a total of 99.8 percent of the country had access to electricity. This achievement came at a cost, with 97.5 percent of generation dependent on natural gas. This heavy dependence on natural gas raises concerns about Tunisia's future energy security in the absence of a serious transition to renewable energy sources, as domestic production has stagnated and even declined in recent years, necessitating increased imports from Algeria, which accounted for 61 percent of total national gas consumption in Tunisia in 2019.[86]
The total energy supply in Tunisia in 2019 showed a large share of fossil fuels (91 percent) in the energy mix, with natural gas contributing 49 percent, oil contributing 41 percent, and coal contributing one percent (Figure 19). Renewable sources combined had a share of 10 percent in 2019.

Renewable energy sources are predominantly composed

[80] Arab Sustainable Finance Forum (2021).

[81] Arab Sustainable Finance Forum (2021).

[82] IRENA (2021). Renewables Readiness Assessment: Tunisia. Abu Dhabi, United Arab Emirates: IRENA.

[83] IRENA (2021). Renewables Readiness Assessment: Tunisia. Abu Dhabi, United Arab Emirates: IRENA.

[84] IRENA (2021). Renewables Readiness Assessment: Tunisia. Abu Dhabi, United Arab Emirates: IRENA.

[85] IRENA (2021). Renewables Readiness Assessment: Tunisia. Abu Dhabi, United Arab Emirates: IRENA.

[86] IRENA (2019). Energy Profile Tunisia.

of bioenergy with a share of 89 percent, wind with seven percent, and solar with four percent (Figure 20). This picture is quite likely to change as Tunisia is planning to expand its solar and wind energy contributions by 2030. Therefore, the energy landscape of Tunisia is expected to undergo further transformation in the coming years. Although the government's target of attaining a 35 percent share of renewable energy in the overall energy mix by 2030 is ambitious, it is, however, feasible with sustained private and public investments in renewable energy projects.

The volatile gas prices on the international market have further exacerbated supply costs and the burden of subsidies. Between 1990 and 2019, primary energy production decreased from 5,400 ktoe to 3,703 ktoe. Notably, the production of oil and natural gas dropped significantly since 2010, with oil declining by 54 percent and natural gas by 47 percent, as depicted in Figure 21. In 2018, natural gas constituted 48.7 percent of the total primary energy supply (TPES), amounting to 5,569 ktoe, while oil (including primary and secondary oil) represented 40.8 percent of TPES, totaling 4,665 ktoe, as shown in the figure below (MISME, 2018b). The remaining energy supply largely relied on biomass and waste sources.

Tunisia's future energy situation appears promising as it possesses significant potential for renewable energy. The Tunisian National Agency for Energy Conservation (ANME) estimates the exploitable potential of PV energy to be several hundred gigawatts, with an average annual production of approximately1,650 kWh/kWp. Additionally, ANME's Wind Atlas reveals favorable wind conditions in Tunisia, particularly in regions like Nabeul Bizerte and the central areas of Kasserine, Tataouine, Médenine, and Gabès, with an estimated wind potential of 8,000 MW. To achieve its renewable energy mix objective by 2030, Tunisia needs to install at least 3,815 MW of renewable energy capacity.[87]

Tunisia's energy mix comprises a combination of fossil fuels, renewable sources, and a growing emphasis on energy efficiency measures to meet the country's energy needs and promote sustainable development.

2.6.2. Fossil fuels

The utilization of fossil fuels in Tunisia has significant environmental implications, contributing to air and water pollution, as well as climate change. The Tunisian

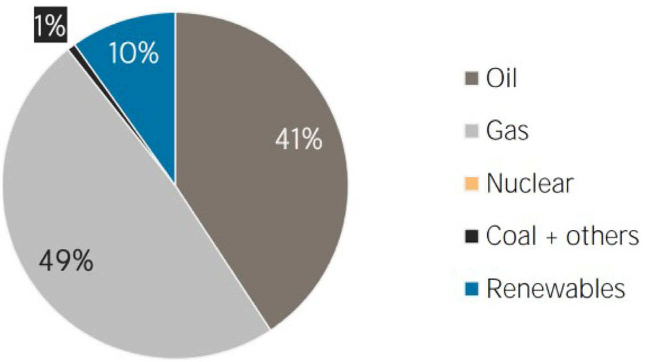
[87] IRENA (2021). Renewables Readiness Assessment: Tunisia. Abu Dhabi, United Arab Emirates: IRENA.

Table 14. Total energy supply, Tunisia, 2014 and 2019

Total Energy Supply (TES)	2014	2019
Non-renewable (TJ)	390 848	425 753
Renewable (TJ)	41128	46 620
Total (TJ)	431976	472 373
Renewable share (%)	10	10
Growth in TES	**2014-19**	**2018-19**
Non-renewable (%)	+8.9	-1.8
Renewable (%)	+13.4	+0.3
Total (%)	+9.4	-1.6
Primary energy trade	**2014**	**2019**
Imports (TJ)	309 395	348 093
Exports (TJ)	133 952	74 457
Net trade (TJ)	- 175 443	- 273 636
Imports (% of supply)	72	74
Exports (% of production)	49	35
Energy self-sufficiency (%)	63	45

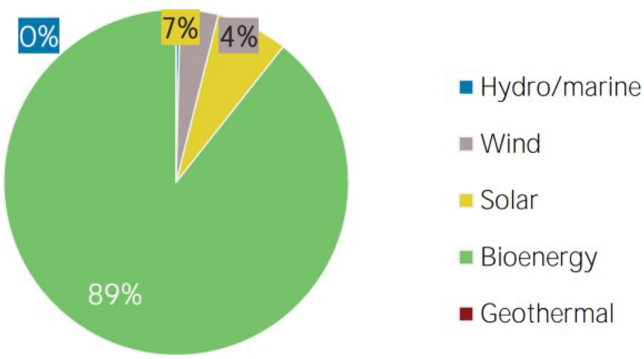
Source: IRENA, Energy Profile Tunisia.

Figure 19. Total energy supply, Tunisia, 2019



Source: IRENA, Energy Profile Tunisia.

Figure 20. Renewable energy supply, Tunisia, 2019



Source: IRENA, Energy Profile Tunisia.

government acknowledges the need to decrease reliance on fossil fuels, yet this endeavor poses challenges. While Tunisia possesses limited oil reserves, it plays a notable role in oil product production. The country experienced its highest level of oil production during the early 1980s, but output has been steadily decreasing since then.[88] Tunisia possesses minimal coal reserves and does not engage in domestic coal production. Instead, the country relies on coal imports to fulfill its limited demand for this energy source.[89] Tunisia encounters various challenges in reducing its dependence on fossil fuels. One of the main obstacles is the high cost associated with renewable energy technologies, which currently remain more expensive than traditional fossil fuels. This cost disparity hinders Tunisia's ability to transition extensively to renewable energy sources. Additionally, the lack of adequate infrastructure poses a significant challenge as the country's electricity grid requires substantial upgrades to accommodate the integration of renewable energy on a large scale. Furthermore, public acceptance of renewable energy projects is not unanimous, with some individuals expressing concerns about potential environmental impacts. Overcoming this opposition and fostering public support for renewable energy initiatives are essential tasks that need to be addressed in Tunisia's energy transition efforts.[90]

2.6.3. Renewable energy

Renewable energy sources play a minor yet expanding role in Tunisia's energy composition. Wind power, solar power, and hydroelectric power are the primary renewable energy sources in the country.[91] Tunisia possesses considerable potential for renewable energy, boasting ample resources of solar, wind, biomass, and hydropower. The government is fully dedicated to the growth of the renewable energy sector, positioning the country favorably to emerge as a frontrunner in renewable energy within the Mediterranean region.

2.6.4. Solar energy

With an annual average of 3,000 hours of sunshine, Tunisia offers an ideal environment for harnessing solar energy. The nation has already established a solar power capacity exceeding 1 GW, and the government aims to augment this further by an additional 2 GW by the year 2030.[92]

2.6.5. Wind energy

Tunisia has favorable wind resources, characterized by average wind speeds ranging from 6 to 8 meters per second. The nation has already implemented more than 2 GW of wind power capacity and is projected to introduce an additional 1 GW by 2030. In terms of biomass, Tunisia boasts substantial resources, including agricultural waste, forestry residues, and municipal solid waste. The country has already established over 100 MW of biomass power capacity and intends to augment this by a further 50 MW by 2030.[93]

2.6.6. Biomass

Tunisia has abundant biomass resources, comprising agricultural waste, forestry residues, and municipal solid waste. The country has already implemented a biomass power capacity exceeding 100 MW, with plans to expand this by an additional 50 MW by 2030.[94]

2.6.7. Hydropower

Tunisia's hydropower resources are relatively limited, currently standing at approximately 100 MW of installed capacity. Nonetheless, the government is exploring the potential for new hydropower projects, recognizing their environmental benefits as a source of clean and renewable energy.[95]

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[88] Hamdi, A., Rebai, A., and Ayadi, M. (2019). Multi-Criteria Analysis of Electricity Generation Mix Scenarios in Tunisia. Energy Policy, 128, 111198. https://doi.org/10.1016/j.enpol.2019.111198.

[89] Hamdi, A., Rebai, A., and Ayadi, M. (2019). Multi-Criteria Analysis of Electricity Generation Mix Scenarios in Tunisia. Energy Policy, 128, 111198. https://doi.org/10.1016/j.enpol.2019.111198.

[90] Hamdi, A., Rebai, A., and Ayadi, M. (2019). Multi-Criteria Analysis of Electricity Generation Mix Scenarios in Tunisia. Energy Policy, 128, 111198. https://doi.org/10.1016/j.enpol.2019.111198.

[91] Hamdi, A., Rebai, A., and Ayadi, M. (2019). Multi-Criteria Analysis of Electricity Generation Mix Scenarios in Tunisia. Energy Policy, 128, 111198. https://doi.org/10.1016/j.enpol.2019.111198.

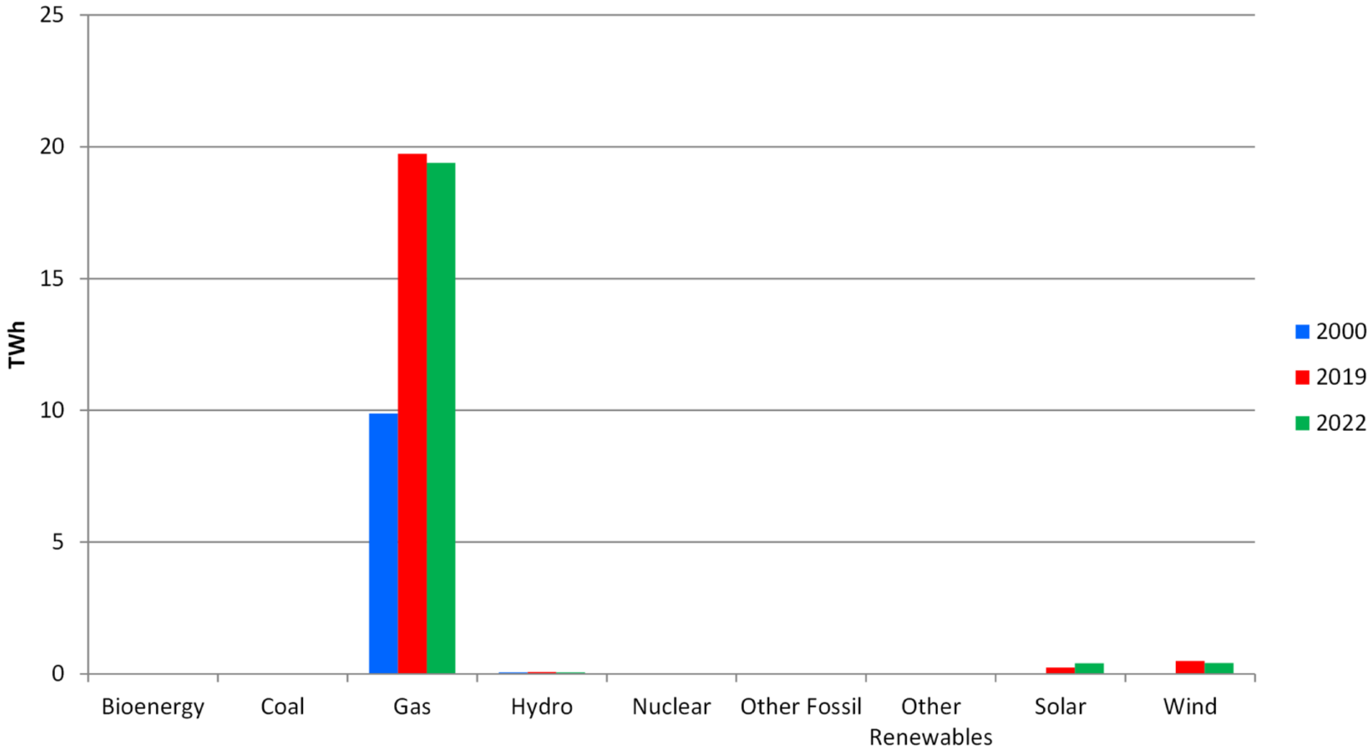
[92] Renewable Energy in Tunisia. REN21, 2022, www.ren21.net/country/tunisia.

[93] Tunisia's Renewable Energy Targets. World Economic Forum, 2022, www.weforum.org/agenda/2022/01/tunisia-renewable-energy-targets/.

[94] Tunisia's Renewable Energy Sector: Opportunities and Challenges. The Arab Gulf States Institute in Washington, 2021, www.agsiw.org/tunisias-renewable-energy-sector-opportunities-and-challenges/.

[95] Hydropower in Tunisia. International Hydropower Association, 2022, www.hydropower.org/country/tunisia.

Figure 21. Sources of fuel for electrivity generation: Tunisia 2000, 2019 and 2022



As discussed above, Tunisia relies heavily on energy imports, primarily in the form of natural gas. In 2020, approximately 75 percent of Tunisia's total energy requirements were met through imports.[96] This reliance on imports will change with the expansion of the planned renewable energy production capacity in 2030. In recent years, there has been a significant rise in the number of renewable energy initiatives throughout the country. Currently, Tunisia has a combined installed capacity of approximately 472 MW from renewable sources, comprising 244 MW of wind power, 166 MW of solar power, and 62 MW of hydroelectric power.

Electricity generation in Tunisia has more than doubled between 2000 and 2022. It increased from a generation stream of 9.96 TWh in 2000 to 20.3 TWh in 2022 (Table 15). Natural gas is shown to have contributed to over 95.6 percent of the power generated in 2022 (Table 15 and Figure 21), but the energy landscape of Tunisia in 2022 is expected to undergo further transformation in the coming years. The government's target of attaining a 35 percent share of renewable energy in the overall energy mix by 2030 appears ambitious but it is feasible with sustained investment in renewable energy projects. This is all the more necessary as fossil fuels will become obsolete under pressure to mitigate climate change and deal with its negative and damaging consequences.

2.7. The Gulf Cooperation Countries (GCC)

GCC countries, which are home to enormous reserves of fossil fuels – whether of oil or gas – are re-evaluating their heavy dependence on fossil fuels. This is in light of increased global concerns about the negative environmental impacts of using fossil fuels, the rise of the global temperature, the increased risk of rendering fossil fuel reserves as stranded assets, and the continued and expected increased volatility of fossil fuel prices. More importantly, GCC countries see a great opportunity to diversify their economies across output, export, and revenue dimensions using renewable energy generation and exports. Renewable energy sources are offering them credible manufacturing alternatives toward broader industrialization activities.

This is increasingly being manifested in the greater potential to produce solar panels, solar heaters, electric vehicles, and green hydrogen and green fertilizers. In parallel, they continue to emphasize the circular economy

[96] Tunisia Energy Profile: https://www.iea.org/countries/tunisia, International Energy Agency, 2022.

Table 15. Sources of fuel for electricity generation, Tunisia, 2000-2022

	TWh									Share (%)								
Year	Bioen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind	Total	Boen-ergy	Coal	Gas	Hydro	Nucle-ar	Other Fossil	Other Renew-ables	Solar	Wind
2000	0	0	9.88	0.06	0	0	0	0	0.02	9.96	0.00	0.00	99.20	0.60	0.00	0.00	0.00	0.00	0.20
2001	0	0	10.6	0.05	0	0	0	0	0.02	10.7	0.00	0.00	99.35	0.47	0.00	0.00	0.00	0.00	0.19
2002	0	0	11	0.06	0	0	0	0	0.03	11.1	0.00	0.00	99.19	0.54	0.00	0.00	0.00	0.00	0.27
2003	0	0	11.5	0.16	0	0	0	0	0.03	11.7	0.00	0.00	98.37	1.37	0.00	0.00	0.00	0.00	0.26
2004	0	0	12.1	0.15	0	0	0	0	0.04	12.3	0.00	0.00	98.45	1.22	0.00	0.00	0.00	0.00	0.33
2005	0	0	12.8	0.14	0	0	0	0	0.04	13	0.00	0.00	98.61	1.08	0.00	0.00	0.00	0.00	0.31
2006	0	0	13.2	0.09	0	0	0	0	0.04	13.3	0.00	0.00	99.02	0.68	0.00	0.00	0.00	0.00	0.30
2007	0	0	12.8	0.05	0	0	0	0	0.04	12.9	0.00	0.00	99.30	0.39	0.00	0.00	0.00	0.00	0.31
2008	0	0	13.4	0.03	0	0	0	0	0.04	13.5	0.00	0.00	99.48	0.22	0.00	0.00	0.00	0.00	0.30
2009	0	0	14.2	0.08	0	0	0	0	0.1	14.4	0.00	0.00	98.75	0.56	0.00	0.00	0.00	0.00	0.70
2010	0	0	14.8	0.05	0	0	0	0	0.14	15	0.00	0.00	98.73	0.33	0.00	0.00	0.00	0.00	0.94
2011	0	0	15.2	0.05	0	0	0	0	0.11	15.3	0.00	0.00	98.96	0.33	0.00	0.00	0.00	0.00	0.72
2012	0	0	16.5	0.11	0	0	0	0.01	0.2	16.8	0.00	0.00	98.10	0.65	0.00	0.00	0.00	0.06	1.19
2013	0	0	16.6	0.06	0	0	0	0.02	0.36	17.1	0.00	0.00	97.42	0.35	0.00	0.00	0.00	0.12	2.11
2014	0	0	17.3	0.05	0	0	0	0.03	0.51	17.9	0.00	0.00	96.70	0.28	0.00	0.00	0.00	0.17	2.86
2015	0	0	17.8	0.07	0	0	0	0.06	0.45	18.4	0.00	0.00	96.84	0.38	0.00	0.00	0.00	0.33	2.45
2016	0	0	17.9	0.05	0	0	0	0.11	0.47	18.5	0.00	0.00	96.59	0.27	0.00	0.00	0.00	0.59	2.54
2017	0	0	18.6	0.02	0	0	0	0.13	0.45	19.2	0.00	0.00	96.87	0.10	0.00	0.00	0.00	0.68	2.35
2018	0	0	18.9	0.02	0	0	0	0.17	0.45	19.5	0.00	0.00	96.72	0.10	0.00	0.00	0.00	0.87	2.31
2019	0	0	19.7	0.07	0	0	0	0.25	0.5	20.6	0.00	0.00	96.01	0.34	0.00	0.00	0.00	1.22	2.43
2020	0	0	18.7	0.05	0	0	0	0.33	0.47	19.6	0.00	0.00	95.66	0.26	0.00	0.00	0.00	1.69	2.40
2021	0	0	19.9	0.06	0	0	0	0.41	0.53	20.9	0.00	0.00	95.22	0.29	0.00	0.00	0.00	1.96	2.53
2022	0	0	19.4	0.06	0	0		0.41	0.42	20.3	0.00	0.00	95.61	0.30	0.00	0.00	0.00	2.02	2.07

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/

Table 16. Installed capacity for electricity generation by fuel type (GW)

Fuel	Egypt	Lebanon	Morocco	Sudan	Tunisia	Jordan	Total
Bioenergy	0.12	0.01	0.01	0.2	-	0.01	0.35
Coal	-	-	4.26	-	-	-	4.26
Gas	53.47	1.6	0.87	0.37	5.78	3.45	65.54
Hydro	2.83	0.28	1.31	1.48	0.07	0.01	5.98
Nuclear	-	-	-	-	-	-	0
Other Fossil	1.33	3.03	0.78	1.93		0.38	7.45
Other Renewables	-	-	-	-	-	-	0
Solar	1.72	0.19	0.85	0.14	0.2	1.52	4.62
Wind	1.64	-	1.47	-	0.25	0.62	3.98
Total	61.11	5.11	9.55	4.12	6.3	5.99	92.18

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/
Note: Data for Egypt and Tunisia are for 2022, the rest are for 2021

imperatives and possibilities where they can re-purpose their oil and gas to produce fertilizers, chemicals, pharmaceuticals, and a host of other products that have low emissions and to target carbon capture technologies to strip carbon from these products. Equally relevant in this regard is their increased realization of the need to re-align their economic strategies with the new reality that suggests the possibility of fossil fuels becoming stranded assets.[97]

Each country in the GCC region has announced its specific goal to increase the share of renewable energy in its energy mix. Bahrain recently doubled its renewable energy share in its total energy supply targeting to achieve a 20 percent share in its total energy mix by 2035. Kuwait has announced a target of 15 percent to be achieved by 2030. Oman also announced a target of 10 percent by 2025 and 30 percent by 2030, whereas Qatar has announced a target share of 20 percent by 2030. The most ambitious target was announced by Saudi Arabia with a goal of generating 50 percent of its electricity using renewable energy sources by 2030, followed by the UAE, which has set a clean energy target share of 44 percent by 2050.[98]

This new vision and targets are now major components in Vision 2030 of Bahrain, Saudi Arabia, and the UAE, Vision 2040 of Kuwait and Oman, and Qatar National Vision 2030. However, some of them still face relatively low levels of foreign direct investment (FDI) in non-hydrocarbon sectors, but this is about to change as new plans and new investment programs are being prepared by their sovereign wealth funds (SWFs) to finance major mega projects in renewable energy expansion and EV production.[99]

The GCC countries have different objectives and programs to guide their transition to renewable energy than other countries in the MENA region. Oil-importing MENA countries are primarily concerned about ensuring energy security by having sufficient energy supplies to replace the fossil fuels that they had exclusively depended on in the past. However, they also realize that renewable energy sources hold the promise to save them large foreign exchange amounts, eliminate a good share of their emissions, and reduce their dependence on imports. The primary concern of GCC countries, however, is focused on the development of a new export alternative that is sustainable and leverages their comparative endowments of solar radiation and wind. In this regard, there is a commonality of interest among all the MENA countries in transitioning to renewable and clean energy, albeit for different reasons.

The GCC region is home to some of the world's largest SWFs, with 12 regional SWFs collectively managing assets above USD 3.8 trillion. More importantly, SWFs have been recognized as one of the main drivers of GCC economic diversification as they support investments in non-oil sectors. Furthermore, they attract and

[97] J. M. Rodriguez et al. (2019). Analysis of the Relations between Circular Economy and Sustainable Development Goals. International Journal of Sustainable Development and World Ecology. September. Pp. 708-720.

[98] Justin Dargin (July 2023). Beyond Green Pledges: Saudi Arabia and Society-Centered Climate Reforms, in Climate Change and Vulnerability in the Middle East. Carnegie Endowment for International Peace.

[99] https://en.wikipedia.org/wiki/Saudi_Vision_2030 and https://www.linkedin.com/pulse/what-you-need-know-saudi-arabias-vision-2030-eid-dalbani/

facilitate both domestic and foreign investment. In this context, they have made substantial investments in technology-driven sectors. Examples of this include the commitment of Saudi Arabia's Public Investment Fund (PIF) to SoftBank's Vision Fund, which focuses on emerging technologies like Artificial Intelligence (AI) and robotics, and the UAE's Mubadala Investment Company's establishment of Advanced Technology Investment Company (ATIC) as a subsidiary to invest in the semiconductor industry which already acquired Global Foundries, a leading semiconductor manufacturing company.[100] They have also recognized that the diversification of their economies could benefit from directing investments into green and renewable energy. Their wind and solar endowments are massive and special. They confer on the region a privileged comparative advantage to become major production hubs of renewable energy and its derivatives. Recent efforts to facilitate their economies' transition to green economies have witnessed determined efforts and massive investments in that direction.

This new direction for investment at home and in the diversification of their economies includes Saudi Arabia's PIF launching NEOM, a USD 500 billion smart city project in Saudi Arabia with a focus on renewable energy, including solar and wind, featuring innovative energy-efficient infrastructure and technologies, and Mubadala's established Masdar, a renewable energy and sustainable technology company, to promote clean energy projects in the UAE and globally. Masdar has already invested in various renewable energy initiatives, including the development of the 800-MW Sheikh Mohammed bin Rashid Al Maktoum Solar Park in Dubai, one of the largest solar parks in the world. In later sections, we will detail the massive investments that are being made in producing green hydrogen and green ammonia as well as EVs.[101]

The installed capacity for energy was the highest in Saudi Arabia at 106.2 GW in 2020 among the MENA region. Most GCC and North African countries were experiencing a power surplus, while several countries in the Levant region were experiencing power deficits.[102]

[100] https://www.mubadala.com/en/news/advanced-technology-investment-company-atic-become-mubadala- technology

[101] Saim Shadab. The New Arab Gulf: Evaluating the Success of Economic Diversification in the UAE. In M Rahman and A. Al Azm. (eds.). Social Change in the Gulf Region. Springer, 2023.

[102] https://www.statista.com/statistics/1240181/mena-installed-power-capacity-by-country/#:~:text=The%20installed%20capacity%20for%20energy,region%20were%20experiencing%20power%20deficits.

3. The case for the transition to green and renewable energy

Over the past few decades, the world has witnessed a significant shift toward renewable energy sources.[103] The widespread adoption of renewable energy technologies – such as solar, wind, biomass, and hydro – has not only helped reduce GHG emissions; it has also had a profound impact on employment, incomes, and social outcomes. The costs of renewable energy production have fallen dramatically, technologies have become more efficient, and solutions for integrating renewables into electric grids have advanced measurably. This study aims to explore the employment impacts of renewable energy, particularly how it is changing the job market in the MENA region, how it stands to address the high unemployment rates, and how it could afford better opportunities for the region's youth and women.

In the US and in virtually every region of the world, when electricity supplied by wind or solar energy is available, it increasingly replaces energy produced by natural gas or coal-fired generators. This has led to a significant reduction of CO2 emissions by about 25-40 percent.[104] Around the world, grid operators are managing larger amounts of wind and solar every year. In 2018, several countries in Europe managed very high hourly penetrations of wind and solar, including Denmark (139 percent), Germany (89 percent), and Ireland (88 percent).[105]

While most energy storage currently comes from pumped hydro storage facilities, the use of battery energy storage is growing very rapidly because of its increased cost competitiveness. Lithium-ion energy storage systems have seen dramatic price declines by as much as 85 percent between 2010 and 2018. Batteries are efficient carriers of energy, with round-trip efficiencies of 85-90 percent. If they are charged by renewable energy sources, they will have no added GHG emissions.[106]

The renewable energy sector has recently emerged as

[103] For example, an NREL study found that generating 35 percent of electricity using wind and solar in the west of the US would reduce CO2 emissions by 25-45 percent. www.nrel.gov/grid/wwsis.html.

[104] www.nrel.gov/grid/wwsis.html.

[105] Susan Tierney and Lori Bird. Setting the Record Straight About Renewable Energy. 12 May 2020. https://www.wri.org/insights/setting-record-straight-about-renewable-energy.

[106] Susan Tierney and Lori Bird. Setting the Record Straight About Renewable Energy. 12 May 2020. https://www.wri.org/insights/setting-record-straight-about-renewable-energy.

a major employer, creating new job opportunities and offering higher-quality jobs compared to the traditional energy sector. In fact, every dollar of investment in renewables creates three times[107] more jobs than in the fossil fuel industry. The IEA estimates that the transition toward net-zero emissions will lead to an overall increase in global energy sector jobs. The report notes that while about five million jobs in fossil fuel production could be lost by 2030, an estimated 14 million new jobs would be created in green energy.[108]

Renewable energy jobs are not evenly distributed geographically or among the different segments and classes of society. More efforts are needed to promote renewable energy development in underrepresented areas and groups. Overall, the employment impacts of renewable energy are positive and are expected to continue to grow as more countries shift toward clean energy, but they need to be more balanced in regard to geography, class, gender, and age.

3.1. Renewable energy and job creation

There are several ways to generate electricity. For over a century, fossil fuels have been the main source of power generation. Although important sources, hydroelectric and nuclear facilities have never truly competed with coal and natural gas for total generation capacity. However, recent advancements in technology have allowed for the rapid expansion of solar and wind generation capacity.

This expansion requires PV installers and wind turbine technicians. PV installers assemble, set up, and maintain rooftop and other systems that convert sunlight into energy, while wind turbine technicians (wind techs) install, maintain, and repair wind turbines. Both occupations are projected to grow much faster than the average for all occupations from 2019 to 2029. These occupations will continue to be needed to meet the expected increased demand for renewable energy generation. The Bureau of Labor Statistics estimates that the employment of PV installers in the US is projected to grow by 50.5 percent from 2019 to 2029, much faster than the 3.7 percent growth that is projected for all occupations. Demand for wind techs is also expected to grow very fast (60.7 percent) over the 2019-29 decade. Both occupations are among the fastest growing occupations from 2019-29.[109] Clean energy jobs are expected to continue growing, notwithstanding the hit to the sector as a result of COVID-19. Under the International Renewable Energy Agency's "Transforming Energy Scenario," the number of renewable energy jobs worldwide could more than triple, reaching 42 million jobs by 2050, while energy-efficiency jobs would grow six-fold, employing over 21 million more people. In contrast, the fossil fuel industry is expected to lose more than six million jobs over the same time period, even without the impact of the virus.[110]

The employment statistical record shows that the renewable energy industry has emerged as a major employer, providing jobs to millions of people worldwide. The growth of the renewable energy sector has the potential to create far more jobs than the traditional energy sector. More interestingly, many of these jobs are likely to be highly skilled and require advanced education and training. Recent analysis suggests that investing in low-carbon energy seems to be more labor-intensive than brown energy investments, revealing the potential of green investments to increase employment measurably. Garrett-Peltier (2017)[111] finds that each one million USD shifted from brown to green energy will create a net increase of five jobs. Other studies have come to a similar conclusion that investments in green energy are more labor-intensive than investing in brown energy (Hepburn et al., 2020; Engel and Kammen, 2009).[112]

According to IRENA, the renewable energy sector employed about 11 million people globally in 2018, up from 10.3 million in 2017. The majority of these jobs were in solar PV, bioenergy, and wind power.[113]

One of the main reasons behind the job growth in the renewable energy sector is the increasing demand for clean energy. As more countries shift toward renewable energy, the demand for renewable energy technologies,

[107] https://www.un.org/sg/en/content/sg/speeches/2021-09-24/opening-remarks-high-level-dialogue-energy.

[108] https://www.iea.org/commentaries/the-importance-of-focusing-on-jobs-and-gariness-in-clean-energy-transitions.

[109] William Lawhorn (2021). Solar and Wind Generation Occupations: A Look At the Next Decade. Beyond the Numbers: Employment and Unemployment, vol. 10, no. 4 (U.S. Bureau of Labor Statistics, February 2021), https://www.bls.gov/opub/btn/volume-10/solar-and-wind-generation-occupations-a-look-at-the-next-decade.htm

[110] Susan Tierney and Lori Bird. Setting the Record Straight About Renewable Energy. 12 May 2020. https://www.wri.org/insights/setting-record-straight-about-renewable-energy.

[111] Garrett-Peltier, H. (2017). Green Versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using An Input-Output Model. Economic Modelling, 61, 439-447.

[112] Engel, D. and Kammen, D. M. (2009). Green Jobs and the Clean Energy Economy. Copenhagen: Copenhagen Climate Council.

[113] https://www.irena.org/news/pressreleases/2019/Jun/11-Million-People-Employed-in-Renewable-Energy-Worldwide-in-2018

products, and services will continue to grow, creating job opportunities in a wide range of sectors. For example, the installation of solar panels requires skilled workers such as electricians, engineers, general technicians, and construction workers. Similarly, the installation and O&M of wind turbines require engineers, technicians, and construction workers with specialized skills.

Renewable energy jobs are also more labor-intensive than jobs in traditional energy sectors. For example, according to an IRENA report, the installation of solar PV systems creates more than twice as many jobs per unit of electricity generated compared to fossil fuels. This means that the growth of the renewable energy sector has the potential to create more jobs than the traditional energy sector.[114]

3.2. Renewable energy and job quality

In addition to creating new jobs, the renewable energy sector also offers higher-quality jobs compared to the traditional energy sector. Many renewable energy jobs are highly skilled and require advanced education and training. This is particularly so for jobs in the solar, wind, and green hydrogen power industries that require special technical skills and knowledge.
Moreover, renewable energy jobs tend to offer better pay and benefits than traditional energy jobs. According to the US Bureau of Labor Statistics, workers in the solar industry earn higher median wages compared to workers in the coal and gas industries.[115] Similarly, a study by the National Renewable Energy Laboratory (NREL) found that workers in the wind energy industry earn higher wages and have better benefits compared to workers in the oil and gas industries.[116]

3.3. Renewable energy and job distribution

Renewable energy jobs are not evenly distributed geographically. In many countries, the renewable energy sector is concentrated in certain regions or states. For example, in the US, California and Texas have the largest number of solar jobs, while Iowa and Texas have the largest number of wind jobs. Similar trends are observed in developing countries where solar power is generated in areas with wide exposure to the sun and wind turbines are installed close to water bodies and mountains.

This concentration of renewable energy jobs can create regional disparities in employment opportunities and economic growth. A few countries and regions are taking steps to address this issue by implementing policies and programs to promote renewable energy development and deployment in underrepresented areas. The decentralization of power generation and manufacturing of parts and downstream development of EVs promise to disperse production and employment into many regions and areas.

3.4. How MENA economies can capitalize on the green transition

A few economists have considered the benefits and risks of capitalizing on transition strategies to renewable energy and even the broader context of transitioning to a green economy. One of the seminal contributions in this area is that of Ricardo Hausmann (December 2022),[117] who argues that it would be a grave mistake for developing countries not to consider climate change as an important aspect of their development strategies. This is because climate change disasters are already imposing a heavy toll on the global economy and many countries are recognizing that the world must slash emissions to prevent a climate catastrophe. More importantly, they are realizing that decarbonization will usher in several structural changes that will present new opportunities and threats as the demand for dirty goods and services reduces and the demand for those that are cleaner and greener increases. This realization will raise the question as to what can be done to reduce every country's emissions, in addition to how countries, particularly developing countries, can supercharge their development by breaking into fast-growing industries that will help the world reduce its emissions and reach net zero.

Drawing on the experience of successful Southeast Asian economies, Hausmann points out that these countries have basically sustained decades of high growth by upgrading their areas of comparative advantage, from garments to electronics to machinery and chemicals. They did not remain stuck in industries bequeathed by the past. Developing countries, including MENA countries, can create jobs that pay higher wages, but they have to find new industries that can grow and export competitively even with higher wages.

[114] https://www.irena.org/News/pressreleases/2022/Sep/Renewable-Energy-Jobs-Hit-12-7-Million-Globally.

[115] https://www.bls.gov/opub/btn/volume-10/solar-and-wind-generation-occupations-a-look-at-the-next-decade.htm

[116] Ibid.

[117] https://www.imf.org/en/Publications/fandd/issues/2022/12/green-growth-opportunities-ricardo-hausmann

At its core, transitioning to a green economy with green energy will create new opportunities – especially for those that move fast. The paths that are opening up have not been trodden by many predecessors. A few are still virgins and transitioning into the green economy will require significant Greenfield investments, and plants will have to find new places to locate. This could be a great opportunity for MENA countries, but to assess it, they must understand the changing landscape, leverage their existing comparative advantages, and develop new ones.

There are many uncertainties embedded in this transitioning strategy as we do not know what technologies will power the low-carbon global economy, what materials and manufacturing capabilities will be needed, or what regulatory regimes the world will adopt. These uncertainties will most likely be resolved by those countries that play an active and early role and master the capabilities that will underpin their future comparative advantage. However, all countries should bear in mind the six themes listed below as they explore and exploit the new opportunities and deal with the new threats.[118]

3.4.1. Embrace global electrification

It is a known fact that about 70 percent of global emissions come from energy use. To decarbonize, the world needs to electrify the things that currently use fossil fuels and generate electricity from green sources such as wind, solar, and biomass. Doing so will require massive amounts of solar panels, wind turbines, electrical cables, and capacitors as well as mechanisms to store energy, such as lithium-ion batteries. At the same time, electrolyzers and fuel cells will be needed to convert electricity into hydrogen and back. All these products intensively use metals and rare earth elements. The production of these minerals will have to expand by several multiples if the world is to achieve net zero.

The future is likely to demand that the energy used in mining be green, especially since mining is energy-intensive. Mining also has local environmental impacts and is water-intensive; the latter is in short supply in most MENA countries unless green energy is used in desalination. Most countries fail to implement a regime that is open to investment but adequately manages these risks and conflicts of interest.

In addition, it is to be recognized that these minerals must be processed into the capital goods needed by the electrification process. This involves long manufacturing global value chains. Today, many mega-factories are being built to produce lithium-ion batteries, mostly in China, Europe, and the US. A good question to ask is why none are being developed in MENA countries. The MENA region must quickly and extensively develop what it takes to host them. If not, MENA countries must acquire the missing capabilities and resources.

Transitioning into the green economy would result in some industries growing but others shrinking. MENA countries, individually but (hopefully) cooperatively, must deal with the many fossil fuel-dependent export industries that will face headwinds because they are high emitters or supply high-emitting value chains. MENA countries, especially oil and gas exporters, will struggle with declining exports and sources of finance sooner than they think, as capital markets will fear that the assets they fund will be stranded. MENA oil and gas exporters are the lowest-cost producers, and this will help delay (but not avert) the expected demise of the industry. In addition, the circular carbon economy will give these countries the opportunity to repurpose their oil and gas reserves to produce petrochemicals, fertilizers, and a host of new products that innovators can produce. The sooner this repurposing is accomplished, the higher the returns and benefits.

3.4.2. Capitalize on proximity to renewable energy

The sun shines and the wind blows in many countries, but some MENA countries are blessed with abundant opportunities and endowments that few regions can match. In addition, oil and coal products are incredibly energy-dense, meaning they contain a lot of energy per unit of weight and volume, making them cheap to transport. It costs less than USD 4 to ship a barrel of oil that is worth about USD 100 at the well halfway around the world. As a consequence, oil and coal made the world flat from an energy perspective. Fossil fuel-poor countries could become competitive in energy-intensive products. China, Japan, and Germany, for example, are major steel exporters but energy importers.

This is unlikely to be the case with the alternatives to oil. Thus, countries with a lot of sunshine produce solar energy for less than USD 20 a megawatt hour, but to move the energy a long distance, it must be stored in a molecule such as ammonia. This conversion will increase the cost of energy six-fold (not counting the cost of transport). This creates enormous incentives to use renewable energy in situ. Energy-intensive industries will likely move toward places rich in green energy. This will make the MENA region a desirable location for energy-intensive production.

[118] These themes are those discussed by Hausmann and are used here in the order he had posted them.

3.4.3. Keep the cost of capital low

Hausmann notes that the sun shines, the wind blows, and the rain falls for free, but most of the cost of renewable energy production is, however, the fixed cost of the equipment, including the cost of the capital to buy it. Germany may be able to obtain funding at a cost of two percent, while in Morocco, it may be seven percent. Therefore, although Morocco is sunnier than Germany, this does not translate into cheaper solar energy. This is a major issue because the sun is strong in the Middle East, but capital markets shun these regions, potentially reversing their comparative advantage. Good institutions and macroeconomic management that keep country risk low are critical determinants of the cost of capital and hence the ability of MENA countries to be competitive in green energy.

According to Hausmann, the world is full of countries that have squandered their natural endowments because of failures in macroeconomic and mining-sector governance. Venezuela arguably has the world's largest oil reserves, but oil production has fallen by 80 percent from a peak in 1998 because of sanctions and possible macro mismanagement that scared off capital markets. It is quite possible that a similar fate could await countries with metals needed for the green transition, such as lithium, cobalt, copper, aluminum, and nickel, if they mismanage their resources.

3.4.4. Manage technological risks

Technological uncertainty is a defining characteristic of the world today. "Who would have thought the smartphone would displace the alarm clock, the camera, the CD player, and even the personal computer? Today one megawatt hour of solar energy when the sun is shining, or the wind is blowing is cheaper than the fossil fuel needed to generate the same megawatt using a thermal plant. This was unthinkable a decade ago."[119]

At this time, it is difficult to predict which technologies will win the race; there are many technologies in the running. MENA countries should be aware of the bets being placed across the world.

While technological surveillance is done regularly by industry, few governments do enough of it. Governments in the region should emulate the success of Singapore in appointing their chief scientists in their economy ministries to anticipate changes that may be coming and decide the most promising R&D bets. Chile's government is investing in a lithium research center with a consortium of global universities so that it can be on top of the technologies that might reduce costs and enhance the use of lithium while tracking those that may displace it.

[119] Solar Power Got Cheap. So Why Aren't We Using It More? https://www.popsci.com/story/environment/cheap-renewable-energy-vs-fossil-fuels/

3.4.5. Explore carbon sinks – net zero is not gross zero

A few countries in the MENA region have not adopted carbon prices in an appropriate manner and a few do not price carbon (e.g., Saudi Arabia). The region does not have large forests and it is not likely to benefit much from carbon sinks. However, it may be worthwhile to consider leasing these to create the credible offsets they need to prolong the life of their huge deposits of fossil fuels as an interim strategy.

There are other sinks, too. There may be geological formations in the deserts that could be ideal for storing carbon that has been captured. MENA countries should figure out where these are and certify that they are safe and sealed. Property rights must be defined on these geological formations so that investment can take place and countries in the region can collect rent from storage space.

3.4.6. Plan to learn

It is reasonable to suggest that no country today excels at the technologies and industries that will shape the future. However, Hausmann believes some will learn and others will not. MENA countries should plan to be in the first group. "Too often countries are told to shun things they don't do well and focus on things they are good at. But growth has never been just about focusing on current areas of comparative advantage. Growth can be anchored on evolving that advantage. France has a long history of being good at wine and cheese, but it also became good at commercial aircraft and high-speed rail." Why cannot MENA countries seek to develop the capacity to manufacture electrolyzers competitively? Who will transform their sunshine and wind into a source of advantage? It will be the countries that focus on attracting strategic investments and global talent, and on facilitating technological adoption by supporting research programs at universities and beyond.

It makes good sense to create value and livelihoods at home to help the world decarbonize rather than to push for global strategies to do so. "Because these are the new challenges, they are bound to be open to new players." MENA countries can be one of these players and, according to Hausmann, the payoffs could be huge.

Another seminal contribution in this area was made by Professor Paul Collier in a paper presented at the 2019 ERF Annual Conference and published subsequently in ERF's Middle East Development Journal,[120] where he argues that the challenge facing the MENA region is all too obvious. One way or another, most countries of the Arab World depend on (or have benefitted from) the oil rents, whether directly by extracting and exporting oil and gas or indirectly through remittances sent by Arab workers in the oil-producing and exporting countries. Other ways include through their development aid, from the exports of goods and services to these countries, or from the investments made by Arab oil-rich countries into the economies of the Arab non-oil producers. This web of strong economic ties between the two groups (the oil-producing countries and the non-oil producing of the Arab World), powered by oil rents and its derivatives, means that every country in the MENA region will be drastically affected by oil and gas becoming stranded assets as concerns over climate change and emissions escalate. The analysis and recommendations made by Paul Collier below emanate from his acceptance of these deep connections and the intricate web of dependence on oil rents in the entire MENA region.

3.5. How MENA Countries can rebase the growth of their economies[121]

Collier's basic premise is that as oil rents are set to wane, and asset values of fossil fuel deposits are set to be transformed into stranded assets, the legacy of four decades of a few MENA countries' dependence on fossil fuel rents is an economic structure that did not generate mass opportunities for employment that are sufficiently productive to sustain the living standards that the population in the region has come to expect. It is now an opportune time to restructure and reform the MENA region's economies and to wean the region out of this dependence on non-renewable assets.

3.5.1. MENA countries need a social transformation and a new development strategy

The real question for now (and for the near and mid-term) is about what can be done about transitioning from this dependence on fossil fuels to developing renewable sources of income and wealth. Collier is suggesting the formulation of a new development strategy and a whole new set of policies that can be put urgently in place. Whether you call this development strategy a new industrial policy or not, or a refocusing of its aims and means or not, is not the issue because the bare bones of building productivity at 21st century levels are not mysterious. Collier urged the building of new clusters of firms capable of innovation and linked to vocational training that equips a workforce with the skills that firms need. This transformation is not about a "grand scheme" or a "master plan." Rather, it is about a "social project" or even a "cultural revolution" that should involve all aspects and sectors of the society and the economy working together to achieve this transformation quickly and cumulatively. This project is far more complex and comprehensive than a transition to renewable energy and a green economy.

"The scale of the change from a rent-seeking economy to a skill-based economy is massive. It requires both cultural and institutional changes, and the changes are too large to be planned in any detail: it is a transformation." This is a serious transformation of a society, which is a complex process and a unique event and so, by its nature, it cannot be planned in detail; any set of proposals will need to be responsive to unanticipated future events and resilient to shocks.

Unique events such as the ones tendered here by Collier are, by their nature, subject to radical uncertainty (Kay and King, 2020). The way to navigate such uncertainty will involve building a process of rapid social learning based on experimentation, not by insisting on implementing a highly specified plan. He envisages a process whereby as society adapts and experiments, new opportunities will open, and the next steps will become clearer. What is needed and recommended is creating an adaptable framework along paths used successfully in other regions and countries such as those used by China and some of the Southeast Asian countries.

3.5.2. Local networks and local jobs

He recommends, first and foremost, that people in the MENA region must become productive workers, but this does not happen automatically and will require a series of conditions that have to be met. The most elementary requirement is to lay down the conditions that allow the potential for economies of scale and economies of specialization to be realized. However, for that to happen, he recommends that workers be organized into teams. This cannot happen without establishing firms, as the

[120] Paul Collier (2019). Rebasing Economic Growth in the MENA Region. Middle East Development Journal. Volume 11 - Issue 2.

[121] This section is based on Paul Collier's ideas and recommendations contained in his Rebasing Economic Growth in the MENA Region (Middle East Development Journal, Volume 11 - Issue 2) often quoting him verbatim.

most fundamental function of the firm is the organization of workers.

In the MENA region, many workers are forced to work solo as there are too few firms; too much of the labor force in the region is either in small informal enterprises or in the public sector. In the most advanced economies, however, one level up from the firm is the cluster. Firms cluster together partly to reap further scale economies that accrue at the sector level rather than within the firm. He advances the example of the city of Qiaotou, which has button-producing firms that make up two-thirds of the world's supply. Firms tend to cluster together to reap the gains of specialization as the firms in the cluster are interdependent. "For example, London has a vast range of firms specializing in distinct aspects of finance and law, enabling complex transactions that require a wide array of distinct skills to be completed swiftly." Most successful clusters tend to depend upon being in cities with good connectivity both internally and externally. Developing such large cities with large populations but avoiding congested gridlock requires huge and timely public investment in infrastructure and organization.
The most crucial factor supporting the transition to productive employment is to organize the training of the local workforce to equip them with the skills needed by the firms in the city. "The labor market does not do this automatically because neither individual firms nor individual workers have sufficient incentives to invest in training. If a firm invests in a general skill, the rational action is for the newly productive worker to quit for a rival firm that can afford to pay him more since it does not need to recover the costs of training. If a worker invests in a firm-specific training, the rational action is for the firm to exploit his new productivity."

3.5.3. Workers should invest in general skills and firms should invest in specific skills

How best to accomplish this? Collier suggests that the best way to address this issue is for workers to invest in general skills and for firms to invest in firm-specific skills, but in practice, efficient training will often intertwine general and firm-specific skills. Given that workers face much higher costs of borrowing than firms, they tend to under-invest even in general skills. It follows that we need public policy to generate the required level of investment in skills.

In general, it is the case that state-provided training is unlikely to be successful because it is too detached from the changing needs of employers. To make sure that training is pertinent, firms must be directly involved in the provision of training, usually in collaboration with local colleges and institutions so that an integrated balance of firm-based and classroom-based methods evolves. This calls for a nuanced public policy that imposes a levy on firms that forces them to finance skill acquisition, and partly to broker the marriage of college-based and firm-based facilities.

3.5.4. Organize and structure authority at the level of urban clusters

The fourth requirement is to organize the structure of authority so that it corresponds to the decisions that need to be taken at the level of the urban cluster. However, this has opposite implications for business and government. "Businesses are organized to compete with each other. But for the provision of city-wide training, they need to cooperate. Locally based businesses need to come together, forming associations that can work as a counterpart to local government, both for appropriate training and as a lobby for appropriate urban infrastructure. Conversely, government needs to be decentralized from national to city-level authority so that training colleges and centers can be organized, as they are pertinent for the changing array of firms located in the cluster."

3.5.5. Equip firms with the skills needed for international competition

The final requirement is not to equip the workforce with skills; rather, it is to equip firms with the skills needed to remain abreast of the international competition. This necessitates the development of direct linkages of firms and workers to university research departments, although the flow of knowledge is not simply from universities to firms but also a flow of new knowledge back to universities. This arrangement requires the decentralization of government; universities need sufficient local autonomy to be able to collaborate with local government in financing the research pertinent to the type of firms that the city hopes to attract.

3.5.6. Nexus approach to skill development, finance, research, and education

At the heart of all of this is the development of a nexus of firms and activities that promote high productivity by combining firms, local governments, and local tertiary education that work together to create and maintain a cluster of high performance. This brings firms that are spatially clustered together by products and interdependence, and organizationally bound into collaboration by business associations and government training levies. The local governments should be guaranteed sufficient financial and policy autonomy to invest in the infrastructure that enhances the productivity of the firms that it seeks to attract to the city. The tertiary education sector should be organized to train the workforce that the firms need and to conduct the research that keeps firms competitive. The whole system is designed to respond flexibly to change; each part has an incentive to spot emerging problems and work within the system to prepare appropriate responses.

3.5.7. Can MENA countries erect similar structures that successful cities used?

The development of some major cities in the US and Europe has followed this mode of development. American cities such as Boston, some European cities such as Munich and Edinburgh, and some Asian cities such as Singapore could not have developed their productive structure and excelled if they had not developed and exploited these productivity-enhancing levels. Can MENA countries erect similar structures? They already have major cities, they already have well-equipped universities, and they already have some capable large firms. However, they need and require a huge shift from the *rent-seeking style of life* that has been endemic. As carefully documented by Diwan, Malik, and Atiyas (2019), firms have relied on *crony capitalism* to prosper rather than on productivity.[122] Perhaps more damaging is the fact that educated young workers in the region have used their education to acquire credentials for entry to the public sector rather than to acquire skills that would make them productive in a sustainable private sector activity. Equally problematic is that governments in MENA have been organized around command-and-control by *highly centralized* authority, rather than into decentralized structures of authority designed according to functional pertinence and trusted to fulfill purposes that they have fully internalized.

3.5.8. Transformation under radical uncertainty: learning by doing

Shifting from a centralized rent-seeking society to a decentralized productive society is such a major transformation that it cannot be fully planned in advance. It will be subject to radical uncertainty; as such, it will depend upon igniting rapid social learning so that the society error-corrects as it attempts to change. This is, in essence, the strategy that Deng adopted in transforming China. It was summarized in two images that he used: '*Feeling your way across a river, stone by stone*' and '*… It doesn't matter whether a cat is black or white as long as it catches mice.*' These advanced the notion that the process involved radical uncertainty and that it permitted experimentation.

[122] I. Diwan, A. Malik, and I Atiyas (2019). Crony Capitalism in the Middle East: Business and Politics from Liberalization to the Arab Spring. Oxford: Oxford University Press.

3.5.9. MENA countries are starting from a very different situation than the Asian tigers

Embarking on a radically uncertain process inevitably arouses fears, but apprehension is compounded because MENA countries are starting from a situation very different from that which characterized East Asian countries at the onset of their successful transformations. East Asia started from low incomes and strong states, whereas MENA countries are starting *from incomes that are quite high because of oil rents, and states that have become somewhat fragile.* The East Asian economic transformation was a simple one of pulling people out of low-wage/low-productivity occupations (such as primitive agriculture) toward more productive, higher-wage manufacturing. In *MENA, wages are too high to ignite such a process.* The East Asian transformation was implemented by states that were effective and purposive.

3.5.10. MENA countries classical features of fragility

MENA states are characterized by some of the classic features of fragility: a weak private sector, a low level of political legitimacy, and limited state capacities (International Growth Centre, 2018). The state is built on a top-down basis, rather than on a set of reciprocal obligations between rulers and citizens that implicitly form a social contract in which citizens pay broad-based taxes in return for public services. The MENA oil countries developed an *authoritarian bargain* where citizens receive generous benefits from the ruler in exchange for acquiescence and political docility.

The present structure is unsustainable, and therefore there needs to be a change. Oil revenues will rapidly wither, and the working-age population will rapidly increase. *Continuing along an unsustainable path is far more dangerous than embarking on uncertain change* since it can only end in crisis. Transformation, albeit uncertain, will succeed as long as strong mechanisms for rapid social learning and error-correction are put in place. The overarching objective is for the growing inflow of young job seekers to find productive employment in the knowledge clusters discussed above instead of working in low-productivity bureaucracy, low-productivity crony capitalism, and low-productivity informality.

Underpinning the change from centralized bureaucracy and crony capitalism to decentralized government, purposive tertiary education, and market-disciplined firms are two profound transformations, one in institutions and the other in norms and cultural practices. The first of these has been discussed extensively in the contemporary literature (Acemoglu and Robinson, 2012), but the latter has received much less attention. However, the two are deeply complementary; many institutional innovations succeed only when the people who work in the institutions bring cultural practices that are well-suited to their operation. Changing these requires a change in mindset and ideas across the society.

3.5.11. Political leaders and governments can lead but cannot affect the success of the transformation

Political leaders rarely have enough power to implement the huge task of transforming their society simply by issuing commands. If people are reluctant to comply, they can usually find a myriad of ways to inhibit change. Hence, leaders need to gain a degree of willing compliance from their citizens. For this reason, they need to go beyond issuing orders: they need to change minds. People's minds are filled with the ideas they get from their social networks such as families, from organizations such as their places of work and prayer, and from the media. The few people who are at the hub of these networks and organizations are vitally important as communicators. Political leaders are not just the Commanders-in-Chief, they are the Communicators-in-Chief; by communicating effectively and consistently, they can gradually reset the ideas that people hold. They have two means of communicating: what they say and what they are seen to do. By far, the most effective form of speech is narrative: most people find stories easy to understand and remember. The use of visible actions to reinforce credibility is analyzed rigorously in the Theory of Signaling.

When well-used, narratives and signaling actions fit together, complementing each other. By using appropriate narratives, leaders can convey the meaning of an idea to people clearly and memorably. By matching this with visible behavior that is consistent with the idea, the leader's message becomes more credible: he 'walks the talk.' While the narrative needs to be aspirational, it is also important to stress the necessity of change by allusion to potential outcomes without transformation. One of the hardest steps is to convince a population to embrace change. Indeed, this is hard in any society, as the recent experience of France has shown.

3.5.12. Do not overload the reform agenda

A key principle of charting a path is not to overload the reform agenda. When an economy has many distortions, it is tempting to deal with all of them (and reform strategies are spoilt for choice). However, a long wish list is unwise. A step-by-step process involves focusing on tangible short-term wins. By acknowledging uncertainty, the leader gradually builds a culture of experimentation in which a range of options are tried and carefully monitored to see what works.

In the process, there is a shift in the source of self-respect from *being to doing*. Prestige is reconnected to achievement. Prestige becomes attached to doing something that is productive for society, not merely being in a position or close to those in power. Given that prestige currently comes from being in the public sector, it might sometimes be necessary, especially in the Gulf, to make this transformation in two stages. First, shift the source of prestige to working productively in the public sector and only later take the second step of shifting it to working productively in the private sector. Hence, the first step might involve creating more productive opportunities within state-owned enterprises. However, any state-owned enterprises need to be subject to genuine market tests; only then will they create sustainable change. Infant industry arguments along these lines would require careful management along a transition path toward self-sufficiency. It is unlikely that these enterprises can compete in world markets and consideration should therefore be given to entering sectors with less exposure to foreign competition.

3.5.13. China's use of scaffolding and narratives

Narratives are most effective when they are culturally specific and credible. The pace of change is not going to be rapid: no MENA country is going to become Singapore. Each country is unique, and so it cannot adopt a narrative that amounts to becoming a replica of somewhere else. Such a narrative could be more dangerous than helpful. It amounts to looking at someone else's finished building rather than erecting the scaffolding to build your own house. The learning from other countries should focus on the scaffolding – the process of how transformation was achieved. The scaffolding used by China had four components:

- An overarching narrative spread around the population, mainly to rebuild a prestigious, proud China.
- A political leadership that encouraged intensive, rapid social learning to understand what would work within the local context.
- To evaluate the performance of those who held positions of authority and hold them to account for success and failure.
- Use decentralization to foster a yardstick competition across jurisdictions, further encouraging experimentation on a local scale.

Rapid social learning can only happen if policymakers and decision-makers acknowledge that there are many aspects of the reform program that they do not yet understand: that they know that they do not know. *Success lies in a step-*

by-step approach and learning from the steps. In China, the political leaders enforced the need to experiment and changed the perception of failure so that it became seen as a positive learning experience. Local leaders were forced to experiment; if companies, institutions, and bureaucracy did not innovate, they were judged to be failures. Bureaucracy changed as leaders encouraged experimentation. Hence, running a series of social experiments should be a core element of the actions to be taken in support of the narrative. The experiments should be done on a small scale; large experiments are too risky.

3.5.14. Development of institutions

Institutional change is not sufficient, but it is important. The development of institutions can create convincing signals, making cultural change credible. Articulating new rules can also facilitate a shared understanding of the steps that need to be taken and can create incentives to do so. Institutional reform can also provide a context for bringing in new people to the policy process with different mentalities, goals, and ambitions.

3.5.15. Institutions and culture co-evolve

Just as institutional rules signal the formal norms, culture embodies the informal norms. The culture of an institution becomes established when its leaders and its people become willing and competent in what the institution is tasked to do. This requires the appropriate level of staffing and analytical resources. There are many examples of institutional reforms in the real world which have been able to change norms and practices as well as create new rules. A good example is having an Independent Office for Budget Responsibility as established in Britain in 2010. It has the potential to instill discipline, particularly around spending, based on realistic long-term projections for the price of oil. This would avoid the current situation of public expenditure following oil prices in a pro-cyclic fashion. Improving the framework for budgetary forecasting can be used to change narratives around public management, forcing policymakers to pay attention to longer-term goals. It also injects an element of independent thinking and analysis into policy. However, the details of institutional design matter. It is important that the institutional goals are carefully specified, that the system of accountability is specified, and that there are sufficient human and financial resources for the body to do its job to a high level. Institutions can be set up to fail. Similarly, attempting to implant Western-style cultures and institutions into MENA will not work.

The importance of not overloading the narrative carries into implementation. *Failure is most commonly due to trying to do too many things at once.* The fear of failure and the reality of failure are demoralizing. Visions are grand leaps. However, actions and initiatives in support of the narrative should not take the form of leaps. Rather, they should be considered more akin to scaffolding. Scaffolding supports the construction of a building, but when it is taken away on completion, the building stands on its own. The scaffolding of actions and narratives for transformation is the gradual change in institutions and ideas that pave the path along which the local knowledge clusters that enable a workforce to be productive get built.

China discovered the scaffolding that it needed for transformation from experiments within its regions. Since these experiments were conducted within an area bounded by a common culture and institutions, the lessons from one place were likely to be pertinent for others. MENA is even better placed to undertake experiments within its own region of cultural and institutional similarities because it consists of many sovereign states. In China, the central government had to convince regional leaders that they would not be punished for branching out from what had been nationally imposed policies.

The MENA region is fortunate that it does not have a MENA-wide central government; experimenting is much easier. In China, however, once experiments got underway, it was easy to spread. MENA's strength in being able to experiment is its weakness in spreading the learning from them. What has been missing in MENA are the institutional structures designed to learn from experiments in other countries within the region. What MENA needs is not regional power structures, but regional knowledge networks capable of evaluating experiments and spreading the lessons from them. All new experience is valuable; societies can learn not only from successes but from failures. ERF is such a network; as the region's premier social science knowledge network, its role in speeding the transformation of the region is exceptionally important. The first 25 years of the ERF have gradually built an organization that can be truly valuable in the decisive period of the next 25 years.

Of course, the real question here is how such clusters of firms can be built. What is the scale of the change from a rent-seeking economy to a skill-based economy that is likely to be needed? The challenges are not purely economic; this transformation requires both cultural and institutional changes, and the changes are going to be too large to be planned in any detail or to be served by an industrial policy or a program of energy transformation. The transformation of a society is a special and unique event and so, by its nature, it cannot be planned in detail; any set of proposals will need to be responsive to unanticipated future events and resilient to shocks. Just as the old strategy of diversification downstream and upstream in the region is no longer feasible or sufficient, so is looking for sunrise industries to replace sunset industries. We need to broaden our diversification perspective to include a cultural transformation aspect that encompasses all sectors and activities and not only those in renewable energy.

Even in the case of adopting a narrow perspective focused on a diversification strategy premised on renewable energy and a transition to a green economy, there are broader considerations to keep in mind. Below, we present the Integrated Energy System Plan (IESP) as a broader perspective within which the transition to renewable and green energy could be centered.

4. An integrated energy system plan to underpin the transition to renewable and green energy

There are typically four distinct program areas in any IESP. The transition to new cleaner and more sustainable energy sources is not only about switching the sources of energy. Rather, it is part of a broader and more nuanced social project where rational energy development and use is a critical component. The latter involves but is not restricted to four components: energy efficiency, demand management, fuel switching, and customer-based generation. The net avoided cost, which is the difference between energy cost savings and the cost of equipment and programs to attain these savings, will be a major driver of net economic benefits. In addition, there is potential in securing sufficient new supplies to meet the expected energy demands, diversifying the economic base, establishing new export engines, and developing massive training and innovation centers and a new development program based on the development of new skills and clusters of firms This process would create enormous job opportunities at the high end of the wage scale.

These total net savings are organized from the highest expected net savings to the lowest in aggregate terms and are represented by a step function displayed in Figure 1 borrowing from the experience of developed countries (in this case, Canada) that had a head start on developing these integrated energy plans. In the example below, it is clear that energy efficiency programs have realized the largest aggregate net savings, followed by fuel switching, then demand management, and, finally, customer-based generation. These impacts differed by region and country and are likely to differ by country and sub-region within the MENA region. The main reason that this example is used lies in the fact that an IESP is not restricted to transitioning to renewable or green energy as much as the development of a social project for a broader and sustainable economic diversification initiative, energy sufficiency, employment creation, women and youth empowerment, and environmental resiliency.

When these net savings were normalized by MW of energy saved, the highest energy saving per MW was realized by fuel switching although the scale (the MWs saved or replaced) of this activity was limited. The second highest was energy efficiency with large-scale savings. This was, however, substantially lower than the per MW savings realized by fuel switching. The lowest per MW savings were realized by customer-based generation. These estimates are for an advanced economy (Ontario's economy), and they are presented here to identify the methodology used in this study to position renewable and green energy development within a total program of a rational socioeconomic-environmental energy strategy.

The impact on production, personal incomes, employment, and government revenues are identified as the secondary benefits or costs of the conservation alternatives. An important finding of a similar analysis undertaken by the authors in Ontario found that energy conservation activities in Ontario will have positive impacts on employment and other macroeconomic indicators.[123] This result is counterintuitive in the sense that reducing the operation of a given activity results in added economic performance. These added economic benefits derive from the savings that reduced production releases to the various sectors of the economy which, in turn, re-spend them on other goods and services. When consumers do not spend on electricity, they can spend the saved money on other consumer bundles, and when businesses do not spend on electricity, they can distribute the saved costs to shareholders as dividends to be spent by households, or businesses can spend it directly on the expansion of their capital stock (investment). The economy benefits when the savings reduce economic activity by less than the added activities generated by the expenditure of the savings by the various sectors realizing them. Other benefits accrue directly on new investment in and production of alternative energy, particularly those that have high local content, are labor- and knowledge-intensive, and involve strong backward and forward linkages to key sectors of the domestic economy.

[123] Atif Kubursi (2008). Comparative Economic Impacts of Conservation and Demand Management Programs in Ontario. Report Submitted to IN-DECO and Ontario Ministry of Energy.

5. Renewable energy as a new comparative advantage of the MENA region

One of the fortuitous advantages embedded into the development of renewable and green energy in the MENA region is the evident inherent comparative advantages of developing these alternatives in the selected countries in the region given their natural endowments of high solar radiation over much of the year and strong wind nodes. Add to this the following general considerations listed below:[124]

- About 80 percent of the global population lives in countries that are net importers of fossil fuels.
- In contrast, renewable energy sources are available in all countries, and their potential is yet to be fully harnessed.
- IRENA estimates that 90 percent of the world's electricity can and should come from renewable energy by 2050.
- Renewable energy is, in fact, the cheapest power option in most parts of the world today, and particularly in the chosen countries for this study.
- The prices of renewable energy technologies are dropping rapidly.
- The cost of electricity from solar power fell by 85 percent between 2010 and 2020
- Cheap electricity from renewable sources could provide 65 percent of the world's total electricity supply by 2030. It could decarbonize 90 percent of the power sector by 2050, massively cutting carbon emissions and helping to mitigate climate change. If for no other reason, these considerations make the transition to renewable and green energy a dominant option.
- Renewable energy creates jobs. This is a crucial consideration given the characteristically high unemployment rates of the selected countries, particularly those rates for the educated, youth, women, and disadvantaged minorities.
- According to the World Health Organization (WHO), about 99 percent of people in the world breathe air that exceeds air quality limits and threatens their health, and more than 13 million deaths around the world each year are due to avoidable environmental causes, including air pollution. Whether you live in Cairo, Beirut, or Khartoum, you are breathing highly polluted air, and much of it is produced by car emissions or electricity generators. Transitioning to clean energy is critical for cleaning the air they breathe.

The literature on the relative importance of drivers of renewable energy adoption by SME firms is in general scant (Rahbauer et al., 2018),[125] particularly in developing countries like Egypt. Several important drivers of renewable energy are identified in the literature (see Seggarra-Blasco and Jove-LLopis, 2019);[126] including perceived responsibility for the environment, reliability of renewable energy, price, firm customers willingness to pay a price premium for goods produced with renewable energy, competitive pressure, age and size of the firm, government regulations…etc. Several other factors that are important in the context of developing countries were not rigorously investigated in the existing literature; a gap that our study will fill with surveys, case studies, and focus groups. These include access to credit and the nature of the trade regime. Access to credit is one of the most important constraints facing MSMEs in developing countries and it is very likely that it would affect renewable energy adoption. By rendering imported capital and equipment more expensive, tariffs along with complicated custom clearance procedures are also a potential constraint on renewable energy adoption.

Operating renewable energy requires specific skills like engineering or technical skills. Since this technology is relatively new, it is reasonable to expect that these skills are acquired by the younger generation and hence firms that adopt renewable energy employ a larger share of youth in their labor force. In developing countries, awareness of the environment is almost lacking but is slowly building up among the young through education. In the absence of pressure from environmentally aware consumers and environmentally lax governments, pressure for environmental protection is likely to come from employees. A young labor force should then be one of the drivers that facilitate the adoption of renewable energy at the firm level. On the other hand, with female students being underrepresented in engineering and technical schools, it is interesting to explore whether firms employing renewable energy hire more or less females and why. In another vein, and supported by evidence in the literature showing women are more concerned about environmental issues compared to men, Atif et. al. (2021) find that gender diversity on firm boards increases renewable energy

[124] Most of these points can be found in https://www.un.org/en/climatechange/raising-ambition/renewable-energy#:~:text=Renewable energy sources are all around us&text=In contrast, renewable energy sources, from renewable energy.

[125] S. Rahbauer et al. (December 2018). Determinants for the Adoption of Green Electricity by German SMEs – An Empirical Examination. Energy Policy 123(2):533-543.

[126] Agusti Segarra-Blasco and Elisenda Jove-Llopis (2019). Determinants of Energy Efficiency and Renewable Energy in European SMEs. Economics of Energy and Environmental Policy, International Association for Energy Economics.

consumption. This suggests that women entrepreneurs might be more inclined to employ renewable energy compared to their male counterparts. In a nutshell, the role of gender and youth as drivers of renewable energy adoption deserves a thorough investigation.

6. Transition to renewable energy is only a part of an integrated energy system plan

In most energy policy studies, the energy sector is typically viewed in isolation from the remainder of the economy and society, and the analysis is performed without consideration of broader impacts. The employment structure and level of other macroeconomic indicators are taken as given – as though they are not affected by the energy sector. This is not satisfactory, since there is a considerable two-way interdependence with the remainder of the economy. Social opportunities and outcomes are also influenced by energy policy, and these are crucial determinants of the sustainability, social inclusion, equity, and political feasibility of energy policies.
As a rough measure of the benefit or cost of a given energy activity or policy, it is often sufficient to calculate the impact upon aggregate output (GDP) and employment. This is, however, not sufficient or comprehensive. Many other aspects of impact need to be ascertained and even quantified.

The direct savings of energy or the substitution of more available or cheaper types of energy for the less available or more expensive types will be identified as the primary benefits of the transition to renewable energy and to conservation activities, and this results in net avoided costs and multiple socioeconomic and environmental benefits that will be documented below.

Over the last decade, there have been growing policy debates on the trade-offs between the development of low-carbon energy technologies and other social goals.[127] Among the many economy-wide impacts, the impacts on employment produced by renewable energy development and the share of women, youth, and disadvantaged groups are important factors to consider when examining social aspects.[128] Employment is a key issue in government energy transition plans, particularly in poor areas due to rising poverty levels and environmental degradation issues. For this reason, one of the key concerns for policymakers is the evaluation of the contributions of renewable energy from the perspective of job creation for the economy of a specific region or country, as the renewable energy industry has become one of the most dynamic sectors in many countries' job markets. In fact, the MENA region faces some of the greatest social challenges ever, with the highest level of social inequality among developing countries.[129] The major potential of renewable energy sources in MENA is located in many of the poor countries of the region; thus, the creation of employment is a key consideration in these areas. The economic bases in MENA are typically undiversified. In fact, the rich fossil fuel endowments in the region have militated against diversification and left most countries of the region with lopsided economies. Renewable energy development and its potential to support upstream, downstream, and off-stream industrial activities is touted to offer excellent and substantive opportunities for diversification and balancing production and employment structures.

In this context, the present study aims to quantify the direct impacts on employment by the massive penetration of renewable energy technologies in the MENA power sector. For this purpose, an analytical assessment model is constructed, and the model is simulated under three different energy scenarios built using the SWITCH-Chile model, in compliance with the national power system design, energy expansion policies, and the targets for reducing GHG emissions.[130]

Our contribution to the literature is twofold. The first contribution of this work is to propose a novel methodology that combines an energy model – the SWITCH-Chile model – and an analytical assessment model. This allows for more realistic technology-based energy scenarios to be examined while quantifying the direct impacts on employment. Moreover, the proposed methodology is simpler to understand and implement and more transparent than the typical IO, Computable General Equilibrium (CGE), and analytical assessment models, which involve big data burden. Even though the energy market simulated in the study and the calculation of impacts on employment is specific to Chile, the proposed methodology can be a valuable contribution to the literature. Particularly, the use of such methodology can be relevant in other emerging

[127] Nasirov S, O'Ryan R, and Osorio H. Decarbonization Trade-offs: A Dynamic General Equilibrium Modeling Analysis for the Chilean Power Sector. Sustainability 2020; 12:8248.

[128] O'Ryan R, Nasirov S, and Alvarez-Espinosa A. Renewable Energy Expansion in the Chilean Power Market: A Dynamic General Equilibrium Modeling Approach to Determine CO2 Emission Baselines. J Clean Prod 2020; 247:119645.

[129] Rowaida Moshrif (2022). Income Inequality in the Middle East. World Inequality Lab - Issue Brief 2022. https://wid.world/document/income-inequality-in-the-middle-east-world-inequality-lab-issue-brief-2022-06/

[130] O'Ryan R, Nasirov S, and Alvarez-Espinosa A. Renewable Energy Expansion in the Chilean Power Market: A Dynamic General Equilibrium Modeling Approach to Determine CO2 Emission Baselines. J Clean Prod 2020; 247:119645.

economies to measure any policy strategy aimed at the reduction of GHG emissions according to its net impact on the job market.
A second contribution of this study is to conduct a systematic analysis of the effects of the deployment and operation of renewable energy plants on job creation, considering CO2 reduction scenarios for the case of MENA. The discussion of this topic is certainly an important one, not only in Chile but at the global level, given that most nations are now striving to shift toward low-carbon energy generation mixes.

Although several similar policy analyses have been found in this respect in the context of several countries, no related studies have looked at the MENA region. No single country in the MENA region has an integrated energy policy that quantifies the impacts on employment and identifies the required skills to develop, operate, and maintain renewable technologies in the medium and long term. In that sense, this study contributes by assessing job creation opportunities given the actual and projected penetration of renewable energy technologies in the five MENA countries. In addition, it provides specific policy recommendations for directly addressing the upcoming employment challenges and barriers in the renewable energy industry.

This study may also be particularly relevant for certain policy interventions, such as for government authorities to further strengthen the renewable energy market by improving job skills and developing forces.

7. The alternative approaches to estimating the employment impacts of renewable energy

In the literature, an increasing number of studies have looked at the impacts of the renewables boom in energy systems on employment.[131] Studies examining the effects of renewable energy on employment have been differentiated by methodological approach for a specific region or country.[132] The IO, CGE models, Meta Econometric Analysis, and the Analytic Assessment Models are among the methodologies most used to examine the impact of renewable energy deployment on the creation of jobs. IO analysis, using national-account-based IO data, provides detailed information on the flows of intermediate goods and services among all sectors of the economy, as well as the interdependencies among sectors. The main advantage of the IO models is that they have a few built-in assumptions and are transparent and easily replicable for estimating both direct, indirect, and induced job creation due to the deployment of renewable energies.[133] It can be applied to each renewable energy technology separately, considering both the positive and negative effects on employment produced by the opening and/or closure of power and thermal energy plants.

A major criticism of the IO approach has to do with its structure, which contains a high level of aggregation of national account-based IO tables, where the renewable energy sector is not always explicitly presented. It also uses some simplistic assumptions, which include fixed input proportions and constant technical coefficients (Leontief production functions) as well as fixed and invariant commodity market shares (as explained in the next section). Moreover, simple IO models ignore the dynamism and technological improvements in the sectors. More generally, the static IO models tend to examine effects from a quantitative perspective and avoid considering qualitative factors such as scale effects, changes in productivity, or substitution possibilities. These modes typically exaggerate the impacts of structures and ignore behavioral economic considerations rooted in consumer and firm optimization norms.

7.1. The mathematical structure of the input/output approach

In this regard, a common language of ‘direct,’ ‘indirect,’ and ‘induced’ jobs is found in most of the literature pertaining to renewable energy and employment effects, derived from the more generic use of this terminology in labor studies at large. IRENA provides not only a clear and operational definition of these terms but also elaborates appropriately on the slight but important variations in their interpretation across studies (IRENA, 2011):

Direct jobs: Precise definitions vary, but, in general, these are jobs related to core activities, such as manufacturing/fabrication/construction, site development, installation, and O&M. Direct jobs are relatively easy to measure,

[131] Fragkos P. and Paroussos L. Employment Creation in EU Related to Renewables Expansion. Applied Energy 2018; 230:935-45. ILO. World Employment and Social Outlook 2018: Greening with Jobs. Geneva. 2018 and Lehr U., Nitsch J., Kratzat M., Lutz C. H., and Edler D. Renewable Energy and Employment in Germany. Energy Pol 2008; 36:108-17.

[132] Simas M. and Pacca S. Assessing Employment in Renewable Energy Technologies: A Case Study for Wind Power in Brazil, Renew. Sustain. Energy Rev. 2014; 3: 83-90 and Kammen D. M., Kapadia K., and Fripp M. Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? Tech. Rep. University of California; 2014. Berkley, http://rael.berkeley.edu/old_drupal/node/585.

[133] Fragkos P. and Paroussos L. Employment Creation in EU Related to Renewables Expansion. Applied Energy 2018; 230:935-45 and Dalton G. J. and Lewis T. Metrics for Measuring Job Creation by Renewable Energy Technologies, Using Ireland As a Case Study. Renew Sustain Energy Rev. 2011; 15:2123-33.

and their absolute number unequivocally correlates to the rate of growth of renewable technologies. All studies cited in B. Vander Zwaan (2013)[134] consider direct renewable energy job impacts (and some also inspect corresponding indirect or induced job effects).

Indirect jobs: These are jobs connected to the supply and support of the renewable energy industry at a secondary level. They can best be thought of as jobs associated with activities such as the extraction and processing of raw materials (e.g., to produce copper and steel), marketing and selling (including at trade fairs), administration at ministries, and others, such as support organizations that have less obvious linkages. Only a small fraction of available studies calculate indirect jobs. Some studies merely note that indirect effects can be expected, whereas others explicitly estimate these effects via a simple multiplier.

Induced jobs: Induced jobs arise from the economic activities of direct and indirect employees, shareholders, and governments (e.g., via associated tax revenues). The spending of their earnings can stimulate other industries that themselves are entirely disconnected from renewable energy but nevertheless have a substantial job creation potential. Induced jobs can be simply conceptualized, consider the example of a renewable energy industry employee dining out in a restaurant: this leisurely outing contributes to creating demand for staff in the culinary sector. In practice, however, induced jobs are difficult to accurately determine since tertiary (and quaternary) employment effects from the deployment of renewables are usually hard to isolate. For this reason, and given the paucity of literature in this domain, few studies include induced jobs. Studies of employment opportunities have been performed for many different types of renewables, including wind power (on- and off-shore), solar energy (PV and thermal), biomass-based energy (from various sources of fuel and feedstock), and geothermal power (for multiple geological formations and depths). A series of conventional energy technologies such as nuclear energy, hydropower, and natural gas or coal-based power generation have also been subjected to job creation assessments.

The organization of these matrices and the corresponding row and column totals may be represented as follows:

	Commodities	Industries	Final Demand	Row Total
Commodities		U	F	q
Industries	V			g
Primary Inputs		Y	YF	Y^T
Column Total	q'	g'	f^T	

[134] B. vander Zwaan et al. (2013). Energy Policy. Vol. 60: 296–304.

The row and column totals, q_i, represent the total value of domestic production of each commodity; the totals, gj, the value of gross domestic output (value of sales) of each industry; the totals, y_{kT}, the total value of each primary input; and the totals, fst, the total value of each final demand category.

The Market Share Matrix (Supply):
Assuming that the share of commodity i produced by industry j is fixed, we may write:

$$V_{ji} = d_{ji} q_i \qquad (1)$$

Where $d_{ji} = \frac{V_j}{q_i}$ represents the proportion of commodity i produced by industry j. This assumption, together with the industry-output identity, implies that industry gross outputs can be calculated from commodity outputs.

$$g_j = \sum_i V_j = \sum_i d_j q_i \qquad j=1,2,...,m \qquad (2)$$

This commodity-industry composition may also be represented by a market share matrix, D = $||d_{ji}||$, so that the vector of industry gross outputs, {g}, is related to the vector of commodity gross outputs, {q}, by the following matrix equation:

$$\{g\} = [D]\{q\}, \qquad (3)$$

Where {˙} indicates a column vector and [˙] indicates a matrix.

Thus, the fixed market share assumption implies that the production of the j^{th} (multi-product) industry is a weighted sum of the commodity outputs that it produces, where the weights are the coefficients d^{ji}. These weights sum to one across industries.

Since

$$q_i = \sum_j V_j = \sum_j d_j q_i$$ which implies

$$\sum_j d_{ji} = 1 \qquad \text{for } i = 1,2,...,n. \qquad (4)$$

The Industry-Technology Matrix:
The production function underlying the production process is assumed to be of the fixed proportion type (generally known as a Leontief production function).

$$g_j = \underset{i}{MIN}\left[\frac{U_j}{b_j}\right] \quad \text{for } i = 1,2,...,n \text{ and } j = 1,2,...,m \qquad (5)$$

Where $b_{ij} = \frac{U_j}{g_j}$ is the amount of commodity i needed to produce one unit of output j.

Thus, the use of each commodity is assumed to be a fixed proportion of the industry gross output:

$$U_{ij} = b_{ij}g_j \qquad (6)$$

This assumption allows the total intermediate use of each commodity to be calculated from the industry gross outputs:

$$\sum_j U_{ij} = \sum_j b_j q_j \qquad (7)$$

If we arrange the input-proportion coefficients in a matrix, B = $||b_{ij}||$, the vector of total intermediate uses of each commodity can be calculated from the vector of industry gross outputs.

$$[U]\{1\} = [B]\{g\} \qquad (8)$$

If we let $F_i = \sum_s F_{is}$ F_i represent the total final demand use of each commodity and arrange these in a "final demand" vector, f, the commodity-balance identities can be represented in matrix form.

$$\{q\} = [B]\{g\} + \{f\} \qquad (9)$$

The matrix equation forms of the commodity-industry model (3) and the commodity-balance model (9) form the core of the IO model. These allow the commodity outputs and industry gross outputs to be calculated from a given vector of final demand commodity uses. Substituting (3) into (9), we have:

$$\{q\} = [B][D]\{q\} + \{f\}. \qquad (10)$$

This matrix equation can then be solved for the commodity output vector:

$$\{q\} = [I - BD]^{-1}\{f\}. \qquad (11)$$

The analogy between (11) and the familiar Leontief system {q} = [A]{q} + {f} is immediately apparent. The matrix [A] would be equivalent to the matrix [B] if the [D] matrix was an identity matrix, implying that every industry produced only one commodity. In this respect, the "square" Leontief framework is inadequate as changes in the matrix [A] may correspond either to a technological change in input proportions or to a shift in market shares. The "rectangular" framework separates these effects.

By pre-multiplying (11) by the market share matrix, [D], we can solve for industry outputs.

$$\{g\} = [D]\{q\} = [D][I - BD]^{-1}\{f\} \qquad (12)$$

An equivalent mathematical expression to (12) may be obtained directly by first pre-multiplying the commodity-balance model (9) by the market share matrix [D]:

$$\{g\} = [D]\{q\} = [D][B]\{g\} + [D]\{F\} \qquad (13)$$

And subsequently solving (12) for the industry gross output vector.

$$\{g\} = [I - DB]^{-1}[D]\{f\} \qquad (14)$$

Once we introduce imports as a leakage, the equation system becomes as follows for the commodities (15):

$$\{q\} = [I - [I - m\hat{}]BD]^{-1} [I - m\hat{}]\{f_o\} \qquad (15)$$

And for the industry output (16):

$$\{g\} = D\,[I - [I - m\hat{}]\,BD]^{-1}\,[I - m\hat{}]\,\{f_o\}. \qquad (16)$$

Closing the Model

The equation systems above solve only for initial and indirect domestic commodity and industry output. Final demand components are treated as exogenous to the system. This treatment is not adequate because consumption can be expected to be linked to the level of labor income. Thus, a final demand vector, which implies a larger labor income, should also imply more consumption. When consumption is related to income, the solution of the system includes not only direct and indirect effects but also income "induced" effects. Therefore, the model is completed by adding a relationship linking consumption, C, to "income," N:

$$C = bN, \qquad (17)$$

Where b, is the Marginal Propensity to Consume (MPC) out of income.

"Income" is defined as the sum of labor income, W, and net income of unincorporated business, UIC. Thus, income is related to gross industry outputs by the vectors of primary input coefficients w and e.

$$N = \sum_j (w_j + e_j)g_j + (w_c + e_c)C + W_F \qquad (18)$$
$$= [\langle w\rangle + \langle e\rangle]\{g\} + (w_c + e_c)C + W_F,$$

Where W_F is the sum of labor income associated with all final demand components except consumption and competitive imports.

The integration of consumption into the model is completed by assuming that the values of commodities and primary inputs that enter into consumption expenditure are fixed proportions of the total value of consumption:

$$Ci = ciC \qquad i=1,2,\ldots,n \tag{19}$$

or, in matrix form:

$$\{f_c\} = \{c\}C,$$

Where ci is the proportion of consumption used to purchase commodity i and {c} is the column vector of c_i's, and by assuming:

$$W_c = (w_c + e_c)C, \tag{20}$$

Where w_c is the proportion of the total value of consumption spent on labor and e_c is the proportion of the total value of consumption which generates net income of unincorporated business.

The "income" concept defined in equation (17) does not include dividends, government and private transfers, or income taxes and other direct taxes and may, therefore, not accurately represent personal income. On the other hand, the inclusion of dividends, government transfers, and direct taxes would require information on the distribution of dividends and other private transfers between Ontario, the other provinces, and abroad. This information is not available.

The inclusion of consumption within the system modifies its structure, which now assumes the following configuration:

$$(52)\quad \begin{bmatrix} \dfrac{I-[D][I-\hat{m}][B]}{-(\langle w\rangle+\langle c\rangle)} & \dfrac{-[D][I-\hat{m}]\{c\}b}{1-(w_c+e_c)b} \end{bmatrix} \begin{bmatrix} \dfrac{g}{N} \end{bmatrix} = \begin{bmatrix} \dfrac{[D][I-\hat{m}]\{f\}}{W_F} \end{bmatrix} \tag{21}$$

7.2. The computable general equilibrium model

Another commonly used methodological approach is the Computable General Equilibrium (CGE) model. CGEs are a macroeconomic approach based on the neoclassical concept of market equilibrium. They have a stronger microeconomic foundation and are mostly used for examining the impact of a particular shock or change in policy on important markets such as job markets. The main advantage of these models is that they represent economy-wide interactions among the different economic agents, illustrating the long-term macroeconomic, sectoral distribution, environmental, and employment impacts associated with specific shocks and future policies.[135] Furthermore, and apart from the direct and indirect effects on employment, these models can capture most types of induced effects from an economy-wide perspective. CGE models have several disadvantages when evaluating the impacts on employment in the renewable energy industry.[136] While these models can provide the most complete picture of the entire economy, as they include the interaction of goods and services between consumers and renewable energy industrial sectors and encompass the direct, indirect, and induced effects on employment by renewable energy demand shifts, they can also be very complex and difficult to understand.[137] Furthermore, the collection of data to build CGE models can be highly data- and labor-intensive, thus leading to a significant time delay between data collection and modeling.

In the CGE model, expenditures are determined by economic agents, notably consumers deriving their demands from utility maximization subject to budget constraints that translate into expenditure functions determined by prices and income variables. Firms maximize profits or minimize costs of production, subject to a specific production function. This maximization (minimization) results in factor demand functions that are sensitive to output prices and factor costs derived from first-order maximization conditions. A simple structure of the facto demands is presented below.

$$Y_{it} = e^{A_{it}} \cdot L_{it}^{\alpha} \cdot K_{it}^{\beta} \cdot C_{it}^{c} \cdot e^{(\varepsilon_{it}+v_i)} \tag{22}$$

Where (*E*) in the equation determines the factor of error, (t) represents time, and (i) represents countries. The production function includes:

- (Y_{it}) measures either the GDP or its growth rate (referred to as y_{it});
- (A_{it}) represents the technological development level;
- (Kit) denotes the physical capital accumulation (or real fixed capital investments);

[135] Nasirov S., O'Ryan R., and Osorio H. Decarbonization Trade-offs: A Dynamic General Equilibrium Modeling Analysis for the Chilean Power Sector. Sustainability 2020; 12:8248.

[136] O'Ryan R., Nasirov S., and Alvarez-Espinosa A. Renewable Energy Expansion in the Chilean Power Market: A Dynamic General Equilibrium Modeling Approach to Determine CO2 Emission Baselines. J Clean Prod 2020; 247:119645.

[137] Wei M., Patadia S., and Kammen D. M. Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US? Energy Pol 2010; 38:919-31.

- (L_{it}) represents the human capital accumulation (number of employed persons); and
- (C_{it}) represents the climate regime, consisting of two subcomponents, namely the annual average temperature levels and the annual average precipitation values (Alagidede et al., 2016: 423).

Demand for resident labor:

$$LRD_{i,r} = \left(\frac{xs_{i,r}}{at_{i,r}}\right)^{(1-sigmak_{i,r})} \left(\frac{vc_{i,r}(1-ava_{ir})}{wre_r}\right)^{sigmak_{i,r}} \tag{23}$$

Demand for non-resident labor:

$$LND_{i,r} = \left(\frac{KND_{i,r}}{atk_{i,r}}\right)\left(\frac{atk_{i,r}\,(1-avak_{i,r})\,pkn_{i,r}}{WNR_r}\right)^{sigmakk_{i,r}} \tag{24}$$

Where the demand for capital-non-resident labor composite is defined as:

$$KND_{i,r} = \left(\frac{xs_{i,r}}{at_{i,r}}\right)^{(1-sigmak_{i,r})} \left(\frac{vc_{i,r}\,ava_{ir}}{pkn_{i,r}}\right)^{sigma} \tag{25}$$

All of the parameters of the model above are either factor shares or representatives of the elasticity of substitution.

7.3. Analytical assessment models

Analytical Assessment Models (AAMs) have been frequently used in the literature on employment. This analytic approach is considered relatively straightforward, more transparent from a methodological perspective, and computationally less complex compared to CGE, IO, or econometric models.

It evaluates the average number of jobs per unit of installed capacity or energy generated based on energy system data. Furthermore, its advantage is that the sensitivity analysis of the impact of specific policies or changing variables can be quickly modeled. Moreover, it can serve as a foundation for future research aimed at assessing the number of indirect and induced jobs created by the renewable energy sector using simulation and microdata.

Special tables borrowed from a number of applied systems are used in this approach to quantify the employment impacts by type of renewable energy. Both gross and net employment will be presented. Gross employment impacts assume that the renewable energy generated is incremental and does not substitute energy production from fossil fuels. On the other hand, net employment impacts subtract the positive employment impacts of an equivalent MW generated by fossil fuels from an equivalent MW generated from renewable sources.

All three methodological approaches have comparative advantages and disadvantages; however, they all have a particularly major weakness when evaluating the impacts on employment in the different renewable energy scenarios. This is mainly because they fail to capture important structural changes with the introduction of various emerging technologies into the energy mix.

7.4. The net and gross employment impacts of renewable energy

The United Nations Environment Program (UNEP) report on Green Jobs lists four expected impacts of green growth on employment:[138]

- Additional jobs will be created.
- Some employment will be substituted.
- Certain jobs may be eliminated without direct replacement.
- Many existing manual labor jobs like plumbers, electricians, metal workers, and construction workers will be transformed as skillsets, work methods, and profiles are greened.

In the literature, three types of job classifications are widely used depending on the level of proximity with a certain activity in the renewable energy sector.[139] These include direct, indirect, and induced jobs. Direct employment arises from activities directly related to electricity generation, involving jobs in design and manufacturing, construction and installation (C&I), or O&M of renewable energy plants. In the design and manufacturing category, job creation is stable and requires a high level of specialization; most of the time, the jobs generated by these activities are outside the region/country of plant installation. Given that the plants have relatively short construction and installation times, jobs generated by the C&I category are typically

[138] Green Jobs UNEP. Towards Decent Work in a Sustainable. 2008. Low-Carbon World, https://www.ilo.org/wcmsp5/groups/public/–ed emp/ emp ent/documents/publication/wcms 158727.pdf.

[139] Fragkos P. and Paroussos L. Employment Creation in EU Related to Renewables Expansion. Applied Energy 2018; 230:935-45 and Wei M., Patadia S., and Kammen D. M. Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US? Energy Pol 2010; 38:919-31.

temporary in nature. Finally, activities included in the O&M category require a medium level of specialization and generate a low volume of employment. However, the latter type of employment is more stable.

Indirect jobs arise due to the supply-chain effects of renewable energy-related activities such as equipment supply, manufacture, materials and delivery of equipment, exploration, extraction and processing of raw materials, marketing and selling, administration, or the work conducted by regulatory bodies, consultancy firms, and research organizations.[140] Finally, induced employment refers to the spending of income generated from direct and indirect employment on a variety of things in the broader economy. The impacts on employment have been estimated by various studies on renewable energy technologies. Although most of the research studied the direct and/or indirect effects on employment related to the deployment of renewable energy power technologies, focusing particularly on jobs created by C&I and O&M activities, only a few studies include labor intensities, which tend to decline in time, as experienced in technology installation and O&M increases. This is mostly due to problems in the units used to measure employment over a project's useful life. The present review highlights studies that are focused on the most commonly used methodological approaches. Moreover, Table 17 presents a list of study findings related to the impacts on employment by renewable energy deployment in a specific region or country.[141]

The Chile study has been selected as a reference to underpin the employment impacts of renewable energy that could be expected in the MENA region, This is on account of the fact that this study is particularly based on a macro-sectoral model applicable to a developing country. This is important as most models dealing with the employment generation capacities of renewable energy are primarily applications to a set of developed and advanced industrial countries. Of course, there are a few other models that focus on renewable energy employment impacts in developing countries such as the Indian model, Ven der Zewaan et al., and Jadin Kim and Adil Mohammad (IMF Working Papers, 2022).[142]

None of these studies, however, have delved into the off-stream employment impacts of EVs that are tied to the renewable energy framework. This is unfortunate as most of the new jobs will be in the manufacturing and operations of EVs.

Besides the issue of non-inclusion of EVs, there is another problem to contend with regarding the existing reference models in this area. Given that detailed analyses of energy technologies from both a technical and economic perspective cannot be included in these models, future scenarios related to renewable energy technologies cannot easily be modeled with the desired scope and detail. As a consequence, more generic and energy-restrictive models can generate doubts among policymakers regarding the utility of policy simulations of the effects of renewable energy on employment. To fill such a research gap, and with the purpose of overcoming technological limitations, the Chilean study proposed the use of a simple hybrid method that combines the technology-rich "bottom-up energy systems model" – the SWITCH-Chile model – and an Analytical Assessment Approach. In the literature, hybrid approaches that combine different models are increasingly being used, particularly linking a bottom-up engineering model and a CGE model in the context of several countries, though mostly developed ones.[143] However, until now, it seems that no hybrid method examining the effects on employment has been found. In this study, we opted to use a number of different models and tried to test the robustness of the estimates of employment generation that would emerge from them. For this purpose, a number of tables have been constructed to probe the sensitivity of the estimates to different assumptions, methodologies, and data sources.

The data in Table 18 presents actual surveys of several energy-producing plants in Chile. Three different types of energy-producing plants are displayed – natural gas, biomass, and hydro – and the employment at these plants is shown for both the operation phase and the construction phase and differentiated by the installed capacity. The former is sustainable over the lifetime of the plant and the latter is temporary and lasts only over the construction period.

[140] Ibid.

[141] Bulavskaya T. and Reynes F. Job Creation and Economic Impact of Renewable Energy in the Netherlands. Renew Energy 2018; 119:528-38 and Van der Zwaan BCC, Cameron L. Kober, T. Potential for Renewable Energy Jobs in the Middle East. Energy Pol 2013; 60:296-304.

[142] Kattumuri R. and Kruse T. Renewable Technologies in Karnataka, India: Jobs Potential and Co-benefits. Clim Dev 2017; 14:1756-5529 and Van der Zwaan B. C. C., Cameron L., and Kober, T. Potential for Renewable Energy Jobs in the Middle East. Energy Pol 2013; 60:296-304.

[143] Hasegawa T., Fujimori S., Masui T., and Matsuoka Y. Introducing Detailed Land Based Mitigation Measures into a Computable General Equilibrium Model. J Clean Prod 2016; 114:233-42 and Murphy R., Rivers N., and Jaccard M. Hybrid Modeling of Industrial Energy Consumption and Greenhouse Gas Emissions with an Application to Canada. Energy Econ 2007; 2007(29):826-46.

Table 17. Impacts on employment from renewable energy development

Authors	Country /Region	Type of Employment	Methodology	Renewables' impact on employment
Fragkos and Paroussos [8] Bulavskaya and Reynes [10] Dvorak et al. [11]	EU The Netherlands Czech Republic	Direct Direct Multi-sector Direct and indirect	CGE modelling Macroeconomic Model Analytical method	200,000 direct jobs in EU energy sectors by 2050 50,000 new jobs by 2030 Over 20,000 jobs created in 2010
Haerer and Pratson [12]	USA	Direct and indirect	1/0 models	21% increase in employment (175,000 jobs) in natural gas, solar and wind industries 5.7 million jobs created between 2011 and
Cai et al. [13]	China	Direct and indirect	1/0 models	2020 from renewable and new energy development
Garrett-Peltier [21]	USA	Direct and indirect	1/0 models	A net increase of 5 jobs per $1 million shifted from fossil fuels to renewable energy 0.1 to 4 job-years/ GWh direct jobs created by
Barros et al. [14] Henriques et al. [15] Liera et al. [16]	Global Portugal Spain	Direct Direct, indirect Direct	Analytical model 1/0 models Analytical model	renewable power plants 26,000 potential jobs by 2020 19,865 jobs created by solar technologies 26,000 potential jobs in wind energy 14,000 potential jobs in biomass energy 833,000
Kattumuri and Kruse [17]	Karnataka,India	Direct	Analytical model	potential jobs in solar energy
Lavidas [18]	Greece	Direct	Analytical model	1,410 potential direct jobs in wave energy 155,000 direct and 115,000 indirect jobs
Van der Zwaan [19]	The Middle East	Direct and indirect	TIAM-ECN model	created
Lehr et al. [22]	Germany	Direct and indirect	1/0 models	Net employment from RE expansion will reach around 150,000 by 2030. Gross employment will increase to 500,000e600,000 by 2030.

Source: S.Nasirov, A. Girard, C. Pena et Al.. Expansion of renewable energy in Chile: Analysis of the effects on employment. Energy, Vol. 226, 2021

To convert "jobs-year/MW" into "jobs/MW," the jobs employed in construction were multiplied by the ratio of total construction time to the project's useful life, as shown below.[144]

Jobs in construction normalized = Labor in construction * (Time under construction / 12) * Lifetime.

The jobs per MW data in Table 18 were further refined and expanded to include a host of other energy-producing plans by including the lower limit, the upper limit, the arithmetic mean, and the geometric mean. These distinctions increased the utility and applicability of the data.

The data in Tables 18 and 19 are for Chile. Another useful source of data on jobs per MW of renewable energy is presented in Table 20, but this time it is for the Middle East. The data in Table 20 distinguish between jobs per MW associated with O&M, installation, and manufacturing. These are, in turn, differentiated by minimum, median, and maximum.

Equally relevant and useful is the IMF data on employment elasticities by type of renewable energy (Figure 23). These elasticities were estimated to include both direct and indirect jobs using IO methodology for most components of energy except for energy efficiency programs, where induced impacts were also estimated and added to the elasticity coefficients.

Solar PV is shown to generate the largest employment impact of 1.5 job-years per GWh. This is about three times larger than the employment impacts of small hydro and 3.75 times the employment per GWh of biomass. Compared to fossil fuels, solar PV generates more than seven times more jobs per MW than either coal or natural gas (Figure 22). This differential in the capacity of job creation per GWh is striking, and it is also higher than other estimates that put this multiple at three times. Energy efficiency is also seen to sustain large employment creation capacity put at 0.4 job-years per GWh (Figure 22).

These elasticities are used in the next section to estimate the expected employment impacts of the transition to renewable energy in the six targeted countries and in the MENA region.

None of these studies cited above ventured into estimating the employment impacts of manufacturing EVs. They stopped at estimating the manufacture of solar plates, wind turbines, and solar heaters.

Another accounting framework detailing the number and type of jobs that are engaged in delivering 50 MW of

[144] Lambert R. J. and Silva P. P. The Challenges of Determining the Employment Effects of Renewable Energy. Renew Sustain Energy Rev 2012; 16(7):4667-74.

Table 18. Survey results from interviews with energy developers and generators in Chile

Plant	Technology	Installed Capacity [MW]	Useful life [years]	Construction time [months]	Construction labor	Operation labor	Normalized jobs/MW
1	Biomass	24	25	12	200	55	2.63
2	Natural gas	253.9	25	16	250	24	0.15
3	Natural gas	874.4	40	32	700	70	0.13
4	Hydro Res	172	40	36	600	19	0.37
5	Hydro Res	474	so	48	1200	81	0.37
6	Hydro Res	323.8	50	48	1000	43	0.38
7	RoR Hydro	25.7	40	22	200	11	0.78

Source: S.Nasirov, A. Girard, C. Pena et Al.. Expansion of renewable energy in Chile: Analysis of the effects on employment. Energy, Vol. 226, 2021

Table 19. Confidence interval factors

Technology	Lower limit [jobs/MW]	Upper limit [jobs/MW]	Arithmetic Mean [jobs/MW]	Geometric Mean [jobs/MW]
Biomass	1.50	3.26	2.38	2.21
Coal	0.24	0.46	0.35	0.33
Geothermal	0.49	0.69	0.59	0.58
Hydroelectric Reservoir	0.35	0.66	0.51	0.48
Run-of-the-River Hydroelectric	0.77	1.30	1.04	1.00
Natural Gas	0.11	0.19	0.15	0.14
Oil	1.37	1.39	1.38	1.38
Solar PV	0.38	0.48	0.43	0.43
Wind	0.19	0.20	0.20	0.19

Source: First two columns from S.Nasirov, A. Girard, C. Pena et Al.. Expansion of renewable energy in Chile: Analysis of the effects on employment. Last two columns are from our calculations

Table 20. Minimum, median and maximum direct employment factors for the main phases of deployment for wind, PV CSP

Option	M&I (personyears/MW)	M (personyears/MW)	I (personyears/MW)	O&M (jobs/MW)
Wind				
Minimum	2.6	2.1	0.5	0.1
Median	8.1	6.6	1.5	0.2
Maximum	15	12.2	2.8	0.6
PV				
Minimum	7.1	3.2	3.9	0.1
Median	28	12.6	15.4	0.3
Maximum	43	19.4	23.6	0.7
CSP				
Minimum	4.6	2.3	2.3	0.2
Median	10.2	5.1	5.1	0.5
Maximum	36	18	18	1

Source: Bob van der Zwaan, Lachian Cameron, Tom Kober. Potential for renewable energy jobs in the Middle East. Energy Policy 60, 2013, Pp 269-304
Note: M stands for Manufacturing and I stands for Installation. PV stands for photovoltaic and CSP stands for concentrated solar power.

solar PV generation is presented in Figure 23 following the value chain connecting all the different sectors and activities involved in this generation of power. A total of 229,055 person-days are needed, distributed as follows:

• Project Planning	1%
• Procurement and Manufacturing	22%
• Transportation	2%
• Installation and Grid Connection	17%
• O&M	56%
• Decommissioning	2%

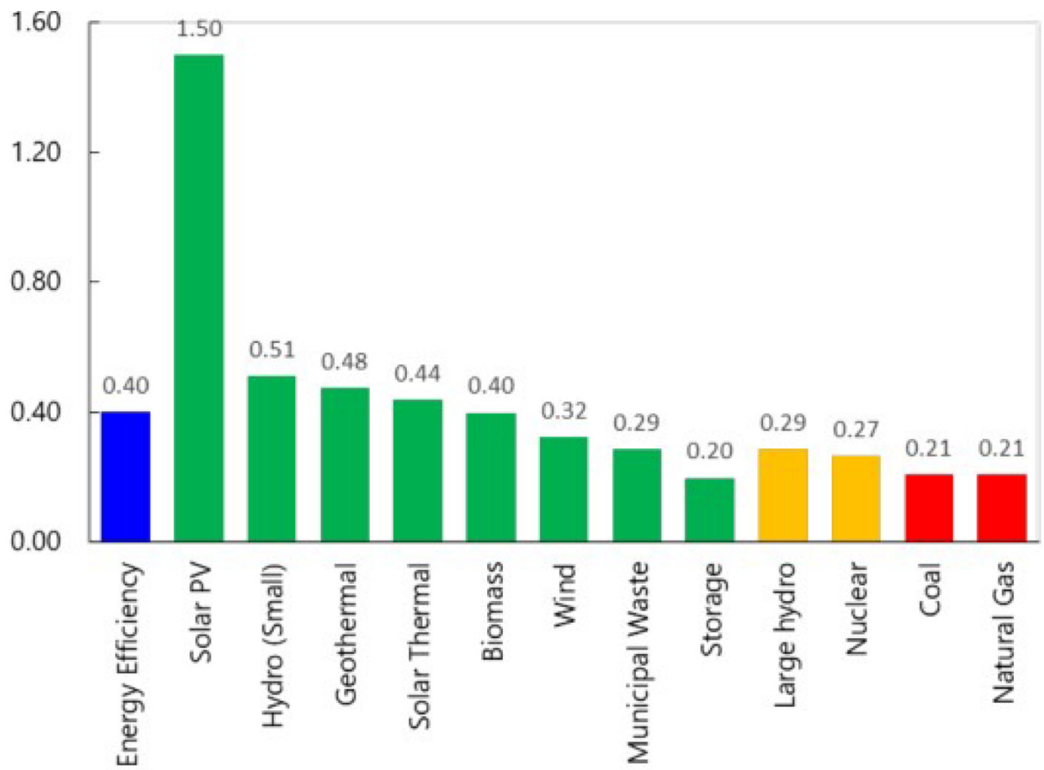
What is more interesting is the display of the type of skills and functions required. These are identified by type of function. What is impressive is the number of engineers, construction workers, administrative personnel, factory workers, technical personnel, logistics experts, financial analysts, taxation experts, energy regulation experts, shipping agents, lawyers…etc. These diverse jobs and skills required augur well for employment opportunities for the educated, women, and youth.

Fifty MW of wind energy require a different set of skills and create less employment, but still require high-quality jobs with respectable pay levels. A total of 144,420 person-days will be needed to deliver 50 MW of energy (Figure 24). Again, a large contingent of engineers and technical personnel will be needed, along with many construction workers and operators. This large number of jobs in different occupations is a strong indication for expecting that the job creation potential of renewable energy is credible and rich. By way of flagging out the main differences between solar energy and wind energy, it is interesting to note that wind energy requires less labor per MW than solar, but a larger share of engineers and construction workers (Figures 23 and 24).

8. Actual and projected employment impacts of energy production by type of fuel in the six selected countries and the MENA region

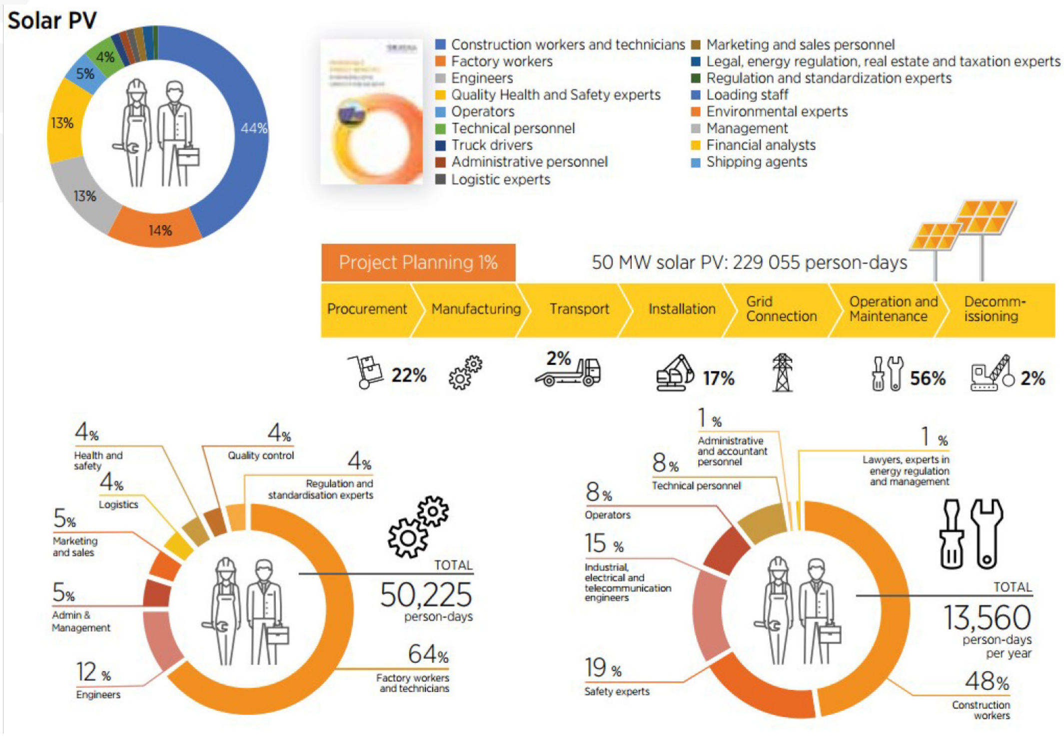
Although there are a few references that can be used to estimate the potential future employment generation capacity of renewable energy, only the elasticity coefficients generated by the IMF and reported in Figure 22 are used here. Of course, the other coefficients in the various tables in the previous section are useful and can be used for this purpose if only for comparison purposes. The choice of the IMF employment elasticity coefficients is based on five

Figure 22. Employment elasticities (direct + indirect) of renewal energy (job-years per GWh)



Source: Jaden Kim and Adil Mohammad (May 2022). Job Impacts of Green Energy. IMF Working Papers WP/22/101.
Note: The Energy Efficiency employment elasticity includes induced effects.

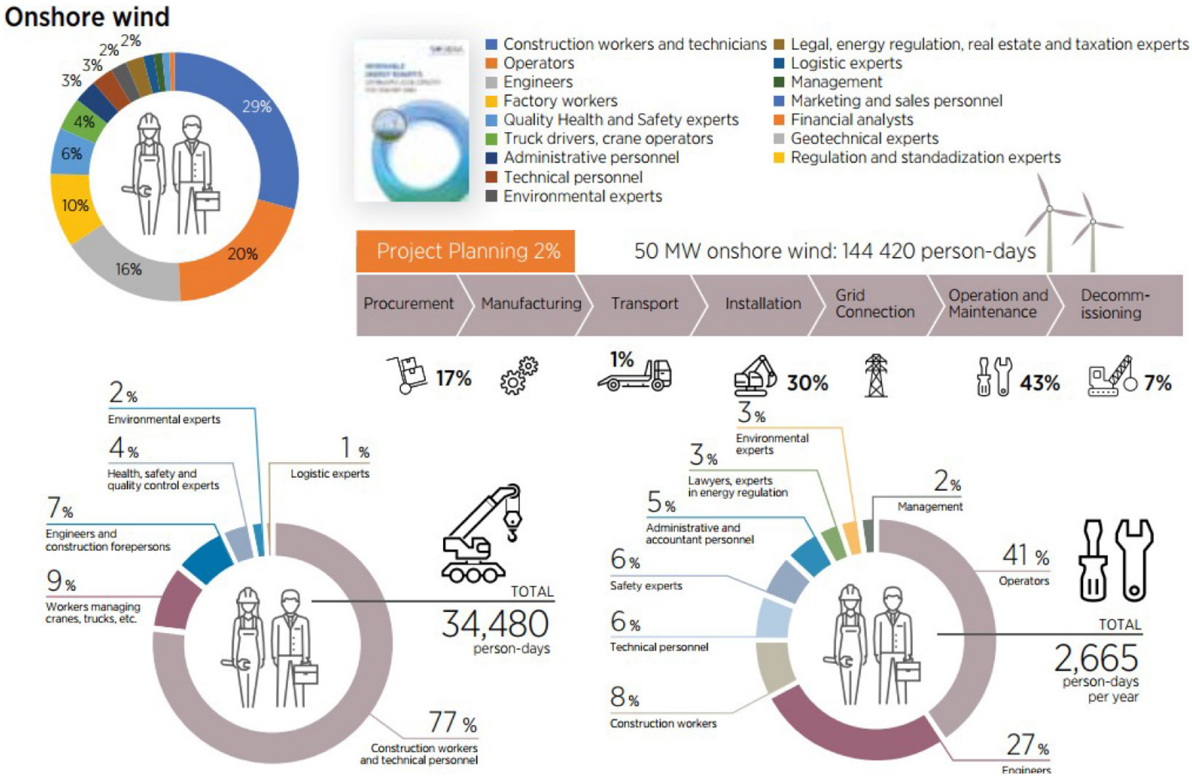
Figure 23. Employment by type of skill and activity in solar energy PV 50 MW production



Source: IRENA (2019).

advantages that these elasticity coefficients have over the other parameter estimates discussed in the previous section. First, the elasticity coefficients are presented for all types of energy inputs, a fact that allows the estimation of gross and net employment impacts. For example, the use of the employment elasticity of 1.5 associated with solar PV per GWh generates the gross employment impacts of solar PV. Given that the employment elasticity coefficient per GWh of natural gas is 0.21, this means that it is possible to estimate the net employment elasticity coefficient of

Figure 24. Employment by type of skill and activity in onshore wind 50 MW production



Source: IRENA (2019).

solar PV. This is equal to 1.29, which is calculated by subtracting the employment elasticity of natural gas from that of solar PV. Thus, 1.5-0.21 is the estimate of the net employment elasticity of solar PV when it is assumed that solar PV will displace natural gas in electricity generation. Second, the elasticity coefficients include the indirect and, at times, even the induced effects, while other similar estimates often include only the direct effects. Third, the elasticity coefficients take into account a large set of countries at different stages of development that have made different strides into renewable energy, whereas the other contending estimates are only for a particular region at a particular time and may therefore be inappropriate to represent the expected future employment-generating potential of renewable energy for MENA. Fourth, the IMF elasticity coefficients include the employment generation capacity on realized energy efficiency which most other studies have excluded. Fifth, the employment-generating potential of the elasticity coefficients takes into account most of the value chains involved in generating electricity, such as construction, installation, manufacturing, and O&M.

In what follows, a set of six tables are presented that benchmark the existing employment generated by electricity generation in each of the six target countries. These estimates are used to present and anchor the renewable energy employment projections in 2030 and 2050 using the NDCs of the respective countries of their plans to expand the production and use of renewable energy in their future targets for generating electricity.
The actual employment associated with renewable energy in the six target countries uses the data presented in Tables 19 and 21. The installed electricity generation capacity is the driving factor; it is used in conjunction with the data in Table 19 to estimate the actual employment in 2021 for most countries and for 2022 for Egypt and Tunisia. The actual calculation of the employment numbers involves multiplying the installed capacity from Table 20 for a particular energy type by 1,000 to convert from MW to GW, then multiplying by the confidence factor from Table 19. For example, the employment for electricity produced using biomass in Egypt is calculated by multiplying 0.12 by 2.38 and then multiplying by 1,000 to convert from 2.38 jobs per MW to 2,380 jobs per GW, resulting in the jobs number of 286 in Table 22.

The average target of renewable energy share in 2030 is 30 percent, which has been set in all six countries. Energy efficiency targets are set at 15 percent in all six countries except for Morocco, which set that target at 30 percent. The 2050 targets are estimated as the shares that guarantee net zero emissions, which are set between 50 and 60 percent share of renewable energy in total energy use.

A total of 1.2 million jobs can be generated in the six countries by simply increasing the share of renewable energy to 30 percent. These employment figures in Table 28 are gross employment estimates with 611,423 person-years in 2030 and 1.222,845 in 2050. Net total employment that takes into account that renewable energy will displace an equal share of that electricity generated by natural gas, which will be about 525,824 person-years in 2030 and 1,051,647 person-years in 2050. This needn't be the case as renewable energy can be thought of fully incrementally and, in that case, the entire 1.22 million person-years could be the expected employment sustained by renewable energy in the six countries.

The employment generation capacity of energy efficiency is not large but will still contribute a total of 89,377 in 2030 and almost twice this level in 2050 when the share of energy efficiency is 30 of the total energy generated (Table 28 and Figure 25).

When the entire MENA region is the focus of estimating the total employment that could be generated and sustained by a 30 percent share for renewables in total energy supply in 2030, a large total emerges of about 2,539,384 person-years in 2030 and over 5,076,728 person-years in 2050 (Table 29).[145] These figures are the total employment generation capacity of both generation of electricity, including all the value chains involved and from realized efficiencies. In 2030, the relative contributions of renewable energy generation exceeded 2,240,633 person-years and that of efficiency is put at 298,751 person-years.

The total installed electricity generating capacity in the MENA region in 2020 was estimated at about 420 GW. This is expected to increase by 40 percent by 2030, reaching 589 GW (Figure 29). The projected employment generation capacity in 2030 is based on a 30 percent renewable energy share in electricity generation for the region as a whole and the use of the IMF elasticity coefficients displayed in Figure 22.

These employment projections indicate a massive increase in employment generation capacity in the region, particularly against the backdrop of high unemployment rates characterizing the region. However, these estimates pale in comparison with the expected employment generation capacity once we include the great opportunities renewable energy has engendered in the region as it opened the gates for rooting a viable and highly productive EV industry in the region. Morocco is already producing a million EVs, Saudi Arabia has partnered with Lucent Industries and is targeting a similar volume, the UAE has

[145] This is the sum of the direct, indirect, and induced employment values in 2050 for renewable energy.

Table 21. Installed capacity for electricity generation by fuel type (GW)

Fuel	Egypt	Lebanon	Morocco	Sudan	Tunisia	Jordan	Total
Bioenergy	0.12	0.01	0.01	0.2	-	0.01	0.35
Coal	-	-	4.26	-	-	-	4.26
Gas	53.47	1.6	0.87	0.37	5.78	3.45	65.54
Hydro	2.83	0.28	1.31	1.48	0.07	0.01	5.98
Nuclear	-	-	-	-	-	-	0
Other Fossil	1.33	3.03	0.78	1.93		0.38	7.45
Other Renewables	-	-	-	-	-	-	0
Solar	1.72	0.19	0.85	0.14	0.2	1.52	4.62
Wind	1.64	-	1.47	-	0.25	0.62	3.98
Total	61.11	5.11	9.55	4.12	6.3	5.99	92.18

Source: https://ember-climate.org/data-catalogue/yearly-electricity-data/
Note: Data for Egypt and Tunisia are for 2022, the rest are for 2021

Table 22. Employment in the electricity -producing sector, Egypt, 2022

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Bioenergy	286	265	278	-	265	196	311	772
Gas	8,021	7,730	7,486	-	7,730	8,834	8,834	25,398
Hydro	1,429	1,360	1,302	-	1,360	1,005	1,597	3,962
Other Fossil	1,835	1,835	1,835	-	1,835	2,097	2,097	6,029
Solar	740	735	740	516	735	543	863	2,141
Wind	320	320	394	328	320	237	376	933
Total	12,631	12,245	12,035	844	12,245	12,912	14,078	39,235

Table 23. Employment in the electricity -producing sector, Jordan, 2021

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Bioenergy	24	22	23	-	22	16	26	64
Gas	518	499	483	-	499	570	570	1,639
Hydro	5	5	5	-	5	4	6	15
Oil	524	524	524	-	524	599	599	1,722
Solar	654	649	654	456	649	480	762	1,891
Wind	121	121	149	124	121	89	142	352
Total	1,846	1,820	1,838	580	1,820	1,758	2,105	5,683

Table 24. Employment in the electricity -producing sector, Lebanon, 2021

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Bioenergy	24	22	23	-	22	16	26	64
Gas	240	231	224	-	231	264	264	759
Hydro	141	135	129	-	135	100	158	393
Other Fossil	4,181	4,181	4,181	-	4,181	4,778	4,778	13,737
Solar	82	81	82	57	81	60	95	236
Total	4,668	4,650	4,639	57	4,650	5,218	5,321	15,189

Table 25. Employment in the electricity -producing sector, Morocco, 2021

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Bioenergy	24	22	23	-	22	16	26	64
Coal	1,491	1,415	1,406	-	1,415	4,447	3,234	9,096
Gas	131	126	122	-	126	144	144	414
Hydro	662	630	603	-	630	466	740	1,836
Other Fossil	1,076	1,076	1,076	-	1,076	1,230	1,230	3,536
Solar	366	363	366	255	363	268	426	1,057
Wind	287	287	353	294	287	212	337	836
Total	4,037	3,919	3,949	549	3,919	6,783	6,137	16,839

Table 26. Employment in the electricity -producing sector, Sudan, 2021

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Bioenergy	476	442	464	-	442	327	519	1,288
Gas	56	53	52	-	53	61	61	175
Hydro	747	711	681	-	711	526	835	2,072
Other Fossil	2,663	2,663	2,663	-	2,663	3,043	3,043	8,749
Solar	60	60	60	42	60	44	70	174
Total	4,002	3,929	3,920	42	3,929	4,001	4,528	12,458

Table 27. Employment in the electricity -producing sector, Tunisia, 2022

Fuel Type	Mean	Geometric Mean	Average	O&M	Direct Jobs	Indirect Jobs	Induced Jobs	Grand Total
Gas	867	836	809		836	955	955	2,746
Hydro	35	34	32		34	25	40	99
Solar	86	85	86	60	85	63	100	248
Wind	49	49	60	50	49	36	58	143
Total	1,037	1,004	987	110	1,004	987	110	1,004

Table 28. Expected employment in renewable energy person-years

	2030			2050
	Direct and Indirect	Energy Efficiency	Total	Net Zero
Egypt	360,020	72,480	432,500	865,000
Jordan	36,956	2,086	39,042	78,084
Lebanon*	25,000	5,910	30,910	61,821
Morocco	69,277	5,460	74,737	149,475
Sudan	12,083	1,971	14,054	28,107
Tunisia	18,710	1,469	20,179	40,358
Total	522,046	89,377	611,423	1,222,845

Source: Authors' calculations
*Note: *: Estimated independently by IRENA*

Figure 25. Employment impact of renewable energy and efficiency, 2030

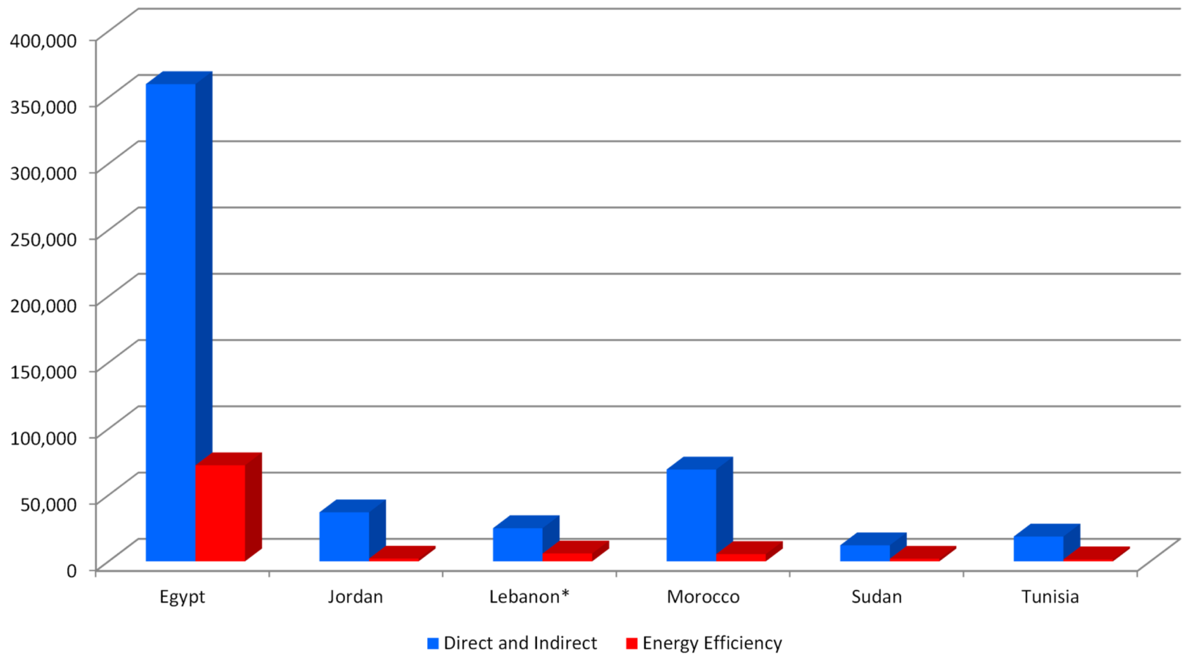
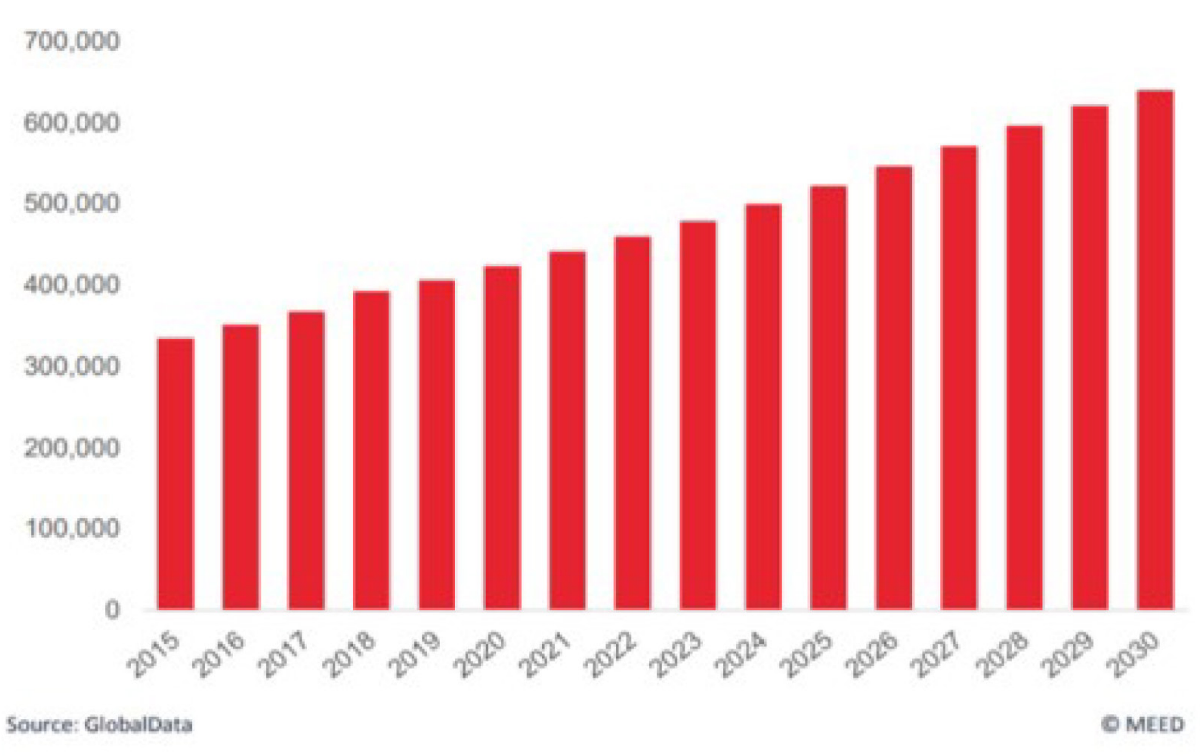


Figure 26. Projected installed generating capacity needs in the MENA region (GW)



teamed with a Chinese firm that is currently producing 55,000 vehicles that could be ramped up to multiples of this volume, and Egypt is on the course to produce a large number of EVS for home use and exports. It is not possible to believe that these opportunities could have existed without renewable energy and the region's determination to fulfill NDC commitments.

9. The economic potential and impacts of EVs

The development of Plug-in Hybrid Electric Vehicles (PHEV) and Battery Electric Vehicles (BEV) in the MENA region is expected to generate many economic, environmental, and technological gains. These gains could be realized in the production, operation, research, innovations, avoided costs, and development of the infrastructure needed to support EVs. These gains alone are sufficient reasons to expect that EVs will gain a large market share in the region's automotive sector and in the export of vehicles. One of the major gains relates to the potential automotive manufacturing activities that in the past were not economic in the region being the preserve of major industrial centers in the west and in Asia. Their liberation from specific geographic areas provides a major potential for the region to become a significant producer of EVs and their parts. While EVs promise to realize large energy savings and other operational efficiencies, the manufacturing gains that the region can capture from producing them constitute a major advantage to be realized by the region saving on imports and creating significant jobs – even new exports and a new industrial comparative advantage. The production and use of electric cars are also likely to cause a few disruptions and readjustments in the economy and labor market. The expected savings and disruptions include the following:

- Large energy savings, particularly those of expensive and non-renewable refined fossil fuels, some of which are imported.
- Reductions in CO2 emissions and the prospect of placing the region and its countries as frontrunners in the struggle to eliminate CO2 emissions.
- Developing a new and dynamically growing industry with a capacity to generate sizeable employment opportunities at the upper end of the wage scale.
- Developing a new infrastructure of charging stations and green electricity generation capacity.
- The phasing out of an old industry and the development of a new industry with significant changes in the labor skill requirements and their development.
- Significant losses of fuel taxes and some major substitutions and changes in the product and factor markets, but also significant savings on expensive fuel subsidies.

The major expected gains in income and employment are likely to be realized primarily in the manufacturing sector, if/when EVs are produced domestically. Substantial economic gains can also be realized on the re-spending of energy savings and other avoided costs of insurance and repairs, on infrastructure development, and in many related other sectors. MENA economies are notoriously undiversified with limited manufacturing activity, particularly in the transport equipment manufacturing side. Imports of expensive vehicles and parts are a major drain on most MENA countries' trade balances. Estimating the net benefits of EVs necessitates, however, the use of complex models that can capture the intricate interconnectedness of the economy. The advantage of the IO models lies in their ability to handle a simultaneous system of relationships where no sector or activity is treated in isolation from the rest of the economy. This is a crucial advantage over analyses that typically view sectors in isolation from the remainder of the economy, and the analysis is performed without due consideration of broader impacts. The employment structure and level of other macroeconomic indicators cannot be taken as given, as though they are not affected by other sectors. This is not satisfactory, for there is a considerable two-way interdependence with the remainder of the economy. This is also typical of the impacts of new structural breaks that new products and the introduction of new technologies generally create. There is a specific need to focus on both the positive and negative impacts of new activities and to take account of substitution effects as well as income effects, as old structures are replaced by new ones, different inputs are required, and new technologies are used.

The direct savings of energy or the substitution of the more available or cheaper types of energy for the less available or more expensive types are identified as additional benefits of the conversion activities, from Internal Combustion Engines (ICE) to EVs, typically referred to as the net avoided costs. The total impacts of manufacturing, using EVs, and developing the supporting infrastructure add up to a large contribution that exceeds by far those realized on producing, operating, and maintaining renewable energy. Adding the two dimensions together promises to add up to a very substantial and substantive development.

Unfortunately, EV activities are limited in the MENA region at this time, which does not allow us to use existing data to estimate these impacts. We are fortunate, however, that one of the principal authors was involved in estimating these impacts for all the provinces of Canada using a dynamic regional input/output framework.[146] Of course, it is not without some difficulty that we use Canadian data and models to estimate these impacts (manufacturing of EVs, avoided costs re-spending, and infrastructural development) in the MENA region. On the other hand, Canada represents a microcosm of the world and of the region with oil-producing and oil-exporting provinces (Alberta and Saskatchewan) and oil-importing ones (Ontario, Quebec, Manitoba, and the Prairie provinces). Besides, Canada already has a presence in the manufacturing of EVs. Perhaps the strongest reason is the familiarity of the authors of this report with all the intricacies and complexities of the comparisons.

There are a few options that the region can turn to in order to capitalize on its competitive advantages. At this time, EVs, driverless cars, and connected cars are presenting themselves as serious contenders. While it is difficult to draw sharp demarcation lines among these options, there are special niches and clusters that can be leveraged to establish the MENA region's fledgling auto industry on firmer and more competitive grounds. These options are not mutually exclusive but will be discussed as if they were.

9.1. Gross and net impacts of EVs

EVs generate savings on account of the lower cost of renewable electricity compared to gasoline, and they are environmentally and renewable resource friendly. These savings can be treated as two separate activities. First, a negative (decline) expenditure arising from reducing the use of more expensive gasoline is counted. Second, a positive expenditure of equivalent magnitude is assumed to represent the savings realized on the consumption of less expensive electricity. The latter triggers increases in the consumption of other goods and services. However, the savings in gasoline costs (avoided costs) would not arise without sustaining programs and expenditures on equipment, products, and infrastructure. The net impacts are typically the net addition of the positive impulses and the negative impulses. More specifically in the case of PEVs, the net impacts are the sum of the positive impacts of producing EVs, the supporting infrastructure (capital and operational expenditures), and the avoided cost and the negative impacts that would arise from the decline in the production or the importing of conventional cars, phasing out of the conventional car supporting infrastructure and the decline in the consumption in gasoline.

It is quite natural to expect to end up with positive overall net employment impacts of PHEVs in the MENA region. The statistical records from other countries like the Scandinavian countries and Canada point out some very positive income and employment impacts. These tend to be concentrated in higher value-added industries and higher levels of employment and wages. It is even equally possible that there will be positive net gains in all taxes collected and in the revenues of all levels of government.

Three distinct employment impacts are typically associated with EVs. First and foremost are the manufacturing impacts. These are very large and can be a game changer for the undiversified economies of the region, but they depend, to a great extent, on two critical conditions: the number of vehicles produced and the local sources of inputs for the parts and the batteries. Equally important are the infrastructural developments that will be needed to support the use of EVs and finally the re-spending of all the gains from the avoided costs and savings on operations, repairs, and insurance.

As for the number of cars that could be sold and produced, almost two million commercial and passenger vehicles were sold in the MENA region in 2019.[147] Most of these vehicles were imported from Europe, Korea, China, and Japan. The market is large and the opportunities of replacing ICE vehicles with EVs are enormous. One of the major factors that make EVs easy to produce in the region is the fact that ICE vehicles typically have 2,000 engine parts, whereas EVs have less than 20 parts.[148] The complexity of ICE was a major obstacle.

If only 20 percent of the cars sold in 2030 are locally produced EVs, then it follows that a significant employment impact can be expected that should be added up to the employment impacts of the assumed 30 percent of electricity generation from renewable sources. However, these two employment impacts will also be augmented by two additional impacts that can be realistically expected. Adding up the employment impacts of developing and constructing the supporting infrastructure of charging stations and the employment impacts associated with re-spending the savings on operating and maintaining EVs, a large but credible employment of impact of 3,861,998 person-years can be expected. If the share of EVs rises to 50 percent, which is not an unreasonable share, the total employment impact in 2030 could reach 5,845,920 person-years (Tables 28 and 29).

[146] Atif Kubursi (November 2018). Economic Implications of EV Incentives in Canada and Provinces. McMaster Institute of Transportation and Logistics (MITL).

[147] https://www.statista.com/topics/2572/automotive-industry-in-the-mena-region/#:~:text=Automotive%20industry%20in%20MENA,dominated%20by%20Turkey%20and%20Iran.

[148] https://driveelectric.org.nz

These large employment levels could almost be doubled in 2050, where a total employment of 10,369,226 person-years could be realized if the market shares of locally produced EVs reach 80 percent and a total of 11,691,840 person-years if this share reaches 100 percent (Table 30). These employment estimates are the expected gross employment potential of EV manufacturing. Deducting the employment that could have been generated by ICE vehicles, we arrive at the net impacts. Given that the MENA region manufactured only a small share of its ICE cars, it stands to reason that most of the employment-generating potential of EV manufacturing could be considered a net employment-generating potential. The data from Canada suggests that the net employment impact of PHEV replacing an ICE vehicle is only about 44 percent (alternatively, this suggests that employment potential needs to be discounted by 56 percent).[149]

The estimates of the gross employment-generating potential of electricity above would have to be discounted by 16 percent (0.21/1.5, Figure 22) if solar energy replaces natural gas in electricity generation and by 66 percent (0.21/0.32, Figure 22). If the new energy is considered incremental (additional and not a substitution), then no discounts apply, and gross employment generation potential is equal to net employment generation potential. The potential employment creation is enormous, but for this to happen, a few conditions and programs must be put in place. A few countries have introduced incentive schemes that provide grants to first purchasers of EVs, while others have gone as far as to legislate zero production of ICE vehicles by 2030. Additionally, many have embarked on building free charging stations in public spaces and made mandatory the provision of these stations and free parking for EVs at government buildings and high-rise apartments.

The surest way for the MENA region to compete is by slashing prices to a level that allows newcomers to the global market to sell their cars. The experience of Lucid cars in the US is instructive in this regard. Saudi Arabia is a major investor in Lucid Motors of Texas, US, and is counting on this company to produce 150,000 EVs in Jeddah by 2026. In the final analysis, the most important current cost component of an EV is the battery. The latter constitutes 40 percent of the total cost of the car. Morocco has teamed up with Chinese company Goshen Hi-Tech to build one of the largest battery-producing factories in the world in Morocco. The main reason is the proximity of Morocco to Europe and its privileged position in the African market, but, more importantly, the large deposits of phosphates (70 percent of the world's deposits) and its large deposits of cobalt. The latter two are becoming potential ingredients in the manufacture of storage batteries.

Table 29. Employment generation capacity in the MENA region renewable energy production, manufacturing of EVs, infrastructure and avoided costs, 2030 and 2050

	2030	2050
Renewable Energy Production		
Direct and indirect	2,240,633	4,481,266
Direct, Indirect and Induced Energy Efficiency	298,751	597,502
Direct, Indireat and induced EV Manufacturing		
20% Market Share Scneario	279,285	-
50% Market Share Scneario	698,213	-
80% Market Share Scneario	-	1,117,141
100% Market Share Scneario	-	1,396,427
Direct, Indirect and Induced Infrastructure		
20% Market Share Scneario	732,547	-
50% Market Share Scneario	1,831,369	-
80% Market Share Scneario	-	2,930,190
100% Market Share Scneario	-	3,662,737
Direct, Indirect and Induced Avoided Cost		
20% Market Share Scneario	310,782	-
50% Market Share Scneario	776,954	-
80% Market Share Scneario	-	1,243,127
100% Market Share Scneario	-	1,553,908
Total		
20% Market Share Scneario	3,861,998	-
50% Market Share Scneario	5,845,920	-
80% Market Share Scneario	-	10,369,226
100% Market Share Scneario	-	11,691,840

Source: Based on Atif Kubursi. (November, 2018). Economic Implications of EV incentives. McMaster Institute for Transportation Logistics

10. Green hydrogen: a renewable clean energy revolution

In the quest for a sustainable and low-carbon energy future, green hydrogen has emerged as a transformative solution. Green hydrogen, produced through the electrolysis of water using renewable energy sources, offers a promising pathway to decarbonize sectors like industry, transportation, and energy production. This section explores the concept of green hydrogen, its production methods, advantages, challenges, and potential role in the transition toward a cleaner and more sustainable energy landscape.

[149] Atif Kubursi (2018). Ibid.

Table 30. Expected employment in renewable energy in the MENA region person-years

2030	
Direct and Indirect from RE Generation (30% Renewable Share)	2,240,633
Energy Efficiency (15%)	298,751
Direct, Indireat and Induced EV Manufacturing (20% Market Share)	279,285
Direct, Indirect and Induced Infrastructure (20% Market Share)	732,547
Direct, Indirect and Induced Avoided Cost (20% Market Share)	310,782
Total	3,861,998
2030	
Direct and Indirect from RE Generation (30% Renewable)	2,240,633
Energy Efficiency (15%)	298,751
Direct, Indireat and induced EV Manufacturing (50% Market Share)	698,213
Direct, Indirect and Induced Infrastructure (50% Market Share)	1,831,369
Direct, Indirect and Induced Avoided Cost (50% Market Share)	776,954
Total	5,845,920
2050	
Direct and Indirect from RE Generation (30% Renewable Share)	4,481,266
Energy Efficiency (30%)	597,502
Direct, Indireat and Induced EV Manufacturing (80% Market Share)	1,117,141
Direct, Indirect and Induced Infrastructure (80% Market Share)	2,930,190
Direct, Indirect and Induced Avoided Cost (80% Market Share)	1,243,127
Total	10,369,226
2050	
Direct and Indirect from RE Generation (30% Renewable)	4,481,266
Energy Efficiency (30%)	597,502
Direct, Indireat and induced EV Manufacturing (100% Market Share)	1,396,427
Direct, Indirect and Induced Infrastructure (100% Market Share)	3,662,737
Direct, Indirect and Induced Avoided Cost (100% Market Share)	1,553,908
Total	11,691,840

Source: Authors' estimates

10.1. What is green hydrogen?

Green hydrogen is hydrogen gas (H2) produced using renewable energy sources, such as wind or solar power, in a process called electrolysis. During this process, water (H2O) is split into hydrogen and oxygen using electricity. The resulting hydrogen can be stored, transported, and used as a versatile energy carrier in various applications.

10.1.1. Production methods

Electrolysis is the primary method for producing green hydrogen. It involves two electrodes submerged in water. When an electric current is applied, it causes the water molecules to dissociate, releasing hydrogen at the cathode and oxygen at the anode. This process is emission-free when powered by renewable energy sources. To ensure the "green" aspect of green hydrogen, the electricity used in electrolysis must come from renewable sources like wind, solar, or hydropower. These sources generate electricity without emitting GHGs, making the hydrogen production process environmentally friendly.

10.1.2. Advantages of green hydrogen

Green hydrogen production generates no GHG emissions, making it a vital tool in mitigating climate change. Besides, hydrogen is a versatile energy carrier that can be used in various sectors, including industry, transportation, and power generation. One of the main advantages of green hydrogen is that it can be stored and used when needed, providing grid stability and energy security. Equally relevant is the fact that it enables the decarbonization of hard-to-abate sectors, such as heavy industry and long-haul transportation, by replacing fossil fuels.

Hydrogen is abundant and can be produced sustainably from water, but the availability of renewable energy ensures that green hydrogen can be produced cheaply and abundantly. This fact alone will confer major advantages to the MENA region given its potential to produce abundant solar renewable energy.

The Russia-Ukraine war has added a new dimension to the value of green hydrogen. Amid the global energy transition, investors, particularly Germans, are anxious to pour billions of dollars into many of these MENA countries to turn the new fossil fuel finds into hydrogen. The element is the key feedstock for fuel cells, which use chemical reactions to generate electricity cleanly, with water as the main by-product.[150]

A few investment projects have been planned and some have been initiated. Enthusiasm around green hydrogen is raging. Projects costing billions of dollars are under consideration in Mauritania, Algeria, Egypt, and other countries. A German developer signed a memorandum

[150] Rabah Arezki (September 2023). North Africa's Hydrogen Mirage. Finance and Development. IMF and ERF.

of understanding with Mauritania with a consortium for a USD 34 billion project boasting an annual capacity of eight million tons of green hydrogen and related products.[151]

10.2. Challenges and considerations

Currently, green hydrogen production can be more expensive than other forms of hydrogen, mainly due to the high cost of renewable energy. However, as renewable energy prices continue to fall, this issue is expected to be resolved in the region's favor. Another challenge is the need to develop the infrastructure for hydrogen production, storage, and transportation. This requires large investments and raises the cost of production and delivery of hydrogen. At this time, the electrolysis process is not very efficient in producing net energy due to significant losses during production. Another challenge is associated with scaling up green hydrogen production to meet the demands of various sectors. This will require significant technological advancements and policy support than is available and can be counted on in the region.

10.3. The role of green hydrogen in a sustainable future

Green hydrogen holds enormous potential in the transition to a sustainable energy future for the MENA region in spite of the challenges listed above and even when we take into consideration the severe scarcity of water in the region and the dangers of explosions.

First, special efforts should be made to integrate green hydrogen into sectors that are difficult to electrify directly, such as heavy industry, long-haul transportation, and even EVs.

Second, green hydrogen can significantly reduce GHG emissions in sectors responsible for a significant portion of global emissions, and this puts green hydrogen at the forefront of climate change mitigation efforts.

Third, countries concerned about their energy security can rely on green hydrogen abundance to secure their energy needs. This will depend on enabling and expanding its storage and transport.

Fourth, green hydrogen is emerging as a beacon of hope in the quest for a cleaner and more sustainable energy future. However, realizing this potential will require collaborative efforts from governments, industries, and innovators worldwide to overcome existing challenges and accelerate the adoption of green hydrogen as a key renewable clean energy source.

10.4. Green hydrogen production in the MENA region: a path to sustainable energy leadership

The MENA region stands at the threshold of a transformative opportunity to become a global leader in green hydrogen production and investment. Leveraging its abundant renewable resources, strategic location, and international partnerships, the region can drive the transition to a sustainable and low-carbon energy future while addressing water scarcity and creating economic diversification. However, achieving this potential will require substantial investments, robust policy frameworks, and a commitment to technological innovation. By embracing green hydrogen, the MENA region can play a pivotal role in shaping the global energy landscape and contributing to a more sustainable and environmentally responsible world.

The MENA region is blessed with an abundance of solar and wind resources. Countries like Saudi Arabia, the UAE, Morocco, and others have some of the world's highest solar irradiance and wind potentials, providing a robust foundation for green hydrogen production. However, the region faces significant water scarcity challenges. Green hydrogen can be produced through the electrolysis of seawater, offering a dual benefit by simultaneously producing hydrogen and fresh water through desalination at the same time.

With its strategic location and well-established energy infrastructure, the MENA region can export green hydrogen to meet the growing global demand. Europe, in particular, has shown interest in importing green hydrogen to support its decarbonization goals. The region has been actively seeking international partnerships and investments to develop green hydrogen projects. Collaborations with European countries and Japan, among others, have the potential to attract substantial investments. SWFs in the region's oil-exporting countries have substantial funds that could be tapped into to support investments in this potentially very lucrative sector.

R&D is of particular relevance and a very critical area of investment. It is this area of development that can lead to technological advancements that enhance the efficiency and cost-effectiveness of green hydrogen production. Public and private sector partnerships can drive innovation in electrolysis technologies and infrastructure development. However, establishing favorable policies and

[151] Rabah Arezki (September 2023). North Africa's Hydrogen Mirage. Finance and Development. IMF and ERF.

regulations is also crucial for attracting private sector investments in green hydrogen projects. Governments in the MENA region can provide incentives, subsidies, and clear frameworks to encourage investments and tap into available international finance to promote the transition to renewable energy. Investing in green hydrogen not only helps reduce the region's dependence on fossil fuels but also supports economic diversification by creating new industries and job opportunities.

The MENA region will face stiff competition from other global players in the green hydrogen market. Maintaining a competitive edge will require continuous innovation, efficiency improvements, large investments, and regional and international partnerships. The privileged position of the region on account of its geographical proximity to large markets in Europe, Asia, and Africa and its rich green energy endowments confer on it a potential competitive edge, but this needs to be actualized by ensuring cost-effective production and pricing.

11. IEA response to criticisms of the transition to renewable energy

There is as much naysaying about the clean energy transition as there are ways to accelerate it. The excuse is that wind and solar take up too much land, that countries planning to transition to renewable energy do not have enough critical minerals, and that the transition to clean energy will be too expensive and not worth it. The IEA has responded to these allegations with counterarguments and a fact-checking exercise. The IEA responded to the 10 myths that have been raised,[152] and the details of the counterarguments are listed below:

1. *The energy transition is cheaper than "business as usual."* Conventional thinking argues that the capital costs of the energy transition are too high, but you also need to look at the costs of the fuel; fossil fuels are expensive, and renewables are free. The IEA looked at both capital costs and operational costs and noted that when you combine them, the energy transition will cost USD 12 trillion less than the IEA's business-as-usual scenario. Whilst capital costs are higher, the ongoing savings from high fossil fuel prices more than outweigh this. In short, saving the planet is cheaper than destroying it. Further, the net-zero scenario will mean lower energy prices for consumers.
2. *We are building enough grids.* Conventional thinking looks at the opposition to the building of new grids but does count the successes, those areas where the grid does get built. The IEA takes a dispassionate look at the totals. They calculate that we need to build 1.25 million miles of grids every year versus the average for the last five years of 1.2 million miles a year that were actually built. Despite all the opposition to change, we are, in fact, building 95 percent of the amount that is required. That final five percent is not easy, but it is certainly achievable.
3. *Carbon removal is not an excuse for inaction.* The IEA notes that it is much cheaper not to put the emissions in the air in the first place than to try to take them out later. Delayed action allowing more emissions would cost USD 1,300 billion per annum to remove the excess carbon from the air in the second half of the century; that is 50 percent more than we invest today in oil and gas capital expenditure.
4. *We have the technology.* In 2021, the IEA calculated that we only had 50 percent of the technology that was required in 2050 to get to net zero. In 2023, that increased to 65 percent as the result of innovation in a range of areas, from batteries to green steel. As is so often the case, necessity is proving to be the mother of invention, and it is reasonable to expect that we will continue to increase the range of technology solutions rapidly over the next few years.
5. *We have enough land.* Even if we calculate the land requirements for solar and wind in the most pessimistic way, we would require a maximum of 2.5 percent of available land. In fact, as noted by many others, this number hugely overstates the land use by counting the space between wind turbines, even though that space can be used for crops. However, it is still clear, even in this case, that land availability is not an insoluble impediment to deploying renewables.
6. *Stranded assets are coming.* Even if we stop building fossil fuel infrastructure today, many fossil fuel power plants and industrial assets will not be needed, and some existing oil and gas wells may be stranded. A total of USD 3.6 trillion is already committed to building out fossil fuel infrastructure above the requirements of net zero.
7. *The supply chain for renewables is being built out.* Factories are already being built to annually produce over 1,000 gigawatts (GW) of solar and 10,000 gigawatt hours (GWh) of batteries by 2030, the key building blocks of the renewable economy. This is driven by the hunt for industrial advantage in the industries of the future because businesses know that "you have to be in it to win it".
8. *More jobs.* Of the 65 million people working in the energy sector, half already work in clean energy. The expansion of the renewable systems will create far

[152] https://cleantechnica.com/2023/10/02/reality-check-the-iea-busts-10-myths-about-the-energy-transition/amp/

more jobs than are lost in the fossil fuel systems. The IEA calculates that by 2030, there will be 30 million new jobs in the clean energy economy versus 13 million jobs lost in fossil fuels. Moreover, the jobs will go to those who seize the opportunities of the renewable era.

9. *Fewer resources for a renewable economy.* The IEA calculates that the total amount of resources needed for a renewable economy is two-thirds less than those required to run the current fossil fuel economy. The reason why is that electrons and the infrastructure needed to move them around is much lighter than the 15 billion tons of fossil fuels we use every year.
10. *Renewables enable justice.* Renewable technologies, such as mini-grids and cook stoves, are the foundation of solutions to ensure that by 2030 we get electricity to the 775 million people who lack access to it and clean cooking to the 2,400 million who do not have it. They help reduce premature deaths from air pollution by 3.6 million people every year, mainly in emerging and developing economies.

12. Conclusions

Today, there is a significant global trend toward transitioning to renewable energy. Over the past few decades, the world has witnessed the widespread adoption of renewable energy technologies such as solar, wind, biomass, and hydro. This has not only helped reduce GHG emissions; it has also had a profound impact on employment, incomes, and social outcomes. The costs of renewable energy production have fallen dramatically, technologies have become more efficient, and solutions for integrating renewables into electric grids have advanced considerably.

This study has explored the employment impacts of renewable energy, how it is changing the job market in the MENA region, and how it could address the high unemployment rates and afford better opportunities for the region's youth and women.

The world renewable energy sector has recently emerged as a major employer, creating new job opportunities and offering higher-quality jobs compared to the traditional energy sector. Every dollar of investment in renewables is estimated to create three times more jobs than in the fossil fuel industry. The IEA estimates that the transition toward net-zero emissions will lead to an overall increase in global energy sector jobs. The IEA Report notes that while about five million jobs in fossil fuel production could be lost by 2030, an estimated 14 million new jobs will be created in green energy.

The findings of this study support the expectation of increased employment opportunities in the green energy sector in the six target countries of the MENA region, as well as in most of the other countries in the MENA region, including the fossil fuel-rich GCC countries. A total of 1.2 million jobs could be generated in the six countries by simply increasing the share of renewable energy to 30 percent in their energy mix. These employment figures are gross employment estimates with 611,423 person-years in 2030 and 1,222,845 in 2050. Net total employment that takes into account that renewable energy will necessarily displace an equal share of that electricity generated by natural gas will be about 525,824 person-years in 2030 and 1,051,647 person-years in 2050. This needn't be the case, as renewable energy can be thought of to be fully incremental and, in that case, the entire 1.22 million person-years could be the expected employment sustained by renewable energy in the six target MENA countries.
On the other hand, the employment generation capacity of energy efficiency will not be large but will still contribute a total of 89,377 in 2030 and almost twice this level in 2050 when the share of energy efficiency is 30 of the total energy generated.

The MENA region is well-endowed with solar radiation and wind, and it can rely on these sources to provide sufficient energy to make up for any decline in fossil fuel production or imports. When the entire MENA region is the focus of estimating the total expected renewable energy employment that could be generated and sustained by a 30 percent share of renewables in the total energy supply in 2030, a large total emerges of about 2,539,384 person-years in 2030 and over 5,076,728 person-years in 2050. These figures are the total employment generation capacity of both electricity generation and those associated with the value chains involved and from realized efficiencies. In 2030, the relative contributions of renewable energy generation is expected to exceed 2,240,633 person-years and that of efficiency is put at 298,751 person-years.

The total installed electricity generating capacity in the MENA region in 2020 was estimated at about 420 GW. This is expected to increase by 40 percent by 2030, reaching 589 GW. The projected employment generation capacity in 2030 is based on a 30 percent renewable energy share in electricity generation for the region as a whole and the use of the IMF elasticity coefficients.

These employment projections suggest that a massive increase in employment generation capacity in the region can be predicted, particularly against the backdrop of the region's high unemployment rates. However, these estimates will pale in comparison to the expected employment generation capacity once we include the great opportunities renewable energy will engender in the region as it opens the gates for rooting a viable and highly productive EVs manufacturing industry. As previously mentioned, Morocco is already producing a million EVs, Saudi Arabia has partnered with Lucent Industries and is targeting a similar volume, the UAE has teamed with a Chinese firm that is producing currently 55,000 vehicles that could be ramped up to multiples of this volume, and Egypt is on the course to produce a large number of EVS for home use and exports. It is not possible to believe that these opportunities could have existed without renewable energy and the determination of the region to realize their NDC commitments.

It is quite natural to expect to end up with large overall net employment impacts of EVs; the statistical records from other countries like the Scandinavian countries and Canada point out some very positive income and employment impacts. These tend to be concentrated in higher value-added industries and higher levels of employment and wages and salaries. It is even equally possible that there will be positive net gains in all taxes and in the revenues of all levels of government.

Three distinct employment impacts are typically associated with EVs. First and foremost are the manufacturing impacts. These are very large and can be a game changer for the undiversified economies of the region, but they depend to a great extent on two critical conditions: the number of vehicles produced and the local sources of inputs for the parts and the batteries. Equally important are the infrastructural developments that will be needed to support the use of EVs and, finally, the re-spending of all the gains from the avoided costs and savings on operations, repairs, and insurance.

As for the number of EVs that could be sold and produced, almost two million commercial and passenger vehicles were sold in the MENA region in 2019. Most of these vehicles were imported from Europe, Korea, China, and Japan. The market is large and the opportunities of replacing ICE vehicles with EVs are enormous. One of the major factors that make EVs easy to produce in the region is the fact that ICE vehicles typically have 2,000 engine parts, whereas EVs have less than 20 parts and most use parts made of plastic that is massively produced in the region.

If only 20 percent of the cars sold in 2030 are locally produced EVs, then it follows that a significant employment impact could be expected that should be added up to the employment impacts of the assumed 30 percent of electricity generation from renewable sources. These two employment impacts, however, will also be augmented by two additional impacts that can be realistically expected. Adding up the employment impacts of developing and constructing the supporting infrastructure of charging stations and the employment impacts associated with re-spending the savings on operating and maintaining EVs, it is possible to project a large but credible employment impact of 3,861,998 person-years. If the share of EVs rises to 50 percent, which is not an all too unreasonable share, the total employment impact in 2030 could reach 5,845,920 person-years.

These large employment levels could almost be doubled in 2050, where a total employment of 10,369,226 person-years could be realized if the market share of locally produced EVs reaches 80 percent, or a total of 11,691,840 person-years if this share reaches 100 percent. These employment estimates are the expected gross employment potential of EV manufacturing. Deducting the employment that could have been generated by ICE vehicles, we arrive at the net impacts. Given that the MENA region manufactured only a small share of its cars, it stands to reason that most of the employment-generating potential of EV manufacturing could be considered net employment-generating potential.

The potential employment creation of EVs manufacturing is enormous, but for this to happen, a few conditions and programs must be put in place. A few countries have introduced incentive schemes that provide grants to first purchasers of EVs, while others have gone as far as to legislate zero production of ICE vehicles by 2030. Many have embarked on building free charging stations in public spaces and made the provision of these stations and free parking for EVs mandatory at government buildings and high-rise apartments.

The surest way for the MENA region to compete in this domain will be by slashing prices to a level that would allow new domestic comers to the global market to sell their cars at competitive prices. The experience of Lucid cars in the US is instructive in this regard. Saudi Arabia is a major investor in Lucid Motors of Texas, US, and is counting on this company to produce 150,000 EVs in Jeddah by 2026. In the final analysis, the most important current cost component of an EV is the battery. The latter constitutes 40 percent of the total cost of the car. Morocco has teamed with Chinese company Goshen Hi-Tech to build one of the largest battery-producing factories in the world in Morocco. The main reason is the proximity of Morocco to Europe and its privileged position in the African market, but, more importantly, the large deposits of phosphates (70 percent of the world's deposits) and its large deposits of cobalt. The latter two are becoming potential ingredients in the manufacture of storage batteries.

The threat of stranded fossil fuel energy assets and the increased likelihood of climate change disasters are persuading countries everywhere to consider transitioning to renewable energy. This is emerging as a preferred strategy and option for many of the MENA region countries despite their huge reserves of fossil fuels. There are many reasons for this preference. First, most of the MENA countries are well-endowed with renewable energy generation potential, particularly from solar and wind sources. Second, the capital costs of renewable energy generation, which constituted an obstacle to investing in renewable energy generation, have recently precipitously dropped. Third, several MENA countries, particularly oil-producing countries, have accumulated large investible funds in their SWFs to finance not only their investment in their transition to renewable energy but also to invest in neighboring MENA countries' transitions. Fourth, a few countries in the region have already capitalized on the opportunities to manufacture EVs and other energy-intensive industries, and these will more likely increasingly agglomerate around renewable energy generation locations. Fifth, the greater employment generation potential of renewable energy and its upstream, downstream, and off-stream derivatives are persuading countries, particularly those that have had limited diversification, to rely on these industries to balance and diversify their economies. Last, but not least, renewable energy is seen as an effective vehicle for promoting the engagement of the youth and women into productive activities and expanding their participation in these industries beyond being consumers and even producers but also as leaders and entrepreneurs. The latter is shaping up as a social and transformative project through renewable and sustainable energy.

There remains a few other issues that the MENA region need to consider to speed and firm up their transition to renewables that need to be emphasized here. First, the transition is seen as a social project that brings together the government, business, the public and institutions. It is not an initiative of one or the other segments of society; it is all or nothing and it is more likely to be effected if all groups work together. Second, the success of the transition is contingent on the economics of the process. Businesses are more likely go invest and get involved if the process is profitable. There is a serious gap that needs to be immediately addressed and this relates to the absence of carbon markets. Carbon pricing is a must and so are carbon markets. If MSMEs can reap profits on carbon savings, they are more likely to invest in carbon-saving technologies and products. Third, incentives and support programs need to be structured and made accessible to businesses, institutions and consumers, including subsidies, grants, access to long-term finance, training programs, skill development and mobilization, export markets, capital equipment and technology are critical to successful transitions. Fourth, regional cooperation and international trade and investment should be facilitated; the transition to renewable is a public good that all could benefit from.

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ERF at a Glance: *The Economic Research Forum (ERF) is a regional network dedicated to promoting high-quality economic research for sustainable development in the Arab countries, Iran and Turkey. Established in 1993, ERF's core objectives are to build a strong research capacity in the region; to encourage the production of independent, high-quality research; and to disseminate research output to a wide and diverse audience. To achieve these objectives, ERF's portfolio of activities includes managing carefully selected regional research initiatives; providing training and mentoring to junior researchers; and disseminating the research findings through seminars, conferences and a variety of publications. The network is headquartered in Egypt but its affiliates come primarily from different countries in the region.*

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