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REVIEW ARTICLE

Capacity and strategies of energy production from renewable sources in Arab countries until 2030: a review from renewable energy potentials to environmental issues

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Abstract
Slowing and reversing climate change and keeping energy prices at affordable levels are the main important achievements of the use of renewable energy. About 210% increase in energy consumption from 1990 to 2018, reduction in fossil fuel reserves, and high capacity of renewable energy in Arab countries encourage them to increase the use of renewable and sustainable energy sources as a key way to supply the energy in future and have a sustainable economy. There is no a comprehensive review study to focus on the capacity and strategies of renewable energy in Arab countries at the transnational level until 2030. To fill this gap, this article investigates the current and future capacities and strategies of renewable energy production by 22 Arab countries, which are the center of fossil energy production in the world, until 2030. Indeed, it provides a roadmap for advancement towards energy production from renewable sources in these countries. It is observed that Egypt and Morocco with an installed capacity of 5980 and 3447 MW, respectively, had the highest installed renewable energy capacity among the Arab countries in 2020. The results also showed that most ambitious goal is related to Djibouti, where it is targeted to supply 100% of energy from renewable resource by 2035. Finally, it should be mentioned that most Arab countries focus on solar and wind energy, and very little attention is paid to geothermal, biomass, and hydroelectric energy.

Keywords Renewable energy · Strategies · Climate change · Fossil energy · Markets

Introduction

The world has begun the fourth economic era, which has also increased energy demand. Due to the structural changes in the economy, caused by the Industrial Revolution, innovation has played an important role in the present era. These innovations are provided to achieve energy efficiency, improve existing production processes, and promote renewable energy (RE). Despite all efforts to reduce energy consumption, global energy demand is growing, while having adverse and irreversible effects on the environment. Sustainable resources, such as wind, solar, and geothermal energy, have less detrimental effects on the environment as compared with other energy sources, including coal, natural gas, and oil (Koc et al. 2019).

In 2014, Arab countries, including 22 countries, accounted for 31.22% of world oil production (Doranehgard and Dehghanpour 2020; Khan et al. 2021), which reached 31.08% by 2020 (see Table 1). Oil production in the Arab countries and the world has increased by 2.53% and 1.89%, respectively, in the last 6 years between 2014 and 2020. This increase in the production is due to the increase in demand as result of the increase in population and the development of industry (IEA 2020a). For example, Saudi Arabia is the largest state in the Arab world with an area of approximately 2.25 million square kilometers. Saudi Arabia became the world's leading producer and exporter of oil over the years (Amran et al. 2020). In 2020, this country with a production of 21,381,720 EJ oil had the share of 12.33% in world oil production and is the largest oil producer in the region. Then, Iraq with 8,435,241 EJ, UAE with 7,270,620 EJ, and Kuwait with 5,464,439 EJ are the largest oil producers in the region, which exports oil to all over the world (IEA 2020a).

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Table 1 The crude oil and natural gas liquid produced by Arab countries (IEA 2020a)

Country	Crude oil (EJ)	Natural gas liquid (EJ)	Year
Algeria	2,127,104	766,938	2014
	1,782,702	681,600	2020
Comoros	Not available	Not available	2014
	Not available	Not available	2020
Djibouti	Not available	Not available	2014
	Not available	Not available	2020
Egypt	1,410,407	61,211	2014
	1,192,956	50,088	2020
Libya	967,695	83,652	2014
	816,272	60,748	2020
Mauritania	Not available	Not available	2014
	Not available	Not available	2020
Morocco	209	0	2014
	172	0	2020
Somali	Not available	Not available	2014
	Not available	Not available	2020
Sudan	257,348	0	2014
	188,517	0	2020
Tunisia	107,684	10,258	2014
	65,175	5654	2020
Bahrain	426,091	15,366	2014
	355,202	27,259	2020
Iraq	6,426,905	57,024	2014
	8,351,883	83,358	2020
Jordan	42	0	2014
	42	0	2020
Kuwait	6,084,216	276,203	2014
	5,130,062	334,377	2020
Lebanon	Not available	Not available	2014
	Not available	Not available	2020
Oman	1,938,070	10,300	2014
	1,946,699	12,275	2020
Palestine	Not available	Not available	2014
	Not available	Not available	2020
Qatar	1,444,781	1,728,688	2014
	1,316,218	1,692,423	2020
Saudi Arabia	20,268,717	2,381,996	2014
	19,009,540	2,372,180	2020
Syria	54,428	3977	2014
	79,476	3988	2020
United Arab Emirates	5,824,383	1,275,969	2014
	5,760,427	1,510,193	2020
Yemen	291,108	26,335	2014
	100,465	483	2020

These countries are also among the largest CO_2 emitting countries in the world. About 5.04% of the world's CO_2 emission in 2019 was for Arab countries, and from 2014 to 2019, it has grown by 4.03%. For example, Saudi Arabia is the largest CO_2 emitter in the region with emitting 495.2 Mt. This is followed by Egypt with 225.5 Mt, the UAE with 178 Mt, and Algeria with 142.4 Mt (IEA 2020a). With fossil fuels, Arab region meets the energy needs domestically and internationally. Abundant fossil fuels and low prices for primary energy and electricity have discouraged Arab countries from using RE sources or at least suitable prioritizing their use. In recent years, however, the abundance of RE in Arab region and economic, political, and climatic factors have encouraged a number of Arab countries to develop RE and to announce national programs and goals for more use of RE. The strategic goals are as follows:

1. Increasing future energy security by diversifying energy sources
2. Meeting national needs and regional development
3. Strategically keeping and storing the region's natural oil and gas as much as possible and helping to solve problems related to oil and gas exploration and transportation (Amran et al. 2020)

The Paris Agreement has set a goal to limit the global mean temperature below 2 °C above pre-industrial levels and to try to limit the boost to 1.5° C (Ramadan et al. 2021; Re 2019). RE, together with energy efficiency gains, can provide 90% of the required CO_2 reduction by 2050 (IRENA 2020).

Many studies have been done on the potential of RE in Arab countries. For example, Abed et al. (2014) reviewed the energy and RE status in Iraq. It was concluded that the availability of hydropower with the generating capacity of 5100 MW was owing to weak management and lack of maintenance running at up to 1500 MW, and its grids are suffered loss of 49% based on the World Bank report. Jamil et al. (2016) investigated the RE systems adopted by the UAE. Their results showed that the suitable solution for the UAE's energy, economy, and environmental issues is provided when the RE systems are explored and better plans are used for the RE sources in UAE. Aliyu et al. (2018) reviewed the RE development in South Africa, Egypt, and Nigeria. They found that the energy storage systems are very essential to store the electricity generated from renewable sources and release when it is required. Lebbihiat et al. (2021) investigated the potential of Algeria in energy and RE. They found that, unfortunately, the country was making slow progress compared to the stated goal of the government, and the installed capacity of RE was very small compared to its enormous potential. More actions should be taken to facilitate investment and support the implementation of policies about the RE. Gherboudj et al. (2021) developed the RE management system for Saudi Arabia. This system can be used to predict the power generation for the real and hypothetical

scenarios. Al Garni et al. (2021) investigated the economic assessment of alternative RE systems employing the capital cost projections. They observed that the projected decrease in photovoltaic (PV) and battery costs to 2025 is faster as compared with the decrease in wind turbine costs.

The literature review showed that there are some studies conducted on the energy and RE status in certain Arab countries, separately. However, it is better to focus on the capacity and strategies of energy production from renewable sources in Arab countries at the transnational level. This is due to the fact that transitioning to renewables primarily in these countries is highly related to the transnational challenges of financial and infrastructural nature, which cannot be tackled at national levels. Due to the importance of RE for green economic growth, social development, and environmental protection and high potentials of Arab countries for energy production from renewable sources, in this paper, a review is conducted on the capacity and strategies of RE production in Arab countries until 2030. It should be mentioned that the regional cooperation and integration between these countries are high. These countries have strong alliances and common culture and social. In general, the energy policy and economy of these countries are intertwined. They have also some joint regional energy projects. The Arab countries are spread over a vast land extending from west Asia through North Africa. The total population of these countries is around 423 million in 2021. In many Arab countries, substantial proportions are living in remote and rural areas. As a result, designing low-capacity RE systems without the need for transmission networks is very essential for them. In addition, the Arab region's RE potential is high. These countries are also placed in the center of fossil energy production in the world, and this may negatively affect their strategies and plans to shift the energy production from fossil fuels to RE sources. Due to these reasons, Arab countries are selected for the investigation in this study. In the first step of the study, the current RE situation in Arab countries is determined. In addition, a discussion about the RE potentials of the selected countries is provided. In the second step, the national and regional courses of actions taken by Arab countries in the field of RE to reach the announced targets are summarized and reviewed. In the third step, the strategies of Arab countries in the field of RE until 2030 are introduced. Finally, the future strategies and policies, which should be considered by Arab countries for the transition to renewables and the fight against adverse climate changes, are provided in the last step to provide a roadmap.

Economic and social aspects of renewable energy

Between 2000 and 2020, the world's RE production capacity is increased from 754 to 2799 GW, about 3.7 times, as their costs were reduced due to continuous technology improvements, economies of scale, competitive supply chain development, and improved supplier competitive experience. The cost of electricity from solar and wind energy has dropped to very low levels. Since 2010, a total of 644 GWh has been added to RE production capacity worldwide, costing less than the cheapest coal fossil fuel option each year. Replacing these coal-based power plants would reduce annual system costs by $32 billion a year and reduce annual CO_2 emissions by about 3 Gt.

- Onshore wind: In 2010, the levelized cost of electricity (LCOE) was 0.089 USD/kWh, which was decreased by 54% during the decade ending 2020 and is reached 0.039 USD/kWh at 2020 (IRENA 2021b).
- Offshore wind: In 2020, the LCOE due to the addition of new onshore wind capacity decreased by 48% as compared to 2010 and increased from 0.162 to 0.084 USD/kWh (IRENA 2021b).
- Solar PV: The global weighted average LCOE of PV power plants is decreased by 85% between 2010 and 2020, from 0.381 to 0.057 USD/kWh. In 2020, a decrease of 7% was observed as compared to 2019 in this parameter. Globally, LCOE costs continue to decline (IRENA 2021b).
- Concentrated solar power (CSP): The LCOE for CSP is decreased significantly between 2010 and 2020 by decreasing the total installation costs, operations and maintenance costs, and financing costs and increasing capacity factors. During that period, the average weight of global LCOE of newly launched CSP power plants is decreased from 0.34 USD/kWh in 2010 to 0.108 USD/kWh in 2020 (IRENA 2021b).
- Hydropower: In 2020, the global weighted average cost of electricity from hydropower plants was 0.044 USD/kWh, which was increased about 16% as compared to 0.038 USD/kWh recorded in 2010. Despite this increase over time, 99% of hydropower projects launched in 2020 had LCOEs in this range or less (IRENA 2021b).
- Geothermal: The global weighted average LCOE was increased from about 0.05 USD/kWh for the projects launched in 2010 to about 0.07 USD/kWh in 2020. For the period 2019 to 2021, available data show that the LCOE remains constant at around 0.07 USD/kWh. However, it depends on whether the projects meet their start-up objectives, and especially for larger projects, they incur excessive costs (IRENA 2021b).

- Biomass: Assuming a capital cost between 7.5 and 10% and feed costs between 1 and 9 USD/GJ, the global weighted average LCOE of biomass power generation for start-up projects was 0.076 USD/kWh in 2020 and did not change as compared to 2010 (IRENA 2021b).

Despite strong resource potential across the region, by 2015, nearly 80% of non-hydropower RE growth was concentrated in only four of 22 Arab countries, where RE accounted for only 6% of total installed electricity generation capacity. However, current trends show that the RE landscape is evolving rapidly and significant progress has been made. In 2016, $11 billion was invested in RE across the Arab region, while this amount was only $1.2 billion in 2008. Today, several countries in the region are among the world leaders in the development of RE. Recent auctions have led to a global decline in solar prices, including 17.8 USD/MWh for the Sakaka project in Saudi Arabia and 24.2 and 29.9 USD/MWh in Abu Dhabi and Dubai, respectively. The Arab region recognizes the socio-economic benefits of deploying RE, which is seen as an opportunity for industrial diversification, new value chain activities, and technology transfer. Relying on this motivation, Morocco has created 13,000 new jobs and expanded its local industry by creating the capacity for solar water heaters. In addition, the world's largest CSP plant in Ouarzazate meets 42% of its plant's domestic demand. Morocco continues to lead the region in terms of total installed RE production capacity (IRENA 2021a).

Subsidies are paid for energy prices in the Persian Gulf countries, and investing in RE will not be profitable. There is no incentive to use RE. In Europe, for example, there are tax incentives, but in Arab countries, there are not these incentives. This suggests that perhaps diversifying the economy should come first because there is currently no economic incentive to switch to RE. Traditional oil-based energy resources are a major economic asset for Qatar, and the lack of incentive to motivate citizens to accept and use RE can be observed in this country (Okonkwo et al. 2021). Renewable energies play a key role in the sustainable energy transfer of the region, which should be considered in the broader context of socio-economic development of the region. Deploying RE throughout society leads to economic growth and diversity, job creation, trade balance improvement, and enhanced water security.

Trend of energy consumption in Arab countries

In the Arab countries, the increase in the rate of economic growth, population, and energy consumption is observed. Historically, low energy prices in the region have made it possible for foreign companies to create and develop jobs in the region, which in addition to improving the economy; this has also increased energy demand. Looking back, the energy consumption grew by 208.34% between 1990 and 2019 (see Fig. 1) in Arab countries, while energy consumption in developed European countries decreased by 5.80%. In addition, the CO_2 emissions of the Arab countries increased by 4.03% between 2014 and 2019. Increasing dependence on oil and gas for energy consumption is affecting the exports and, consequently, the economy of Arab countries (IEA 2020a).

Many reasons, such as climate change, rising prices for fossil fuel resources, rising air pollution, and declining energy independence, have led to the rapid use of RE technologies in many countries (Nematollahi et al. 2016). The use of RE is very important for the Arab countries, not only to meet the growing need for energy, but also to achieve sustainable growth by reducing carbon emissions. Initiatives in RE also lead to industrial diversity. Fluctuations in fossil fuel prices have led to adverse outcomes, such as budget deficits and sharp declines in export earnings for Arab countries. Financial pressures from falling oil prices have forced Arab countries to implement RE reforms.

Destructive effects of climate change and environmental degradation

Climate change and environmental degradation are two main challenges to the growth of global sustainable development. Greenhouse gas emissions are the major reason of climate change. Large-scale greenhouse gas emissions are mainly due to fossil fuel consumption. The natural gas emissions from oil and gas production account for 5.8% of the global greenhouse gas emissions (Doranehgard et al. 2021), and 76.7% of greenhouse gas emissions are owing to CO_2 emissions (Abokyi et al. 2019; Chedid and Chaaban 2003; Hao and Shao 2021).

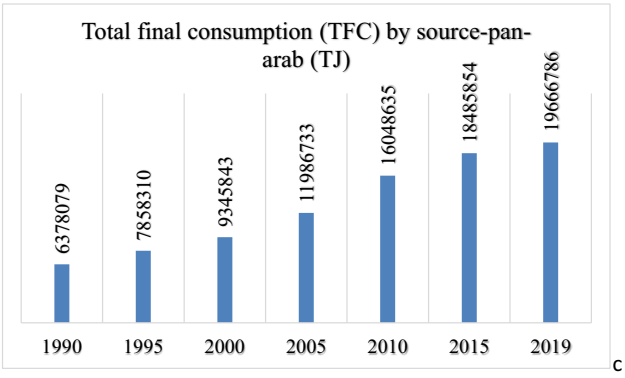


Fig. 1 Trend of energy consumption in Arab countries between 1990 and 2019

Arab countries account for a large share of global greenhouse gas emissions, so that 5.04% of global CO_2 emissions in 2019 were from Arab countries. The total CO_2 emission in 2019 was 1695.2 Mt, which Saudi Arabia with the emission of 495.2 Mt is the largest CO_2 emitter in the Arab region. This is followed by Egypt with 225.5 Mt, the UAE with 178 Mt, and Algeria with 142.4 Mt. The amount of CO_2 emitted in 2014 and 2019 by Arab countries is presented in Table 2. It can be seen that CO_2 emission is increased about 4.03% between 2014 and 2019 in Arab region. This alarming situation encourages services and politicians to develop the solutions to implement environmental protection and universal and sustainable energy supply (Martin-Martínez et al. 2016). Today, worldwide, special attention is paid to clean and sustainable energy systems (Elkadeem et al. 2019) and RE is used to achieve future energy security and reduce the harmful environmental effects of human activities (Shields et al. 2011). RE sources have less detrimental effects on the environment as compared with other energy sources (Koc et al. 2019). However, excessive and unplanned use of RE, such as tidal energy, can be considered a threat for habitat and regions (Shields et al. 2011). The Arab countries are very vulnerable to the effects of climate change and pollution. With the changing situation and pollution generated as a result of continued consumption of fossil fuels, Arab countries face environmental challenges such as desertification, biodiversity loss, water pollution in coastal and marine regions, and water shortages. A number of countries, e.g., Qatar, have already seen a mean temperature rise of more than 2 °C. According to studies conducted in this field, by 2050, temperatures will rise, which will lead to severe phenomena such as tornadoes, storms, and droughts. Cold days and nights have reduced in recent years, and the Arab region has also seen rising temperatures and declining rainfall in the summer that coincides with periods of drought. Warm weather will have considerable effects on the energy needed by the region to maintain a normal life. In some countries, 70% of the peak demand for residential electricity is on the hottest times for cooling residential space. Electricity demand for cooling is predicted to triple by 2050 (Al-Saffar and Van der Beeuren 2020; Praveen et al. 2020).

Table 2 CO_2 emissions by Arab countries in 2014 and 2019 (IEA 2020a)

Total CO_2 emissions (Mt)		
Country	2014	2019
Algeria	123.2	142.4
Comoros	Not available	Not available
Djibouti	Not available	Not available
Egypt	194.3	225.5
Libya	50.8	45.9
Mauritania	Not available	Not available
Morocco	53.5	65.9
Somali	Not available	Not available
Sudan	14	18.5
Tunisia	25	26.2
Bahrain	29.7	32.6
Iraq	140.9	138.2
Jordan	24	22.8
Kuwait	81.9	89.4
Lebanon	22.5	25.5
Oman	59.9	69
Palestine	Not available	Not available
Qatar	76.9	86.9
Saudi Arabia	506.9	495.2
Syria	25.3	23.6
United Arab Emirates	176.4	178
Yemen	24.2	9.6

Renewable energy potentials in Arab countries

Direct normal radiation (DNR) is an important criterion to diagnose the suitability of an area for the use of solar energy. Some data about the potentials of RE in different Arab countries, including the global horizontal radiation, normal direct radiation, full load hours, and temperature at a depth of 5000 m in the ground, in 2012 are provided in Table 3. The data presented in this table confirm the significant RE potentials of Arab countries (IRENA 2014). The optimal range of DNR is between 2050 and 2800 kWh/m^2 during a year. In the Arab countries, the maximum average DNR is 2445.5 kWh/m^2 during a year and the minimum average DNR is 1496.5 kWh/m^2 during years, which fall in the optimal range. In addition, less than 21% of all days of year are cloudy in this region (Alnaser et al. 2004; IRENA 2014). From the available data, it can be concluded that the geographical conditions of the Arab countries are among the most favorable areas for the use of solar heating, concentrated solar power (CSP), and photovoltaic (PV) systems. The International Energy Agency (IEA) predicts that CSP technology in the Middle East and North Africa alone could produce hundreds of times the energy consumption of the Arab and the European Union countries. In addition, the solar condition of the Arab countries is very favorable for the use of PV systems (IRENA 2014). For site quality assessment technology selection, and optimal design of solar power plants, the solar radiation conditions and accessibility and diversity of solar energy should be investigated. As a result, it is necessary to prepare aerial maps to evaluate these factors (IRENA 2014).

It is recommended that the investment on wind farms is profitable for the minimum annual wind speed in the range

Table 3 Data about the potentials of renewable energy in different Arab countries

Country	Global horizontal irradiance (kWh/m^2/year)	Direct normal radiation (kWh/m^2/year)	Wind full load (hours/year)	Geothermal/temperature (°C) at a depth of 5000 m
Algeria	1970	2700	1789	213
Bahrain	2160	2050	1360	100
Comoros	Not available	Not available	Not available	Not available
Djibouti	Not available	Not available	Not available	Not available
Egypt	2450	2800	3015	180
Iraq	2050	2000	1789	100
Jordan	2320	2700	1483	100
Kuwait	1900	2100	1605	100
Lebanon	1920	2000	1176	100
Libya	1940	2700	1912	100
Mauritania	Not available	Not available	Not available	Not available
Morocco	2000	2600	2708	281
Oman	2050	2200	2463	100
Palestine	Not available	Not available	Not available	Not available
Qatar	2140	2200	1421	100
Saudi Arabia	2130	2500	1789	275
Somali	Not available	Not available	Not available	Not available
Sudan	Not available	Not available	Not available	Not available
Syria	2360	2200	1789	100
Tunisia	1980	2400	1789	188
United Arab Emirates	2120	2200	1176	100
Yemen	2250	2200	1483	295

of 4.9 to 5.8 m/s (Potić et al. 2021). The wind resources in the Arab region are as rich as the solar resources, although they are denser in some places. Especially, the shores of the Red Sea and the Atlantic Ocean have the potentials to become wind farms. Wind speeds in these areas are more than 9.75 m/s, which provide the criteria of desirability. For example, in the Suez Canal of Egypt, the wind speed is varied between 7 and 10 m/s, which satisfies the criteria well (IRENA 2014).

There is also good potential for the usage of geothermal energy and biomass in Arab region. Algeria, Morocco, Saudi Arabia, and Yemen have the sites with the temperatures above 200 °C at the depth of 5000 m in the ground. Countries with adequate agricultural activities, e.g., Sudan, have the chance to use biomass and expand its efficiency in energy production (IRENA 2014).

Current situation of Arab countries in using renewable energy

The total installed capacities of RE between 2011 and 2020 in Arab countries are provided in Table 4. Based on the available data, the total installed capacity of RE in the Arab countries in 2020 is equal to 22,596 MW. However, this capacity was only 11,991 MW in 2014. This reflects the growing interest of these countries in the adoption of RE in the field of climate action under the Paris Agreement and the United Nations Sustainable Development Goals (SDGs). However, the Arab countries yet have a long way to go to completely achieve their RE goals. Egypt has the largest share in 2020 with the installed capacity of 5980 MW. This is followed by Morocco, Iraq, and UAE with the capacities of 3447 MW, 2490 MW, and 2540 MW, respectively. The share of hydropower, wind, solar and bioenergy power plants in the capacity of 2019 is 11,121 MW, 3287 MW, 7235 MW, and 349 MW, respectively. The capacity in wind energy is currently under the influence of the new installation in Egypt, Morocco, Tunisia, and Mauritania. Some new capacities of CSP have created in the Saudi Arabia and added to the projects developed in Algeria, Morocco, Egypt, and the UAE (RCREEE 2019). In most Arab countries, including 14 countries, the share of the population with accessibility to electricity has more than 98%. Just a few numbers of Arab countries have lower electricity rates. This share is 92%, 69%, 47%, 45%, 42%, 30%, and 17% for Syria, Comoros, Yemen, Sudan, Djibouti, Mauritania, and Somalia, respectively (RCREEE 2019).

Table 4 Total installed capacity of RE between 2011 and 2020 in Arab countries (IRENA 2021)

Country	Capacity (MW)									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Algeria	253	253	253	264	312	482	663	686	686	686
Comoros	1	1	1	1	1	1	1	1	1	1
Djibouti	0	0	0	0	0	0	0	0	0	0
Egypt	3452	3452	3452	3452	3662	3676	3797	4789	5948	5980
Libya	4	5	5	5	5	5	5	5	5	5
Mauritania	0	0	22	23	53	69	69	121	122	122
Morocco	1596	1597	1837	2143	2303	2407	2535	3267	3267	3452
Somali	0	2	2	2	3	7	10	11	11	27
Sudan	1692	1800	1800	1800	1803	1805	1965	2119	2125	2125
Tunisia	119	241	272	312	334	347	357	370	386	401
Bahrain	1	1	1	6	6	7	7	7	10	11
Iraq	2274	1865	1895	1902	2311	2311	2311	2490	2490	2730
Jordan	17	17	17	17	153	524	634	1119	1500	1904
Kuwait	0	0	3	4	6	33	44	55	106	106
Lebanon	282	285	288	292	298	318	303	330	330	330
Oman	0	0	1	1	2	2	8	8	59	159
Palestine	0	1	1	3	12	25	35	40	82	117
Qatar	39	39	40	42	42	43	43	43	43	43
Saudi Arabia	3	14	22	24	24	24	37	87	413	413
Syria	857	857	857	1501	1579	1501	1497	1499	1500	1500
United Arab Emirates	13	13	128	136	136	142	356	599	1919	2540
Yemen	1	1	2	5	60	80	100	250	250	253

Water management resources and desalination in Arab countries

Arab countries are placed in the arid regions. The lack of freshwater resources is a serious threat to their sustainable and balanced socio-economic growth and development. This threat is clearly more pronounced in less developed countries (Tlili et al. 2020). With the scarcity of drinking water, it becomes essential to find ways to better manage and produce low-cost drinking water. In order to supply water and energy, the selection of RE sources in the production of freshwater is very necessary. Such sustainable methods can significantly reduce the stress on the water and energy sources with little ecological effect. For desalination with RE sources, solar collectors (Saffarian et al. 2020), photovoltaic arrays, geothermal energy sources, wind, and tides can be used. Arab countries usually use fossil fuel plants to produce freshwater. However, due to increased pollution, reduced fossil fuels, and to support the 2030 goals, they have also considered RE for desalination purposes. In a study, Tlili et al. (2020) concluded that a small desalination plant equipped with the solar collectors is more economically cost-effective as compared with the thermal desalination plant that runs on fossil fuels.

Share of hydropower plants in Arab countries

The total capacity of hydropower plants installed in different Arab countries in 2014 and 2020 are presented in Table 5. In 2020, the Arab countries have produced about 11,074 MW from water energy. Egypt has the largest installed capacity of hydroelectric power production with 2832 MW. This is followed by Iraq with 2514 MW, Sudan with 1907 MW, and Morocco with 1770 MW.

Share of solar power plants in Arab countries

The total amount of energy produced by solar source (photovoltaic (PV) and concentrated solar energy technologies (CSP)) in 2014 and 2020 in Arab countries is presented in Table 6. In 2020, the Arab countries have produced about 8221 MW energy from the sun. The UAE has the largest installed capacity with the total solar power generation of 2539 MW in 2020. This is followed by Egypt with the capacity of 1681 MW and Jordan with the capacity of 1360 MW. Solar energy can be controlled by direct conversion of solar energy into electrical energy using PV technology or by thermodynamic cycles using CSP (Awan et al., 2021). Owing to the high potentials and good solar radiation and

Table 5 Total installed capacity of hydropower plants installed in different Arab countries in 2014 and 2020 (IRENA 2021)

Country	Capacity (MW)	
	2014	2020
Algeria	227.6	228
Comoros	1.45	1.45
Djibouti	0	0
Egypt	2800	2832
Libya	0	0
Mauritania	0	Not available
Morocco	1770	1770
Somalia	Not available	Not available
Sudan	1593	1907
Tunisia	62	62
Bahrain	Not available	Not available
Iraq	2105.34	2514.34
Jordan	12	16
Kuwait	Not available	Not available
Lebanon	282	253
Oman	Not available	Not available
Palestine	Not available	Not available
Qatar	Not available	Not available
Saudi Arabia	Not available	Not available
Syria	1494	1490
United Arab Emirates	Not available	Not available
Yemen	Not available	Not available

Table 6 Total installed electricity capacity of solar plants in different Arab countries in 2014 and 2020 (IRENA 2021)

Country	Capacity (MW)			
	CSP		PV	
	2014	2020	2014	2020
Algeria	25	25	1.1	423
Comoros	0	0	0	0
Djibouti	0	0	0.30	0.36
Egypt	20	21	15	1660
Libya	0	0	4.90	5.11
Mauritania	0	0	18.15	88
Morocco	25	545	19.60	194
Somali	0	0	0.10	22.54
Sudan	0	0	8.04	18.27
Tunisia	0	0	17	95
Bahrain	0	0	5.01	9.76
Iraq	0	0	36.5	216
Jordan	0	0	0.22	1360
Kuwait	0	50	2.05	43.34
Lebanon	0	0	5	78.65
Oman	0	0	0.70	108.74
Palestine	0	0	3	116.83
Qatar	0	0	3.97	5.10
Saudi Arabia	0	50	24.26	360
Syria	0	0	0	2.47
United Arab Emirates	100	100.11	33.17	2439.15
Yemen	0	0	5	253

the continuous reduction in costs of technologies used, PV power generation is growing at a high rate in this region (Amran et al. 2020). Due to the growth in global electricity demand and the intensification of environmental concerns, new strategies must be developed. In various strategies for future electricity supply, the installed capacity of PV will increase significantly and lead many countries to invest heavily in the installation of PV systems (Sohani et al. 2021; Barhoumi et al. 2020).

The most popular usage of CSP technology in this region is integrated solar cycle power plants that can be observed in Algeria, Egypt, and Morocco. The UAE has built one of the largest CSP power plants with capacity of 100 MW in January 2013 with the name of Shams 1 (Amran et al. 2020). In 2014, four Arab countries, including Algeria, Egypt, Morocco, and the UAE, used CSP technology to generate electricity, but over time and cost reductions in 2020, Kuwait and Saudi Arabia also used this technology. Morocco increases its installed capacity from 25 MW in 2014 to 545 MW in 2020. The International Energy Agency (IEA) estimates that CSP technologies alone in the Middle East and North Africa can generate 100 times more than the electricity consumption in the Arab region and Europe (IEA 2020a).

Share of wind power plants in Arab countries

The total amount of energy produced by wind source in 2014 and 2020 in Arab countries is presented in Table 7. Five Arab countries, including Oman, Morocco, Egypt, Tunisia, and Jordan, have 99% of the Arab region's wind capacity. Morocco with 1.4 GW and Egypt with 1.3 GW are the first countries in the Arab region to have more than 1 GW of wind projects. About 80% of the total installed wind capacity of Arab region can be observed in these two countries (RCREEE 2019).

Geothermal

The Arab countries have rich sources of geothermal energy, but so far, no geothermal power plant has been built and installed to generate electricity (Amran et al. 2020). The hot mineral water is used recreationally for physiotherapy in the pools (Abu-Rumman et al. 2020). This energy with the temperature higher than 150 °C can be used to generate electricity (Aghahosseini and Breyer 2020). In some areas of Saudi Arabia, such as neighbors, the ground temperature is in the range of 150 to 300 °C, which are very suitable for

Table 7 Total installed capacity of wind plants in different Arab countries in 2014 and 2020 (IRENA 2021)

Country	Capacity (MW)	
	2014	2020
Algeria	10.2	10
Comoros	0	0
Djibouti	0	0
Egypt	555	1380
Libya	0	0
Mauritania	4.40	34.40
Morocco	797	1405
Somalia	2	4
Sudan	Not available	Not available
Tunisia	233	244
Bahrain	0.68	0.68
Iraq	Not available	Not available
Jordan	1.4	515
Kuwait	2.4	12.4
Lebanon	3	3
Oman	0	50
Palestine	Not available	Not available
Qatar	Not available	Not available
Saudi Arabia	0	3.25
Syrian AR	0.60	0.60
United Arab Emirates	1.70	0
Yemen	Not available	Not available

Table 8 The total installed capacity of bioenergy plants in different Arab countries in 2014 and 2020 (IRENA 2021)

Country	Capacity (MW)	
	2014	2020
Algeria	0	0
Comoros	0	0
Djibouti	0	0
Egypt	0.67	12.67
Libya	0	0
Mauritania	0	0
Morocco	1	7.40
Somalia	0	0
Sudan	199	199
Tunisia	0	0
Bahrain	0	0
Iraq	0	0
Jordan	3.5	13
Kuwait	0	0
Lebanon	2	9
Oman	0	0
Palestine	0	0.34
Qatar	38	38
Saudi Arabia	0	0
Syrian AR	6.71	6.71
United Arab Emirates	1	1
Yemen	0	0

the construction of geothermal power plants (Amran et al. 2020). With the installed thermal capacity of 153.3 MW, Jordan is the leading country in the Arab region in the direct use of geothermal energy, which all of this capacity is used only for bathing and swimming (Lebbihiat et al. 2021).

Biomass energy

Biomass energy is another RE (Salah et al. 2021; Almaktar and Shaaban 2021). The total installed capacities of bioenergy plants in different Arab countries in 2014 and 2020 are presented in Table 8. Despite the high potentials for waste and biomass production in the Arab world, unfortunately, only nine countries use this energy, on a very small scale. Sudan with an installed capacity of 199 MW has the highest installed capacity among the Arab countries. This is followed by Qatar with the capacity of 38 MW.

Situation of renewable energy production in Arab countries

The situation of RE production in different Arab countries is investigated in this section.

Algeria

Algeria is one of the OPEC (Organization of the Petroleum Exporting Countries) member countries, which is one of the largest producers of hydrocarbons in the Arab region and exports natural gas to Europe. Thirty percent of Algeria's GDP (gross domestic product) comes from fossil fuel revenues, which makes up a large part of the country's economy. Almost all of the country's primary energy is supplied by oil and gas, and only 3.39% of the total installed energy capacity is related to RE. The amount of installed renewable capacity in Algeria in 2020 is displayed in Fig. 2 (IRENA 2021). As shown in this figure, the installed capacities of hydropower, CSP, PV, and wind energy in this country are 228 MW, 25 MW, 423 MW, and 10 MW, respectively. As a result, more than 50% of installed capacity of RE belongs to the PV panels in this country (RCREEE 2021). The Ministry of Energy and Mines is responsible for controlling RE and managing energy savings in Algeria. Responsible for the development and support of energy in this country is the Electricity and RE Company (SKTM) affiliated to SONELGAZ. Algeria is an attractive market for developing RE owing to its market size and strong resource potentials. Algeria is at present adopting the bidding and auction

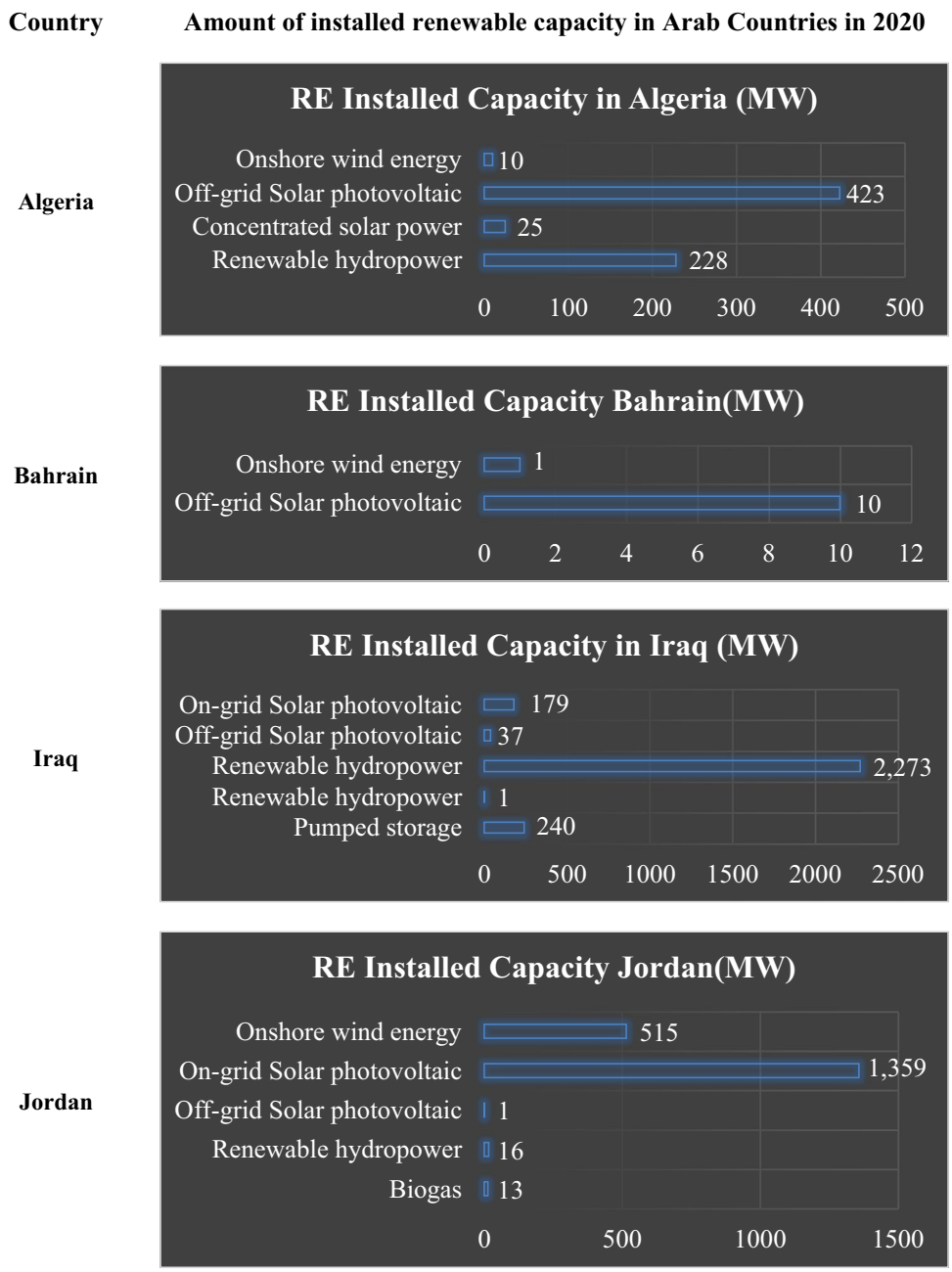


Fig. 2 Amount of installed renewable capacity in different countries in Arab region in 2020 (IRENA 2021)

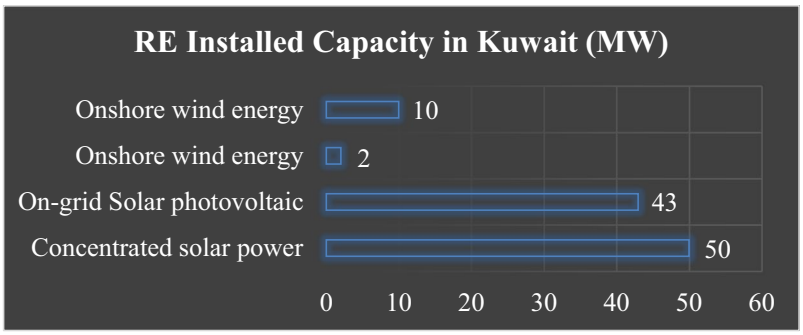
plans to attract private investments, where different projects are in the tendering and pipeline phases. In addition, the companies of gas and oil in this country are encouraged for investing in RE projects (RCREEE 2019). Lekhneg 1 and 2 power plant, placed in Laghouat province, is the largest power plant in Algeria, which was established in 2016 and 2017. This power plant has the capacity of 60 MW and placed on a land area of 120 hectares (Bouraiou et al. 2020). The investment framework of this country may be enhanced to permit more participation of foreign investors and to permit for small scale decentralized RE systems in different sectors (RCREEE 2019). It is shown that about 60% of the country's methane emissions belonged to landfills (Cheniti et al. 2021). Algeria has the wind and solar atlases, the latest of which were published in 2020.

Bahrain

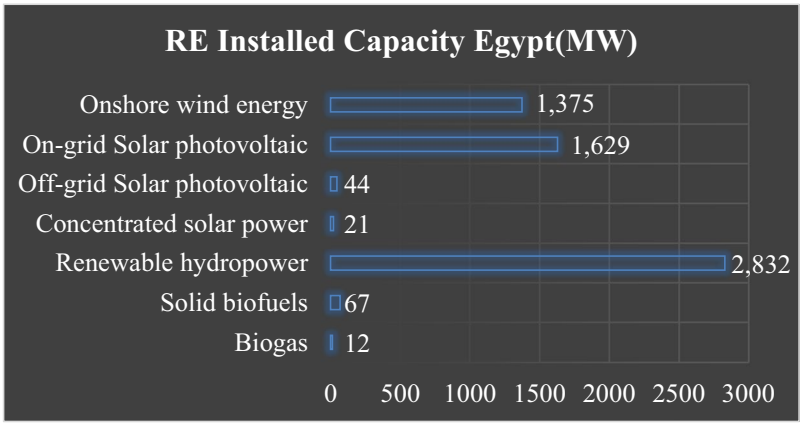
Bahrain is a major producer of oil and natural gas and is not a member of OPEC. The country still imports fossil fuels to meet its domestic energy needs, and its primary energy is entirely based on fossil fuels (RCREEE 2021). This country is among the early GCC countries, which opened their power sector for independent power producers (IPPs). It is also

Fig. 2 (continued)

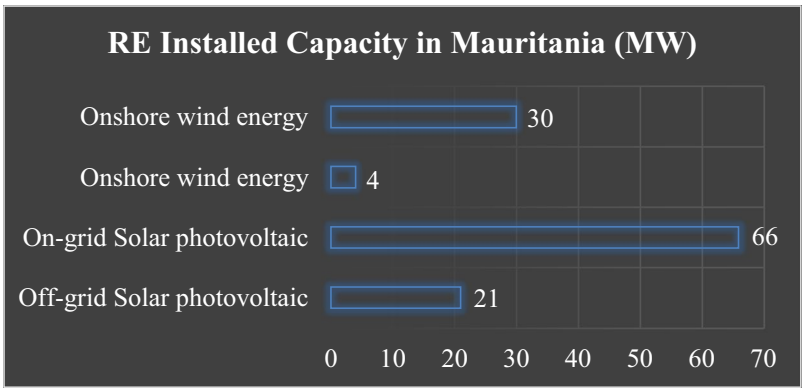
Kuwait



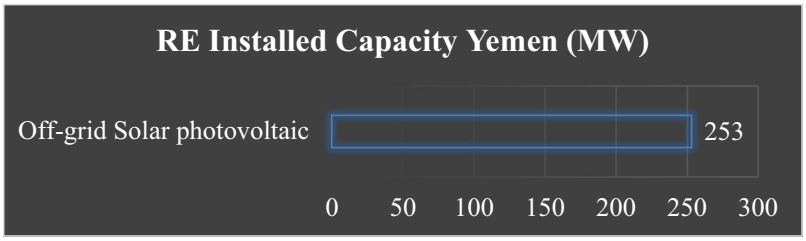
Egypt



Mauritania



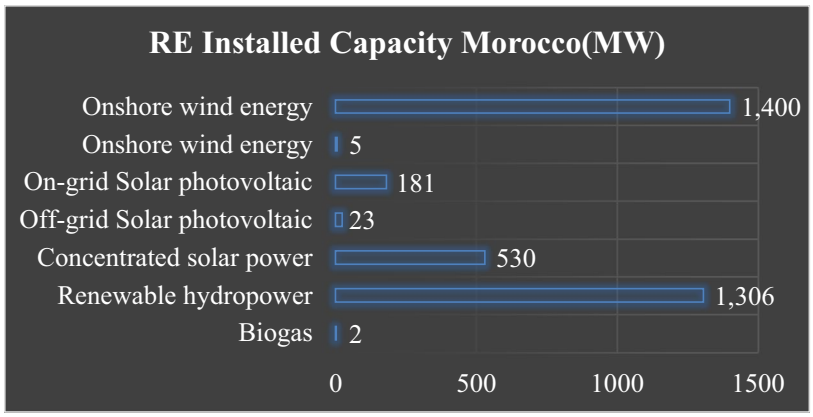
Yemen



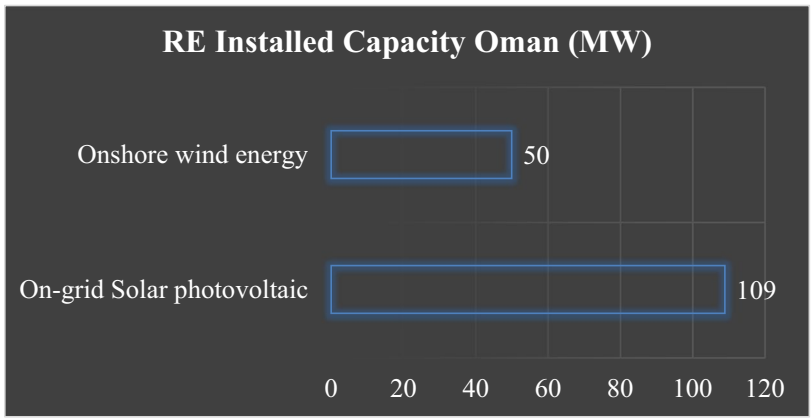
among the Arab countries, which has undergone successful subsidy reform programs. In addition, the private unit for sustainable energy is provided. The electricity and water authority of this country pursued competitive bidding and net-metering plans for attracting dedicated investments. The competitive bidding was held by the signature of the PPA for its first IPP PV project with the capacity of 100 MW. This country has desirable macroinvestment conditions and the potential for attracting investments in RE owing to its compact size, accessible financial resources, and desirable business conditions. With the proper focus, this country has the potential to show leadership in innovative applications and trade models for dedicated investments in RE (RCREEE 2019). This country was able to produce a small amount, about 11 MW energy form renewable resources in 2020. The construction of the Al Dibdibah/Shagaya Phase II power

Fig. 2 (continued)

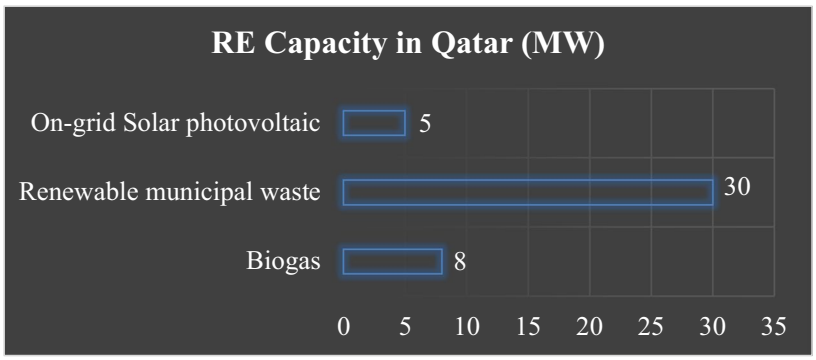
Morocco



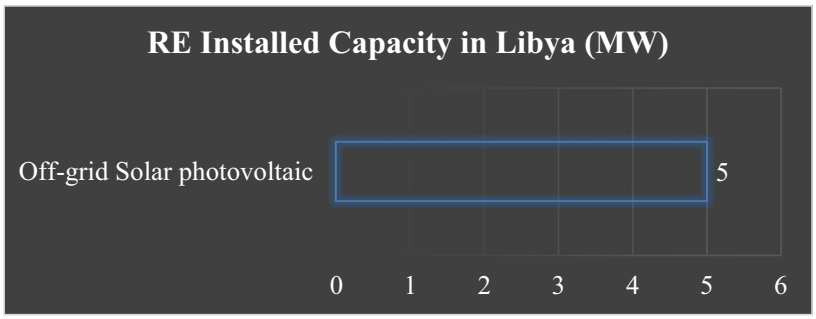
Oman



Qatar

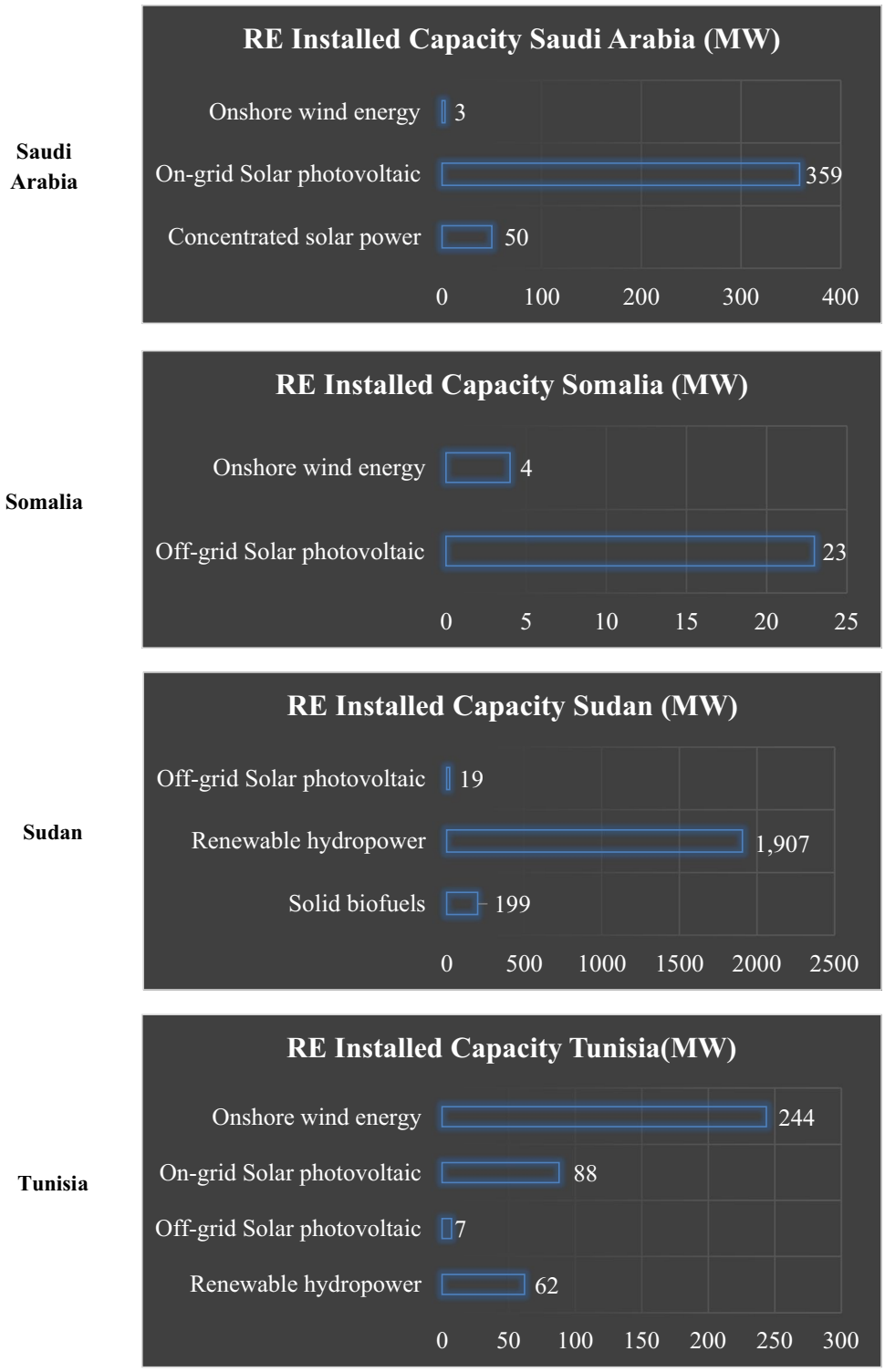


Libya



plant, with the capacity of 1200–1500 MW, based on PV technology, is the largest RE project that Bahrain intends to implement (Praveen et al. 2020). The amount of installed renewable capacity in Bahrain in 2020 is displayed in Fig. 2. As shown in this figure, Bahrain, with an installed capacity of 11 MW (10 MW solar and 1 MW wind), has a very low capacity, and unfortunately, from 2011 to 2020, the development of RE did not work well (see Table 4) (IRENA 2021).

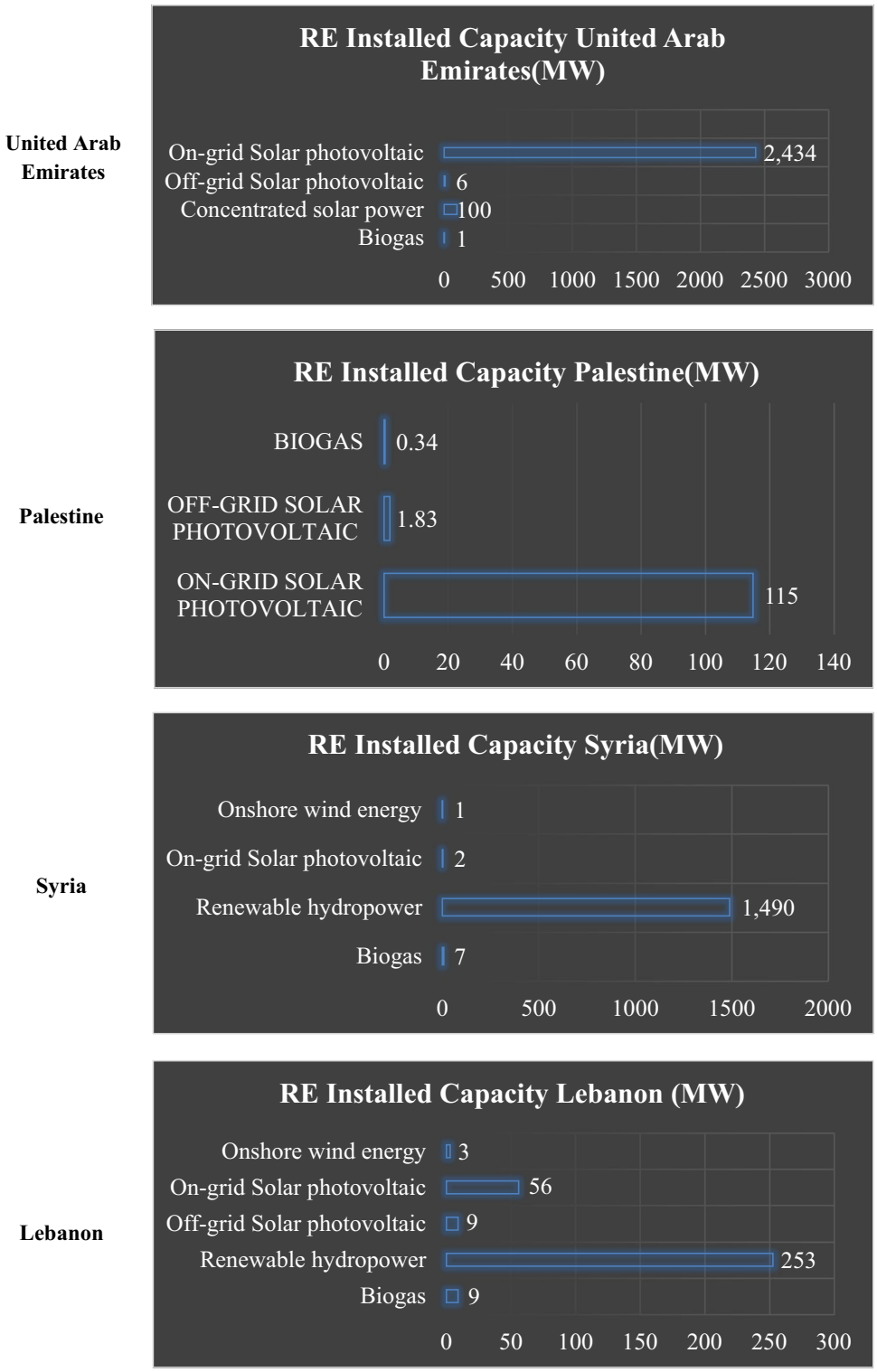
Fig. 2 (continued)



Iraq

Iraq has the largest proven oil reserves and is one of the most important oil producers in the world. Over the past few years, the energy demand in this country has exceeded the production capacity. In addition, Iraq's energy sector has been damaged by the war (RCREEE 2021). If oil prices remain low, Iraq's oil revenues will fall by at least 70% in comparison to last year. This country will have a huge deficit of about $3.5 billion a month only to pay salaries and pensions and fund the government's operations. The latest World Bank outlook predicts that Iraq's economy will shrink

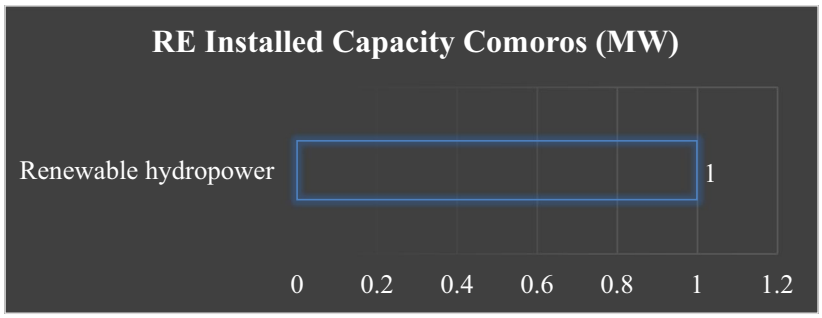
Fig. 2 (continued)



by almost 10% in this year and that the widening current account deficit is one of the most severe in the world (Al-Saffar 2020). In 2014, when global oil prices began to fall, Iraq reacted by sharply reducing its spending capital. The effects of these events were yet being felt in 2019, as the national government budget in 2019 was 20% lower than in the 2013 budget. Due to declining private sector participation in the economy, the public sector was suffered, and the government delayed almost all essential services, including investment in hospitals, roads, and schools (Al-Saffar 2020). The energy sector was also damaged. The annual capital budget allocated to the Ministry of Oil has decreased by

Fig. 2 (continued)

Comoros



one-fifth in the period 2015 to 2018 as compared to 2013, and this has affected Iraq's decisions and ability to achieve its long-term oil and gas goals (Al-Saffar 2020). There are early indications that the current slump in oil prices is affecting the country's capital budgets. There are signals that all the capital investments planned by the Ministry of Electricity for this year have been postponed indefinitely. This jeopardizes the large number of investments required in the network. The country's transmission and distribution losses are among the largest in the world (Abed et al. 2014). Solar energy is recognized as part of the most practical way to address these problems (Al-Douri and Hashim 2014; Al-Douri and Abed 2016). Iraq established a private RE division in the Ministry of Energy and set short-term goals for useful scale projects. Useful scale PV projects are announced. However, inefficiency in the process caused retendering. The enhanced competitive bidding process is under development for attracting trustworthy developers. Expression of interest for IPP PV projects with the capacity of 700 MW was lately announced. No financial or fiscal incentives were adopted. However, the financial mechanism for supporting small PV systems through local banks is considered (RCREEE 2019). The amount of installed renewable capacity in Iraq in 2020 is shown in Fig. 2. Iraq was able to increase the installed capacities of its hydroelectric power plant and the PV to 2514 MW and 216 MW, respectively. Iraq did not make significant progress in increasing RE capacity between 2011 and 2020, but remains one of the top Arab countries in RE production (see Table 4) (IRENA 2021).

Jordan

Jordan's energy demand is growing at an annual rate of 3%. Jordan imports about 94% of its oil and gas for the primary energy supply, which accounts for 10% of the country's gross domestic product. This makes the country vulnerable to price changes of energy carriers. The real share of RE, despite efforts performed to develop this type of energy, is only about 7% of total average energy demand (Abu-Rumman et al. 2020; RCREEE 2021). Recently, Jordan has made substantial progress to attract dedicated investments for RE development. Jordan is among first Arab countries to attain its RE provided targets ahead of its due date in 2020. It continues to be the only country in the Arab region to have operated the full ownership separation of its electricity sector, with considerable performance of its private RE fund. In addition, Jordan has also advanced considerably in the implementation of the net metering plan. The power pricing reform, together with the supporting policies, leads to attract the investments in RE. Project developers have high interest in the direct proposal plan adopted with remarkable success in this country (RCREEE 2019). The amount of installed renewable capacity in Jordan in 2020 is disclosed in Fig. 2. In 2020, Jordan was able to increase the installed capacity of on-grid photovoltaic to 1359 MW. The share of wind, off-grid photovoltaic, hydropower, and biogas from the installed capacity are 515, 1, 16 and 13 MW, respectively. Jordan is one of the few countries that use biogas energy. This country has been able to increase its installed RE capacity from 17 MW in 2011 to 1904 MW in 2020, which shows the country's detailed plan to achieve the goal.

Kuwait

Kuwait is one of the richest countries in the world in terms of fossil fuels. It is a member of OPEC and has one of the largest oil reserves in the world. In addition, this country is one of the top exporters of oil. Oil sales account for about 50% of the country's GDP and 95% of government revenue (RCREEE 2021). Kuwait has provided a comprehensive plan for the Shagaya RE park project with the capacity of 2 GW to expand RE. In this country, some scenarios with different focuses on the technology integration are selected from 14 technology options, including three technologies in wind energy, five technologies related to PV systems, and six technologies related to CSP. These scenarios emphasize high annual power generation or low power cost (Lude et al. 2015). No announced framework for renewable IPPs is available in this country. Kuwait National Petroleum Company (KNPC) has a plan for the installation of the first utility scale solar project with the capacity of 1.5 GW. Kuwait Foundation for the Advancement of Sciences (KFAS) has started funding projects for commercial application such as homeowners for installation of rooftop solar systems by offering

to finance projects, provided that the homeowner pays the initial insurance fee. Although, the small decentralized PV capacity is available but no net metering plan or FiT policy in place. The clear regulations are required to support the growth of both dedicated RE utility scale and distributed generation with fiscal incentives for ensuring the successful implementation of the regulations (RCREEE 2019). The amount of installed renewable capacity in Kuwait in 2020 is disclosed in Fig. 2. It can be seen that this country is focused on solar energy. The installed capacity of grid-connected PV, CSP, and wind are 43, 50, and 12 MW, respectively. The country has made the progress in the development of RE from 2011 to 2020, but this amount is very small (see Table 4).

Egypt

Egypt is a major producer of fossil fuels and plays an important role in global energy trade. This country is not a member of OPEC. Owing to population growth, economic expansion, and increasing industrial production, and many other factors, the energy demand in this country is rapidly increasing and it is the largest consumer of oil and gas in Africa (RCREEE 2021). Of new generation capacity, 25,500 MW is added between 2015 and 2019 by Egypt. Not only has this compensated for the country's electricity shortage, but it has also generated 25% more electricity than the country needs. The new capacity includes 1000 MW of solar PV and about 840 MW of new wind capacity. There are some reasons to achieve such success in a short period of time for this country. Egypt identified the basic rules and regulations, which this made private investment in this sector possible. In addition, in 2014, Egypt introduced redemption tariffs, and in 2017, it pursued this by permitting long-term electricity purchase agreements to make investments more attractive to electricity producers. Due to these policies, solar PV park with the capacity of 1800 MW in Bonban, one of the largest solar power plants in the world, was completed and developed. At the same time, it submitted bidding projects through auctions, and this is currently being implemented for solar and wind projects, e.g., development of Kom Ombo solar PV plant with the capacity of 200 MW. Egypt also increased its investment by liberalizing currency, permitting investment guarantees, and implementing a methodical restructuring of electricity subsidies (Rovzar 2020). Figure 2 displays the amount of installed renewable capacity in Kuwait in 2020. And as can be seen, the focus of this country is on the wind, solar, and water energy. The installed capacities of them are 1694, 1375, and 2832 MW, respectively. With an installed capacity of 79 MW, Egypt is the second country in the Arab region in terms of bioenergy share. Egypt was able to increase its installed capacity about 2528 MW from 2011 to 2020 (see Table 4). The installed capacity of 5980 MW is achieved and this makes it the leading country in the Arab region in terms of installed RE capacity.

Mauritania

Mauritania is relied heavily on fossil fuels to supply its domestic energy demand. Due to rising domestic energy demand and a lack of installed capacity, total energy consumption of this country is about 35% higher than national energy production. This has led to fossil fuel imports. Fossil fuels make up about 66% of primary energy, while the rest of 34% is from biomass that is mostly employed for cooking and heating. Most of electricity is produced by thermal diesel engine generators (RCREEE 2021; Tlili 2021; Tlili et al. 2021). In terms of RE share in the overall installed capacity, if hydro is excluded, Mauritania is among the leading Arab countries. It is a large country with the small population where load centers are spread throughout the country that implies the strong requirement for decentralized services. Different plans and electrification projects in this country have focused on poor rural areas not connected to the grid. This country has the functioning regulator and developed the unique system for financing the portion of the cost of extending services to rural areas from telecommunications sector earnings. The new energy strategy has also developed recently. It is necessary to provide the regulatory framework and needful administrative processes to make more options for dedicated investments (RCREEE 2019). Figure 2 shows the amount of installed renewable capacity in Mauritania in 2020. As can be seen, this country has not invested much in RE. It has provided the capacities of 34 MW and 87 MW for wind and solar energy, respectively, in 2020.

Yemen

Yemen is a producer and exporter of oil and gas. The primary energy consumed by this country is based entirely on fossil fuels. Yemen's economy is mainly related to oil and gas that accounts for about 60% of government revenue. Yemen is also faced low electricity access rates (40%). The infrastructure of this country is destroyed, and the available infrastructure is not enough to meet the country's energy needs, leading to frequent blackouts (RCREEE 2021). Yemen is a country in crisis and it is proved that PV technology can be used as a solution to provide electricity in difficult war conditions. Yemen is facing a challenge to supply electricity to a large part of its population, and the current difficult political situation that directly affects access to electricity across the country has provided a huge market for small solar energy projects for the residential and agricultural sectors. Owing to the war, this country has not received high investments in RE (RCREEE 2019). Yemen

recently is investigating feasible business models, which helps the recovery of its electricity sector according to mini and microgrids as transitional solutions, such as IPP solar power stations with small to medium sizes (RCREEE 2019). Figure 2 shows the amount of installed renewable capacity in Yemen in 2020. The installed capacity of grid-connected PV was 253 MW in 2020 for this country. The country has increased the installed capacity of RE from 1 to 253 MW from 2011 to 2020 (see Table 4).

Morocco

Morocco's domestic energy supply depends on fossil fuels. About 93% of Morocco's total primary energy is supplied by oil, natural gas, and coal. Morocco generates some oil and natural gas for domestic use, but has to import most of its fossil fuel requirement. This country is trying to reduce its dependence on fossil fuel imports to supply energy demand by leveraging its high potential for RE. About 68% of the installed capacity in energy sector is related to fossil fuels, and the rest of 32% is supplied from RE sources (mainly wind and solar energy) (RCREEE 2021). Morocco has made the transition to RE a top priority in its 2009 National Energy Strategy. Morocco has tried to use a legal and regulatory framework for launching its broader transfer strategy, with the aim of creating a market. Since then, the next law has been passed, which permits tenders and auctions for large solar and wind projects to operate and encourage private investment in the sector. Trust among investors and lenders were increased by the creation of "one-step" agencies, e.g., the Moroccan Agency for Sustainable Development (MASEN) (Rovzar 2020). Morocco's resilience has been consistent in its strategy, and the uncertain atmosphere did not destroy the initiative in 2020. Morocco successfully launched two wind projects in 2020. Morocco has established ties with Spain and Algeria and is now seeking for integration into other markets in North and sub-Saharan Africa and Europe (Rovzar 2020). However, the market's development for distributed RE generation with small scale in this country is slow. This country most move quicker to open up its electricity markets for small-scale generation of RE projects and allow small and medium companies enter into the business development sectors. This reform will help Morocco to improve the socio-economic impacts of RE (RCREEE 2019). Ouarzazate solar power station with capacity of 580 MW, established in 2018, is the largest power plant of this country (Boulakhbar et al. 2020). Figure 2 discloses the amount of installed renewable capacity in Morocco in 2020. It is clear that this country is focused on water, wind, and solar energy, and the installed capacities of wind, PV, CSP, hydropower, and bioenergy were 1405, 204, 530, 1306, and 7.4 MW, respectively, in 2020. This country was able to increase its installed capacity from 1596 to 3452 MW from 2011 to 2020 (see Table 4). This country has the second rank among the Arab countries in terms of installed RE capacity. This shows the exact plan and framework considered by this country for RE development.

Oman

Oman is one of the countries that has implemented complete separation of ownership in its electricity sector and 100% of the production capacity of the main interconnected system (MIS) belongs to the first person of the monarchy (RCREEE 2019). The interest and support of the Omani government for the use and investment in RE has increased. As a step forward, the Oman Research Council began working to fund research projects in various sectors. Also, the government and power companies in Oman cooperate with foreign power companies that work in renewable sources to generate electricity (Kazem 2011). Oman Electricity and Water Supply Company has awarded a tender for an IPP solar project with the capacity of 500 MW, and other similar tenders are underway. Oman Oil Development Company will build solar power plant with the capacity of 1 GW to increase oil recovery and extract heavy and viscous oil in Amal oil field. Such a project is a model project for the rest of the Arab countries. Oman also launched a project, called by Sahim. In this project, the residential PV systems with the capacity in the range of 3 to 5 kW are installed. Sahim allows consumers to sell electricity to the grid at the current bulk electricity tariff. Oman considers financial and regulatory incentives to accelerate the deployment of RE in the country (RCREEE 2019). The density of solar energy in Oman is one of the highest in the world. Also, there is significant coastal wind energy potential in the coastal areas in the southern part of Oman and in the mountains north of Salalah (Kazem 2011). Oman intends to implement three projects, including Dhofar Phase I, Dhofar Phase II, and Miraah Solar Thermal, with a capacity of 1000 MW (Praveen et al. 2020). Two first projects are based on wind technology, while the third project is based on solar technology. The amount of installed renewable capacity in Oman in 2020 is shown in Fig. 2. This country has installed the capacities of 109 MW and 50 MW for the PV and wind technologies, respectively, in 2020. This country has also increased its installed RE capacity by a limited amount each year and has not yet seen significant growth in this area.

Qatar

Qatar is rich in fossil fuels but has not yet been able to use them extensively and effectively (Al-Marri et al. 2018). With an area of 11,400 km^2, this country has arid lands and scarce freshwater resources due to its geographical location. Conversely, the country is rich in RE sources (solar and wind)

and non-renewable energy (oil and natural gas). Due to the lack of vegetation that can block the movement of air, the country is usually windy and the summer is dry and the peak daytime temperature is between 35 and 45 °C. These conditions offer deceptive prospects for solar power generation (Okonkwo et al., 2021). Qatar intends to build the Al-Kharsaag power plant based on solar PV technology with a capacity of 700 MW (Praveen et al. 2020). This project will be implemented in two phases and can be expanded to 800 MW. The first phase with the capacity of 350 MW is completed in 2021, and the second phase with the capacity in the range of 350–450 MW will be projected by 2022. The project will be based on build-own-operate-transfer (BOOT). This project is recognized as a necessary step towards attaining Qatar's RE goal. This country is among the few countries, which has invested in waste to energy solutions. This country requires fostering other policy plans, particularly those focusing on decentralized ways and corporate sourcing of RE to expand the market beyond the large-scale projects and to keep the commitment to rely more on RE in its energy mix. (RCREEE 2019). As can be seen from Fig. 2, unfortunately, the installed capacity of RE in Qatar by 2020 is only 43 MW. Five megawatts is related to PV technology, and 38 MW is related to biomass energy. By considering the high potential of this country, this amount is very small and can be increased.

Libya

Libya has one of the largest crude oil reserves in the world and is a major exporter of natural gas and OPEC oil to the world. However, since 2011, the fossil fuel sector of this country has been severely damaged by the civil war and has not yet recovered, and rising energy demand in the domestic sector is leading to increased blackouts. Libya's economy is highly related to fossil fuels and oil and gas account for 96% of total government revenue. Almost 100% of the total energy consumption and energy capacity installed in this country is related to fossil fuels (Almaktar and Shaaban 2021; RCREEE 2021). Despite the difficult political situation, Libya has a plan to open its RE market to IPPs, where lately, the RE Authority of Libya (REAOL) has established a new affiliated company, which uses public–private partnerships to permit for more reliance on dedicated investments. The updated RE strategy is also recently developed, outlining its main targets as well as the institutional framework needed under the presently difficult situation for future stability (RCREEE 2019). The Center for Solar Energy Studies (CSES) conducts investigations and research programs in the field of solar energy and promotes the usage of solar technology in Libya (Hawila et al. 2014). Solar and wind energy are the most important sources of RE in Libya. Solar PV, dry wind, and CSP can be controlled on a large scale and can even be stored or exported. Biomass potential in this country is estimated at 2 TWh per year and is thought to be proper for domestic consumption only. However, the current use of biomass in total final energy consumption in this country is 0% (Almaktar and Shaaban 2021). The amount of installed renewable capacity in Libya in 2020 is disclosed in Fig. 2. The installed capacity of RE in this country is very small. There is only the capacity of 5 MW provided by the PV technology. This number was constant for the past 9 years (see Table 4).

Saudi Arabia

The supply of basic energy needs in Saudi Arabia depends on fossil fuels, and currently, more than 80% of the total energy needs are supplied by fossil fuels in this country. Saudi Arabia is one of the richest countries in terms of RE, which has invested a lot in this field (Al-Douri et al. 2019a). Saudi Arabia is enriched by geothermal resources and related to the tectonic activity of Red Sea, volcanic rocks, and ridges (Al-Douri et al. 2019b). The latest project implemented in Saudi Arabia is solar-based water distillation projects, which are 12 prefabricated projects with a total capacity of 3100 MW (Amran et al. 2020). Saudi Arabia is one of the most attractive RE markets owing to its market size, resource potentials, land accessibility, and high energy need. The RE targets are provided by the RE Project Development Office (REPDO) of the Ministry of Energy, Industry, and Mineral Resources. REPDO has successful bids on large-scale wind and solar plans and has the most competitive energy prices worldwide. In addition to PV plans, Saudi Arabia has implemented its first CSP tool scale plan and awarded its first wind plan in 2018. Saudi Arabia has ambitious goal in this regard to achieve the largest capacity installed in the region, which this requires intensive efforts (RCREEE 2019). Saudi Arabia's largest renewable project is a solar system-based project, with a capacity of 200 GW, which is built in 2018 and will be operated in 2030 (Amran et al. 2020). Figure 2 shows the amount of installed renewable capacity in Saudi Arabia in 2020. This country is focused on solar energy and 409 MW of installed capacity in 2020 is related to solar energy. The share of PV technology is 359 MW, and the share of CSP technology is 50 MW. The capacity of 3 MW is also related to wind technology. The country was able to increase its capacity from 3 to 413 MW from 2011 to 2020, which indicates the effort to achieve the set goal (see Table 4).

Somalia

Somalia is one of the lowest energy consumers in the Arab world. This country relied on scrap wood, charcoal, and imported oil to supply its energy requirement, which

account for 82% of the total energy consumption. This country is suffered from electricity shortages in rural regions. In urban regions, such as Mogadishu, 60% of the population has access to electricity, while in smaller cities, only 23% has access to electricity (RCREEE 2021). RE is a solution to solve the problems associated with current energy shortages in this country. Based on the African Development Bank (AFDB) Group, Somalia has the highest potentials for onshore wind energy among other African countries (RCREEE 2021). More than 50% of Somalia has wind speeds of more than 6 m/s, which is excellent for generating electricity. In terms of solar energy, Somalia receives an average of 2900 to 3100 h of sunlight per year and has one of the highest daily mean of total sunlight in the world (RCREEE 2021). Figure 2 shows the amount of installed renewable capacity in Somalia in 2020. The installed capacities of this country were 23 MW for the PV technology and 4 MW for the wind technology. Unfortunately, Somalia has not been able to expand its RE and installed capacity due to lack of a detailed plan and lack of financial budget, and the capacity of this country has increased from 0 to 27 MW from 2011 to 2020.

Sudan

Ninety-two percent of Sudan's primary energy consumption is come from fossil fuels and 8% from hydropower. However, the current installed capacity is only 60% of the capacity of the hydropower plant (RCREEE 2021). RCREEE is working with the Ministry of Water Resources, Irrigation, and Electricity (MWRIE) to develop Sudan's long-term RE policy and regulations. In addition, RCREEE pays special attention to identifying, mapping, and developing secondary RE laws to expedite private sector investment. Main results of this cooperation are the development of long-term RE policies and regulations in Sudan, the development of secondary wind energy regulations to accelerate private sector investment, and creating a "one-stop shop" (OSS) for investors and developers of RE (RCREEE 2021). This country has increased its installed RE capacity to 2125 MW by 2020. Of this capacity, 1907 MW is related to the hydropower systems and only 19 MW of this capacity is related to the PV systems. This country with the capacity of 199 MW has the first rank among the Arab countries in terms of installed bioenergy capacity.

Tunisia

Tunisia is relied almost entirely on fossil fuels to supply its domestic energy requirement. About 94% of the installed capacity is related to the fossil fuels, and the rest of 6% is for RE sources (mainly hydropower and wind). Tunisia is one of the windiest countries among the Mediterranean region. Tunisia imports most of its energy requirement, despite the fact that it produces relatively little natural gas and oil. Tunisia has made significant progress in its private investment partnership policies. Tunisia has successfully introduced both auctions and competitive bids. The design of these projects allows the implementation of medium and practical projects that helped attract domestic and international investors to the Tunisian markets.

The smartly designed Tunisian net metering plan has resulted in the deployment of PV projects with small scale in different sectors. This country has the potential for attracting more investments in RE according to its generally desirable business situation. This country must focus on providing a sustainable pipeline of dedicated RE projects. Because the energy price in this country is rather high, the new plan may be further opening the power generation market to private-to-private sale of renewable power (Boubaker 2012; Nayak et al. 2021; RCREEE 2021). The amount of installed renewable capacity in Tunisia in 2020 is displayed in Fig. 2. This country has focused on three RE sources, including wind, solar, and water, which they have the installed capacities of 244, 95, and 62 MW, respectively. From 2011 to 2020, this country made good progress in the development of RE and was able to increase its capacity from 119 to 401 MW.

United Arab Emirates

In 2018, the UAE became the eighth and fifteenth largest producer of oil and natural gas in the world, respectively. The UAE also had the highest per capita energy and electricity consumption rates. Its domestic fuel use is currently dominated by national gas that supports for about 87% of its electricity generation (Eveloy and Gebreegziabher 2019). The UAE Shams Solar Power Plant, which was commissioned on March 13, 2013, and placed at the distance about 120 km from Abu Dhabi, near the city of Zayed, is one of the UAE's solar power plants with a production capacity of 100 MW. It is a centralized technology plant that is one of the largest solar power plants in the world (Eveloy and Gebreegziabher 2019). This country is leadership in attaining new records for the lowest cost of PV generation in the world. The strong support and engagement of the UAE's utilities, including the Dubai Electricity and Water Authority (DEWA) and the Abu Dhabi Electricity and Water Authority (ADEWA), were successful in developing the large-scale IPP projects. This country may require to focus on providing more options for the dedicated sector through more adoption of its RE policies (RCREEE 2019). Mohammed Bin Rashid Al Maktoum Solar Power Plant (phase 1), which was put into operation in Dubai on October 22, 2013, is other important project with the production capacity of 13 MW. This power plant has PV technology, and this power plant has 3 other phases that are under construction, and phase 4,

which is the largest phase with a capacity of 1000 MW, will be operated in 2030 (Eveloy and Gebreegziabher 2019). Due to the high potential of solar energy, the UAE has focused on solar technologies, so that 2440 MW of installed capacity is related to PV technology and 100 MW is related to CSP technology. Only, 1 MW of the installed capacities is related to the bioenergy. With a precise strategy and financial support, this country has increased its installed renewable capacity from 13 to 2541 MW during 10 years (2011–2020), which shows the careful planning of the country to increase the use of RE.

Palestine

The Palestinian energy sector relies almost entirely on energy imports. Eighty-nine percent of the total electricity supply comes from the Israeli Electricity Company, while 3% comes from Egypt and Jordan (RCREEE 2021). RE is a small part of national electricity, and only 2.63% of total electricity is produced by RE sources in this country. Solar energy can be a key energy supplier for future generations in Palestine, due to the total annual hours of sunshine of 3000 h and annual solar radiation of 5.4 kWh. In May 2019, the largest solar plant in Palestine was announced where a solar energy power station has been successfully built in Jericho, as part of the Noor Palestine's first phase. The Jericho station has a production capacity of 7.5 MW produced by 20,000 solar panels over a surface area of 100,000 m^2. In Palestine, the Palestine Energy Organization is planning to use wind energy as the main source alongside solar energy, but no real use has been made yet. The use of biomass will be a strategic source of energy for Palestine, as it has many rural areas with agriculture and trade that provide the main resources (Salah et al. 2021). The country is most focused on solar energy; the installed capacity of grid-connected PV systems is 115 MW, and the installed capacity of stand-alone PV systems is 1.83 MW in 2020. The bioenergy capacity was only 0.34 MW.

Djibouti

Djibouti's energy requirement is provided primarily by imported petroleum products and traditional biomass fuels. About 70% of Djibouti's domestic electricity consumption is through hydropower, which is imported through interconnected networks from Ethiopia. The remaining 30% of diesel fuel generation capacity is consumed locally. The production and delivery of Djibouti electricity has high cost, and the Djibouti's grid infrastructure is subject to frequent power outages owing to delays in maintenance and investment. The Djibouti's growing electricity demand is more concentrated in the capital, while remote areas have relatively little access to electricity (RCREEE 2021). RE is recognized as the practical solution for addressing the weak energy access in the country (around 42%). Governmental policies have focused on both large-scale projects and remote communities electrification through a mix of RE and non-renewables, where different small projects are usable. For the IPPs, the preferable policy plan is direct proposals, where Djibouti's Ministry of Energy signed the contract and PPA for the implementation of the wind project with the capacity of 60 MW as the first contract with IPP. The utility EDD is presently constructing the power line permitting evacuating this energy from the project site. In addition, the Ministry of Energy signed a Memorandum of Understanding for developing PV solar power plant with the capacity of 30 MW. Djibouti requires to consider more different policy options and incentives for dedicated decentralized and utility scale projects for achieving its goals (RCREEE 2019). Dabar et al. (2019) evaluated the wind resources in Djibouti for the first time and found that three wind farms could generate 1073 GWh of electricity per year. This amount is approximately equal to the average annual electricity demand expected in Djibouti in 2030. The installed capacity of RE in this country is zero.

Syria

The Syrian energy sector is highly affected by the ongoing civil war. Prior to the civil war, Syria was one of the leading producers of natural gas and oil in the region. The energy sector accounts for a quarter of government revenue. Syria faces problems in meeting domestic energy needs, such as electricity, heating, and fuel oil, leading to frequent blackouts (RCREEE 2021). Ninety-four percent of electricity generated from conventional oil and gas power plants is supplied, while 6% is supplied by hydropower (RCREEE 2021). Because the political condition in Syria is gently improving, this country has been focusing widely recently on resuming its RE plans. Syria adopted progressive measures in 2011 for attracting interests and activities in the RE sector. However, owing to the deteriorating political situation, all activities are paused. Presently, the new strategy, including updated measures, is developing, with boosted reliance on dedicated investments. In addition, great capacity building activities are taking place with support of regional and international bodies (RCREEE 2019). The installed capacity of the hydropower plant is 1490 MW, which is more than 99% of the installed renewable capacity of this country. The installed capacities of wind energy, PV technology, and bioenergy are 1, 2, and 7 MW, respectively.

Lebanon

Lebanon is relied on fossil fuel imports to supply its domestic energy requirement. Ninety-four percent of the

total primary energy consumption of this country is supplied by fossil fuels. Eighty-eight percent of the installed energy capacity is supplied from fossil fuels, and the rest of 12% is provided from renewable resources, of which 78% is hydropower (see Fig. 2) (RCREEE 2021). Lebanon is committed to decreasing its greenhouse gas emissions by at least 15% by 2030. Electricite du Liban (EDL) holds the monopoly of energy supply in this country. It is an integrated national utility accountable to the Ministry of Energy and Water (MoEW) that is responsible for policy formulation for electricity, fuel, and water sectors (Moore and Collins 2020). The National Energy Efficiency and RE Action (NEEREA) is a national financing mechanism initiated in 2010 by Lebanese Central Bank (BDL) with support from the European Union and technical assistance from LCEC. It provides incentive for RE projects through interest free and long-term loans. NEEREA supports the financing of new and existing energy efficient, RE, and sustainable building projects. It permits dedicated sector entities to apply for subsidized loans for environmentally friendly projects (Moore and Collins 2020). Lebanon's biggest accomplishment over recent years was the successful bidding process for large-scale wind projects that caused the signature of different PPAs with IPPs. The wind energy IPPs are the first authorized utility scale private generation in the electricity sector of Lebanon. This country has also continued leveraging of dedicated funds to finance the small-scale projects through different innovative financing mechanisms in collaboration among international and local banking institutions. Lebanon still needs the independent regulatory body for upscaling and operationalizing effectively dedicated sector participation in both utility scale and small-scale electricity generation (RCREEE 2019). The installed capacity of the country's RE in 2020 is 3, 253, 9, and 65 MW for wind, water, bioenergy, and PV energy, respectively. Unfortunately, the installed capacity of this country did not increase much between 2011 and 2020 and is reached from 282 to 330 MW. This indicates that the country needs careful planning in the field of RE.

Comoros

The energy situation of the Comoros is mainly related to the import of fossil fuels. The economic development of this archipelago depends entirely on energy security in terms of sustainability, availability, and cost-effectiveness. Deploying RE is essential to diversifying electricity generation as a forward-looking approach to an energy source. However, despite the high potential for RE, only 3.8% of Comoros' electricity supply comes from hydropower. Despite the good solar potential, there is no power plant. Ngazidja Island is characterized by an active "Karthala" volcano, which rises to an altitude of 2361 m. The volcano does not produce any geothermal energy, despite its estimated potential of 10 MW. There is no specific policy in the Comoros that would motivate the development of RE. This is due to the fact that the economic situation of this country is not suitable for investment. In addition, the frequent political instabilities hinder foreign investment. The lack of accurate statistical data also prevents the determination of the renewable energy roadmap in this country (Praene et al. 2021). The amount of installed renewable capacity in Comoros in 2020 is shown in Fig. 2. It can be seen that the installed renewable capacity is only 1 MW in this country.

Actions taken by Arab countries in field of renewable energy

Global energy demand, CO_2 emissions related to energy consumption, and energy consumption have decreased by 5%, 7%, and 18%, respectively. The estimated 8% drop in oil demand and 7% in coal use contrast sharply with a slight increase in the share of RE. The long-term contracts, preference accessibility to the grid, and ongoing installation of new power plants indicate substantial growth in renewable electricity. The decrease in natural gas demand is about 3%, while global electricity demand has decreased by a relatively average of 2% per year (IEA 2020b). While the growth of renewable capacity in the last decade has been greater than the new capacity installed in fossil fuels, the progress of heating and cooling in renewable sources is still far behind the existing potential, especially in the industrial sector. Heating and cooling are very important for reducing carbon because they account for almost 50% of the total final energy consumption worldwide, and the industrial sector accounts for 75% of heating and cooling (Murdock et al. 2019). For the first time, the Arab regional capacity of the solar energy has exceeded the capacity of the wind. This indicates enormous potential of solar energy in the Arab region that has one of the highest levels of solar radiation in the world (RCREEE 2019). Activities designed to implement the Pan-Arab 2030 RE Strategy, approved by the Arab Economic and Social Development Summit in January 2013, include training courses in Spain in 2014 and 2016 and the partnership between the League of Arab States (LAS), the Regional Center for RE and Energy Efficiency, the Euro-Arab Foundation, the United Nations Economic and Social Commission for Western Asia (ESCWA), and the German Agency for International Cooperation (GIZ) (RCREEE 2021). The first 5-day training workshop entitled "Design and Implementation of RE Action Plans" aimed at successfully designing and implementing National RE Programs (NREAPs) was held in December 2014 in Spain. This workshop introduced the concepts of planning, implementing, monitoring, and evaluating actions and tools related to NREAP. In collaboration with the GIZ, experiences and best

practices based on RE Europe action plans were presented and analyzed (RCREEE 2021). The second 5-day training workshop entitled "Smart Grids and Integration of RE projects" was held in April 2016. The aim of this workshop was creating knowledge and sharing experiences of RE projects for integration in smart grids and smart grid applications. This workshop provided a great opportunity to share the experiences of Europeans, related to increasing the share of RE and the basic elements for monitoring, sending, and controlling decentralized production and its impact on network performance and sustainability. This program also aimed to provide in-depth operations and practical knowledge to participants by organizing two technical visits to the Network Control Center in Malaga and Seville (RCREEE 2021). The report of Arab Future Energy Index (AFEX) was the first Arab index devoted to monitoring and analyzing sustainable energy competition in the Arab region. This report provided the quantitative and qualitative analysis of major RE markets and energy efficiency. Initially, this report was presented by the Regional Center for RE and Energy Efficiency (RCREEE) as a benchmark report in 2013 and it ranked and analyzed the Arab countries based on 28 indicators including four groups. These groups were the financial and investment status, market structures, policy frameworks, and institutional capacities. RCREEE launched the third major edition of the Arab Future Energy Index (AFEX) in 2016 in collaboration with the United Nations Development Program (UNDP) and the Arab Climate Resilience Initiative (ACRI). The evaluation is according to the compilation and analysis of accurate and country-specific data based on a set of predefined indicators (Aldabesh et al. 2021; RCREEE 2021).

For the first time, RE capacities exceeded 3000 MW in 2016 in Arab region. This showed that politics is gradually becoming more interested in increasing sustainable energy transfers. Most countries now have detailed plans for RE expansion, such as initial rates, inflation measurement, competitive offers, and direct offers (RCREEE 2021). The following activities about RE are also conducted by the Arab countries:

- Morocco, Jordan, Egypt, UAE, Palestine, and Algeria lead competitive Arab RE markets and investment space for project development.
- Tunisia and Lebanon have successfully used small-scale investment with pioneering financial solutions dedicated to RE and energy efficiency.
- Sudan and Mauritania have high RE production capacity stocks, such as hydropower.
- Saudi Arabia, Bahrain, Kuwait, Iraq, Qatar, and Oman have taken encouraging steps to facilitate the RE production in their energy basket.
- Yemen's residential and commercial sectors have resorted to solar PV solutions to address the vulnerable energy situation posed by current political challenges.
- In 2016, for the first time, the installed capacity of (non-electricity) RE exceeded 3000 MW in the Arab region. They have also targeted the plans to have more than 80,000 MW by 2030.
- The Arab region is starting to visit outstanding solar and wind plans around the world with very competitive electricity prices, particularly in the UAE, Morocco, and Egypt.
- Many Arab countries have skills, human resource potentials, and industrial bases, which can be adapted locally and regionally for the growth of renewable sectors.
- Scattered generation is accelerating in the Arab region, including in least developed countries seeking to extend access to energy for the poor, e.g., Djibouti, Mauritania, Sudan, and Yemen. However, middle-income countries are focused on large scales and useful projects.
- In Algeria and Egypt, a number of small and medium-scale PV plants were put into operation in 2015 under tariff plans fed of these countries.
- Ten countries, including most oil-rich Gulf States, have approved energy subsidy reforms.
- Almost all Arab countries now support some form of private participation in electricity generation and have enacted laws to allow IPPs.
- Uncertainty over the readiness of grid infrastructure to absorb RE and grid access conditions remain a significant challenge for further RE expansion in the Arab region. However, seven countries at present are developing grid codes for RE plans.

By the end of 2018, the total installed capacity of new RE systems (excluding hydropower plants) in Arab countries exceeded 7 GW, which is more than double the capacity recorded in the previous two years (RCREEE 2019). The Arab Water Council, UNDP, and the Arab League, in cooperation with stakeholders, organized an online version of the regional dialogue "Towards an Integrated Climate Security Program for the Arab Region" on December 6–8, 2020. This dialogue brought together stakeholders to discuss about the operational challenges related to current climate security frameworks. In addition, the online chat encouraged the involvement of all stakeholders to help for developing a "Regional Strategic Policy Framework" for the successful integration of climate security into policy-making throughout the Arab world. After organizing various certification courses in Egypt, Jordan, Libya, Syria, and Lebanon, RCREEE, in cooperation with the Arab League, invited all Arab industrial, service, and commercial institutions and those interested in the energy management market to register for Pan Arab Certified Energy Management Professionals program (PA-CEMP). PA-CEMP program is an in-depth professional certification program for energy managers. This program is designed for the Arab region. PA-CEMP was

approved by the Executive Bureau of the Arab Ministerial Council of Electricity during its 32nd meeting on May 31, 2016. PA-CEMP has a target for cooperation with organizations and program managers in planning and implementing programs and taking the necessary steps for the energy efficiency in the Arab region. It has also a plan to equip individuals and professionals with the recent technologies, essential energy supplies, and effective tools with solutions to decrease energy consumption in an affordable approach (RCREEE 2021).

Despite economic uncertainty, investors' interest in RE remains. From January to October 2020, the renewable capacity was increased 15% as compared with that at the same period last year, which is a new record. In the meantime, the stocks of renewable equipment manufacturers and developers of publicly listed projects outperformed most major stock market indicators and the overall energy sector. This is due to the expectations of healthy growth in trade and finance in the medium term. In October 2020, the value of shares of solar companies worldwide has more than doubled since December 2019 (Kent 2018).

Algeria's economy is heavily related to the fossil fuel market, where 93.6% of its exports are mainly oil and natural gas. Over the past decade, the market price of crude oil has fallen sharply, and to this day its price is yet fluctuating that has highly affected the national economy. As a result, the transition to RE and technology development has become an essential goal for the Algerian government. Algeria has a target to transition to a green economy that is an inimitable way to supply future energy requirement while reducing environmental risks. Algeria is characterized by abundant RE sources such as solar, wind, hydropower, biomass, and geothermal energy. The installed capacities of both photovoltaic and wind power plants were 0.354 GW in June 2018 (Bouraiou et al. 2020). The UAE has added projects with capacity of 1.5 GW to its electricity capacity. Finally, the capacity of Arab countries for the production of RE is increased 100% during only 2 years (2017 to 2018) (RCREEE 2019).

Strategies of Arab countries in field of renewable energy until 2030

Rapid action is needed to achieve the ambitiously RE goals set by Arab countries for 2030. The tenfold increase in the installed capacities of solar and wind energy in the Arab region over the past decade and the doubling of capacities in just the last 2 years are signs of the region's determination in this regard. Seven countries in the Arab region account for 90% of the region's current capacity, with Egypt and Morocco accounting for almost half, followed by Jordan, the UAE, Algeria, Tunisia, and Sudan. Jordan has the highest per capita rate of RE installations, while Yemen has made great strides in the midst of the crisis through emergency development interventions (RCREEE 2019). Other countries in the Arab region are expected to increase their capacity in the short term. Currently, every country in the Arab region has RE facilities, while in 2008, only four countries in the Arab region had renewable facilities. Countries can be sorted in terms of progress in creating possible conditions for renewable investments. Egypt, Jordan, and Morocco are placed as the top three countries in this regard, and this is followed by the UAE, Tunisia, Algeria, Palestine, and Saudi Arabia (RCREEE 2019). The Arab RE Framework (AREF) is a guideline for Arab countries to develop their National RE Action Plans (NREAPs) by 2030 based on a custom template and progress reports. Five Arab countries, including Bahrain, Lebanon, Tunisia, Palestinian, and Sudan, have taken the lead and have consolidated/drafted the national plan according to those documents (RCREEE 2019).

The promotion of RE development in Arab countries needs additional reforms based on the following points:

- Improving the needed conditions for the implementation of Arab countries RE programs
- Supporting national authorities in the review and institutional elaboration of desirable regulatory and implementation of sustainable energy policies
- Contributing facilitate medium and long-term dedicated investments in RE
- Reinforcing the technical capabilities of the institutions and organizations in the RE field

The strategies of Arab countries in field of RE until 2030 are summarized as follows:

Algeria The Algeria government has a target to achieve 27% of electricity generated from RE by 2030 according to the strategy of the National RE and Energy Efficiency Program 2030. By focusing on solar energy and increasing its PV production capacity to 13,575 MW, this country intends to meet more than half of its target from PV technology.

Comoros Unfortunately, Comoros has not provided a detailed plan for RE, setting only ambitious goals of 43% of electricity capacity by 2030 and 100% by 2050 without any plans or strategies.

Djibouti Djibouti plans to use 100% of the country's renewable resources in an ambitious goal by 2035. This country intends to focus on geothermal energy and generate 500 MW of electricity from this energy, which is the highest goal for the use of geothermal energy among the Arab countries.

Egypt The aim of the Egypt government is to diversify energy basket in favor of RE sources. Based on the National RE Strategy 2020, approved in 2008 and updated in 2012, Egypt's solar plan aims to achieve 20% of electricity generated from RE by 2022 (see Table 9) and has set a target of achieving 42% of electricity generated from RE by 2035. This country aims to generate 54,000 MW of its electricity in 2035 by RE sources with more focus on solar and wind energy. A total of 17,300 MW, 11,100 MW, and 21,000 MW will be generated by PV, CSP, and wind technologies, respectively. In addition, with the aim of generating 4700 MW of electricity from bioenergy, this country has the highest goal of generating electricity from the renewable sources among the Arab countries. In addition, the cumulative energy efficiency targets for 5% improvement in energy efficiency as well as a national energy action plan have been set and approved (RCREEE 2021).

Libya The Libya government is trying to diversify its energy basket and use the country's solar and wind power. Libya has set a target of 10% by 2025 (see Table 9), and until 2030, it will supply 22% of electricity production through RE. A total of 3350 MW, 400 MW, and 850 MW will be generated by PV, CSP, and wind technologies, respectively. Libya is also in the process of fulfilling its National Energy Action Plan (RCREEE 2021).

Mauritania Mauritanian's latest goal is for 2020, and it has been able to produce more than its target, indicating the country's persistence in using RE. However, this country still has not specified a goal for 2030.

Morocco In Morocco, the wind energy proposals are evaluated by the National Office of Electricity and Drinking Water (ONEE), while the solar energy proposals are evaluated by the Moroccan Agency for Solar Energy (MASEN) evaluates (RCREEE 2019). In 2009, Morocco announced a target to supply 42% of electricity from renewable sources by 2030. During 21st Conference of the Parties (COP21) in Paris in 2015, this goal boosted to 52%, which is now expected to be reached 5 years earlier. In fact, this country has decided to increase its share of RE to 60–65% and generate 10,090 MW of its electricity by renewable sources in 2030 (Boulakhbar et al. 2020). The government also seeks to reduce energy consumption by 20% by 2030 (RCREEE 2021).

Sudan Sudan is working to further integrate RE sources with the goal of generating 50% of its electricity from RE by 2031, excluding hydro. In addition, Sudan energy policy is updated, and based on the Study of Sudan RE Action Plan 2018, the country will generate about 11% of its energy from renewable sources by 2031. This country has decided to produce 1,602 MW of its electricity with wind and solar energy resources. It is one of the few countries that has a plan for geothermal energy and intends to produce 54 MW of this energy. Sudan also adopted a National Energy Action Plan in 2013 (RCREEE 2021).

Tunisia On November 22, 2016, Tunisia announced the Tunisia 2030 RE Action Plan. By considering a number of energy investigations and owing to the lack of a single energy strategy, the Ministry of Energy, Mines, and RE provided a new plan and strategy. The goal of this strategy is to strengthen national fossil resources and RE sources. This strategy is provided to improve energy intensity by 3% per year during 2016 to 2030. This strategy is also aimed at saving 17% of energy during the period 2016 to 2020. In addition, the project aims to generate 30% of Tunisia's electricity from RE resources in 2030 by installing 1 GW in the first phase (2017 to 2020) and 1.25 GW in the second phase (2021 to 2030) (RCREEE 2021). As can be seen in Table 9, Tunisia has mostly focused on the PV development with a production capacity of 1510 MW and wind energy with a production capacity of 1755 MW. It has also targets to produce 100% electricity from renewable resources by 2050 (see Table 9).

Bahrain Bahrain launched its National RE Action Plan in 2017. Of generation capacity, 700 MW will be achieved by employing solar, wind, and energy from waste projects by 2035. This country has a target to bring online 255 MW of PV capacity by 2025 employing net metering, 100 MW IPP PV tender, and the RE mandate for new buildings. Recently, the sustainable energy unit of this country with the help of the United Nations Development Program launched 3 MW tender for solar arrays at eight sites containing 66 government buildings (RCREEE 2019). Bahrain intends to focus on solar energy by 2025, supplying 200 MW of the specified capacity from the sun. This country has also decided to double the solar energy capacity by 2035 and increase the wind capacity to 300 MW.

Iraq Iraq suffers from severe electricity shortages due to lack of production capacity and increased energy demand. The government intends to increase production by generating natural gas and RE facilities. Iraq plans to supply 2.24 GW of electricity through RE by 2025. Iraq established its first National Energy Action Plan in 2013 (RCREEE 2021).

Jordan Jordan government plans to increase electricity generation capacity from renewable sources to 3.22 GW (15% of total energy) by 2025. This is done by focusing on solar energy and a production capacity of 2500 MW of PV systems. Jordan's strategy has target to decrease energy consumption by 18% by 2030 and increase electricity generation capacity from renewable sources by 30% (see Table 9)

Table 9 RE targets of Arab countries until 2030 and 2050 (Abed et al. 2014; Abu-Rumman et al. 2020; Alnaser et al. 2004; Amran et al. 2020; Boulakhbar et al. 2020; Bouraiou et al. 2020; Kent 2018; Praveen et al. 2020; RCREEE 2019 and 2021; Almaktar and Shaaban 2021)

Country	RE strategy/action/program	Renewable capacity target							Target date
		Wind (MW)	PV (MW)	CSP (MW)	Biomass (MW)	Geothermal (MW)	Total		
							(MW)	%	
Algeria	National Program for RE and Energy Efficiency 2030	5010	13,575	2000	1000	15	21,600	27	2030
Comoros	–	–	–	–	–	–	–	43	2030
	–	–	–	–	–	–	–	100	2050
Djibouti	National Program for Development of RE and Energy Efficiency	300	200		–	–	1000	100	2035
Egypt	National RE Strategy 2020 adopted in 2008, updated in 2012; Egyptian Solar Plan	7200	At least 2300	–	–	–	9500	20	2022
	SE Action Plan for the Power Sector (2018)	21,000	17,300	11,100	4700	–	–	42	2035
Libya	Libya RE strategic plan 2013–2025	1000	840	400	–	–	2240	10	2025
	Strategic Plan for Renewable Energies 2018–2030	850	3350	400	–	–	4600	22	2030
Mauritania	Update Target of the Ministry of Oil, Energy and Minerals	30	30	–	–	–	60	60	2020
Morocco	Moroccan Solar Plan 2030. Morocco INDC submission to CoP 21	4200	4560		–	–	10,090	60–65	2030
Sudan	–	–	–	–	–	–	5300	50	2031
	Sudan Energy Policy Paper — Updated 2018 Sudan's RE Action Plan Study	680	750	50	68	54	1602	11	2031
Tunisia	National RE Action Plan 2018	1755	1510	450	100	–	–	30	2030
	–	–	–	–	–	–	–	100	2050
Bahrain	National Energy Action Plan (NREAP) adopted in 2017	50	200		5	–	–	2	2025
		300	400		10	–	–	10.3	2035
Iraq	PV Solar Plan 2017–2020b and the Ministry of Electricity		2240	–	–	–	2240		2025
Jordan	Master Strategy for Energy Sector 2015–2025	670	2500	–-	50	–	–	15	2025
		–	–	–	–	–	–	–	2030
Kuwait	Kuwait Energy Security Vision	–	–	–	–	–	4266	15	2030

Table 9 (continued)

Country	RE strategy/action/program	Renewable capacity target							Target date
		Wind (MW)	PV (MW)	CSP (MW)	Biomass (MW)	Geothermal (MW)	Total		
							(MW)	%	
Lebanon	Prime Minister decision	–	–	–	–	–	–	30	2030
	–	–	–	–	–	–	–	–	2050
Oman	–	–	2250	600	100	–	3100		2030
Palestine	National Energy Strategy (2012–2020); Palestinian Solar Initiative	50	400	–	50	–	500	7.1	2030
Qatar	NEEAP 2018	50	400	–	50	–	500	25	2030
	Qatar Vision 2030	–	–	–	–	–	1800	20	2030
Saudi Arabia	REPDO RE Plan 2019	7000	20,000	300	–	–	27,300	–	–
	Saudi Arabia's RE Strategy	16,000	40,000	2700	–	–	58,700	30	2030
Syria	The 11th Five-Year Plan for 2011–2015	1000	2000	1300	250	–	4550	30	2030
United Arab Emirates		300	18,900	6000	600		30,000		2030
	UAE 2050 Energy Strategy	–	–	–	–	–	–	44	2050
Yemen	National RE and EE Strategy adopted in 2009	400	8.25	100	6	200	714.25	15	2025
	–	–	–	–	–	–	–	100	2050

(RCREEE 2021). Production RE resources, such as abundant solar, wind, and biomass resources, increase economic growth and reduce pollution. RE policy with ambitious $20 billion plans as well as its strategy to improve energy efficiency creates future opportunities for investors. In Jordan, the Ministry of Energy and Mineral Resources is responsible to issue permits for tenders and evaluate bids for RE plants (RCREEE 2019).

Kuwait Kuwait government intends to increase the energy production capacity in the coming decades. Most of the recent planned capacity comes from natural gas or oil. However, the government also plans to supply 15% of its electricity from renewable sources in 2030, by increasing its RE capacity to 42,266 MW. These goals must be achieved by using the potential of wind and solar energy in this country. A key project that will help Kuwait to achieve its goal is the second phase of Dabdaba solar energy project with the capacity of 1500 MW. It is expected that this project engages the private sector in exploitation-related business activities and creates more job opportunities. Kuwait National Oil Company is leading the project with the aim of replacing the need for 5.2 million barrels of oil per year and reducing carbon emissions by 1.3 million tons per year. It is scheduled that this project will be completed by February 2021 (RCREEE 2019). Kuwait has also set energy efficiency goals to decrease energy consumption by 10% in the residential and industrial sectors, as well as to enhance electricity production efficiency by 5% in the service sector (RCREEE 2021).

Lebanon Lebanon still suffers from disruptions in energy imports as well as sustainable electricity. The first milestone for the development of RE in this country came in 2010 when the MoEW committed to the Policy Paper for the Electricity Sector (PPES) for launching, supporting, and reinforcing public, private, and individual initiatives to adopt RE. MoEW is also committed to reach 12% of electric and thermal supply from RE by 2020 (Moore and Collins 2020). NREAP in Lebanon was officially approved in 2017. Lebanon plans to supply 30% of its electricity through renewable sources by 2030. Lebanon established its second national energy action plan in 2016. The goal of this plan was to save 5% of Lebanon's total electricity demand by 2020 (RCREEE 2021). In addition, generation of 100% electricity from RE by 2050 is also one of the country's goals (see Table 9).

Oman According to the strategy adopted by the government of this country, Oman intends to increase its RE capacity, with the focus on solar energy, by 2030 to produce 3100 MW of its electricity from RE.

Palestine NREAP of Palestine proposes the target of 500 MW for 2030. Energy produced by the renewable resources is about 7.1% of the projected final electricity consumption in 2030. Eighty percent of the target must be met by PV system, 10% by wind systems, and 10% by biogas/biomass systems.

Qatar Qatar has two strategies for the goal of generating electricity from RE by 2030. The focus of this goal is on solar energy, and 400 MW of the total target is supplied by the PV technology. The capacity of the total target is 500 MW. The goal set in the National Energy Action Plan 2018 is to generate 25% of electricity from RE, and based on Qatar vision strategy, 20% of electricity should be supplied from RE sources by 2030 (see Table 9).

Saudi Arabia According to the REPDO RE Plan 2019, Saudi Arabia plans to generate 27,300 MW of RE by 2023, focusing on solar energy and the development of PV technology, of which 7000 MW by wind, 20,000 MW by PV technology, and 300 MW by CSP. According to Saudi Arabia's RE Strategy, the country has set an ambitious target of 58,700 MW, which is 30% of total electricity generation, by 2030. This is the highest target among Arab countries. This strategy also focuses on wind and solar energy, and the largest capacity is related to PV technology with the aim of generating 40,000 MW of electricity (Barhoumi et al. 2020).

Syria Syria plans to generate 30% (4550 MW) of electricity from RE by 2030. The share of wind energy is 1000 MW, PV technology is 2000 MW, CSP is 1300 MW, and biomass is 250 MW.

UAE The UAE has set a target of 30,000 MW of electricity from RE by 2030, according to which 300 MW of electricity will be generated from wind energy, 18,900 MW from photovoltaic technology, 6,000 MW from CSP, and 600 MW from biomass. The country has also set a target of generating 44% of its electricity from RE sources by 2050, according to the UAE 2050 energy strategy.

Yemen According to the RE and EE National Strategy adopted in 2009, Yemen aims to generate 15% of electricity from renewable sources by producing 714.25 MW of RE, by 2025. It has also set a 100% target by 2050.

Finally, according to the announced goals, by 2035, Arab region will have an operating capacity of more than 190 GW.

The most ambitious goal is for Djibouti, which aims to achieve 100% of energy from renewable resources. The second ambitious target is for Morocco, which intends to use 60–65% of its renewable capacity. Saudi Arabia also has an ambitious target of 59 GW (30% of energy), which makes it the highest target in terms of installation capacity among Arab countries, followed by Egypt with 54 GW (see Table 9). Most of Arab countries focus on solar and wind energy, and very little attention is paid to geothermal and biomass energy.

Markets of Arab countries

The global market response to new opportunities has been strong, indicating a great potential for continued growth of RE (Pieter 2018). Countries in the Arab region have increased their ambitions for RE capacity from 6.2 to 190 GW by 2030. As mentioned before, the most ambitious program is shown by the Djibouti, which intends to supply 100% of the energy needs with RE by 2035 (RCREEE 2019). All Arab countries have opened or are opening their markets for private investment. Like Masdar in the UAE and Masen/SIE in Morocco, SKTM in Algeria and more recently Libya, Morocco, Jordan, Egypt, the UAE, Saudi Arabia, and Algeria are leading competitive Arab markets. International budget institutions are also active in the Arab region (WB, KFW, AFDB, EIB, IFC, EBRD, JICA, etc.) (Kent 2018). In countries such as Egypt, Tunisia, and Lebanon, increasing private sector investment in RE projects is seen as a sign of improving public investment conditions. In Lebanon, the first projects are three wind projects with the capacity more than 200 MW. This is a historic milestone as the projects move more towards solar PV technology and then wind. This region has outstanding solar and wind projects around the world (RCREEE 2019). Electricity prices are very competitive, especially in Saudi Arabia, the UAE, Morocco, and Egypt. Such prices, due to their excellent sources of solar and wind energy, encourage investment in the renewable sector. Jordan, Tunisia, Palestine, and Lebanon use decentralized investment with pioneering financial solutions (RCREEE 2019). The 20 major PV markets are projected to account for 83% of new global demand by 2023. Egypt and Saudi Arabia are among the fastest movers. The market response to the RE trade in the Arab region has been very positive, which indicates the market's trust in the region's wide RE potentials and investment space (RCREEE 2019).

Conclusion and policy implications

In this manuscript, the capacity and strategies of RE production by 22 Arab countries were investigated using available data until 2030. For the RE transition in Arab

countries, the governments should adopt policies that encourage the adoption and investment of RE technologies at the corporate and consumer levels. The solar and wind energy are the most practical RE in Arab countries. From the current projects, it is clear that PV technology is the most optional use of RE. However, it is obvious that centralized solar power plants with thermal energy storage systems may also be the good option in Arab countries because these power plants can provide a constant power to the grid. Newer centralized solar energy technologies show lower installation costs and can be a promising alternative to using solar energy in Arab countries. It is also necessary to prepare solar atlases in which normal direct radiation and global horizontal radiation are measured in the Arab region to study the criteria for the use of CSP and CPV technology. For example, it seems that the desert region of Iraq has more radiation than other regions. On the other hand, wind energy production is more appropriate in certain areas of Oman, Kuwait, and Saudi Arabia. Geothermal and hydroelectric technologies also need further investigation in Arab countries. Arab countries in some regions, such as Saudi Arabia and the Comoros, have a high geothermal potential that is suitable for electricity generation. However, due to the high initial costs and absence of national incentives, this energy is not used and is considered only for tourism and hot springs. In addition, Arab countries are among the largest producers of waste and can use this waste to generate electricity and heat, but unfortunately, not much attention is paid to this sector and waste is left in nature and increases environmental pollution. In recent decades, as drought has increased, the supply of freshwater has become very important for Arab regions, and the construction of solar water desalination plants has become one of the priorities, which should be given more attention.

In general, Arab countries have rich sources of RE and, in recent years, with decreasing fossil fuels reserves and increasing pollution and drought, these countries tend to use more RE. Shafiee and Topal (2009) conducted a study and approximated the time of depletion of fossil fuel reserves in 2040, 2112, and 2042 for oil, coal, and gas, respectively. However, they have not yet been able to make significant progress in this regards and use the abundant renewable resources of their regions. The reasons for the lack of progress are:

- First, subsidies are paid for energy prices in these countries and as a result, investing in RE will not be profitable and there is no incentive to employ RE. In Europe, for example, there are tax incentives. However, in Arab countries, there are no tax incentives.
- The high initial cost for construction of the renewable power plants is another reason for this lack of progress.

Arab countries must implement appropriate policies and regulations and create more incentives. The Arab countries must diversify their energy sources and include more RE in their energy mix. To attain this goal, policymakers must address challenges in general, both in terms of reform and strategy, at the social and political levels. The collective success of Arab countries in adopting RE is a good sample for other developing countries. In conclusion, to improve the situation, most Arab countries need technical support for the following actions:

- Assessing RE resource base and existing technologies
- Developing sufficient institutional and human capacities, as well as financial resources, to perform national RE planning and implementation
- Articulating a national RE strategy, which includes clear and realistic RE goals for the following: (a) electricity production; (b) specific sectors within the energy system such as heating and cooling; and (c) specific technologies
- Implementing medium- to large-scale, as well as distributed RE projects, for developing institutional and human capacities in the country and for acquiring the practical knowledge required for wide-scale deployment
- Adopting the set of financial and fiscal incentives for overcoming economic barriers to RE deployment and encouraging dedicated sector participation
- Putting in place the required regulations to ensure access to the market for RE developers
- Creating codes and standards for RE technologies, as well as certification programs for RE installers and equipment manufacturers
- Assessing the readiness of the grid infrastructure for transmission and distribution of renewable power to the end-consumer and for putting in place plans to enhance the infrastructure, as needed

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Declarations

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