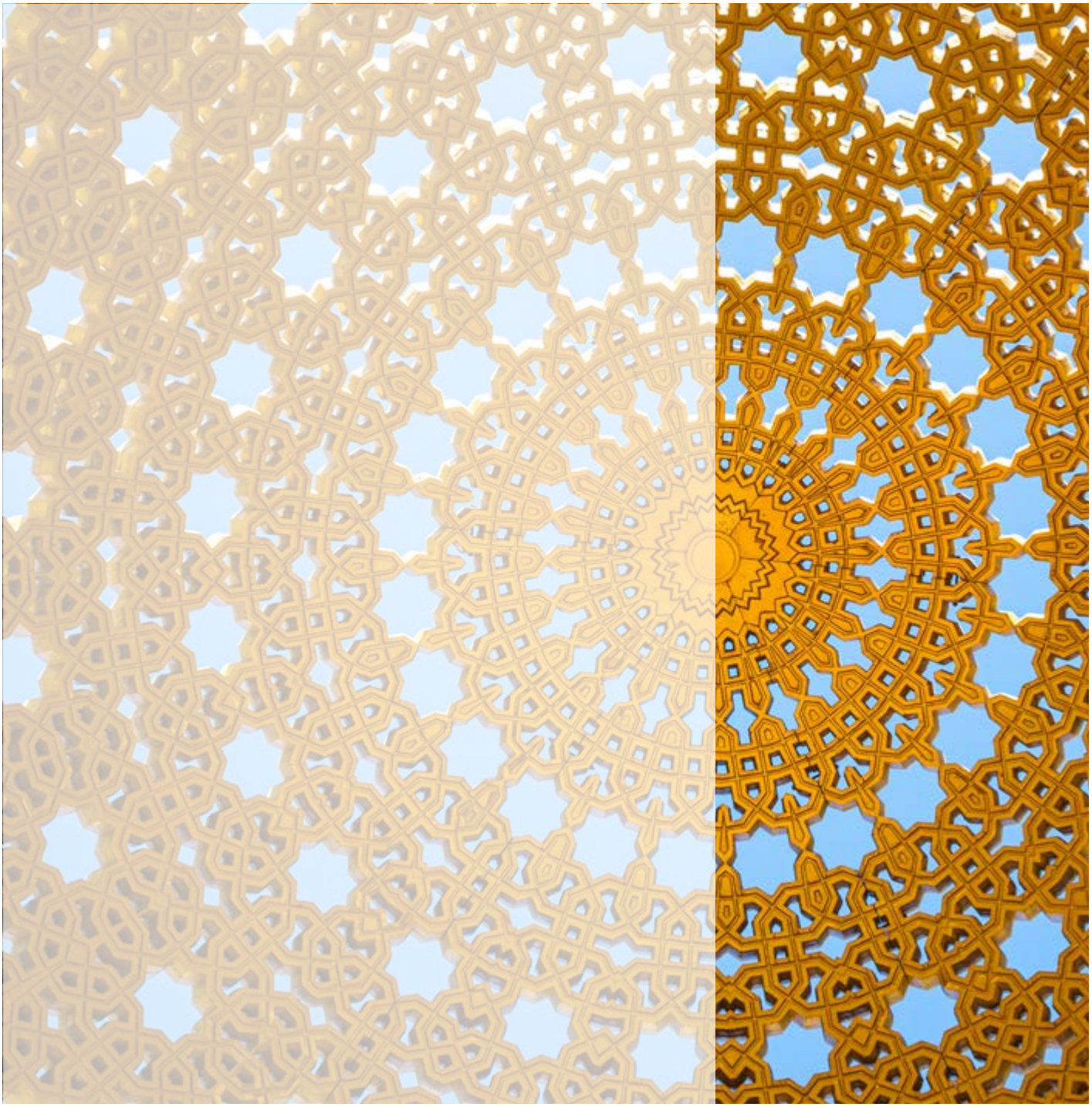
IRENA
International Renewable Energy Agency

RENEWABLE ENERGY MARKETS

GCC 2023



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ABOUT IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation; a centre of excellence; a repository of policy, technology, resource and financial knowledge; and a driver of action on the ground to advance the transformation of the global energy system. An intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy and geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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DISCLAIMER

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This report was developed under the overall guidance of Rabia Ferroukhi (ex-IRENA) and Ute Collier (Acting Director, IRENA Knowledge, Policy and Finance Centre) and was authored by Laura El-Katiri, Arslan Khalid (consultants), Emanuele Bianco, Mirjam Reiner, Diala Hawila and Hannah Sofia Guinto (IRENA), jointly with Robin Mills and Maryam Salman (Qamar Energy; Chapter 4) as well as Alejandro Longeira and Miguel Barbosa (Roland Berger; Chapter 5), and relying on substantive inputs from Nazik Elhassan, Michael Taylor, Na Hee Lee, Imen Gherboudj and Sibghat Ullah (IRENA).

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FOREWORD

This month, energy, climate and development champions from around the world gather at COP28 in the United Arab Emirates (UAE) to discuss how to avert the global climate crisis. In our *World Energy Transitions Outlook* we have shown that there is a need to radically transform the way we produce and use energy. Together with the COP28 Presidency, we have called for a tripling of global renewable power capacity and a doubling of energy efficiency by 2030 to swiftly reduce greenhouse gas emissions.

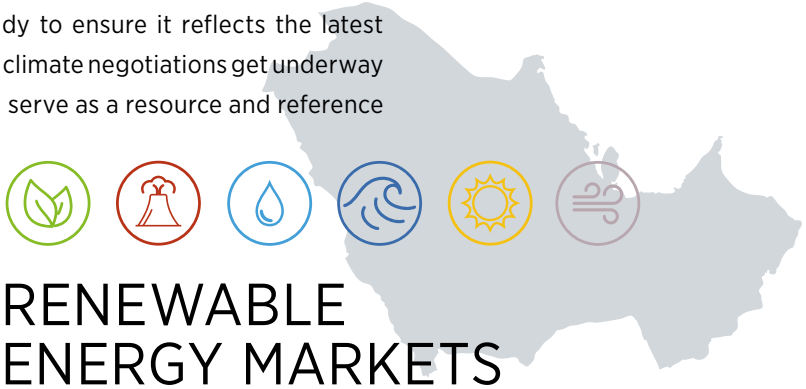
The UAE and fellow countries of the Gulf Cooperation Council (GCC) owe their economic development and prosperity to fossil fuels. At the same time, they are highly vulnerable to climate change and have recognised that change is needed. Recently, we have seen increasingly ambitious renewable energy targets across the region, as well as net-zero targets in five out of six GCC states.

This report, which updates IRENA's 2019 analysis, provides a broad overview of drivers and developments in the renewable energy sector across the region. It highlights how the region's renewable power capacity has increased rapidly to more than 5.6 gigawatts in 2022 from close to zero only a decade earlier. However, renewables still only account for a negligible amount of the region's total electricity generation capacity, while end-uses continue to rely on fossil fuels. More action to translate ambitious targets into delivery on the ground is therefore needed.

As GCC countries develop increasingly ambitious renewable energy and hydrogen strategies, and pursue the implementation of net-zero commitments, momentum in the region will continue to build. Renewables are now cost-effective, with highly successful auction rounds in Saudi Arabia and the UAE in the past ten years resulting in world-record-low prices for solar photovoltaic (PV) and concentrated solar power (CSP), boosting the economic case for their adoption and paving the way for the introduction of high shares of renewables in the electricity mix. Further sustained action is therefore needed to translate ambitious targets into delivery on the ground.

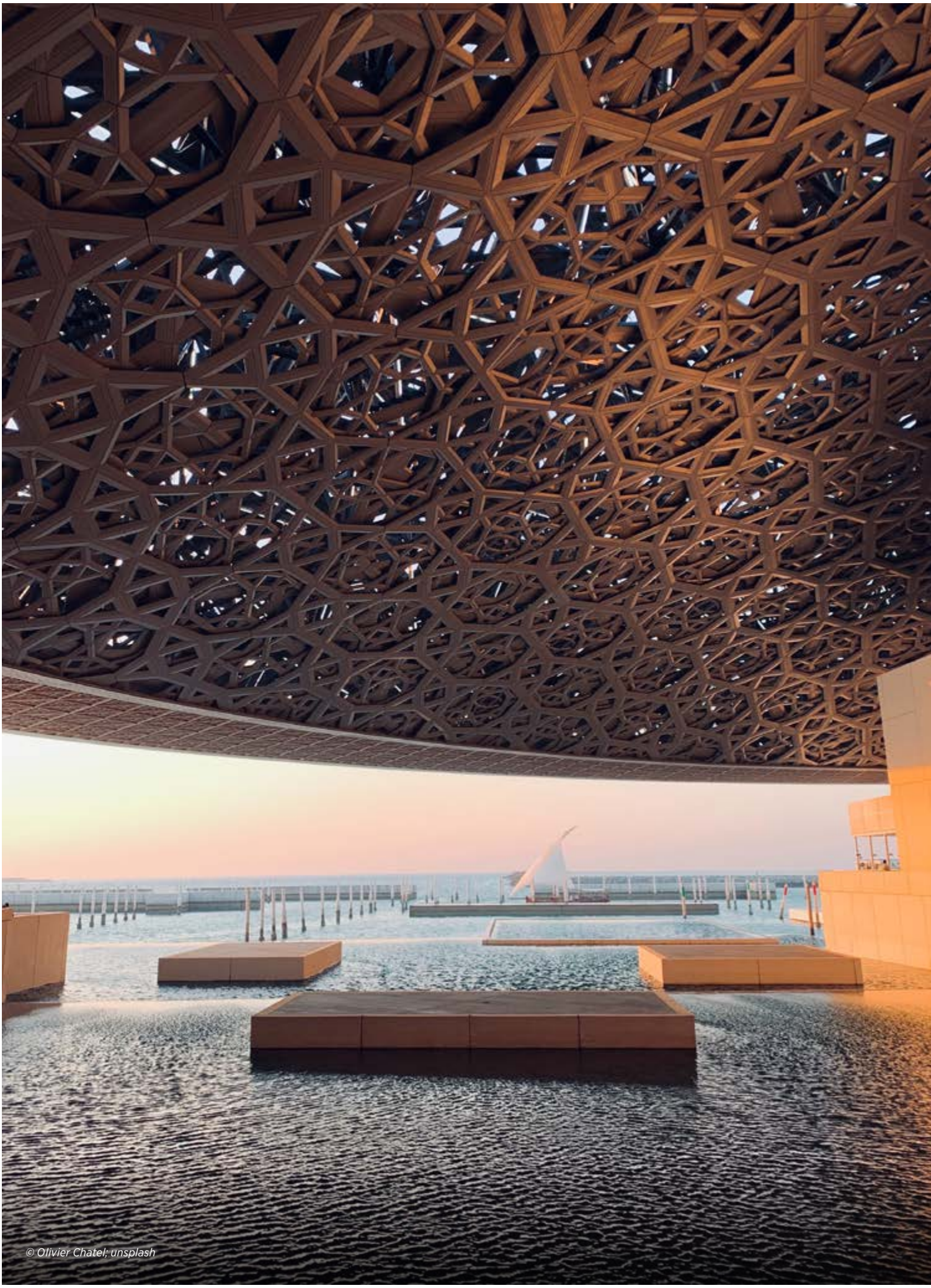
I wish to thank the GCC states for their cooperation and support for the work of IRENA, and for their engagement in the production of this study to ensure it reflects the latest developments in the region's renewable energy sector. As climate negotiations get underway in the heart of the GCC, it is my hope that this report will serve as a resource and reference point for policy makers, businesses and civil society in harnessing the region's vast renewable resource potential, ingenuity and capacity in support of our common ambition to secure a more sustainable future in the years to come.

Francesco La Camera
Director-General
IRENA



RENEWABLE ENERGY MARKETS

THE GCC REGION



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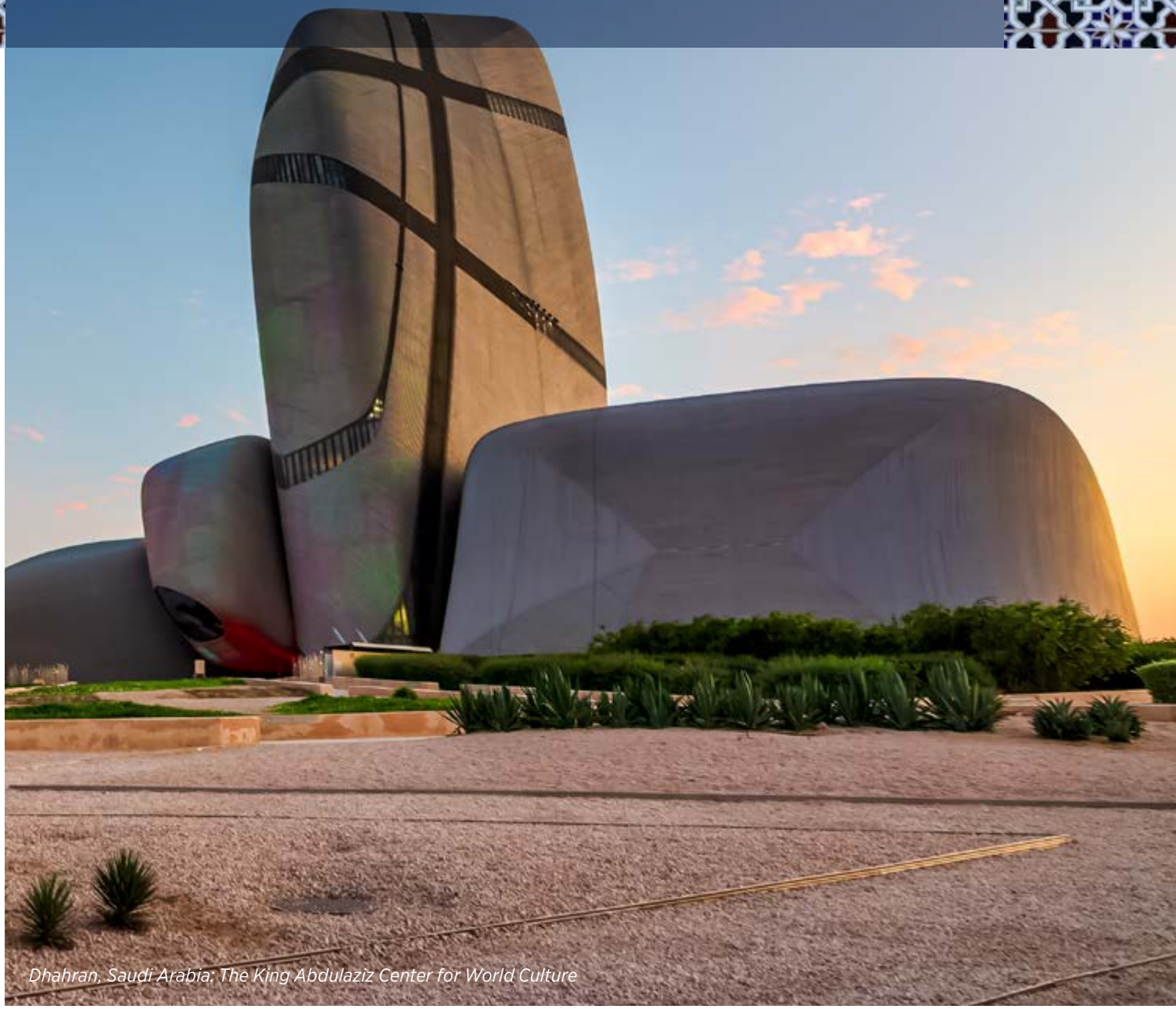
ABBREVIATIONS

AC	alternating current
ADGM	Abu Dhabi Global Markets
ADIA	Abu Dhabi Investment Authority
ADIB	Abu Dhabi Islamic Bank
ADNOC	Abu Dhabi National Oil Company
ADWEC	Abu Dhabi Water and Electricity Company
AED	UAE dirhams
AI	artificial intelligence
AIIB	Asian Infrastructure Investment Bank
ALJ	Abdul Latif Jameel (co.)
AMF	Arab Monetary Fund
APICORP	Arab Petroleum Investment Corporation
BNEF	Bloomberg New Energy Finance
BNA	Bahrain News Agency
BNPP	BNP Paribas
bps	basis points
CA-CIB	Credit Agricole Corporate & Investment Bank
CBAM	Carbon Border Adjustment Mechanism
CBI	Commercial bank international
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CIA	US Central Intelligence Agency
CO_2	carbon dioxide
COP28	28th Conference of the Parties to the UNFCCC
CSP	concentrated solar power
DC	direct current
DEWA	Dubai Electricity and Water Authority
DNI	direct normal irradiation
DRI	direct reduction of iron
DTU	Technical University of Denmark
DWMC	Dubai Waste Management Centre
EDC	Export Development Canada
EDF	Électricité de France
EOR	enhanced oil recovery
ESCWA	UN Economic and Social Commission for Western Asia
ESMAP	Energy Sector Management Assistance Program
ETAF	Energy Transition Accelerator Financing platform
ETIP	Energy Tariff Incentive Programme
EU	European Union
EV	electric vehicle
EWEC	Emirates Water and Electricity Company
FAB	First Abu Dhabi Bank
FAO	Food and Agriculture Organisation of the United Nations
FDP	Five-year Development Plan of Oman
FID	final investment decision
GCC	Gulf Cooperation Council
GDP	gross domestic product
GCCIA	Gulf Cooperation Council Interconnection Authority
GHGGDP	greenhouse gas gross domestic product
GHI	global horizontal irradiation
GHG	greenhouse gas
GIC	Gulf Investment Corporation
GIZ	German Agency for International Cooperation
GPG	Global Power Generation
GW	gigawatt
HYDROM	Hydrogen Oman
ICBC	Industrial and Commercial Bank of China
IDB	Inter-American Development Bank
IEA	International Energy Agency
IPP	Independent power producer
IRENA	International Renewable Energy Agency
KACARE	King Abdulaziz City for Atomic and Renewable Energy
JV	Joint venture
KACST	King Abdulaziz City for Science and Technology
KAUST	King Abdullah University of Science and Technology
KSA	Kingdom of Saudi Arabia
kV	kilovolt
LCOE	levelised cost of electricity
LHS	Left-hand side
LIBOR	London Interbank Offered Rate
LNG	liquefied natural gas
Mbd	million barrels per day
MBRAMSP	Mohammed bin Rashid Al Maktoum Solar Park
MEED	Middle East Economic Digest
MENA	Middle East and North Africa
MMBtu	metric million British thermal units
$MtCO_2eq$	million tonnes of carbon dioxide equivalent
NBAD	National Bank of Abu Dhabi
NBAD	National Bank of Dubai
NDC	Nationally Determined Contribution
OIA	Oman Investment Authority
OPEC	Organization of the Petroleum Exporting Countries
PDO	Petroleum Development Oman
PIF	Public Investment Fund
PPA	power purchase agreement
PPP	purchasing power parity
PV	photovoltaic
REPDO	Renewable Energy Project Development Office
RHS	Right-hand side
SAR	Saudi Arabia Railways
SDG	Sustainable Development Goal
SWF	sovereign wealth fund
UAE	United Arab Emirates
UN	United Nations
UNB	Union National Bank
UN-CCHLC	UN Climate Change High-Level Champions
UNCTAD	UN Conference on Trade and Development
UNFCCC	UN Framework Convention on Climate Change
UNEP	UN Environment Programme
US	United States
USD	United States dollar

EXECUTIVE SUMMARY



Dhahran, Saudi Arabia: The King Abdulaziz Center for World Culture

Urgent global climate imperatives are reshaping energy sectors across the globe, presenting challenges and opportunities for the nations of the Gulf Cooperation Council (GCC)

In its latest Assessment Report (AR6), the United Nations Intergovernmental Panel on Climate Change sent a clear message to the world that this decade is critical to the goal of limiting the increase in the average global temperature by the end of this century to 1.5°C above pre-industrial levels. An overwhelming scientific consensus stresses the need for rapid and immediate action by 2030 to cut global carbon dioxide (CO_2) emissions in half from the 2019 level (IPCC, 2023). IRENA's 1.5°C pathway highlights that electrification and energy efficiency are key drivers of the energy transition, enabled by renewable energy, clean hydrogen and sustainable biomass (IRENA, 2023e).

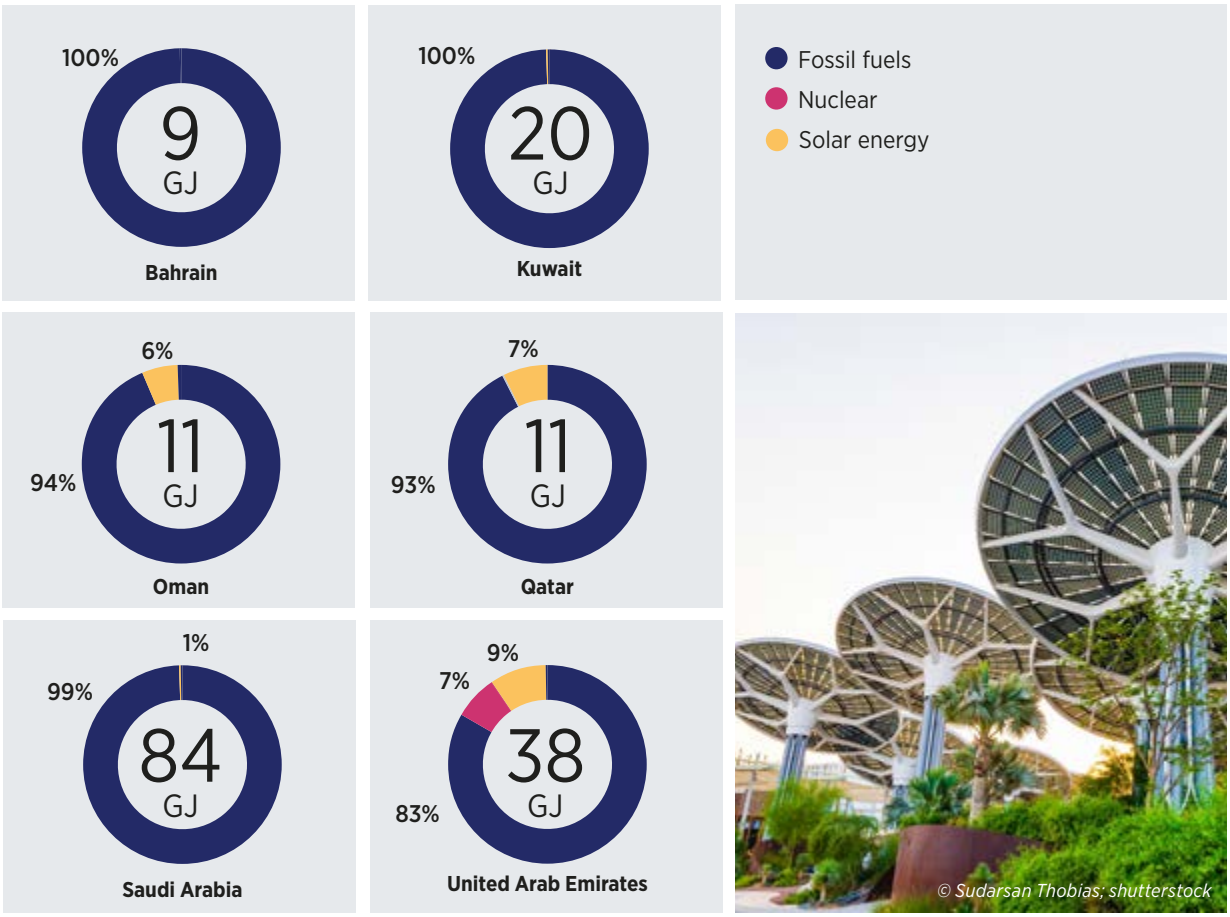
Against this backdrop, the Presidency of the 28th Conference of the Parties (COP28) hosted in the United Arab Emirates encouraged policy makers, energy authorities, industry and civil society to agree on global targets to triple power generation capacity from renewable sources and double the rate of improvement in energy efficiency by 2030. The fundamental changes to the global energy system needed to meet these goals require significant reform, but also offers new economic opportunities for the GCC states – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates – which comprise the world's most important region for fossil fuel-based energy supply.

The GCC countries are some of the world's largest fossil fuel producers and exporters and among the world's largest per capita emitters of CO_2

Fossil fuel exports account for a large share of government revenue in the GCC region. In 2020, the share of hydrocarbon export revenues in total government revenues ranged from 39% in the United Arab Emirates to just over 50% in Saudi Arabia – and over 80% in Kuwait and Qatar (Arab Monetary Fund, 2021). Hydrocarbon revenues account for equally substantial shares of GDP in the region, ranging from 11.5% in the United Arab Emirates to close to 50% in Kuwait. Because 2020 was an exceptional year due to COVID-19, and oil prices were comparably low, the figures are expected to be higher in succeeding years (IMF, 2023c,2023d,2022b,2022c,2022d).

Oil and natural gas account for almost all the GCC countries' final energy consumption, including electricity. While the GCC economies have historically been small energy consumers compared with major world demand markets, their consumption has grown more than fourfold over the past 30 years. This growth reflects historical choices of industrialisation based on energy-intensive industries, rapidly growing populations enjoying high income levels and living standards, and the need for year-round air conditioning, among other factors. Electricity markets have grown rapidly over the past decades. Traditionally, limited regulation of energy efficiency in the building and energy sectors – aided by heavily subsidised electricity – have further added to the rise in consumption. The generating capacity needed to meet that consumption is powered almost entirely by fossil fuels, primarily natural gas, but also oil products (and even, at peak times, crude oil) in Saudi Arabia and Kuwait (Figure S.1).

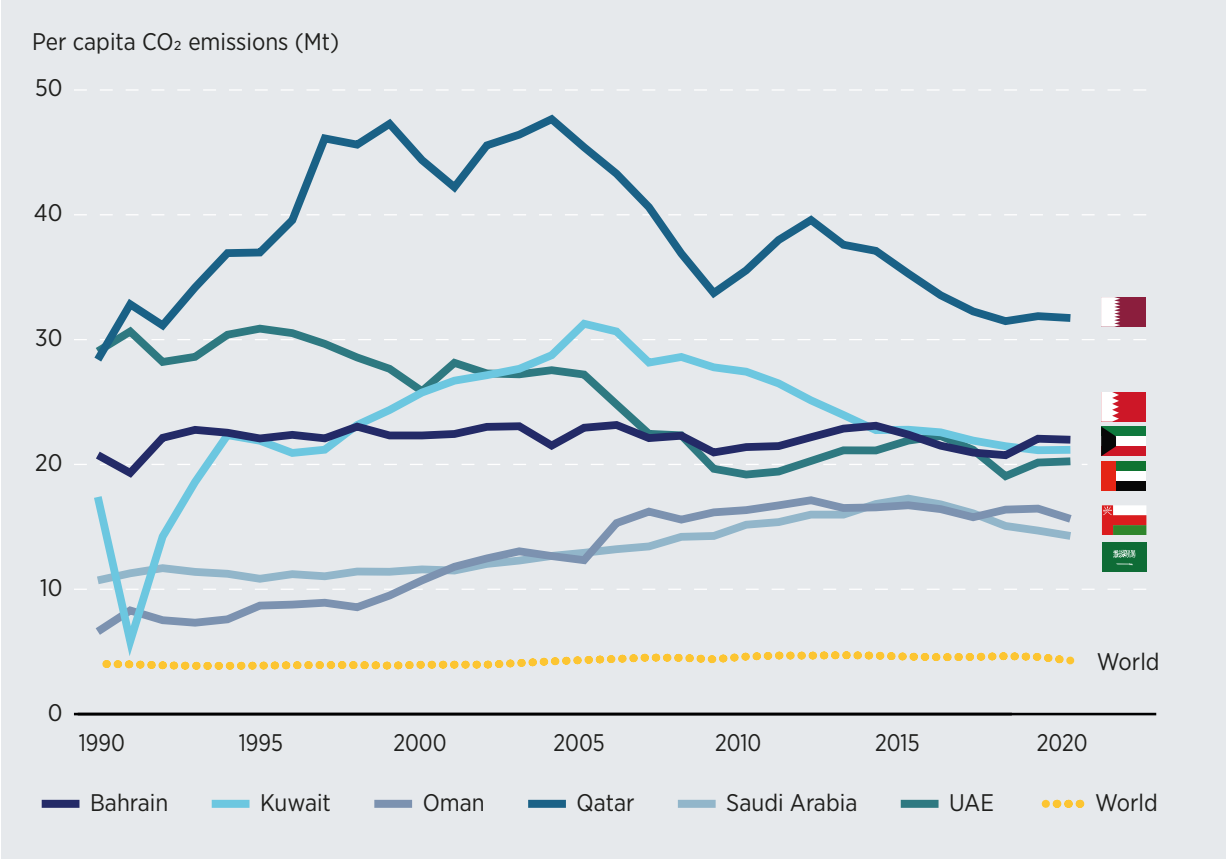
Figure S.1 Electricity generation by fuel source (%) in the GCC countries, 2020



Source: (IRENA 2023b).

Resulting greenhouse gas (GHG) emissions more than doubled between 2000 and 2020, making the GCC countries among the world's largest per capita emitters of CO_2. All GCC countries' per capita emissions are above the world average; Qatar is the world's largest emitter on a per capita basis, while Saudi Arabia is the world's ninth-largest total emitter of GHGs (Figure S.2).

Figure S.2 Per capita CO_2 emissions of the GCC countries versus the world



Source: (World Bank 2023a; Climate Watch 2023).

The energy transition, including renewable energy deployment, can help to mitigate climate change and diversify the region's economies

Climate vulnerability is high in the region, underlining the urgency of climate mitigation and adaptation actions in which renewables play a critical role. Located in one of the most arid and water-stressed regions in the world, GCC countries are highly vulnerable to climate change. The GCC region is especially vulnerable to challenges such as urban heat island effects, high levels of air pollution, extreme weather events (GFDRR, 2020; UNCTAD, 2021; World Bank, 2021a, 2021b) and higher sea levels (RCRCCC, 2021). Tackling climate change drivers and impacts has therefore become a necessity for the region.

The energy transition and the development of innovative solutions – including renewable energy, energy efficiency, green hydrogen and renewables-based desalination – offer an opportunity for economic diversification and innovation. GCC countries looking to diversify their economies to reduce fossil fuel dependence, reduce vulnerability to volatile international oil prices, and respond to increasing pressure for the creation of new jobs and businesses can leverage existing resources –abundant solar energy and public funds among them – to develop innovative solutions of global relevance. Examples include the early-stage production of green hydrogen in Oman, Saudi Arabia and the United Arab Emirates; the development of biofuels for aviation in the United Arab Emirates; the development of green cities powered entirely by renewable energy, such as the vision for the urban project Neom in Saudi Arabia; the use of geothermal energy to produce chilled water for district cooling in Masdar City in the United Arab Emirates; and the use of renewables for desalination using reverse osmosis in Saudi Arabia and the United Arab Emirates. As global temperatures rise and more countries experience drought, these solutions will be in global demand.

The cost-effective, enormous resource potential in the region further supports the case for greater investments.

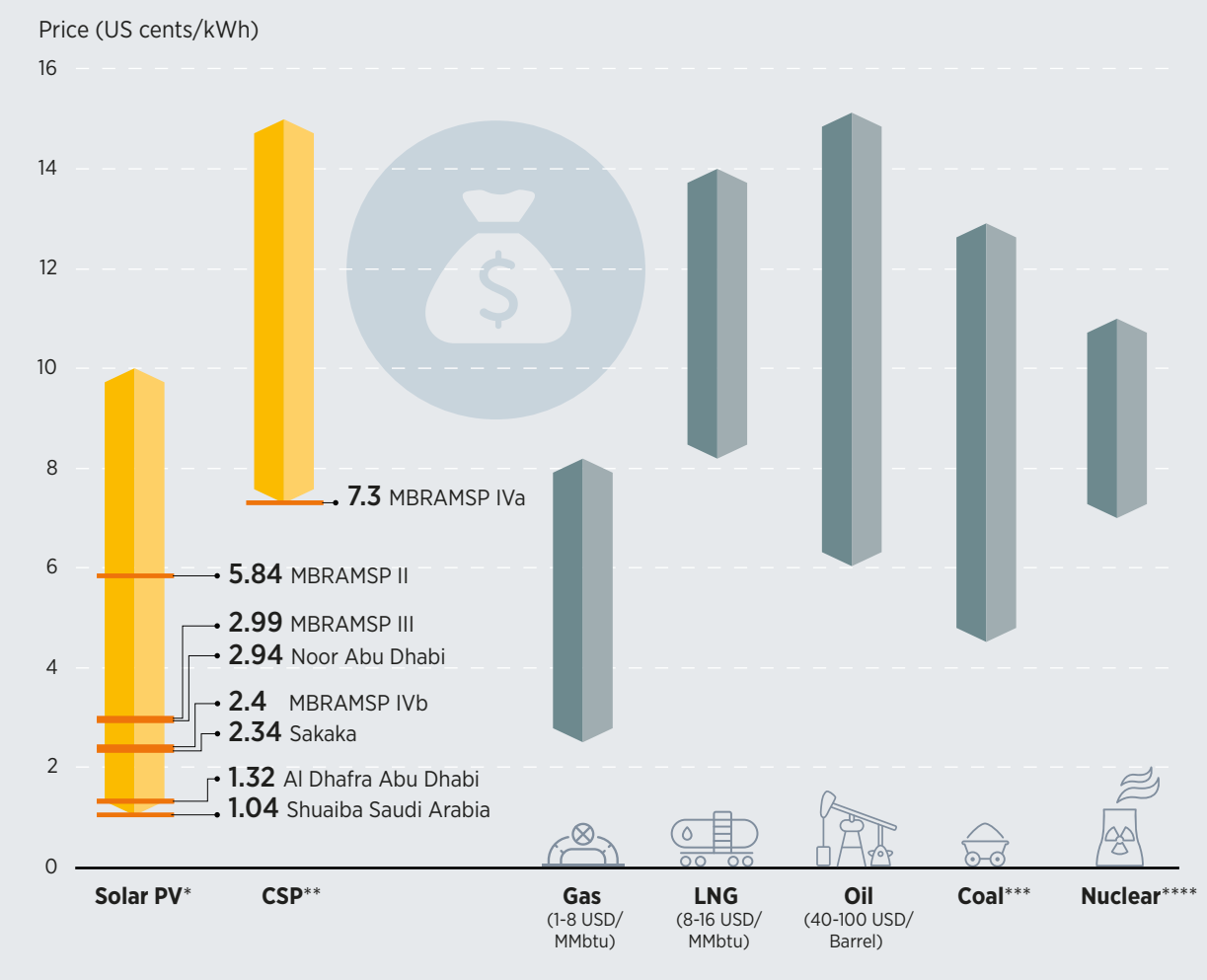
The GCC region's renewable energy potential has long been recognised. The GCC countries are blessed with high solar resource potential, especially for solar photovoltaics. Some areas, notably in Oman and Saudi Arabia, also boast good resources for concentrated solar power. The wind potential across the region is lower than that of solar, but still promising and a growing number of wind projects are being constructed in the region.

The increasing cost competitiveness of renewable energy technologies is particularly evident in the large-scale, grid-connected market segment. The declining cost of utility-scale projects can be attributed to enhanced technologies, availability of low-cost financing, competitive procurement processes, increased deployment rates, and stakeholders' deeper understanding and familiarity with technologies. In 2010, solar PV had a global weighted average levelised cost of electricity (LCOE) of US¢ 44.5/kWh, which by 2022 had plummeted by 89% to US¢ 4.9/kWh. At less than US¢ 2/kilowatt hour (kWh), solar PV emerges as the least-cost option for power production, easily outpacing natural gas, liquefied natural gas, oil, coal and nuclear (Figure S.3). Competitive prices and potential also open the door for other clean energy technologies, such as green hydrogen, to become competitive globally.

Long-term renewables targets have been set and public investment mobilised to kick-start deployment, although actual deployments have proceeded at different rates

Renewable energy has become an important part of ambitious long-term plans for sustainable energy in the region. To date, five GCC countries have net zero targets for 2050-2060, but those commitments have yet to be translated into implementing policies and milestones. All GCC countries have submitted Nationally Determined Contributions and adopted renewable energy targets; three have announced targets to improve energy efficiency. These ambitions differ across countries, as do market size and readiness. Broader renewable energy targets not limited to the power sector are needed to provide a comprehensive roadmap for decarbonisation of the whole economy. Similarly, comprehensive policy frameworks must encourage long-term stability, adaptability to technological and market developments, and facilitate structural and just transition policies. With all six countries' emissions targets only recently introduced, much current debate centres on what policies are best suited to each country's goals and circumstances.

Figure S.3 Price of utility-scale electricity generation technologies in the GCC countries, 2015-2023



Sources: Renewables (Zawya 2021; Apostoleris et al. 2018; ACWA Power 2020; Dipaola 2018; Carvalho 2011); non-renewables (Zywietz 2023; Sabga 2020; Mills 2017; Channell et al. 2015; Manaar 2014; Scribbler 2015).

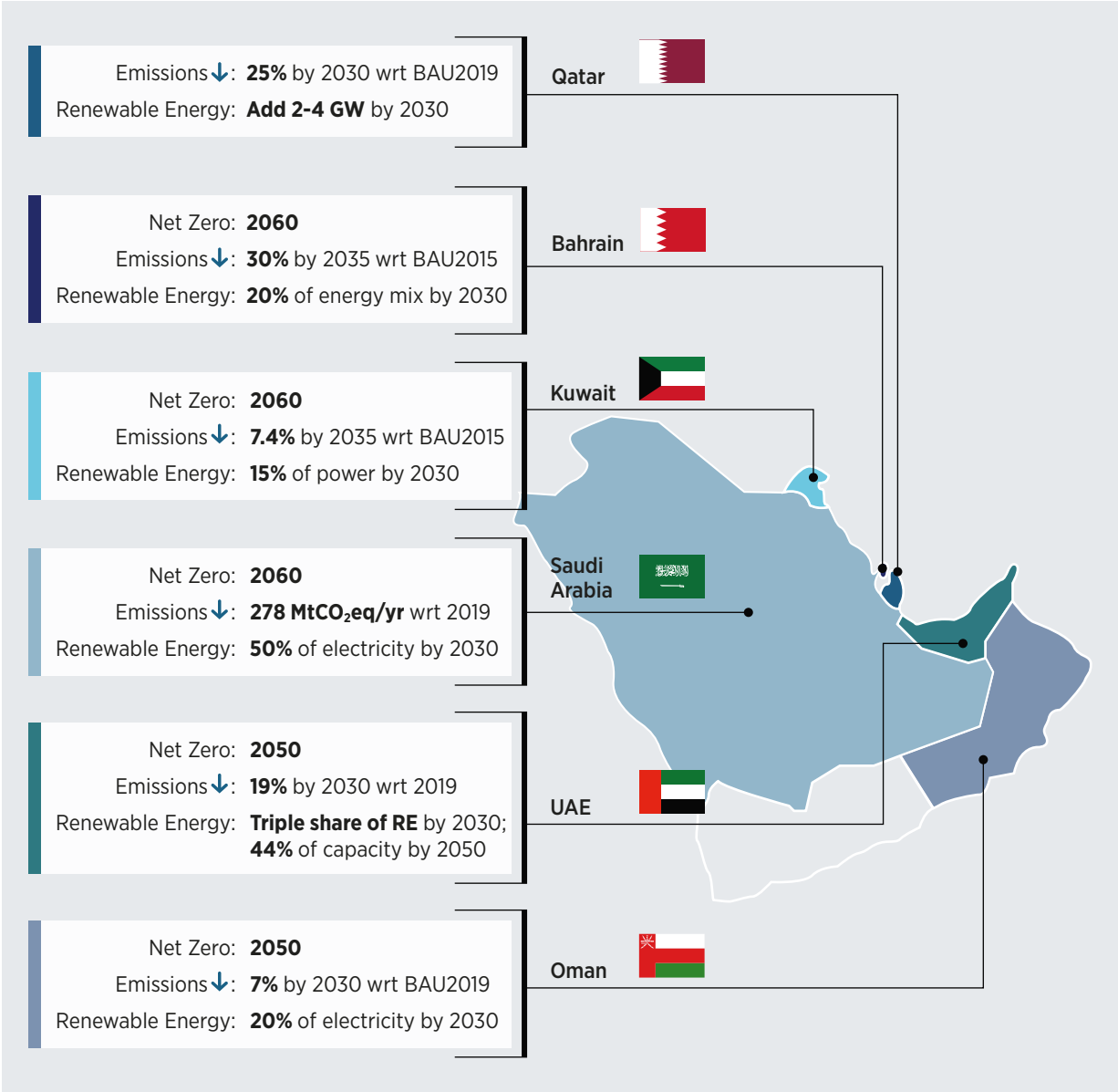
* *Low = price for Shuhaiba solar PV; High = conservative assumption based on expert opinion.*

** *Low = price for 700 MW MBRAMSP IV in Dubai; High = price for Morocco's Noor II.*

*** *Low = price for the Hassyan Clean Coal Power Plant; High = estimate for coal with CCS.*

**** *Estimated range for nuclear power based on (Mills 2012; Sabga 2020; Scribbler 2015).*

Figure S.4 Key climate change policies and targets in GCC countries



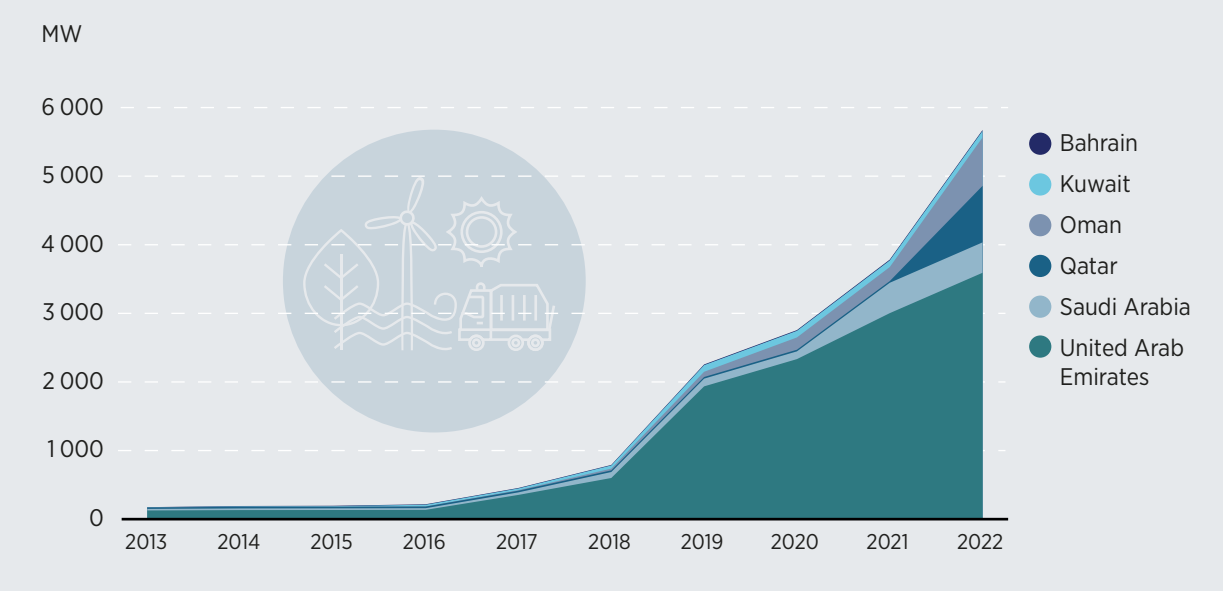
Notes: BAU = business as usual; GCC = Gulf Cooperation Council; GHG = greenhouse gas; GW = gigawatt; $MtCO_2eq$ = million tonnes of carbon dioxide equivalent; wrt = with respect to.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply an opinion on the part of IRENA concerning the status of any region, country, territory, city or area or its authorities, frontiers or boundaries.

Renewable energy deployment in the region is concentrated in one country and in the power sector. The GCC countries have built all their renewable energy capacity within the past ten years, based almost entirely on solar power. Installed capacity has grown from just 176 megawatts (MW) in 2013 to 5 673 MW in 2022 (Figure S.5). Despite this significant increase, the region's ambitious plans and the increased cost competitiveness of solar energy, the share of renewables in the electricity mix remains negligible. In 2022, renewables accounted for only 3% of the region's generation capacity. Moreover, the deployment has been concentrated in the United Arab Emirates, which hosts more than 60% of the region's capacity (Figure S.6). Renewable energy policies must evolve beyond power generation to achieve decarbonisation of the broader economy. In this context, the ongoing development of national and sector energy strategies, including green hydrogen strategies, when supported by concrete projects and policies, could be key to reducing the carbon footprints of the transport and industrial sectors.

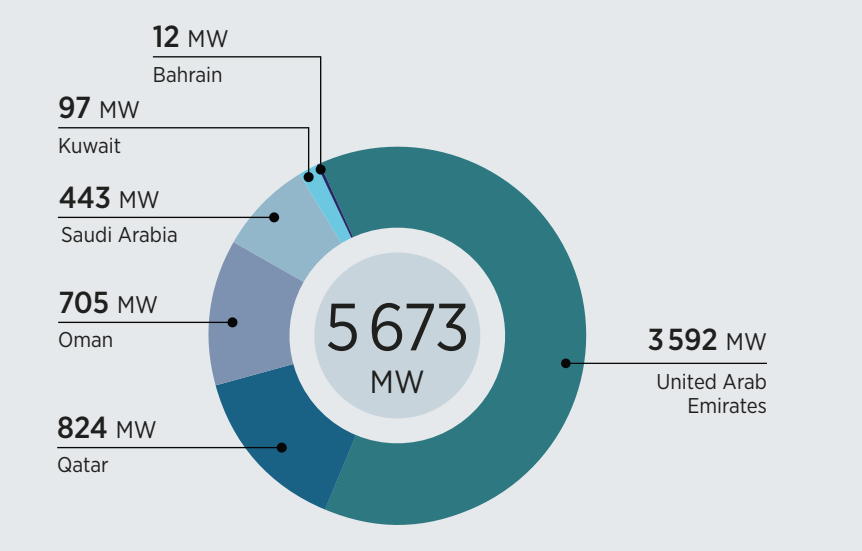
Investment trends mirror deployment trends. The UAE accounted for close to 70% of investments in the 2013-2022 period (Figure S.7). Most of the investment was driven by a few large projects, implying considerable year-on-year fluctuations in volumes. Beyond renewable energy projects, public sector investments have also targeted manufacturing and research and development initiatives with the aim of creating economic value in the growing sustainable energy industry. Institutional reform, clear mandates and political commitment, as well as incentives to attract private investment, could all contribute to accelerating the widespread deployment of renewables in other countries in the region.

Figure S.5 Renewable energy generation capacity in the GCC countries (MW), 2013-2022



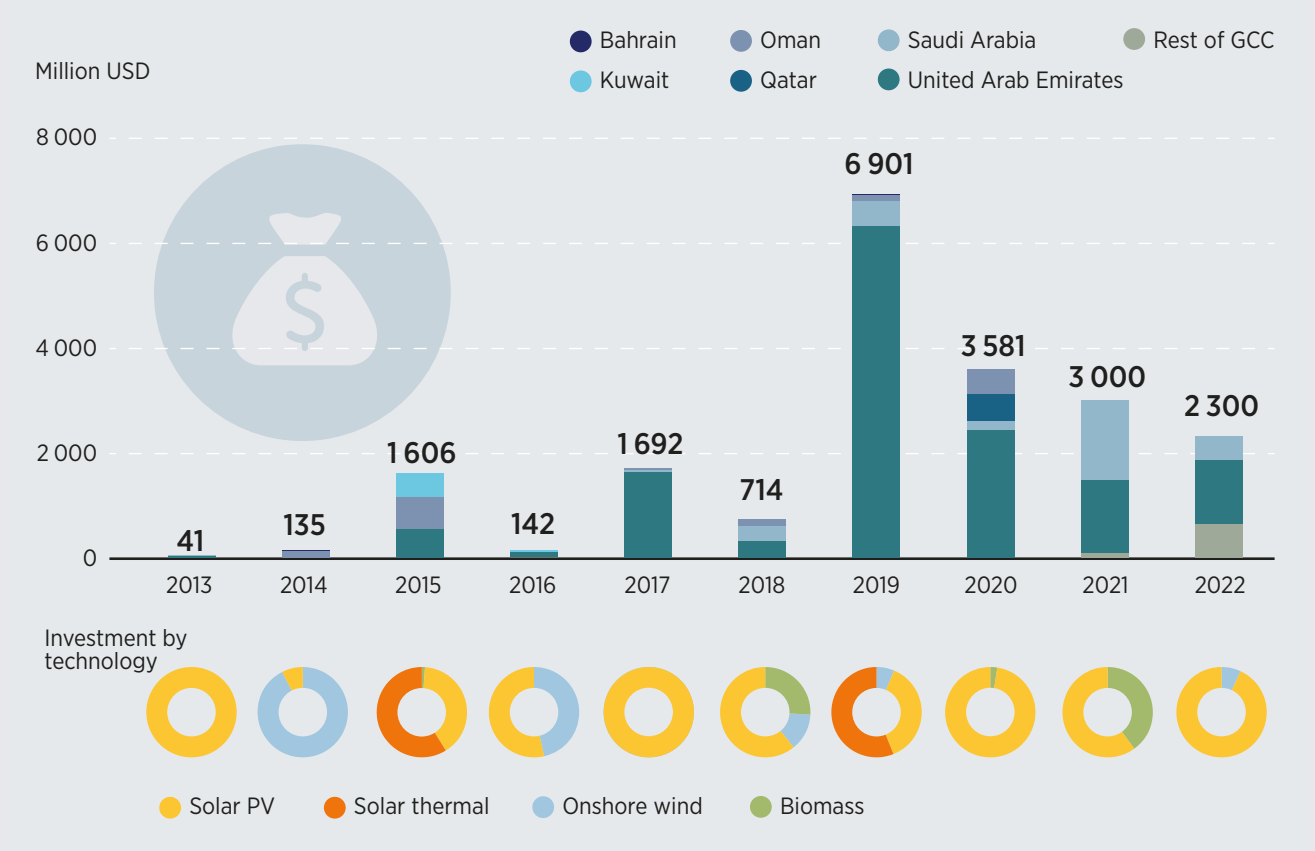
Source: (IRENA 2023b).

Figure S.6 Renewable energy generation capacity by country (MW), 2022



Source: (IRENA 2023b).

Figure S.7 Renewable energy investments in GCC by technology and country Add (million USD by country).



Based on: (BNEF 2023).

Note: In 2021 and 2022, national level investment data were available only for Saudi Arabia and the UAE; the rest of the investments are aggregated under "Rest of GCC".

Investments are characterised by a diverse blend of public and private entities, involving both local stakeholders and foreign financial institutions. Favourable financing conditions have contributed to the record-low prices of large-scale projects achieved in several rounds of renewable energy auctions. These conditions include low interest rates, extended loan durations and high debt-to-equity ratios, making the financial landscape for sizable projects particularly enticing. As deployment speeds up, auctions can be designed to achieve broader objectives such as providing system support and ancillary services, as well as fostering industry development. Smaller-scale projects often face more significant financing challenges. Net metering, for example, has achieved only limited success in Dubai, UAE, the only jurisdiction where it was introduced. Leasing plans, standardisation, aggregation mechanisms and, to some extent, crowd funding have emerged as financing solutions in the small-scale market segment. Replication across the region could unlock deployment, while creating an ecosystem of local renewable energy companies.

Public investments in infrastructure and in building local capacity and value chains can further drive and enable the deployment of renewable energy and associated benefits

The GCC region has a solid energy infrastructure that can be leveraged for increased shares of renewables. The GCC established a regional grid in 2009. Extending its capacity and creating a wholesale market similar to those of several European systems and Latin America is technically possible and could be economically beneficial. The benefits could be large for countries such as Bahrain, Kuwait and Qatar, whose comparably small land surface does not allow for the same extent of large-scale renewable energy deployment as in some larger neighbouring countries. In addition, an expansion of the grid to the Middle East and North Africa, through individual grid links between countries such as Saudi Arabia, Jordan and Egypt, could further increase the scope for economic savings while supporting the integration of variable renewables-based electricity – such as solar photovoltaic (PV) and wind – and addressing intra-regional differences in load patterns and peak demand.

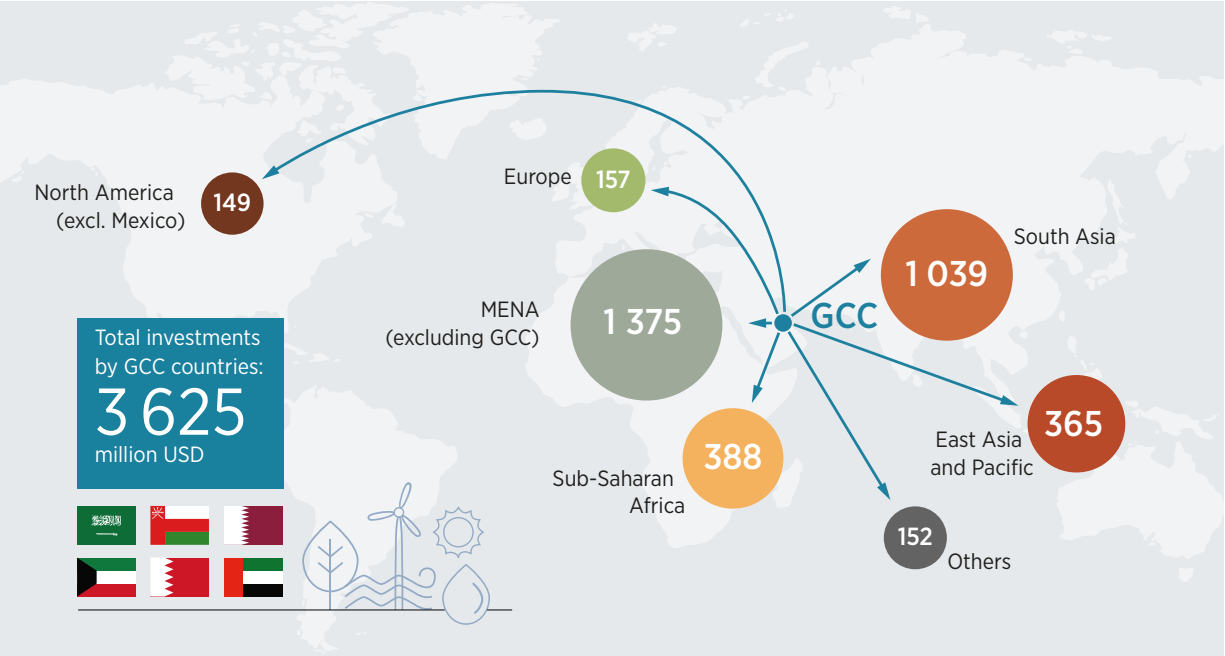
Developing infrastructure beyond power generation will be important. As the region builds and bolsters its infrastructure, more efforts will be needed to develop infrastructure to support end uses of renewables. For instance, infrastructure for the transport of hydrogen, which is essential for the export of green hydrogen, is limited in the region. Upgrading transport infrastructure to support the electrification of vehicles, along with enabling alternative transportation modes like electrified rail and buses, will be critical for decarbonising transport. The United Arab Emirates has developed a National Electric Vehicles Policy that aims to establish a countrywide network of electric vehicle (EV) chargers, while regulating the EV market in the Emirates. The policy aims to reduce energy consumption in the transport sector by 20%. To date, similar plans are lacking in other countries.

Government strategies to diversify the economy have emphasised the development of knowledge economies and skills which can be leveraged for the development of transition-related solutions, including renewables. However, such efforts have been concentrated in just a few countries. The United Arab Emirates' Green Agenda 2030, for instance, includes the creation of a competitive knowledge economy and efforts to support national green innovation and green diversification. Among those efforts are programmes to license and accredit professional training in green fields, student scholarships for postsecondary courses in environmental fields, financing for studies and research on green specialties, and research initiatives that support the emergence of a knowledge-based green economy. Saudi Arabia's Vision 2030, a comprehensive strategy for systematically restructuring the Saudi economy, includes programmes focused on goals such as human capability development. The energy transition offers an opportunity for development of intellectual capital in emerging clean energy industries, with the potential of positioning the region as a hub for clean technologies. To take advantage of this opportunity, investments in education, training, reskilling and upskilling initiatives are needed across the region.

The GCC countries need to play a larger role in achieving global targets, both domestically and internationally.

Beyond national efforts, GCC countries are in a position to support the energy transition in developing countries through international collaborative investments in renewable energy. While investment is largely commercially driven, some GCC investments abroad are made to support partner countries in achieving their objectives for energy security and sustainable development across key regions (Figure S.8). The Middle East and North Africa region has received GCC investments amounting to USD 1.4 billion, underlining the GCC's focus on strengthening renewable energy and development initiatives with neighbouring states.

Figure S.8 Renewable Energy Investments by GCC countries in regions around the world (2016-2020)



Source: (IRENA and CPI 2023).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This includes solar and wind projects in Jordan, Egypt and Morocco. South Asia and Sub-Saharan Africa have also benefitted significantly, with investments exceeding USD 1 billion and USD 388 million, respectively, contributing to the expansion of sustainable energy solutions in these areas. GCC countries extended their renewable energy funding to East Asia and the Pacific, Europe and North America (excluding Mexico), collectively allocating USD 823 million to facilitate renewable energy development.

International collaboration and renewable energy investments in countries that have so far not been able to attract private capital without the backing of multilateral support will be crucial to achieving both climate and sustainable development goals, including tripling renewables and doubling energy efficiency across the globe. More active engagement of GCC countries in this regard can make a valuable contribution.

Domestically, investments in renewables in the GCC are expected to reach new heights in the years following COP28. The United Arab Emirates is expected to retain its leadership by generating 44% of its power from renewable sources by 2050 and tripling renewable capacity by 2030, backed by investments of USD 54 billion in the energy sector (Arabian Business, 2023). Investments are likely to step up in Saudi Arabia, as further rounds of renewable energy auctions get underway. Investments in Bahrain, Kuwait, Oman and Qatar are also set to pick up as these countries embark on their renewable energy plans. With its large resource potential, the region must play a larger role in helping to triple global renewable power and double energy efficiency by 2030 to mitigate climate change and diversify the region's energy mix and economies (IRENA, 2023d).

BACKGROUND AND ENERGY SECTOR OVERVIEW

Bahrain

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01

The Gulf Cooperation Council (GCC) states – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates – are the Middle East's most important source of conventional energy supplies, as well as an emerging economic powerhouse of global significance. This chapter provides an overview of the GCC's economies and the role of energy in their economies and societies. It first provides some socio-economic background, including economic and trade figures (section 1.1), followed by an overview of the region's energy landscape (section 1.2). The chapter closes with an examination of the region's greenhouse gas (GHG) emissions and its vulnerability to climate change (section 1.3).

1.1 SOCIO-ECONOMIC BACKGROUND

The GCC economies are the Middle East's fastest-growing, and wealthiest countries. The combined gross domestic product (GDP) of the six GCC countries in 2020 was more than USD 1.4 trillion, equivalent to around a third of Latin America's combined GDP and accounting for some 45% of the total GDP of the Middle East and North Africa (MENA) region (Figure 1.1).[1] Saudi Arabia alone accounted for around half of the region's total GDP in 2020; it and the United Arab Emirates generate some three-quarters of the GCC's GDP.

The GCC countries' economic weight, both regionally and by now also globally, stands in contrast with their small landmass and population size. The populations of the GCC's smaller countries range from less than 3 million in Bahrain, to more than 4 million in Kuwait and Qatar, 5 million in Oman and some 10 million in the United Arab Emirates, barely more than the population of New York City. Saudi Arabia has a population of more than 35 million (World Bank, 2023b). With such relatively small populations, and endowed with significant oil and gas resources, Bahrain, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates are some of the world's richest countries on a per capita basis (Figure 1.2).[2] Qatar stands out as the world's sixth-wealthiest country on a per capita basis (IMF, 2023a). Expatriates make up over half of the GCC countries' population, ranging from 35% in Saudi Arabia, 85% in Qatar and 88% in the United Arab Emirates (Zawya, 2022; Online Qatar, 2019; CIA, 2023).

[1] *GCC total calculated by authors, regional sums used as per World Bank stats. World Bank (2023a) numbers for 2020.*

[2] *Measured on the basis of per capita GDP (purchasing power parity, PPP).*

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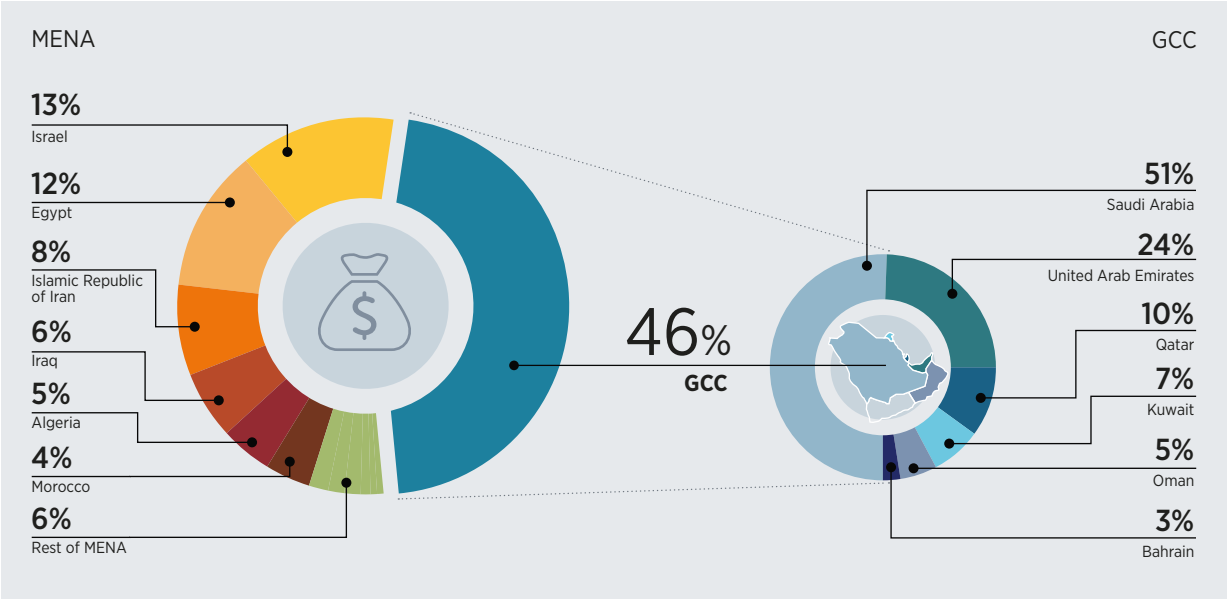
Figure 1.1 The GCC region's share in total MENA GDP (current USD), 2020

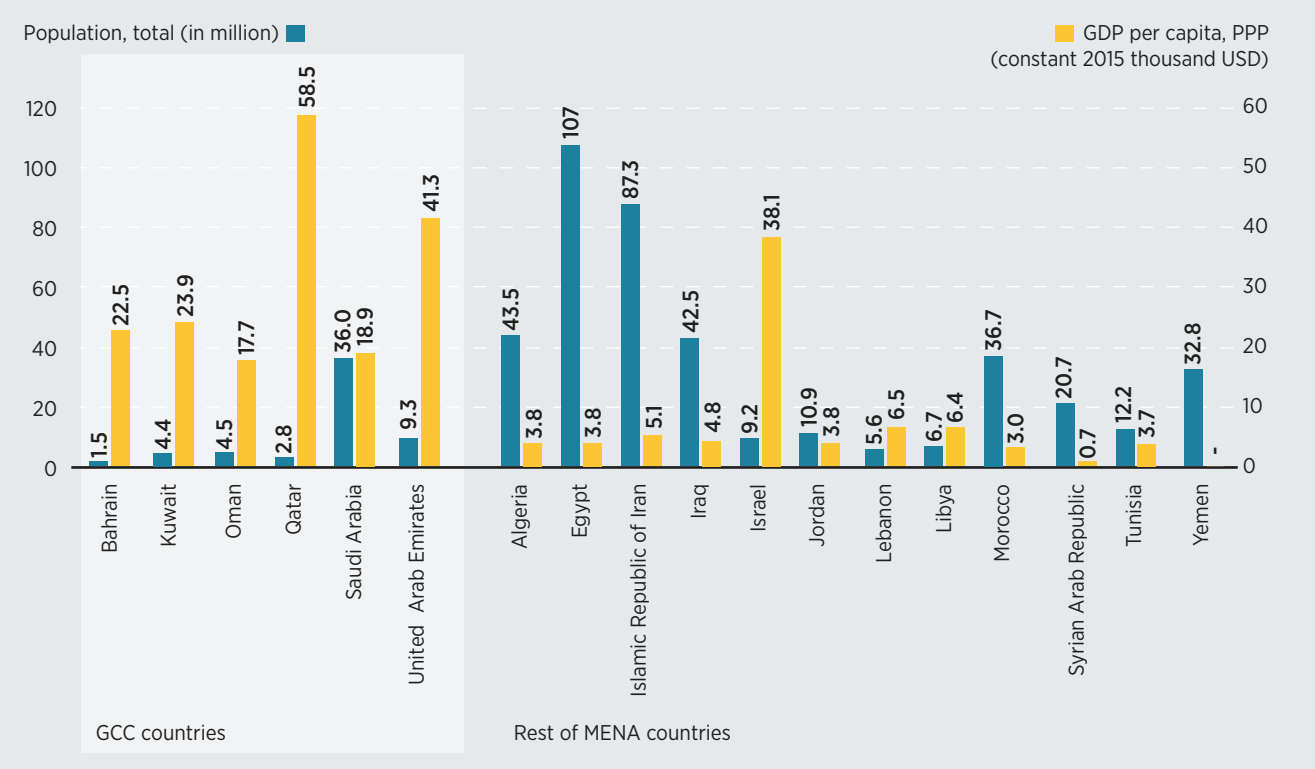


Source: (World Bank 2023a).
Note: No data are available for Yemen.

The region's considerable wealth, combined with its demographics, geography and government structures, explain their development model. The populations of the GCC states are wealthy and young – with 15-26% of the population being under the age of 14; they are highly urbanised and enjoy modern infrastructure, most of which has been built over the past 50 years. More than 90% of people live in the region's urban centres, and in the Gulf's smaller states – Bahrain, Kuwait and Qatar – almost the entire population lives in the capital (World Bank, 2023b).

Systematic investment in modern infrastructure over the past decades and generous welfare states have led to high living standards for most nationals and many expats; they have also yielded the characteristic Gulf skylines of modern, high-rise buildings, multi-lane highways and luxury resorts. While stark differences in income levels remain, in particular between nationals and low-skilled expatriate labour, the region has also been characterised by universal access to low-priced electricity and modern cooking fuels, as well as modern health systems and education. GCC states score high in many international rankings, such as the UN Human Development Index (United Nations, 2022), as well as business-related indices such as the World Bank's Enterprise Surveys (World Bank, 2023a).

Figure 1.2 Population and wealth in the GCC and the wider MENA region, 2020



Source: (World Bank 2023a).
Note: No GDP data are available for Yemen.

Economies and external trade

Much of the GCC states' modern-day economic wealth is founded on fossil fuels. Combined, the GCC countries account for around 30% of the world's proven reserves of crude oil – more than any other region in the world – and over a fifth of its proven reserves of natural gas (Figures 1.3 and 1.4). Saudi Arabia is the world's second-largest producer of crude oil after the United States and is, together with the United Arab Emirates and Kuwait, among the world's ten-largest oil producers (Figure 1.5). The region also holds around a fifth of the world's natural gas reserves, with Qatar being the world's fifth-largest producer of gas (Figure 1.6).

The GCC's small populations over the past decades meant that domestic demand for energy remained limited compared with the region's large fossil fuel assets. This has meant that most of the fossil fuels produced in the region were exported. In 2022, Saudi Arabia exported over 60% of its crude oil production, the United Arab Emirates almost 70%. Qatar, similarly, exported almost 75% of its gas production (EIA, 2023a, 2023b, 2023c). The GCC oil and gas producers thus play an important role as suppliers of fossil fuels to international markets. Saudi Arabia alone accounts for some 15% of the crude oil traded globally, the United Arab Emirates for another 6% (Figure 1.7). Qatar is the world's third-largest exporter of fossil gas after the Russian Federation and the United States (Figure 1.8).

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Figure 1.3 Total proven reserves of oil by world region, at end-2020 (% of world total)

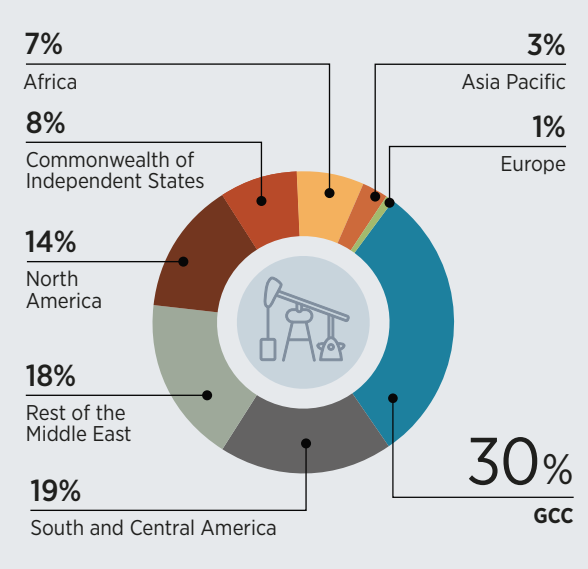


Figure 1.4 Total proven reserves of natural gas by world region, at end-2020 (% of world total)

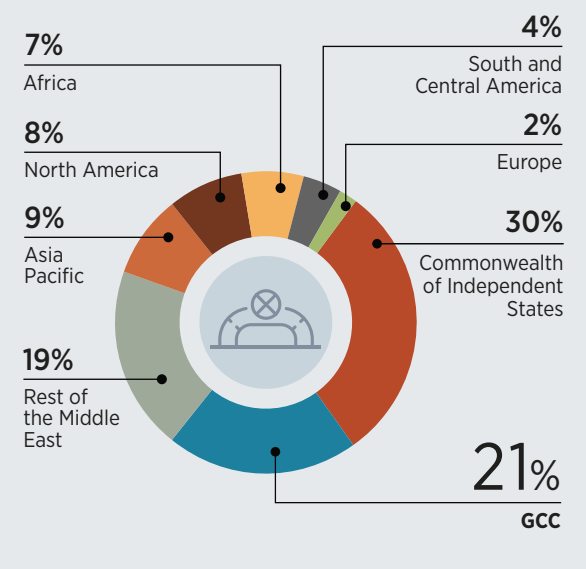


Figure 1.5 Ten largest oil producers in the world, 2021

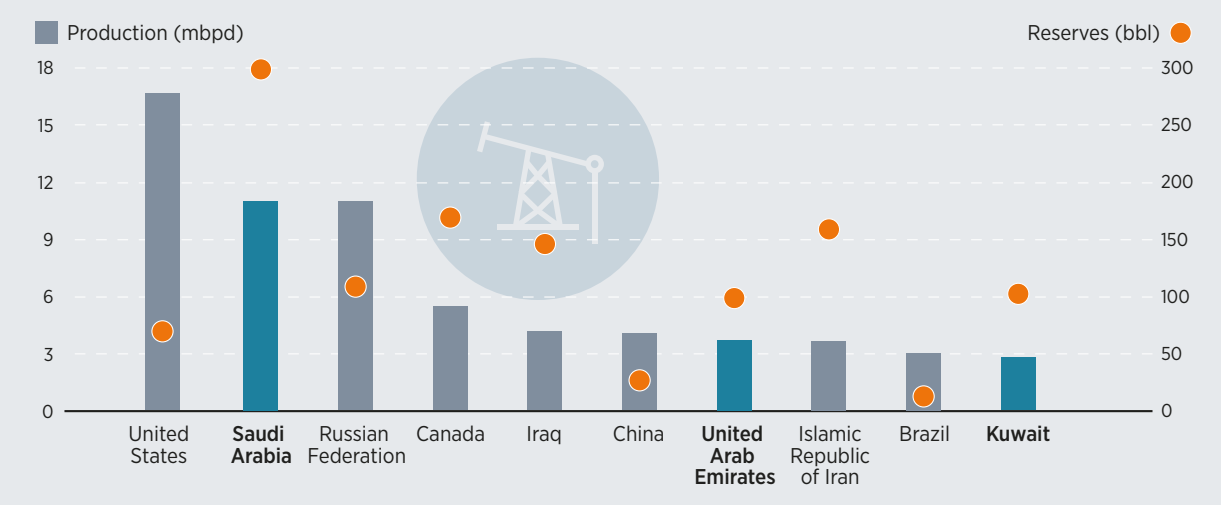
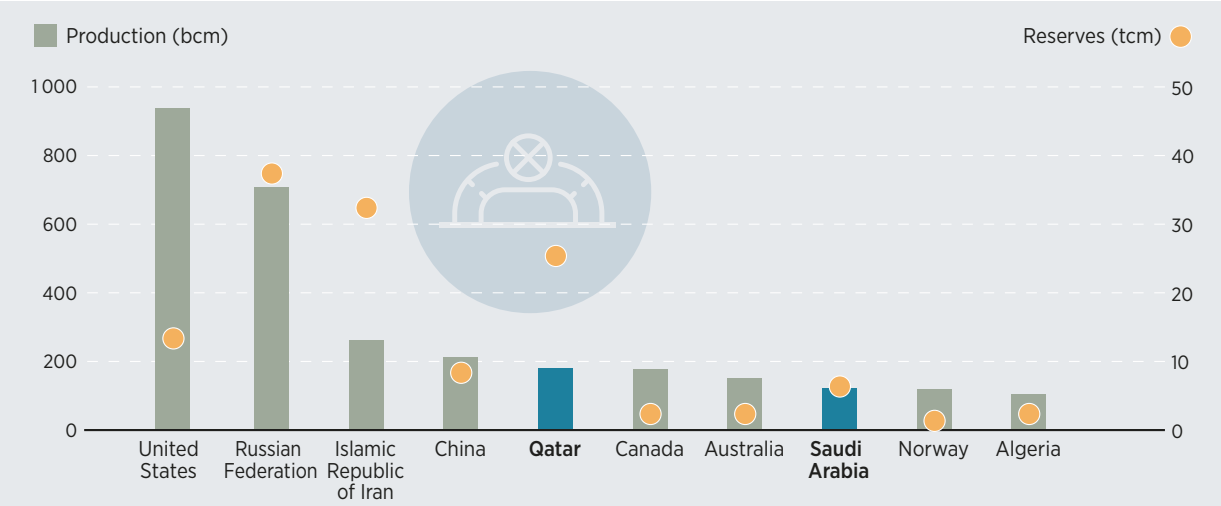
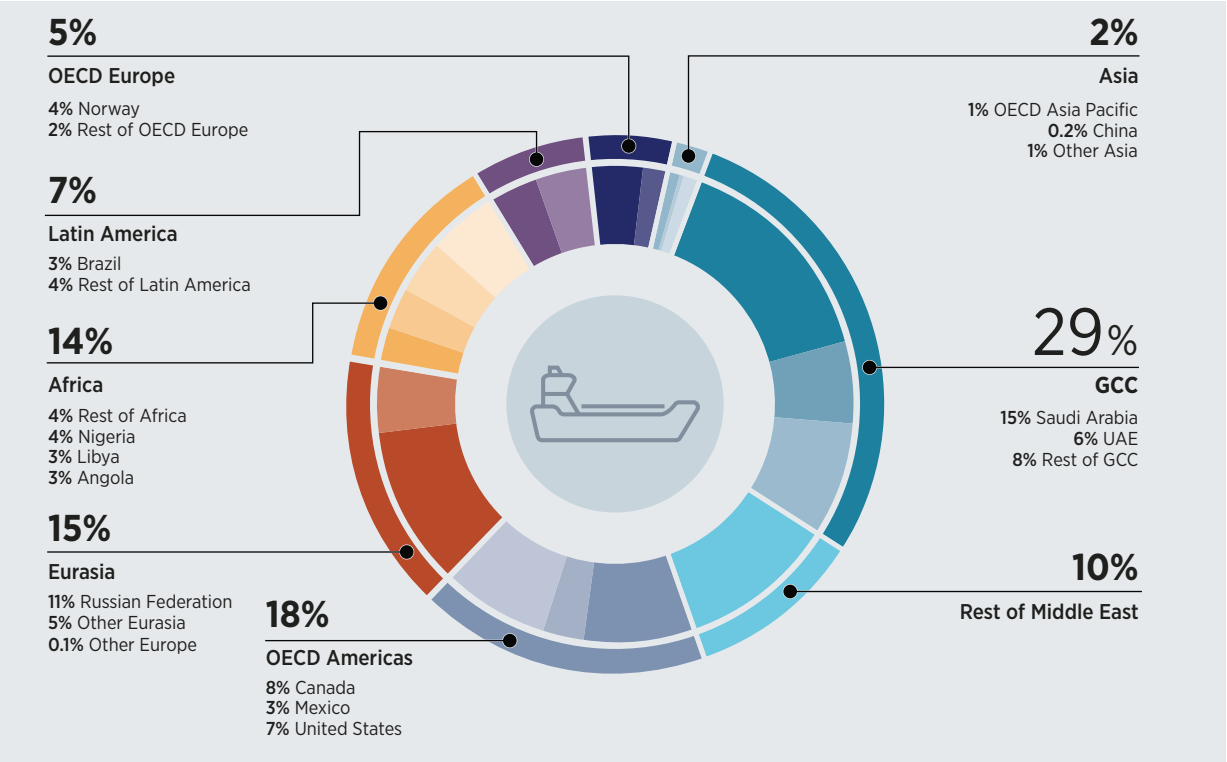


Figure 1.6 Ten largest natural gas producers in the world, 2021



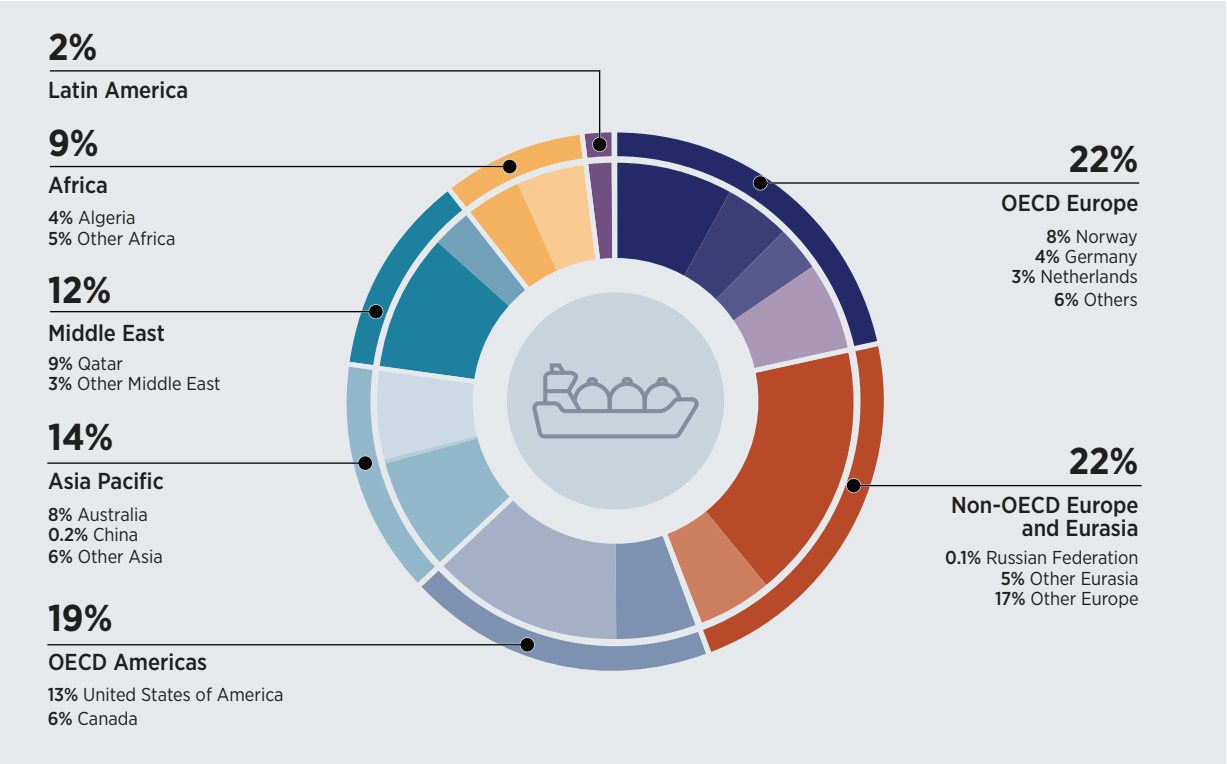
Notes: bbl = barrels; bcm = billion cubic metres; mbpd = million barrels per day; tcm = trillion cubic metres.

Figure 1.7 Crude oil exports by exporting country/region (% of world total), 2021



Source: (BP 2023).

Figure 1.8 Natural gas exports by exporting country/region (% of world total), 2021



Source: (BP 2023).

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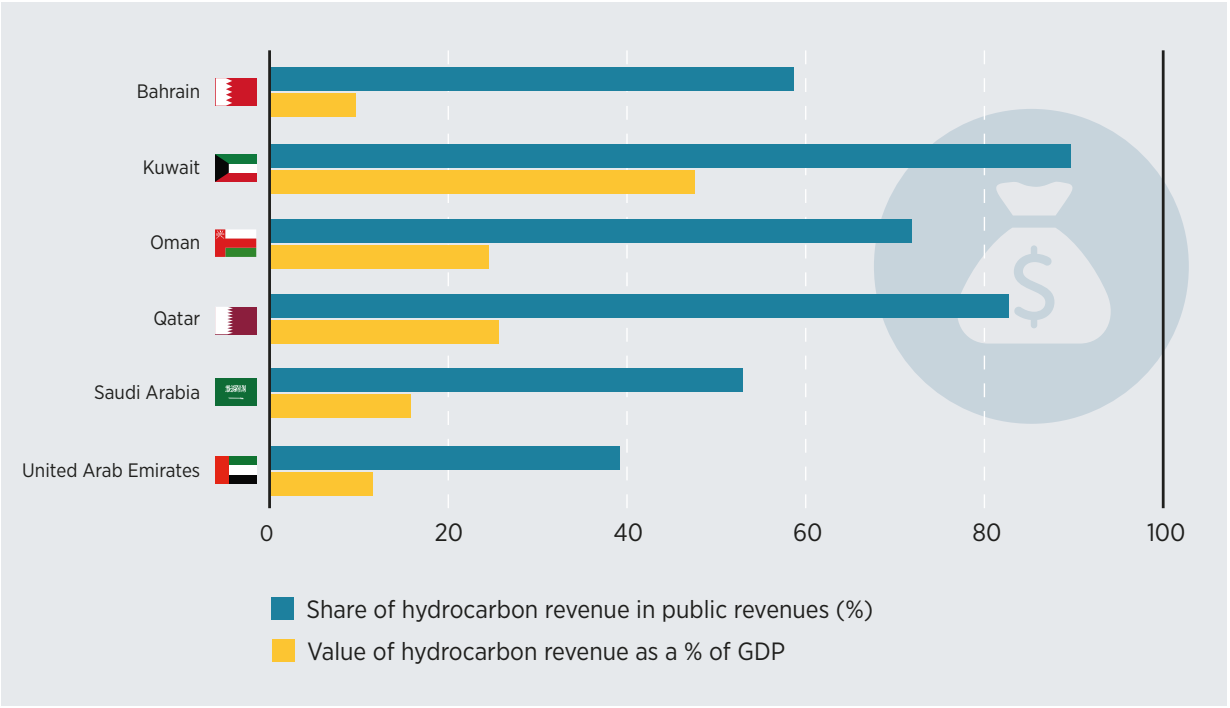
Fossil fuel exports continue to account for a large share of central government revenue. Only in recent years have some of the GCC states begun to introduce a value added tax and a corporate tax (United Arab Emirates Ministry of Finance, 2022; Al Khalaf, 2022). In 2020, the share of hydrocarbon export revenues in total government revenues ranged from a low of 39% in the relatively diversified United Arab Emirates, to just over 50% in Saudi Arabia, and over 80% in Kuwait and Qatar (Arab Monetary Fund, 2021). Similarly, hydrocarbon revenues account for substantial shares of GDP, ranging from 11.5% in the United Arab Emirates to close to 50% in Kuwait (Figure 1.9). Since 2020 was an exceptional year due to COVID-19, and oil prices were comparably low, those figures are expected to be higher in subsequent years (IMF, 2022b, 2023c, 2023d, 2022c, 2022d).

Government investment remains a critical driver of economic activity, including in non-hydrocarbon sectors, through state companies, direct public investment, and employment of nationals in the public sector at comparably high salaries, which in turn drives domestic consumption (IMF, 2017).

Most of the region's exports of crude oil and natural gas go to Asia. Only a small fraction goes to Europe and North Africa, but Europe was the biggest market for Saudi exports of petroleum products in 2020 with a share of 40% of total exports (EIA, 2021). Around 20% of Qatar's natural gas exports are destined for Europe (EIA, 2021), a share that might rise in the future as Europe looks to diversify its suppliers. The Ukraine conflict has shifted some additional volumes of Gulf oil to Europe since 2022, as Middle East oil producers have started to substitute

Figure 1.9 Share of hydrocarbon revenues in public revenues and GDP (%), 2020

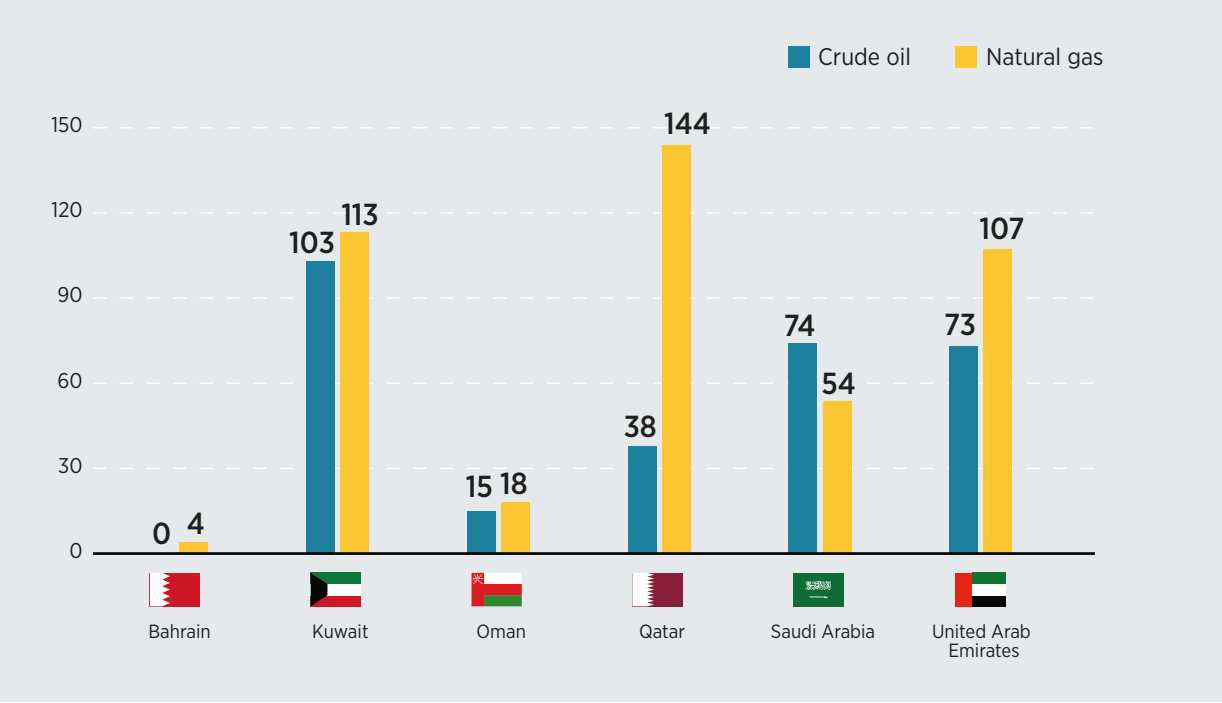


Source: (Arab Monetary Fund 2021).

for oil and gas from the Russian Federation (IMF, 2023b). Most of the region's hydrocarbon reserves have long-term horizons (Figure 1.10), meaning they can continue to produce oil and gas at current rates for many more decades. Only Bahrain and Oman expect to see their oil and natural gas resources depleted in the coming decades. Due to large oil and gas industries, the GCC states also consider themselves a "last window" for low-cost petrochemicals production, even as decarbonisation policies make this sector increasingly uncompetitive in other parts of the world (APICORP, 2022). This also has implications for the region's position in international climate negotiations, as discussed in more detail in Chapter 4.

The GCC is also a major producer of petroleum products – among them gasoline, liquid petroleum gas, propylene, naphtha (a key source of feedstock in petrochemical production), diesel and fuel oil, kerosene and jet fuel. The region boasted a refining capacity of more than 5.8 million barrels per day (mbpd) in 2021, about half of which was in Saudi Arabia. At some 3.3 mbpd, Saudi Arabia has the largest refining capacity in the MENA region, although it exports only around a third of this, which still makes it one of the world's largest exporters of oil products (OPEC, 2022). The refining capacity of the United Arab Emirates has doubled in the last decade, from around 675 000 barrels per day in 2010 to over 1.27 mbpd by 2021, making the United Arab Emirates and Kuwait the second- and third-largest exporters of petroleum products, respectively, in the GCC (OPEC, 2022).

Figure 1.10 Reserves to production (R/P) ratios for oil and gas in the GCC region, at end-2020



Source: (BP 2023).

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Economic diversification

Economic policy in the GCC countries has emphasised diversification for decades, driven by concerns about the vulnerability of a development model based entirely on one sector and the need to create more – and a greater variety of – jobs for the region's young population. Both job and business creation stand at the core of all GCC countries' long-term strategies to secure their citizens' welfare and living standards, and to shift to economic models that can weather declining oil and gas revenues over the long term. The GCC states are also positioning themselves in the context of changing global industrial and trade dynamics, with considerable interest in industries relocating from other parts of the world, not least in the aftermath of the global COVID-19 pandemic, and the effect of the Ukraine crisis on energy-intensive industries in Europe (IMF, 2022a, 2023b).

Higher oil prices have improved fiscal balances in the GCC region owing to increased windfall oil revenues in 2022 (IMF, 2022a). The parallel recovery of the service and hospitality sectors from the pandemic was made possible through high-profile, tourism-related events such as Dubai Expo 2020, the World Cup in Qatar in 2022 and the reopening of Saudi Arabia for Hajj (IMF, 2022a; World Bank, 2021a).

While the region has been affected by higher commodity prices in the wake of the Ukraine crisis – especially with regard to food import costs – the impacts have remained manageable (IMF, 2022a; World Bank, 2021a). The GCC countries benefited in 2022 from a return to a relatively stable oil price range of USD 60-80/barrel, reflecting the 2015-2023 average. Stabilisation of the oil price has, in turn, helped stabilise countries' fiscal space at a time of economic crisis in many other parts of the world, while fixed exchange rates and fuel and food subsidies managed to keep inflation rates well below the global average (Gatti *et al.*, 2023; Belhaj *et al.*, 2022; IMF, 2023b). Although lower oil production and prices may affect growth rates in 2023, the region maintains ample fiscal buffers and account surpluses (IMF, 2023e).

Government strategies to diversify have become more elaborate over the past decades, placing increased emphasis not only on traditional sectors such as finance, health care, construction and energy-intensive industries, but also on skills development for nationals, knowledge economies, services, and environmental and energy sustainability. The services sector is the most important sector after oil and gas in the GCC region, accounting for between 50% and 70% of regional GDP, based on tourism, leisure and banking (World Bank, 2023b). Box 1.1 summarises wider economic diversification strategies.

Ambitions are high across the region, but progress has been varied, both across countries and sectors (Arab Times, 2023). One key step towards diversifying energy sectors more effectively, and to introducing stronger incentives for energy efficiency, is the reform of energy and water prices, which have historically been highly regulated and continue to be extremely low in parts of the region. Chapter 4 looks more closely at the subject of reform.

Box 1.1 National economic strategies of the GCC countries as of March 2023

Bahrain's ***Economic Vision 2030*** calls for a "shift from an economy built on oil wealth to a productive, globally competitive economy, shaped by the government and driven by a pioneering private sector". Efforts are being made to attract foreign direct investment so as to create jobs. By 2030, financial services are set to become a pillar of the economy, together with oil and gas, and complemented by tourism, business services, manufacturing and logistics. In October 2021, the Bahraini government announced a new national multi-year economic growth and fiscal balance plan with the aim of enhancing the economy's long-term competitiveness and supporting the post–COVID-19 recovery. The new five-pillar plan, which is aligned with Bahrain's Economic Vision 2030 and the Kingdom's intention to achieve net zero carbon emissions by 2060, includes a new labour market reform plan, a regulatory reform package and a strategic investment plan valued at more than USD 30 billion (BNA, 2021). A Priority Sectors Plan further aims to generate growth in six sectors over the period of 2022-2026 (Oxford Business Group, 2022b). In addition to the sectors named above, the plan includes the digital economy.

Kuwait's **Vision 2035** – "New Kuwait" – aims to transform Kuwait into a financial and trade hub regionally and internationally, making it more attractive to investors. This includes greater competition within the private sector; institutional reform to cultivate a business-friendly environment; economic diversification; the modernisation of infrastructure, education and health care; and environmental sustainability (Ministry of Foreign Affairs, 2021).

The Sultanate of Oman launched its own social and economic long-term plan, **Oman Vision 2040**, in January 2020, to prepare the country for falling oil and gas production in the coming decades. Spans a wide range of sectors, the plan emphasises social protection; economic diversification and fiscal sustainability; labour market competitiveness; sustainable environmental and natural resource management; and smart and sustainable cities (Government of Oman, 2020; Prabhu, 2021). Non-oil economic activities are expected to constitute more than 90% of GDP by 2040, up from 25% in 2020 (Government of Oman, 2020). Oman's **Tenth Five-year Development Plan** ("10th FDP", Royal Decree 1/2021), covering the period of 2021-2025, places further emphasis on promoting sustainable human development, stimulating economic activity and diversifying the economy, creating 135 000 job opportunities (Ministry of Health, 2021; PwC, 2021).

Qatar's **National Vision 2030** and National Development Strategy (2011–2016) foresee a dominant role for hydrocarbons in the future economy but also provide a gradual and managed diversification strategy with greater involvement of the private sector. National institutions are developing strategies for investments in transport infrastructure, housing, and industrial activities to prepare for the FIFA World Cup in 2022.

Box 1.1 National economic strategies of the GCC countries as of March 2023 **(continued)**

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Saudi Arabia's **Vision 2030**, launched in early 2016, is a comprehensive strategy for systematically restructuring the Saudi economy away from its historical dependence on oil (Kingdom of Saudi Arabia, 2022a). Among the plan's key vehicles are so-called vision realisation programmes focusing on a variety of goals, among them financial sector development, privatisation, the transformation of the health sector, human capability development, national industrial development and logistics. Core to the Vision 2030 is the **National Transformation Program** and the newly empowered **Public Investment Fund**, which is tasked with developing and investing in sectors that promise to diversify the economy. Vision 2030 also emphasises the Saudi government's commitment to sustainability. Key initiatives with this focus include the **National Renewable Energy Program** and the **King Salman Renewable Energy Initiative** (both launched in 2017), the **National Environment Strategy** (2018), the **Green Riyadh Project** (2019), the launch of the **Environmental Fund** (2020), the **Saudi Green Initiative** and the **Middle East Green Initiative** (2021). Also in 2017, the Saudi government announced the launch of NEOM, a sustainable urban development effort in the northwestern region, which aims to become a regional innovation and low-carbon hub.

The United Arab Emirates (UAE) has a range of economic development strategies, both at the federal and emirate level. The federal **UAE Energy Strategy 2050, UAE Green Growth Strategy, UAE Future Strategy** and **UAE Centennial Plan** (2071) all highlight economic diversification and technological innovation as pivotal to future development. Besides a conventional focus on tourism, aviation, advanced manufacturing and services, the plans place great emphasis on creating a "competitive knowledge economy", positioning the country as a regional hub for research, innovation and sustainable energy (Government of the United Arab Emirates, 2023b). Emirate-level strategies include **Abu Dhabi Economic Vision 2030**, **Abu Dhabi Environment Vision 2030**, **Plan Abu Dhabi 2030** and **Dubai Strategic Plan 2030**. Individual sector strategies aim to promote the development of new technologies and modern transport systems, such as **Abu Dhabi Transportation Mobility Management Strategy**, Abu Dhabi's **Surface Transport Master Plan**, **Dubai Autonomous Transportation Strategy** and **Dubai Industrial Strategy 2030** (Government of the United Arab Emirates, 2022a).

1.2 DOMESTIC ENERGY CONSUMPTION

The GCC countries are not only major exporters of fossil fuels. Oil and natural gas also account for almost all of their final energy consumption, including electricity (Figure 1.11). (Coal, which is imported, is used only in the United Arab Emirates and in very small volumes.) While the GCC economies have historically been minor energy consumers compared with major world markets, consumption has increased more than fourfold over the past 30 years (Figure 1.11). This growth reflects high income levels and living standards, historical choices of industrialisation based on energy-intensive industries and low levels of energy efficiency linked to the region's history of a perceived abundance of low-cost energy.

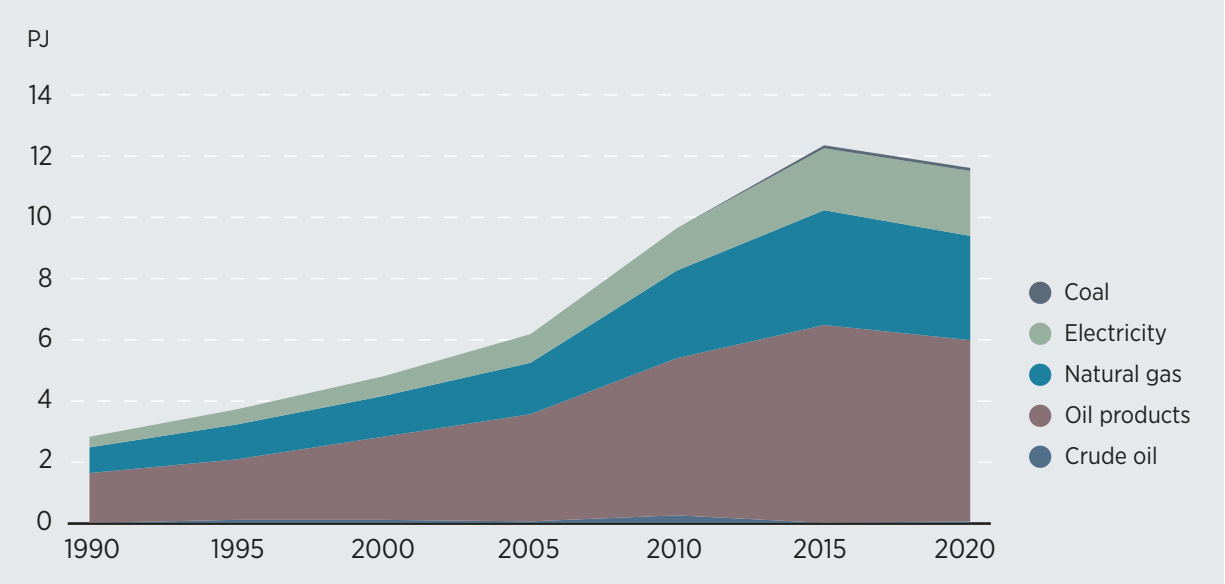
While making up less than 15% of the MENA region's total population, the GCC countries accounted for over 60% of its total final energy consumption in 2021 (IEA, 2023b; World Bank, 2023b). Saudi Arabia alone accounts for more than half of the GCC group's consumption (Figure 1.12) and is the world's 11th-largest consumer (IEA, 2023b).

Industry – much of which is centred on energy-intensive activities such as steel, aluminium and petrochemicals production – accounts for around a third of GCC-wide final energy consumption (Figure 1.13). Industry is followed by transport and non-energy use. Transport across the GCC is centred on road transport, with very high rates of private vehicle ownership relative to the population.[3]

Shares vary significantly by country. In Saudi Arabia, industry accounts for less than a quarter of total final energy consumption, with non-energy uses being the single largest consumer of energy, followed by transport, and only then industry. In Kuwait and Bahrain, by contrast, industries are the largest final energy users (Figure 1.14). Most non-energy use in the GCC is industrial, since oil and natural gas are not only a source of energy, but also a feedstock, particularly in the petrochemicals industries, which produce intermediate and final goods such as asphalt/bitumen, lubricants, waxes, naphtha, kerosene, olefins and ammonia.

[3] *Latest data available on vehicle ownership is from 2016 via the WHO website. Per capita vehicle ownership is calculated by dividing those numbers by population data by the authors. Vehicle ownership data from WHO (2022).*

Figure 1.11 Historical total final energy consumption in the GCC, by energy source (PJ), 1990-2020



Source: IEA (2023b).
Note: PJ = petajoules; TFEC = total final energy consumption.

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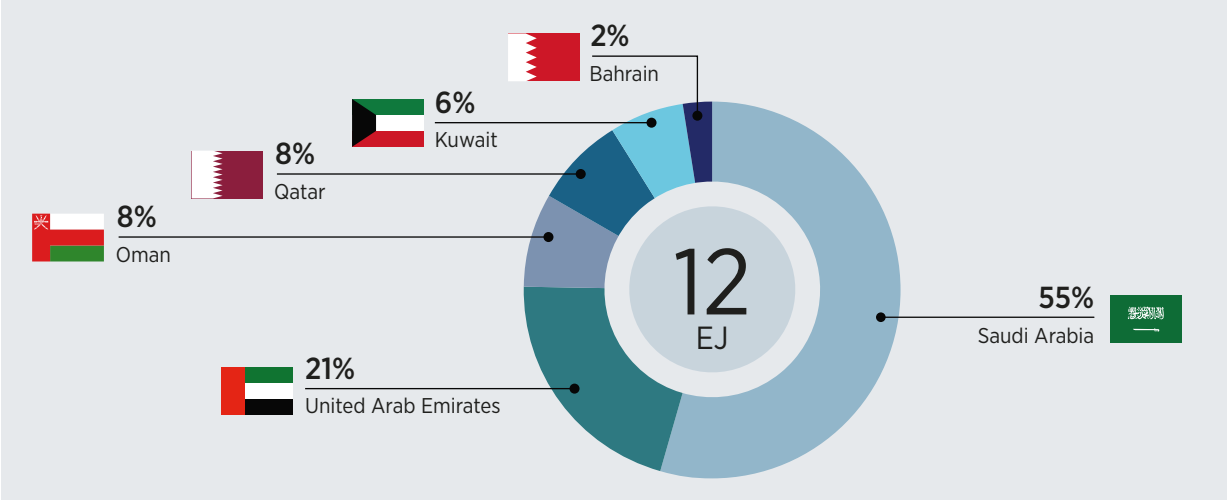
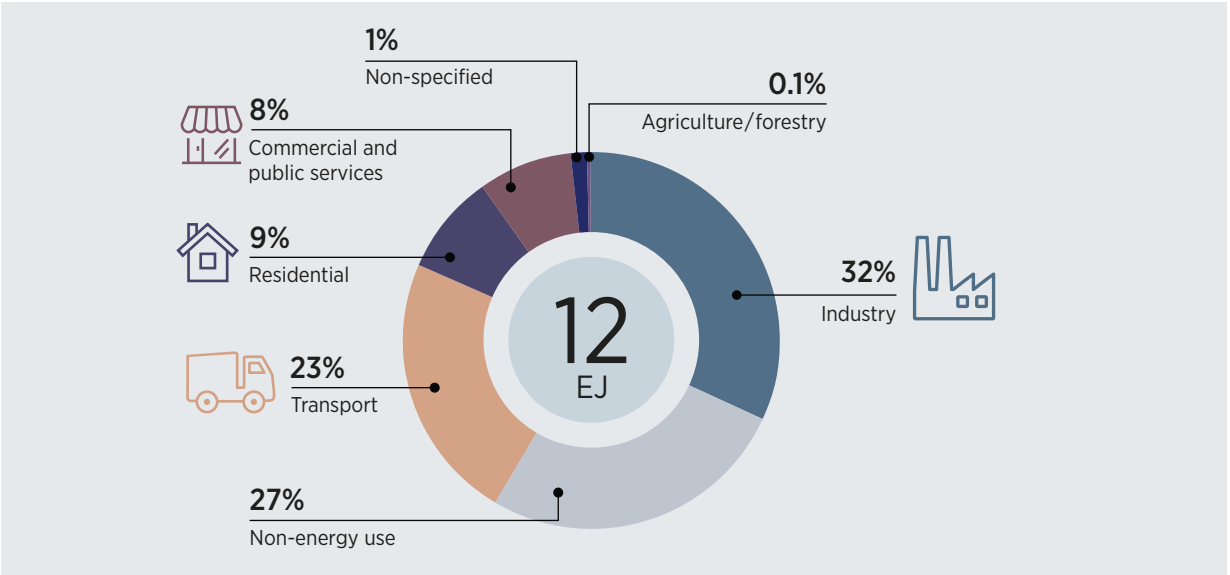
Figure 1.12 Total final energy consumption by country as a share of the GCC region's total, 2020



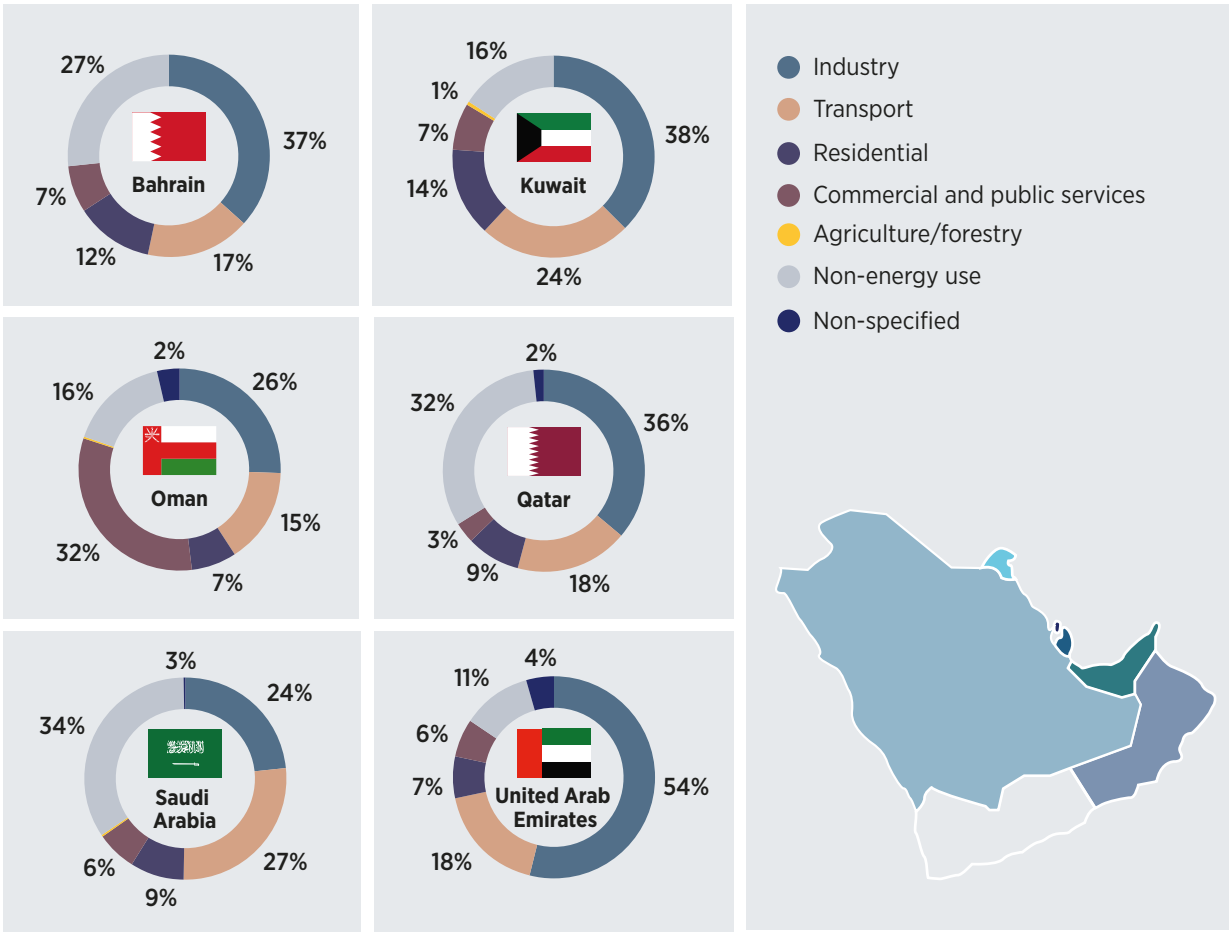
Source: IEA (2023b).

Figure 1.13 Total final energy consumption in the GCC by sector as a share of the total, 2020



Source: IEA (2023b).

Figure 1.14 Total final energy consumption by country and sector as a share of the total (%), 2020



Source: IEA (2023b).

Overall, the shares of transport and industry have dropped somewhat over the past 20 years, while the shares of residential, commercial and public service energy consumption have grown, although from low levels. Here, too, the degree of change differs between countries (IEA, 2023b).

Only Saudi Arabia and the United Arab Emirates have domestic rail networks, and they are powered by diesel-electric locomotives (except in the case of the Haramein High Speed Rail, which is fully electrified) (Etihad Rail, 2023; SAR, 2022). Saudi Arabia operates several rail links, mostly for the purpose of moving commercial freight between industrial centres. The country is currently expanding its rail links, including for passenger transport, to connect Riyadh to the northwest and the Jordanian border (SAR, 2022). The United Arab Emirates has plans for extensive commercial and passenger links to connect Abu Dhabi with Dubai, Sharjah, Ras Al Khaimah and Fujairah by the end of 2024 (Etihad Rail, 2022). For the time being, the Emirates rely almost entirely on private vehicle transport for all goods and passengers within its borders; buses carry a small share. None of the other GCC states have rail lines, although Oman has signalled interest and has signed a contract to connect its port in Sohar with the United Arab Emirates' network (Etihad Rail, 2022; Oman Rail, 2023).

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Rising demand has driven inefficient and wasteful uses of domestically produced fossil fuels and driven up imports of natural gas. The United Arab Emirates is currently the region's largest importer of natural gas, with imports of around 13.7 billion standard cubic meters in 2021, equivalent to roughly the annual gas consumption of Belgium (Figure 1.15). Production has lagged demand growth for more than a decade despite ample gas reserves and a smaller volume of liquefied natural gas exports. Qatar is currently the only country in the GCC that can maintain large export volumes while also supplying 100% of domestic demand.

The GCC countries' electricity markets have grown rapidly over the past decades on the back of universal access to electricity since the 1980s, burgeoning domestic demand from the countries' industries, commercial and residential consumers. Energy-intensive industrialisation, high incomes and living standards, large family homes and the need for year-round air conditioning are all major drivers of this growth. Historically limited regulation of energy efficiency in the building and energy sectors – aided by heavily subsidised, and thus cheap electricity – have further added to the growth in electricity consumption.

Saudi Arabia is the region's largest electricity producer, with some 83 500 megawatts (MW) of installed generation capacity, followed by the United Arab Emirates and Kuwait (Figure 1.16). The size of the GCC states' electricity markets is by no means small; the region's total generation capacity as of 2022 was around 173 gigawatts (GW), more than the size of the electricity system of Canada and close to that of Brazil. Saudi Arabia's generation capacity exceeds that of Viet Nam and Indonesia, countries with populations of more than hundred million people. The size of the United Arab Emirates' electricity sector, in a country of 10 million people, exceeds that of Malaysia, a country with three times the population.

Virtually all of the GCC capacity is powered by fossil fuels, primarily natural gas, but also oil products – and even, at peak times, crude oil – in Saudi Arabia and Kuwait (Figure 1.17). Only around 3% of the region's current installed capacity is based on renewable energy, concentrated in the United Arab Emirates, Qatar and Oman in the form of solar photovoltaic (PV) power, with nuclear energy playing an increasingly important role in the United Arab Emirates.

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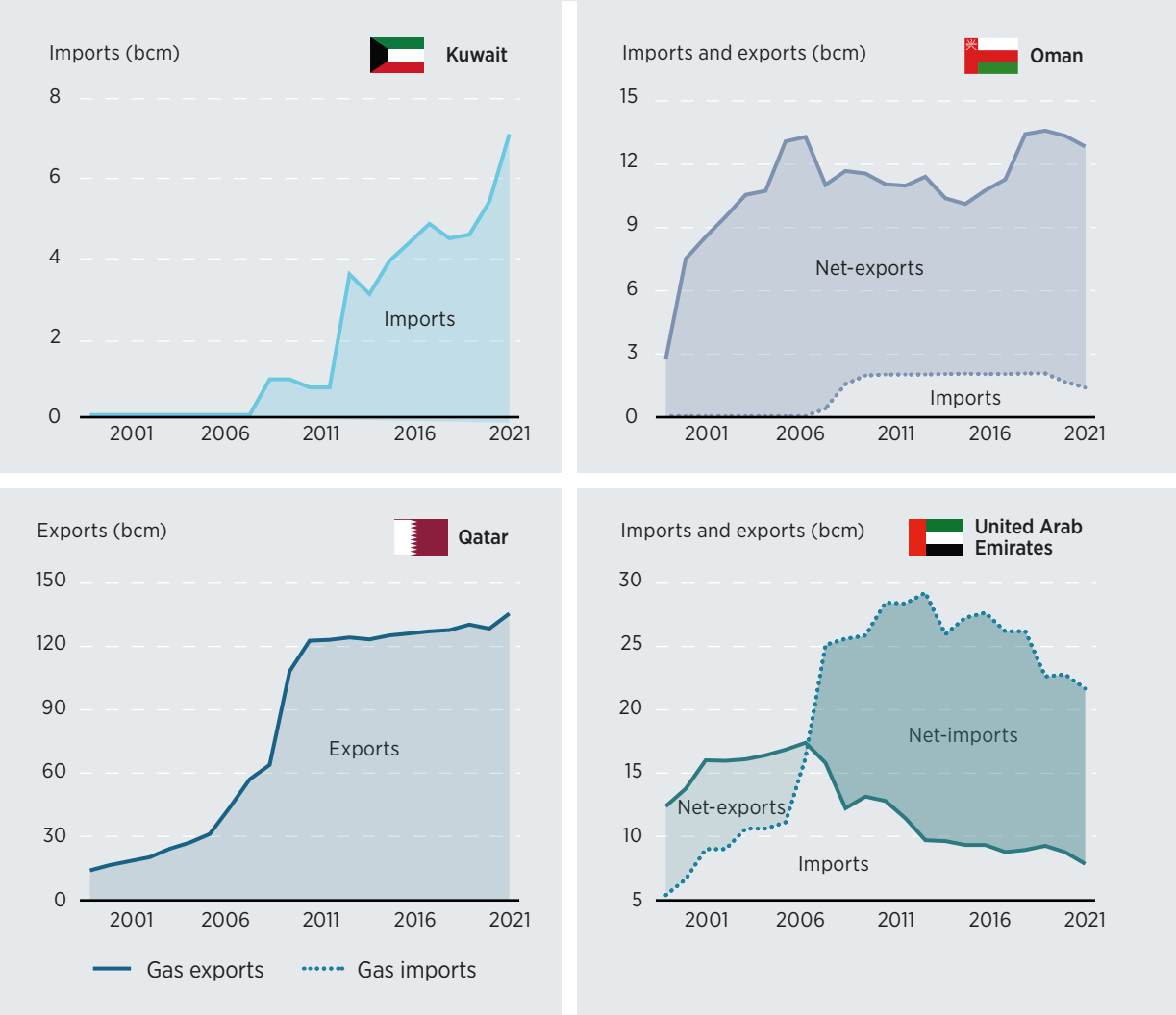
Figure 1.15 GCC Gas Trade, 2000-2021



Source: (OPEC 2022).
Note: bcm = billion cubic metres.

The GCC countries took a step towards interconnecting their electricity sectors by establishing a regional grid in 2009. The interconnection has a relatively small capacity of 2.4 GW, primarily because it was designed in the 1990s, when demand was lower (El-Katiri, 2011; GCCIA, 2017; see also Box 1.2). Updating the grid by expanding its capacity and creating a wholesale market similar to those of several European systems and Latin America is technically possible and could be economically beneficial. The benefits could be particularly great for smaller countries such as Bahrain, Kuwait, and Qatar, whose comparably small land surface does not allow for large-scale renewable energy deployment. In addition, an expansion of the grid to neighbouring countries in the Middle East and North Africa via links between neighbouring countries such as Egypt, Jordan and Saudi Arabia could increase the use of variable renewables-based electricity such as solar PV and wind power – as well as accommodating intra-regional differences in load patterns and peak demand.

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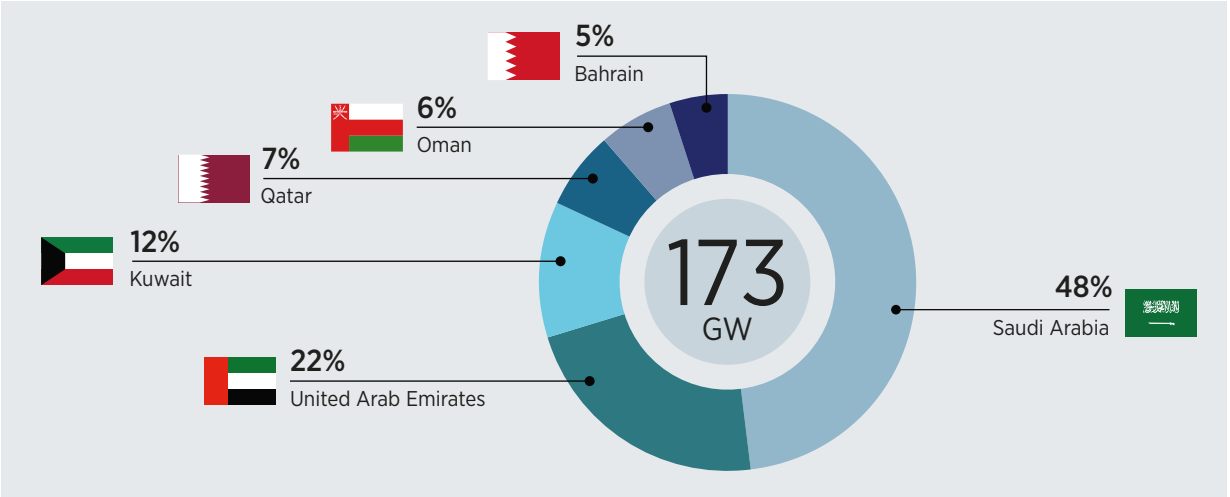
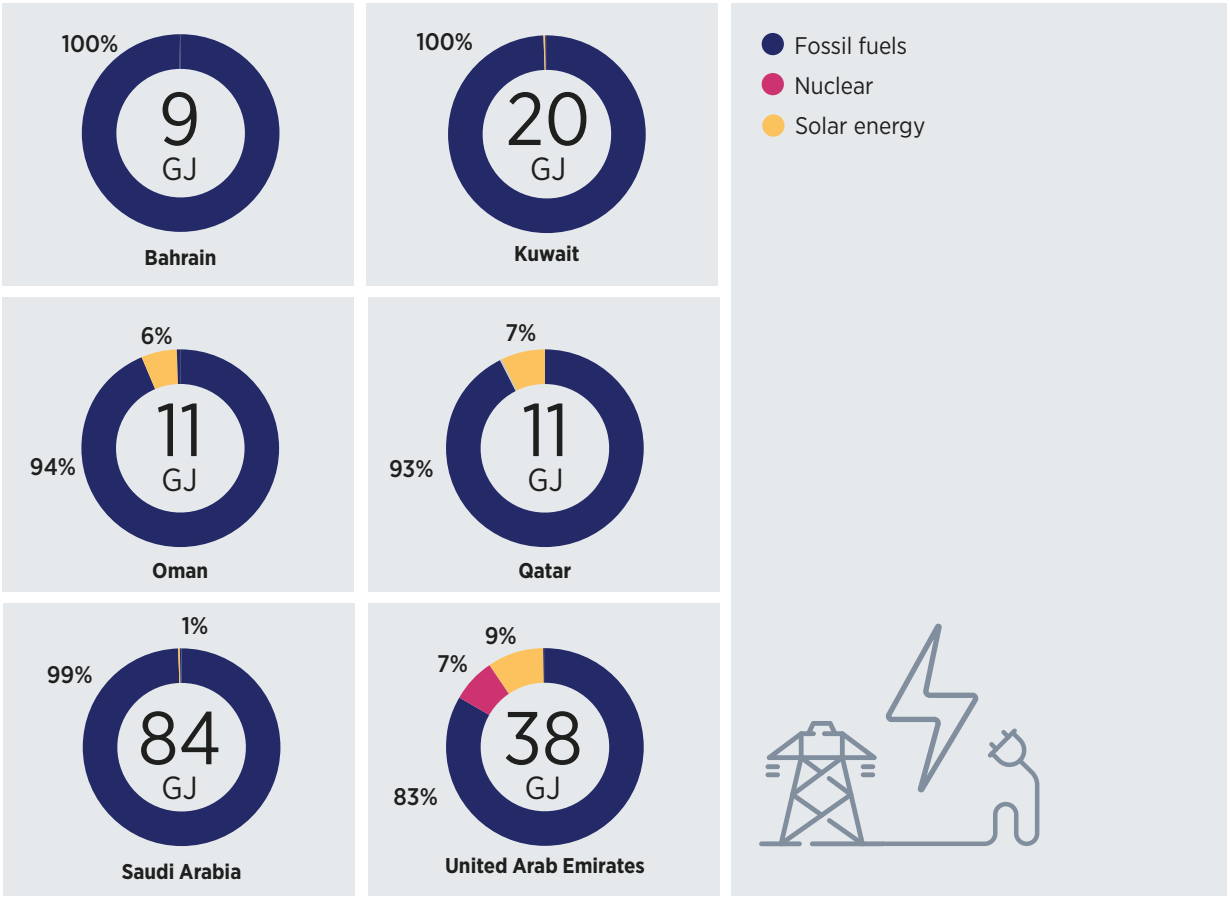
Figure 1.16 Installed electricity generation capacity in the GCC by country (GW), 2020



Source: (IRENA 2023b).
Note: MW = megawatt.

Figure 1.17 Electricity generation by fuel source (%) in the GCC countries, 2020



Source: (IRENA 2023b).
Note: GJ = gigajoule.

Box 1.2 The GCC Interconnection Grid

The Gulf Cooperation Council (GCC) Interconnection Grid connects the national grids of the six GCC member states. It began operations in 2009, when initially four and later all six members linked their national grids. Conceived in the 1980s, the grid has a total capacity of 2 400 megawatts (MW). A double-circuit 400 kilovolt (kV), 50 hertz (Hz), alternating current (AC) line connects the six countries along the Gulf's western shore. The northern and southern members are brought into the interconnection via 400 kV lines, and a 220 kV line links Oman through the United Arab Emirates. Saudi Arabia is linked to the grid via a separate back-to-back high-voltage, direct current (DC) interconnection using a 380 kV line. Bahrain is linked via a 400 kV subsea cable.

The grid was originally expected to facilitate intra-regional electricity trade within the GCC, but today it primarily serves the purpose of sharing spinning reserves and exchanging small volumes of scheduled or unscheduled power transfers in emergencies. The amount of electricity actually exchanged between the GCC countries has been limited by the absence of a commercial trading market. The GCC Interconnection Authority (GCCIA) estimates that between 2011 and 2017, member countries saved some USD 2.2 billion by sharing spinning power and through occasional electricity exchanges. The annual benefits, including savings in installed capacity investment, operation and fuel costs, are approximated between USD 200-300 million.

There has been considerable interest in expanding use of the grid for commercial purposes. The GCCIA has positioned itself as one of the most important advocates of regional power trading. When the United Arab Emirates' link to the grid opened in April 2011, energy ministers and other regional leaders described it as both an emergency tool and a backbone for future trade. In November 2017, a six-month trial of spot trading was initiated, with the aim of developing a commercial platform from this experience.

A complex but technologically feasible task, a regional power market based on the existing interconnection would need to overcome several hurdles, including, initially, an upgrade of the grid's capacity to accommodate larger volumes of traded electricity to justify investment in large-scale projects such as Saudi Arabia's Solar Power Project 2030. A regional market would also necessitate a new legal framework, which, in turn, would depend on overcoming intra-regional political hurdles between neighbouring countries. Tariffing questions would have to be agreed on, and national utility markets would probably have to be reformed to allow utilities to buy electricity from abroad under a commercial mechanism.

The successful use of the GCC interconnection grid for commercial electricity trading could also provide incentives for expanding the grid beyond the GCC. Egypt and Saudi Arabia are linking their national grids via a 3 000 MW link below the Red Sea to take advantage of different demand peaks between Egypt and the Gulf countries via Saudi Arabia (MEED, 2021). This, in turn, could incentivise further GCC investment in clean energy projects in Egypt. Yemen provides another grid expansion option; it could benefit tremendously from the added generation capacity and power system stability that access to a GCC electricity pool could provide. An interconnection could be an important form of post-conflict economic restructuring in Yemen. As of 2023, the GCC interconnection was being upgraded through several projects, including a second interconnection with Oman, an interconnection between Kuwait and the United Arab Emirates, and a connection to Iraq.

Source: (IRENA, 2019a and Asaba, 2023).

01

1.3 CLIMATE CHANGE AND GHG EMISSIONS IN THE GCC

As part of the Middle East, which has been labelled the "global ground zero for climate change" (Bou Serhal, 2022), a "climate change hotspot" (Shahid, 2022), and the area that will "be most affected by climate change and global warming", the GCC countries are highly vulnerable. Additionally, the GCC region is one of the areas "most vulnerable to sea level rise" (RCRCCC, 2021). Tackling climate change has therefore become a necessity for these countries.

Climate shocks like temperature rises, extreme heat waves, scorching summers, intensified depletion of freshwater resources, regional desertification with intensified dust storms, extreme precipitation events, coral bleaching and sea-level rise (threatening up to 11% of Bahrain's total land area, for example) are expected to become routine by mid-century (Bayram and Öztürk, 2021; Feitelson and Tubi, 2017; IPCC, 2023, 2018; Kamrava and Babar, 2012; Lelieveld *et al.*, 2016; Waha *et al.*, 2017; Wodon *et al.*, 2014; Zittis *et al.*, 2021). Kuwait is already regularly breaking global heat records in July and August (BBC News, 2021; Michaelson, 2017), and climate change will likely make these heat periods longer and more extreme. Oman, owing to its geography, is exposed to more frequent extreme weather events such as tropical and severe cyclonic storms (Reuters, 2021b; World Bank, 2021b).

With the GCC population highly urbanised, climate change presents some additional challenges. As noted at the outset of the chapter, 90% of the GCC region's population lives in urban areas, which cover just ~1.5% of the available territory, making inhabited areas extremely dense (EcoMENA, 2021; Dumortier, 2016). Density will further aggravate the effects of climate change and other environmental issues, such as urban heat island effects, high levels of air and noise pollution, and vulnerability to sea level rise and extreme weather events (GFDRR, 2020); UNCTAD, 2021; World Bank, 2021a). The impact of climate change on biodiversity and desertification are additional risks that add to existing pressures in nature in the region as a result of rapid land development, particularly in coastal areas.

Most of the emissions associated with the GCC region's fossil fuels are generated in countries that import their oil and gas; historically, the GCC has been a marginal direct emitter of GHG emissions. That is changing (Figure 1.18). As of 2020, the MENA region as a whole accounted for around 9% of the world's total GHG emissions (with a similar share in global carbon dioxide [CO_2] emissions), of which the GCC countries accounted for around 40% (Figure 1.19). Total GHG emissions in the GCC more than doubled over the 2000-2020 period. Saudi Arabia alone accounts for around half of GCC emissions, followed by the United Arab Emirates, making Saudi Arabia the second-largest emitter of GHG in the Middle East and North Africa, after the Islamic Republic of Iran, and the world's ninth-largest emitter of GHG, larger than Germany, a highly industrialised country with twice the population of Saudi Arabia (World Bank, 2023b).

Figure 1.18 Historical, total GHG emissions by region ($MtCO_2eq$), 2000-2020

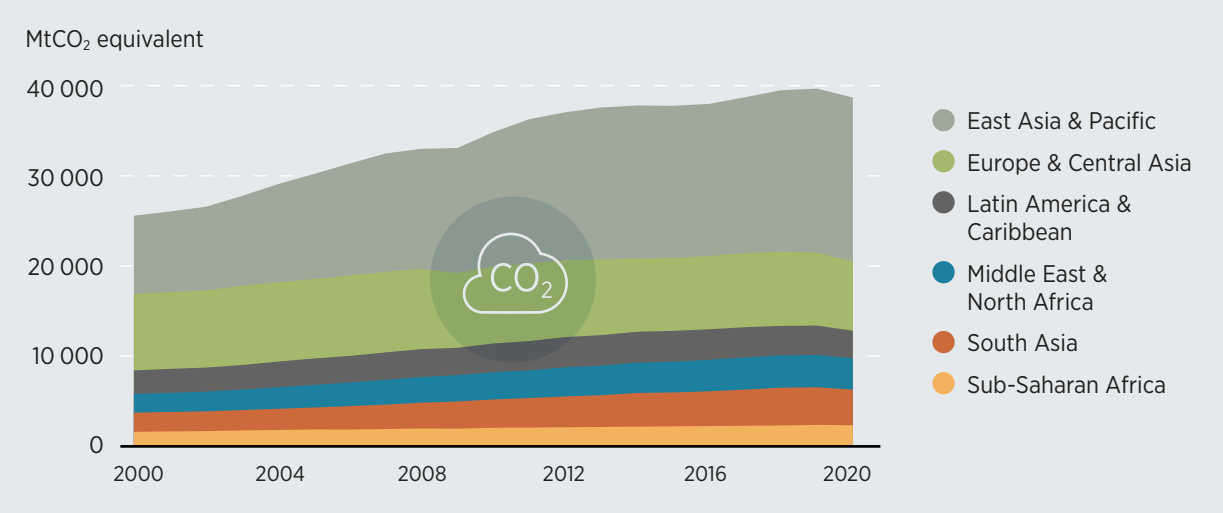
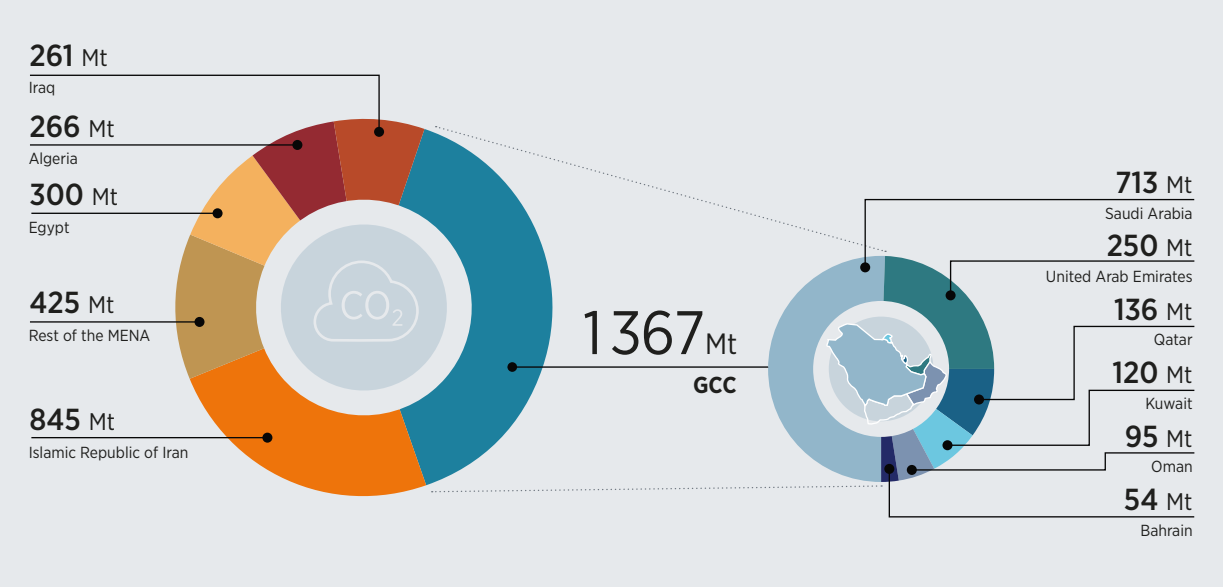


Figure 1.19 GHG emissions in the MENA region ($MtCO_2eq$), 2020



Source: (World Bank 2023a).

Notes: The MENA region here follows the World Bank's definition: Algeria, Bahrain, Djibouti, Egypt, the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, Tunisia, United Arab Emirates, State of Palestine, and Yemen. Data do not include emissions from exported fossil fuels.

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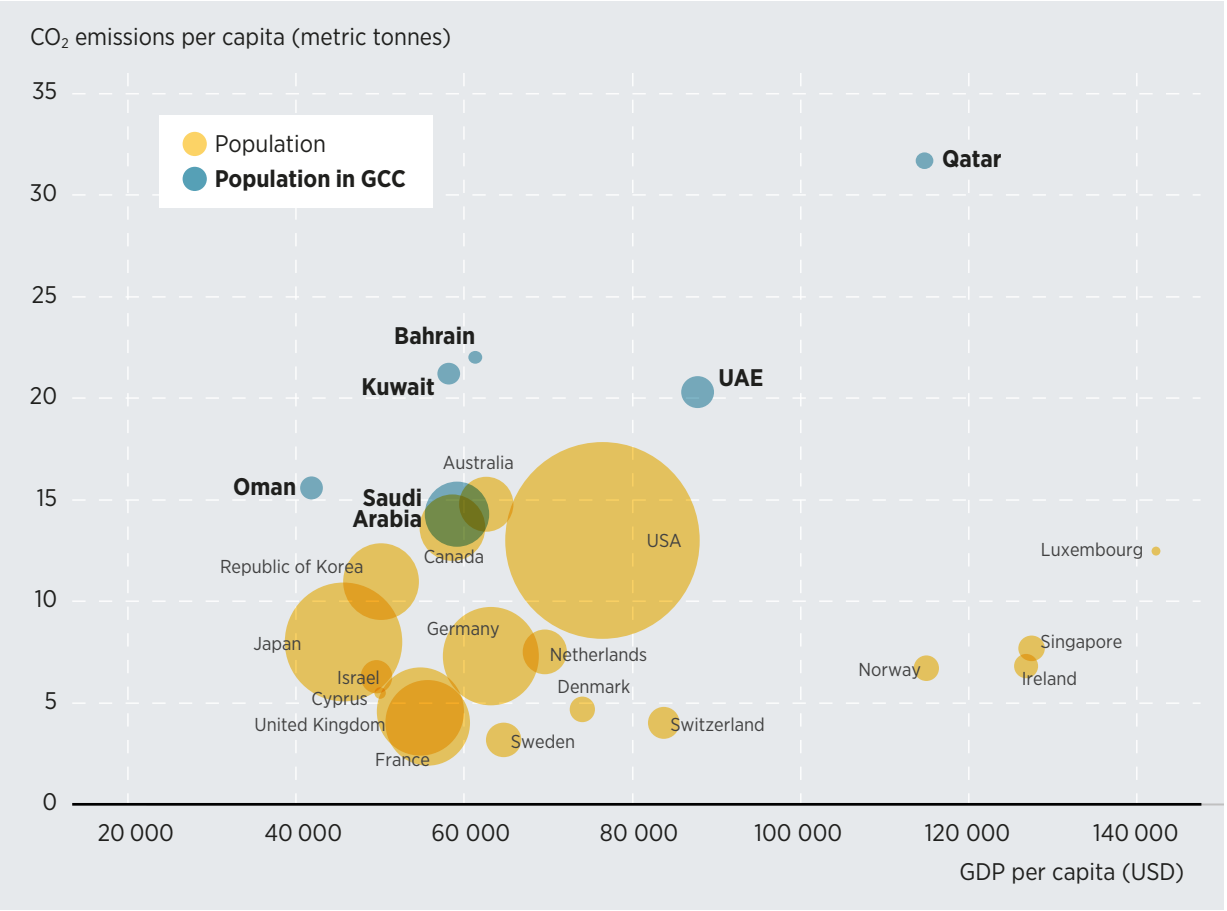
With energy provided almost exclusively from hydrocarbons until recently, the GCC countries are also among the world's largest per capita emitters of CO_2 (World Bank, 2023b). Qatar stands out as the world's single largest emitter on a per capita basis, far larger than all other countries (Figure 1.20).

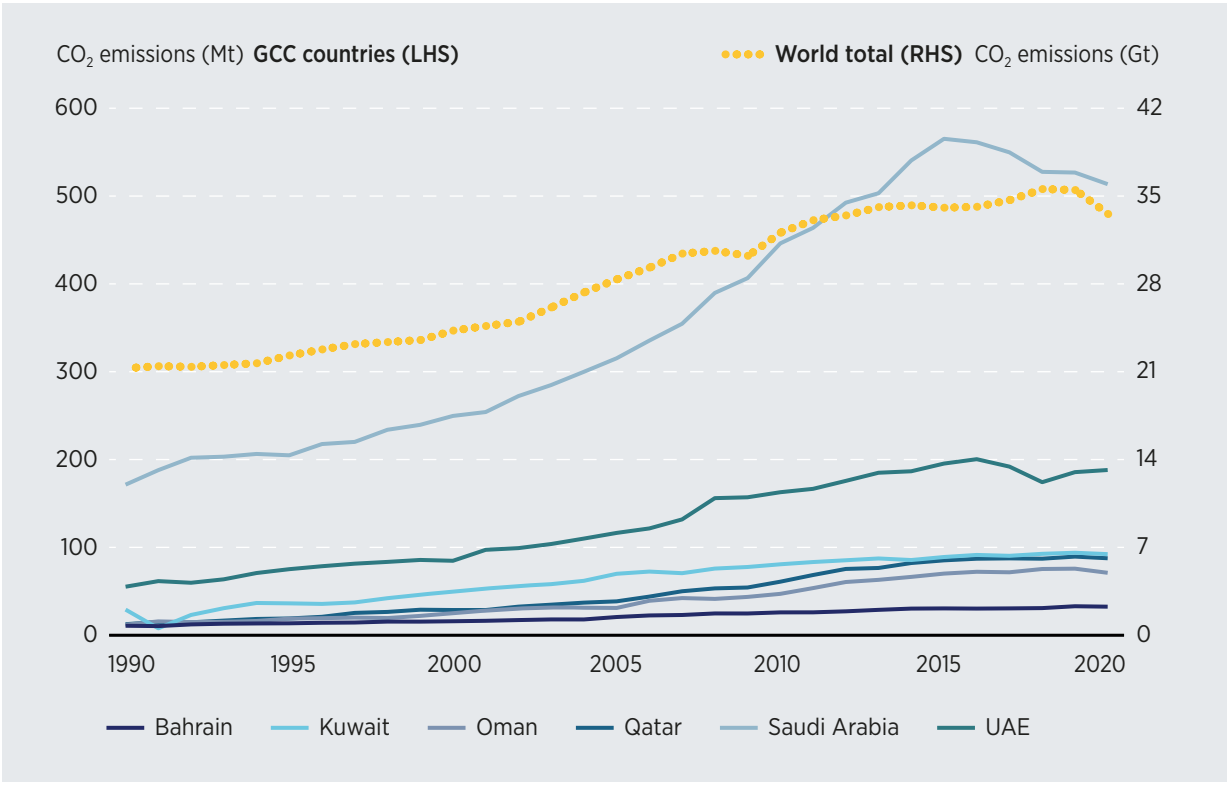
Figures 1.21, 1.22 and 1.23 present a schematic of the GCC region's emissions and energy intensity. Both emissions and the energy intensity of GDP (the amount of energy required to produce a unit of economic output) have risen over time, although per capita emissions have declined somewhat for some, such as Qatar, though it remains the world's highest per capita emitter. Qatar's energy intensity has not risen greatly in recent years, but this is because rapid growth in GDP has outpaced energy production. For comparison, other countries with a high energy intensity, such as the Russian Federation and the United States, have managed to reduce it, as four out of the six GCC countries (Kuwait, Oman, Saudi Arabia and the United Arab Emirates) have risen above the level of the United States.

Figure 1.20 CO_2 emissions per capita versus GDP per capita (current USD) of selected countries, 2022



Source: (World Bank 2023a; Climate Watch 2023).
Note: Bubble size represents population.

Figure 1.21 CO_2 emissions of the GCC countries versus the world



Source: (World Bank 2023a).
Notes: LHS = Left-hand side; RHS = Right-hand side.

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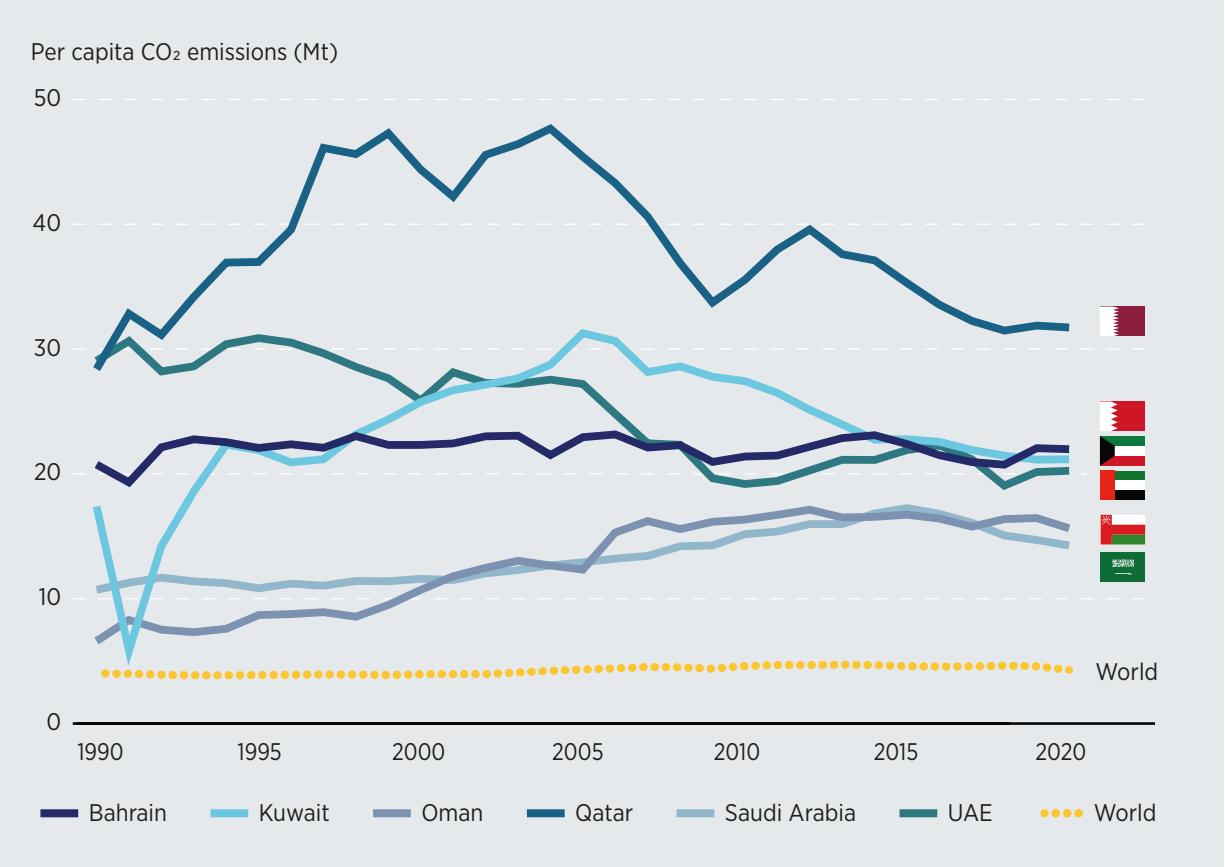
Figure 1.22 Per capita CO_2 emissions of the GCC countries versus the world



Source: (World Bank 2023a; Climate Watch 2023).
Note: Mt = million tonnes.

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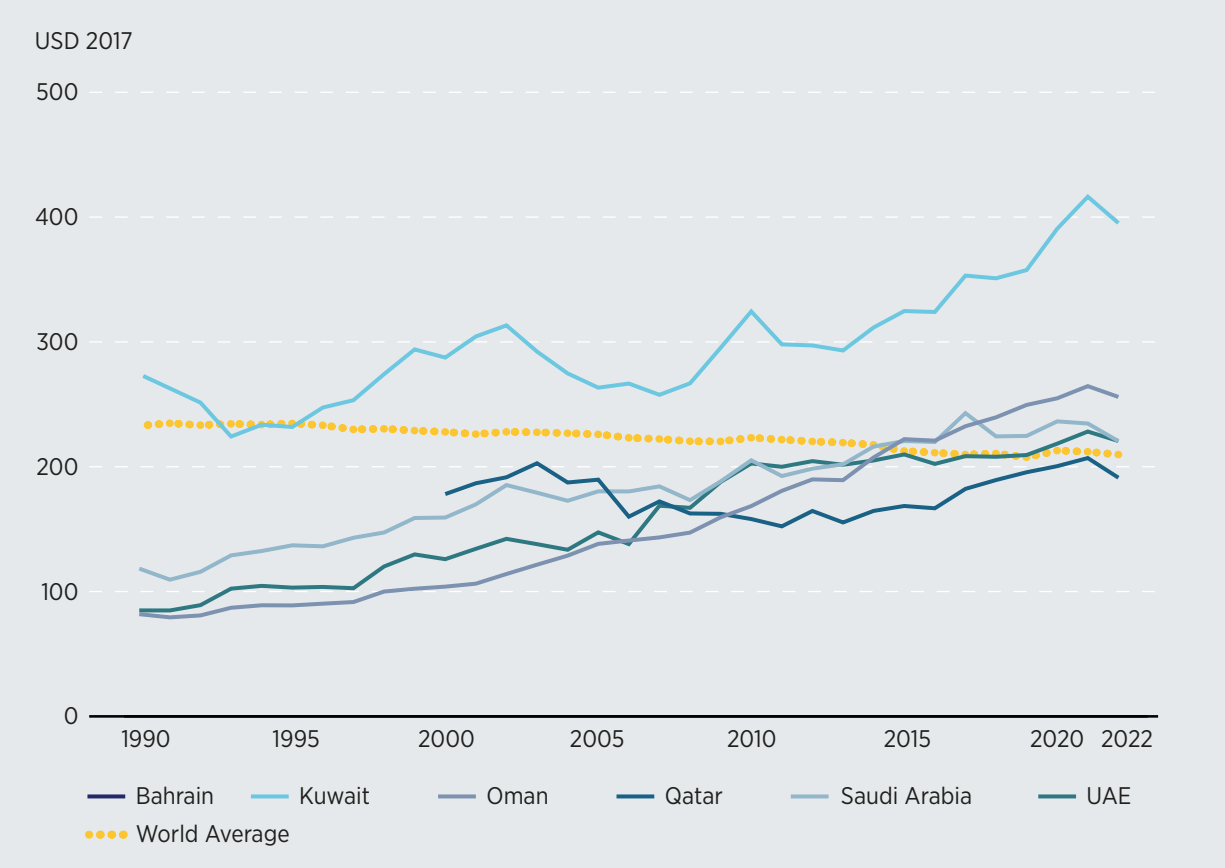
Figure 1.23 Energy Intensity of GDP (PPP, constant USD 2017)



Source: (World Bank 2023a).

RENEWABLE ENERGY POTENTIAL, COSTS AND DEPLOYMENT STATUS

Dubai, UAE: HH Sheikh Mohammed Bin Rashid Al Maktoum solar park

02

The Gulf Cooperation Council (GCC) region's renewable energy potential has long been recognised. Excellent solar resources (and, in parts of the region, wind), auctions designed to facilitate lower costs, favourable financing conditions and declining technology costs, all contribute to renewables' prospects of becoming the most cost-effective source of power generation in the region (Smith, 2023; Padmanathan, 2018). Renewables' affordability – along with key developments such as the reduced domestic consumption of fossil fuels, increasingly ambitious climate targets, economic diversification and industrial innovations (*e.g.* in clean hydrogen production) – is likely to spur investments in renewable energy in GCC countries in the upcoming years. This chapter outlines the region's resource potential (section 2.1) and the current status of renewables' deployment in select countries (section 2.2) before taking an in-depth look at renewables' cost reductions (section 2.3).

2.1 RENEWABLE RESOURCE POTENTIAL

The GCC countries are blessed with high solar resource potential: their average annual global horizontal irradiation (GHI) ranges between 1 700 and 2 500 kilowatt hours per square metre (kWh/m^2) (Figure 2.1a). These GHI levels are comparable to those of other countries in the Middle East and North Africa (MENA) region, such as Jordan and Morocco (IRENA, 2019a). GHI, which is crucial for power generation via solar photovoltaic (PV), is particularly strong in the north-west, centre and south of Saudi Arabia and in southwest Oman. Bahrain, Qatar and the United Arab Emirates (UAE) have moderate wind resource potential, characterised by relatively low on-shore wind speeds. Large areas in the centre and north of Saudi Arabia, southern Oman and north-western Kuwait have good wind resources (above 7.5 metres per second) (Figure 2.1b). Wind speeds are world class along the northern Red Sea coast (where Saudi Arabia is building its first hydrogen export facility at NEOM).

Some areas, notably in Oman and Saudi Arabia, also boast good resources for concentrated solar power (CSP). Beták *et al.* (2012) suggest that Saudi Arabia may have the best direct normal irradiation (DNI) locations in the GCC region, comparable to select locations in Jordan, Morocco and Spain. The combination of dust and high humidity along the region's Gulf coast affects DNI and the optimal choice of CSP technology. Year-round dust and humidity cloud solar PV panels and mirrors, meaning that less sunlight is absorbed or reflected, as the case may be (IRENA, 2019a). Climatic differences across the Arabian Peninsula also decide GHI levels. Looking beyond the GCC region, extreme dust events in North Africa trigger GHI to drop by 40-50% and DNI by 80-90% (Kosmopoulos *et al.*, 2017).

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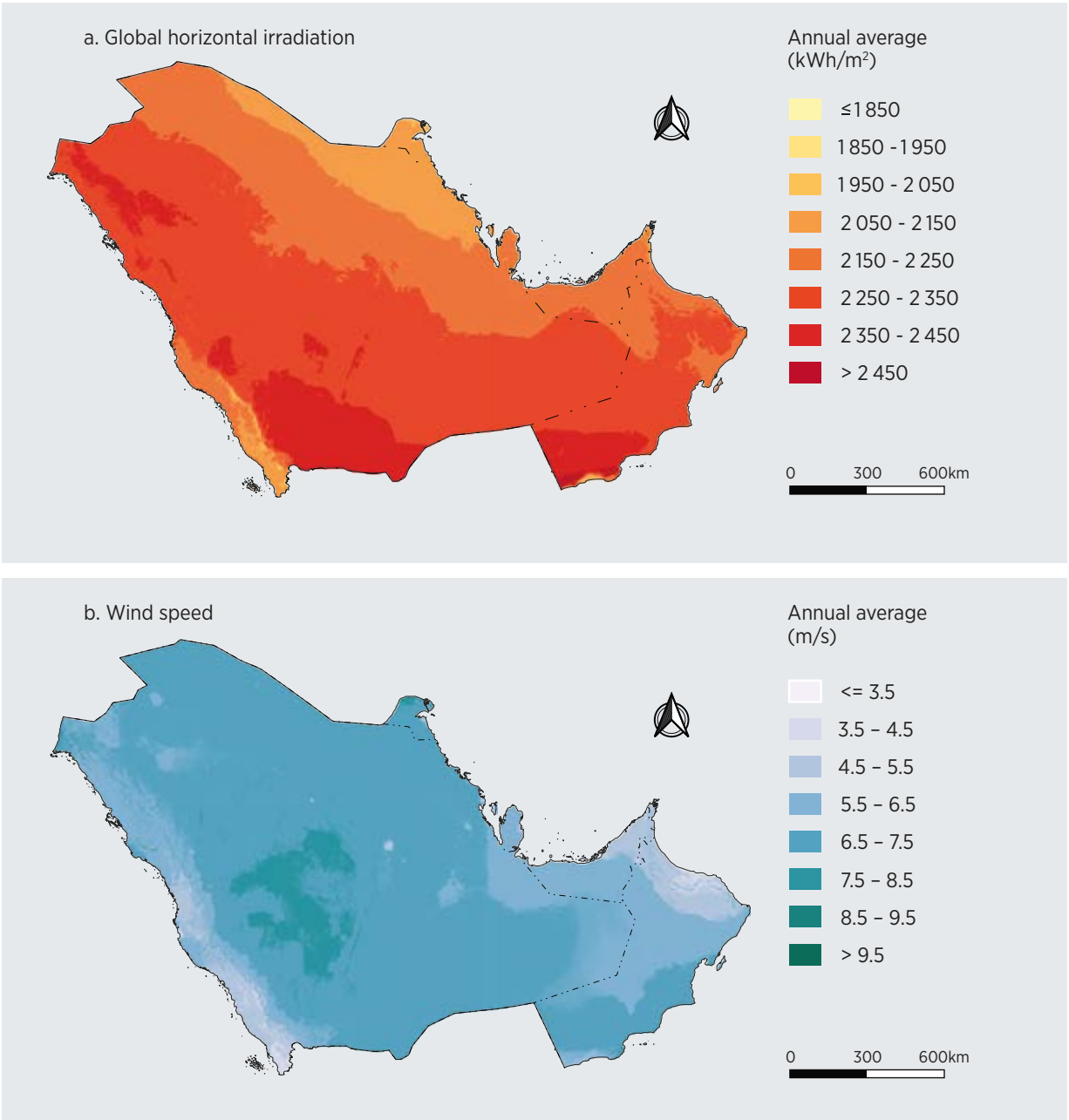
Figure 2.1 Solar and wind resources in GCC countries

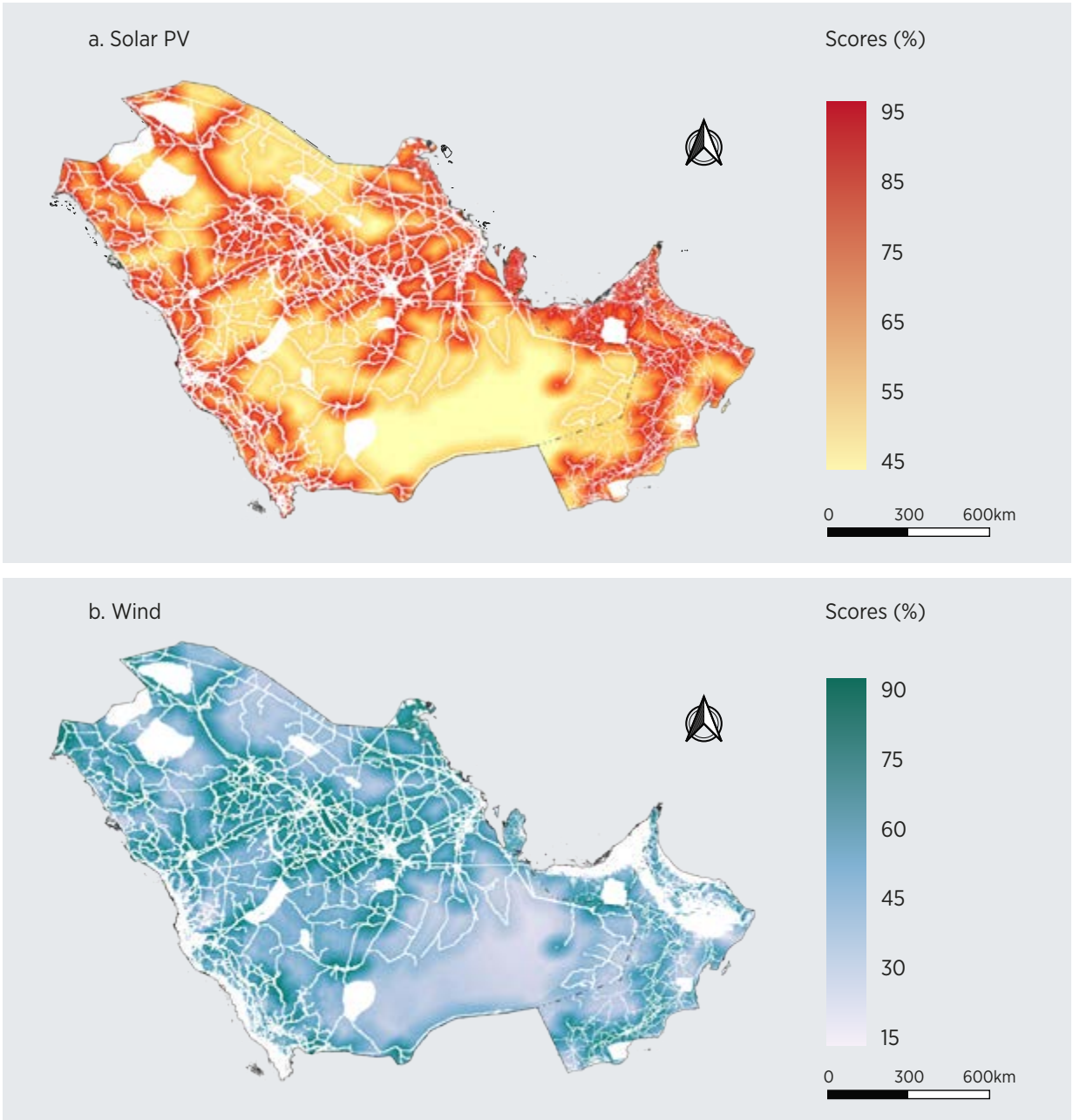


Source: (a) ESMAP (2019); (b) DTU (2015); Base map: UN boundaries. Maps are also available on the IRENA Global Atlas for Renewable Energy.

Notes: kWh/m² = kilowatt hours per square metre. m/s = metre per second; m = metre.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Figure 2.2 Most suitable areas for utility-scale solar PV and onshore wind



Source: IRENA (2021a); Base map: UN boundaries. Maps are also available on the IRENA Global Atlas for Renewable Energy.

Disclaimer: This map is provided for illustration purposes only. Boundaries shown on this map do not imply any endorsement or acceptance by IRENA.

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Zoning analysis of wind and solar PV

Under the Pan-Arab Clean Energy Initiative, endorsed by the Arab Ministerial Council in September 2014 to promote the integration of greater shares of renewables into power systems of the Arab region, IRENA mapped investment opportunities for utility-scale solar PV and on-shore wind projects in GCC countries (Figures 2.2a and b). In so doing, IRENA analysts considered renewable resource potential, existing infrastructure (including road and transmission line networks), topography, protected areas and population density.

The mapping exercise identifies the best zones for deployment and suggests that covering just half of these zones would result in 3 143 gigawatts (GW) of solar PV capacity and 100 GW of on-shore wind. Saudi Arabia has the highest development potential for solar PV, at approximately 2 324 GW, followed by Oman, the UAE, Qatar, Kuwait and Bahrain (Figure 2.2a). The wind potential across the region is lower than that of solar, with the highest potential in Saudi Arabia, at around 58 GW, followed by Oman, Kuwait, Qatar, the UAE and Bahrain (Figure 2.2b). To put these numbers in context, the GCC region's total installed renewable capacity stood at 173 GW in 2022 (Chapter 2).

2.2 DEPLOYMENT STATUS

The past decade has seen the rapid development of renewable energy in GCC countries, starting from virtually nothing and transforming into a significant growth market in the MENA region[4] (Figures 2.3 and 2.5). Today, GCC countries account for over 10% of the MENA region's total renewable energy generation capacity (Figures 2.3 and 2.4).

About 90% of the GCC capacity is solar PV, and 4% CSP, and almost all is based in the UAE, Qatar and Saudi Arabia, putting the UAE and Qatar among the MENA region's top ten capacity holders (see Table 2.1). These two countries' trajectory contrasts with the rest of the MENA region, where renewable energy capacity has grown slowly, over decades, and with a few exceptions (*e.g.* Egypt, Israel and Morocco) is based almost entirely on hydropower (IRENA, 2023b). As of 2022, wind power deployment remained limited in the GCC region, at 67 megawatts (MW) installed, three-quarters of which were in Oman (Table 2.1).

© izzet ugutmen; shutterstock

[4] *The MENA region includes Bahrain, the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Palestine, Syrian Arab Republic, UAE and Yemen.*

In spite of the recent meteoric rise of renewables deployment in the GCC region, the share of renewable energy in the region's electricity mix remains negligible. In 2022, renewables accounted for only 3% of electricity generation capacity, in spite of the region's ambitious plans (Chapter 3) and the increased cost competitiveness of renewables (section 2.3).

Key deployment trends and power projects

The region's renewables-based electricity capacity is concentrated in the UAE, where installed capacity was 3 592 MW in 2022, most of it from solar PV (Figure 2.8). The UAE's share of regional solar power (Figure 2.7) has further expanded in 2023, as more than 1 000 MW of solar capacity came onstream. As has been noted, wind power deployment in the GCC region remains limited, and is mostly in Oman (Table 2.1). The UAE is home to the world's largest single-site solar plant – Mohammed bin Rashid Al Maktoum Solar Park in Dubai, with a generation capacity of 2 800 MW, bringing that emirate's renewable production capacity to over 15% of Dubai emirate's total (DEWA, 2023; Casey, 2023). The UAE also boasts Abu Dhabi's 1 200 MW Noor solar PV plant (similarly, one of the world's largest single-site solar power plants), as well as the Abu Dhabi Shams, Dubai Shams and Hatta wind farm. Smaller solar power systems include Masdar City's 10 MW solar PV plant in Abu Dhabi. In October 2023, the UAE launched its first commercial wind project, a 103.5 MW project spanning four locations, run by the renewable energy firm Masdar, and set to power more than 23 000 homes a year (Reuters, 2023). Meanwhile, Abu Dhabi's 2 100 MW solar PV plant at Al Dhafra is expected to become operational in the near term, as one of the world's largest renewable energy power plants, further boosting the UAE's renewable energy capacity.

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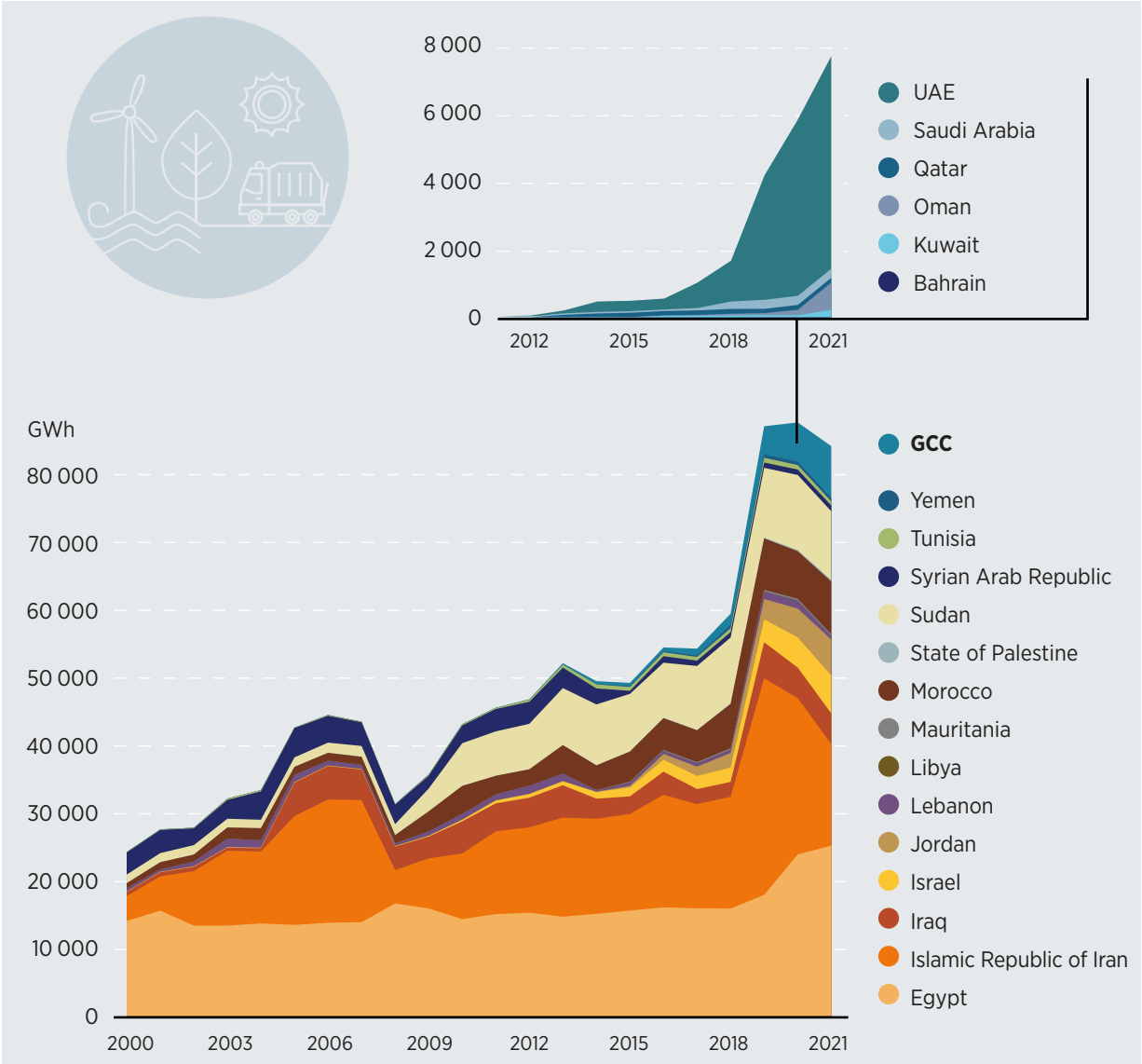
Besides solar power, the **UAE** has also been the first country in the GCC region to invest in waste-to-energy technology. In April 2022, the emirate of Sharjah completed construction of the country's first waste-to-energy plant, which is part of the emirate's strategy to become the first zero-waste city in the region (The National, 2022). At full capacity, the plant will help divert up to 300 000 tonnes of unrecyclable waste each year, while producing 30 MW of low-carbon electricity, enough to power 28 000 homes (The National, 2022).

Figure 2.3 Renewable energy-based electricity generation in the MENA region (GWh), 2000-2021



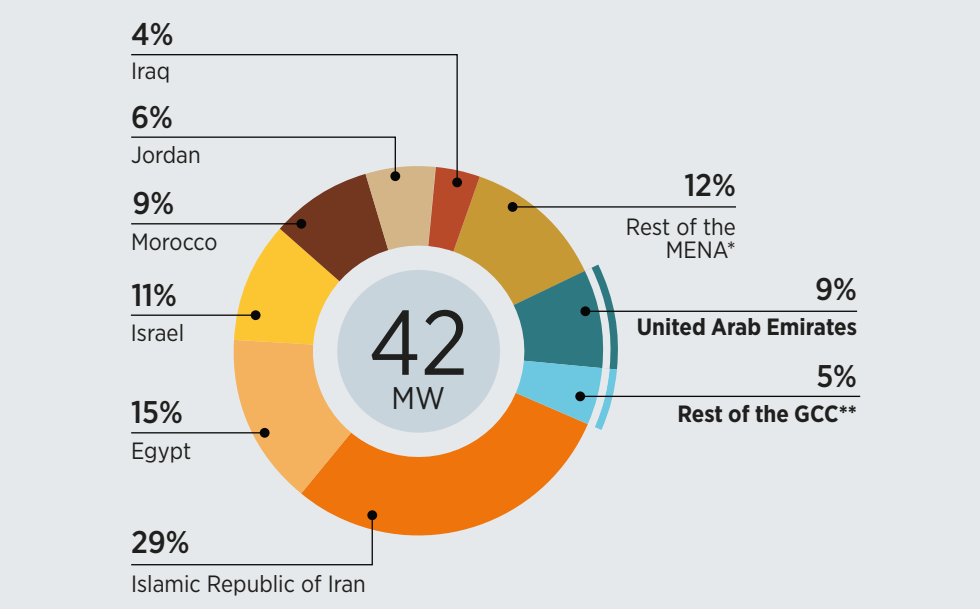
Source: (IRENA 2023b).

Notes: GWh = gigawatt hours.

**Rest of the MENA includes Algeria, Jordan, Lebanon, Libya, Mauritania, Sudan, Syrian Arab Republic, Tunisia and Yemen.*

*** Rest of the GCC includes Bahrain, Kuwait, Oman, Qatar and Saudi Arabia.*

Figure 2.4 Renewable energy-based electricity generation capacity in the MENA region (MW), 2022

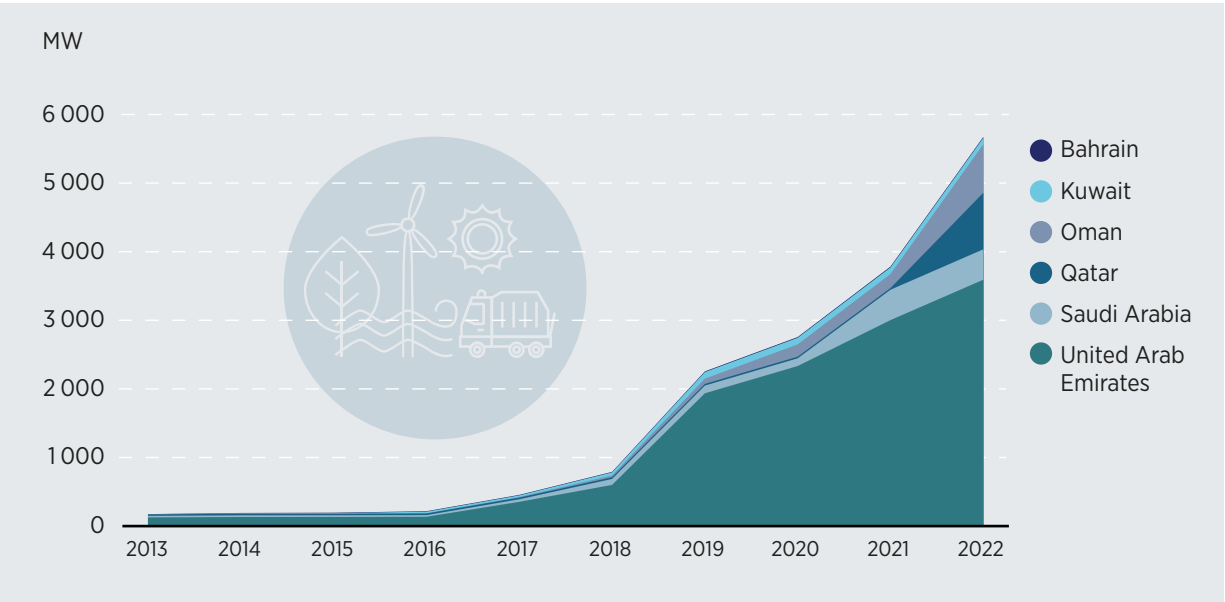


Source: (IRENA 2023b).

*Notes: *Rest of the MENA includes Algeria, Jordan, Lebanon, Libya, Mauritania, the Sudan, Syrian Arab Republic, Tunisia and Yemen.*

*** Rest of the GCC includes Bahrain, Kuwait, Oman, Qatar and Saudi Arabia.*

Figure 2.5 Renewable energy generation capacity in the GCC countries (MW), 2013-2022



Source: (IRENA 2023b).

Note: MW = megawatts.

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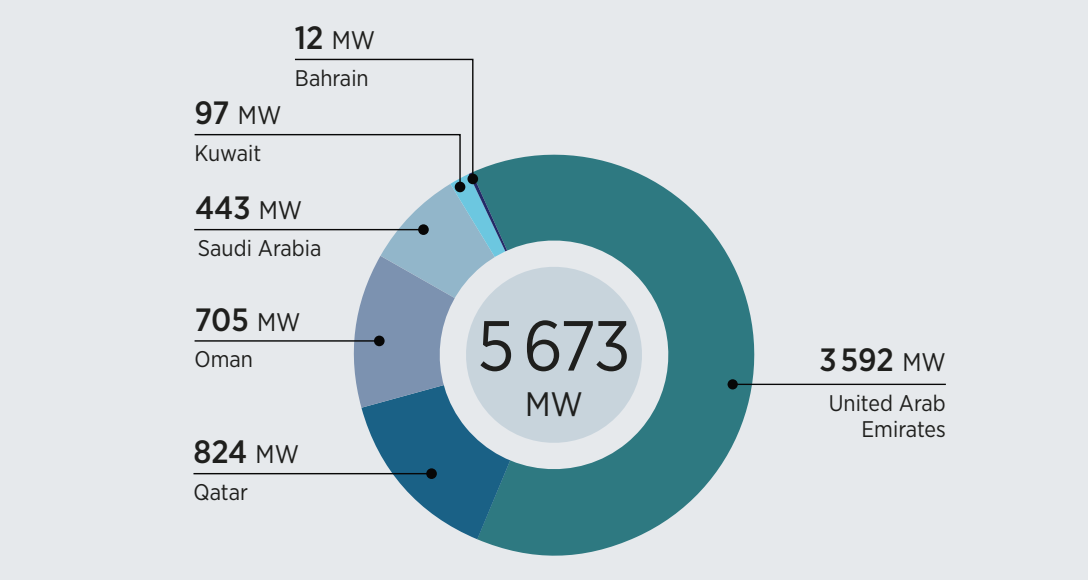
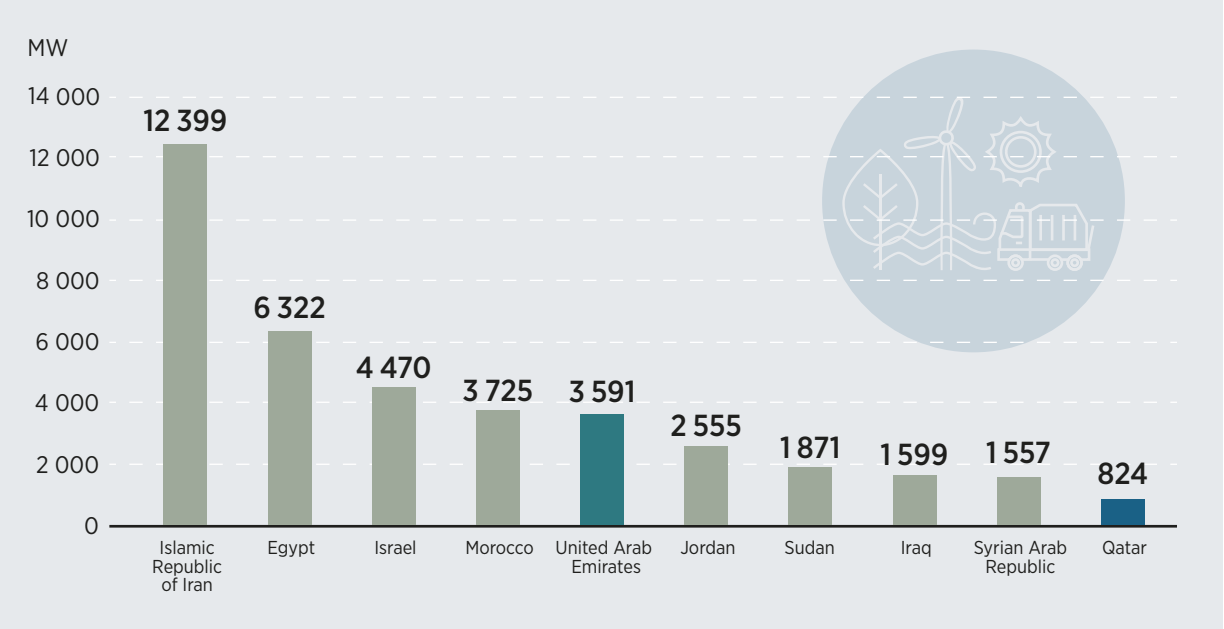
Figure 2.6 Renewable energy generation capacity by country (MW), 2022



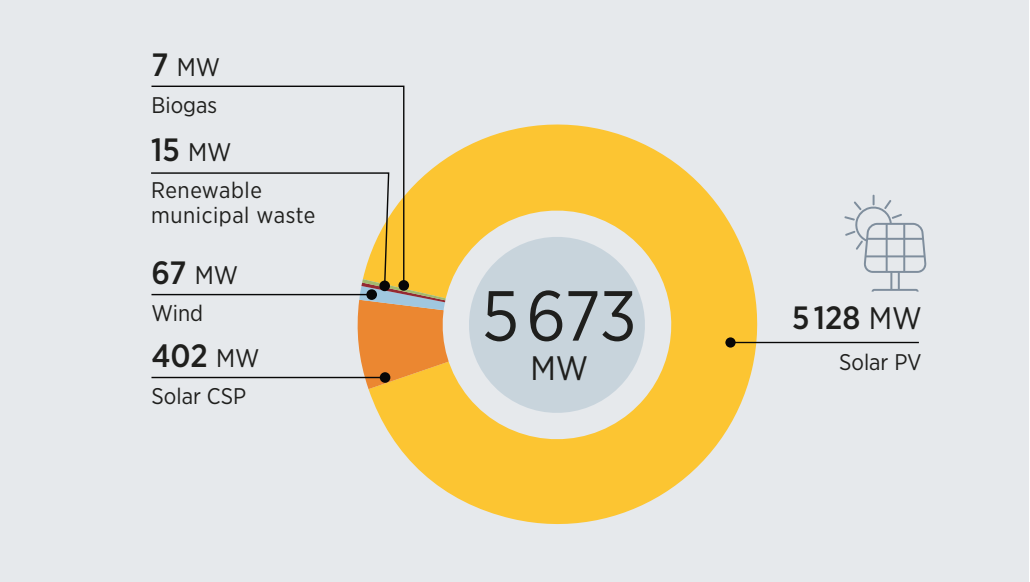
Source: (IRENA 2023b).
Note: MW = megawatts.

Figure 2.7 Ten largest renewable energy producers in the Middle East (MW installed renewable electricity production capacity), 2022



Source: (IRENA 2023b).
Note: MW = megawatts.

Figure 2.8 Installed renewable energy-based electricity generation capacity in the GCC countries by technology (MW), 2022



Source: (IRENA 2023b).
Note: MW = megawatts.

Table 2.1 Installed renewable power capacity (MW) in the GCC (Status: at end-2022)

	Solar PV	Solar CSP	Wind	Renewable municipal waste	Biogas	**Total renewable energy**
Bahrain	11.7	–	0.7			**12.4**
Kuwait	32.8	50	12.4			**96.7**
Oman	655.1	–	50			**705.1**
Qatar	805.1	–	–	15	4	**824.1**
Saudi Arabia	389.9	50	3.3*			**443.1**
United Arab Emirates	3 287.6	100	1		3.4	**3 592**
Gulf Cooperation Council	**5 182**	**402**	**67**	**15**	**7**	**5 673.4**

Source: (IRENA 2023b).
Notes: CSP = concentrated solar power; MW = megawatts; PV = photovoltaic.
** Saudi Arabia brought 400 MW wind power online late in 2022, which Is not reflected in this data.*

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In May 2023, the plant reached its first milestone, the use of 100 000 tonnes of waste (The National, 2023). In the same month, Dubai also completed the construction of a new biogas-to-energy project at its Warsan Wastewater Treatment Plant, with a capacity of 44 250 megawatt hours of electricity annually, enough to cover 50% of the wastewater plant's electricity needs (Gulf News, 2023). In summer 2023, Dubai also opened the Dubai Waste Management Centre, planned to process 1.9 million tonnes of waste a year and become the world's largest waste-to-energy project (Gulf News, 2022; WWMC, 2023). The UAE is also the first GCC country at present to explore geothermal energy (ADNOC, 2023).

Qatar has, after many years of lagging progress in deployment, completed the 800 MW Al-Kharsaah solar PV plant in time for the FIFA World Cup 2022. Al-Kharsaah has increased renewables' share of the electricity mix from zero to 7%, putting Qatar's solar energy capacity in second place regionwide.

In Oman, too, renewable energy's share is becoming more substantial, accounting for 6% of the country's grid-linked electricity generation capacity. In addition to its more than 650 MW installed grid-connected solar PV capacity, in 2019 the country completed the 50 MW Dhofar Wind Power Project, developed by the UAE energy company Masdar (Masdar, 2023b).

Despite its ambitious renewable energy plans and vast available space, Saudi Arabia's installed renewable capacity ranks only fourth in the region, at 443 MW in 2022, almost all of it solar energy. **Saudi Arabia**'s first utility-scale solar energy project, with 300 MW capacity, was commissioned in April 2021 by a consortium of ACWA Power and Al Gihaz.

The power generated from the project is sold to the Saudi Power Procurement Company under a power purchase agreement (PPA) for a period of 25 years. The project set a new world record for low costs in the solar PV subsector, which amounted to US¢ 2.34/kWh (Kingdom of Saudi Arabia, 2022b; Power Technology, 2021). In the same year, the country signed seven other solar projects with a combined generation capacity of 1515 MW, including the 600 MW Shuaiba project with a world record low electricity price from solar of US¢ 1.04/kWh, and the 400 MW Dumat Al-Jandal onshore windfarm. All are contracted under 20-25-year purchase agreements (Carpenter, 2021; Reuters, 2021c; Power Technology, 2019). As of end-2023, Saudi Arabia had the following PV plants in operation: Sakaka (300 MW), Jeddah (300 MW) and Rabigh (300 MW), as well as the partially operated 1200 MW connected project Sudair Solar PV (Ministry of Energy, 2023).

Off-grid and decentralised renewable energy generation

Off-grid uses of renewable energy applications remain limited in GCC countries, with around 8.5 MW of regionwide capacity, although they hold significant potential to expand in the coming years. With electricity access being virtually universal in the region, the largest potential for off-grid renewables is for electricity generation on islands, and at remote and off-shore locations used by the oil and gas industry, including oil rigs. Most of the region's existing off-grid capacity is in the UAE (5.9 MW of solar PV capacity), followed by Kuwait, and projects in Oman and Saudi Arabia (IRENA, 2023b).

Oman has been piloting the use of solar heat for steam injection as part of enhanced oil recovery for many years at its Miraah Project, a 1021 MW solar thermal facility and one of the world's biggest solar plants, located at the Amal oilfield in the south (Sustainable Oman, 2021; Power Technology, 2018).

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Beyond off-grid solutions, GCC countries have the potential to generate decentralised renewable energy, utilising rooftop installations for residential, commercial and industrial self-generation. Virtually all of the past decade's additions to renewable energy generation capacity in the region have been from state-commissioned, utility-scale flagship projects (see also table 2.2). The agriculture sector, too, especially agrovoltaics, could benefit from decentralised renewable energy (ESCWA, 2017).

In the future, solar rooftop installations could become common on commercial buildings such as warehouses and malls, at carparks, and at island resorts. Mandating the installation of solar PV systems over open parking lots, as in France (Birnbaum, 2023), could be a practical and effective policy maximising the use of solar power across the region. In more recent years, a number of cities have piloted solar-powered street lighting, as at Abu Dhabi's sustainable flagship, Masdar City; the KAPSARC campus in Riyadh, Saudi Arabia, and around Qatar's 2022 World Cup stadiums. Renewable energy could fuel other end uses, too. The UAE initiated a pilot scheme using rooftop PV to heat water in the Sheikh Zayed Desert, with a capacity of 840 kilowatt thermal (Weiss and Spörk-Dür, 2023).

Under the Shams Dubai net metering programme, rooftop solar PV installations are becoming a regular feature on commercial and industrial facilities in Dubai. Since its start in 2015, the programme has reduced the permissible installation size to be based on the power demand of the given facility, which has made project development more challenging. That said, the programme had fostered over 500 MW of approved distributed solar PV installations in just seven years of operation (Zawya Projects, 2023), with another 150 MW or so in the pipeline. Implementation of net metering programmes in other GCC countries could help unlock more rooftop solar PV potential (Provenzani, 2023). However, low retail prices for electricity, gas and diesel and lack of financing remain key challenges to distributed solar PV in the UAE (Zywietz, 2023), along with the challenge of keeping PV panels clean amid a dusty and humid climate (section 3.3).

Renewables in transport

Renewable energy's use outside the power sector remains limited in the region, a gap apparent in most GCC countries' climate and renewable energy strategies. One potential area of development is renewables-based electrification of transport. Transport systems, particularly in cities, are dominated by road infrastructure and privately owned vehicles, leading to considerable CO_2 emissions, congestion, and the consequent economic and environmental costs (PwC, 2023). In an effort to reverse this trend, several GCC cities are investing heavily in building new, and modernising existing, public transport systems including new metro, tram and bus networks. Some countries also have increasingly ambitious goals to adopt leading smart mobility technologies within the next decade (PwC, 2023).

Saudi Arabia aims for at least 30% of its cars to be electric-powered by 2030, following its pledge to reach net-zero carbon emissions by 2060 (Arab News, 2022b). Electric vehicle (EV) manufacturer Lucid in 2021 announced plans to build the first international manufacturing plant in Saudi Arabia, targeting 150 000 vehicles per year at the King Abdullah Economic City (Arab News, 2022b). Lucid initiated EV production in Saudi Arabia in September 2023. The Public Investment Fund (PIF) is also partnering with Foxconn to set up Ceer Motors in Saudi Arabia, with the aim of producing EVs in 2025 (Wu, 2022). In October 2023, the government's PIF, together with the Saudi Electricity Company, announced the formation of an EV infrastructure firm – EVIC – to further the Kingdom's emission targets and make EV ownership more attractive to the local population (Al Arabiya, 2023b).

The UAE's **National Electric Vehicles Policy** aims to establish a countrywide network of EV chargers, while also regulating the EV market in the UAE. Together with its Global EV Market initiative, the UAE aims to become a global market for EVs, to increase EVs' share of all vehicles on UAE roads to 50% by 2050 and to reduce energy consumption in the transport sector by 20% (Government of the United Arab Emirates, 2023c). To meet the rise in demand for green mobility, the UAE opened its first EV manufacturing facility in Dubai Industrial City in 2022, aimed to eventually produce 55 000 cars per year (Arab News, 2022b). About 50% of Dubai's taxi fleet is already electric or hybrid vehicles, and the emirate aims to convert the entire fleet to green vehicles by 2027 on the way to making public transport emission-free by 2050 (Khaleej Times, 2021; Raouf, 2021). Dubai was also the first in the region to actively incentivise private EV ownership, by offering free charging for non-commercial EV owners through its network of more than 300 DEWA (Dubai Electricity and Water Authority) green chargers across the emirate between 2017 and 2021 (Government of Dubai, 2021).

Qatar, too, plans to electrify its transport sector. The country's Ministry of Transport aims to switch 35% of vehicles in its fleet and 100% of its public transport buses to electric by 2030, and to deploy charging infrastructure and to promote EV-charging stations for personal use (The Peninsula, 2023).

While plans are becoming more ambitious, the EV market is still in its early stages in the region, with a need for streamlined regulatory frameworks, supply chain development and investment in necessary infrastructure, in addition to technological solutions for the region's hot climate. The Qatar Environment and Energy Research Institute (QEERI) has been conducting tests on commercial battery systems in Qatar's extremely hot climate to understand their degradation patterns and the impact of high dust levels on associated power electronics. Future research plans include assessing the performance, power consumption and battery degradation of EVs (IEA, 2020).

Electrification of a jurisdiction's vehicle fleet will curb significant emissions only if the electricity that drives these vehicles is produced from low-carbon energy sources, in particular renewable energy. This means that the transport sector's electrification will only be sustainable in the long term if coupled to more renewable energy deployment in the region.

Electric car charging station near EXPO City, Dubai
© Captured Blinks; shutterstock

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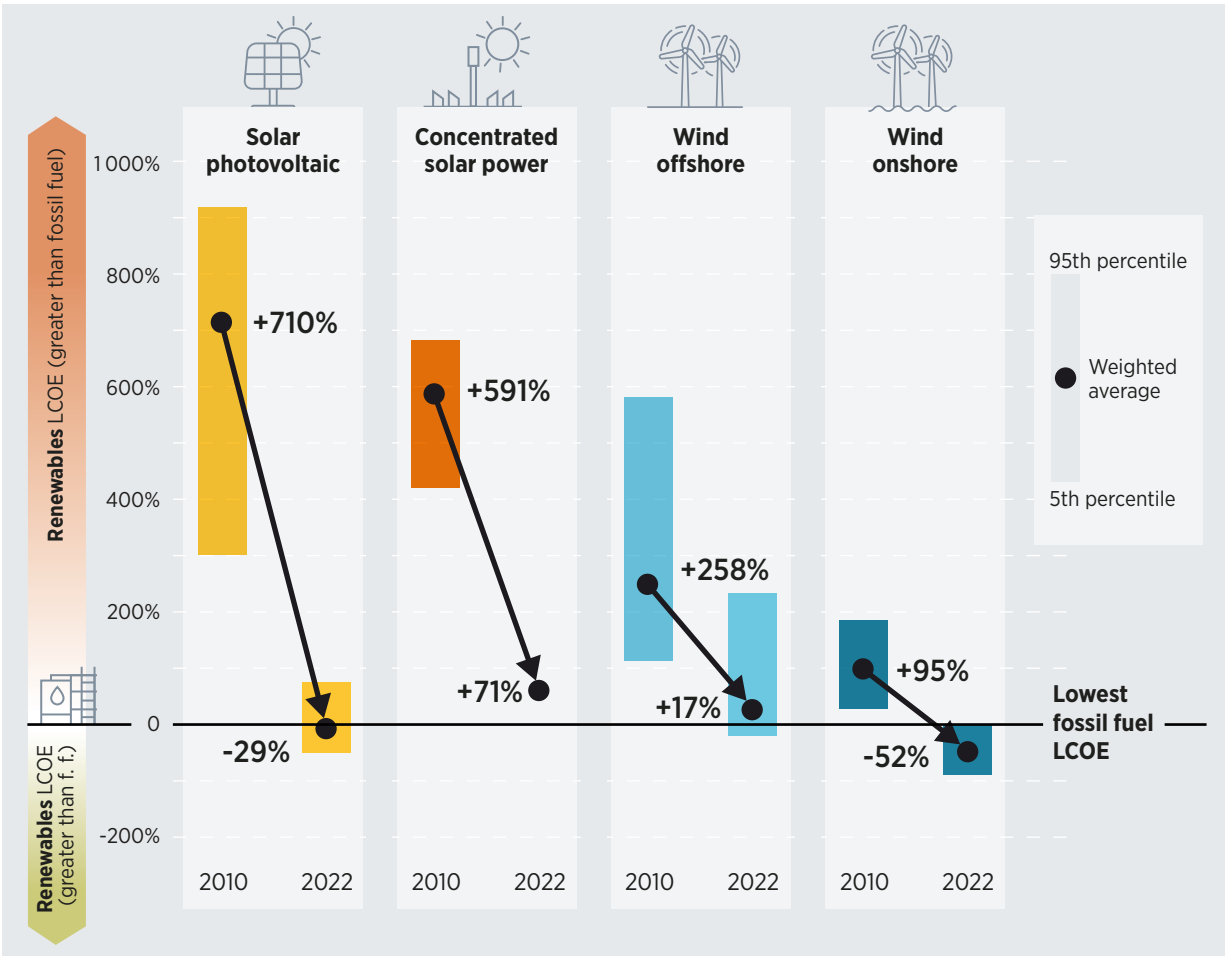
2.3 DECLINING COSTS

The increasing cost competitiveness of renewable energy technologies is evident in the large-scale, grid-connected market segment. The declining cost of utility-scale projects can be attributed to enhanced technologies, availability of low-cost financing, competitive procurement processes, increased deployment rates, and stakeholders' deeper understanding and familiarity with technologies. In 2010, solar PV had a global weighted average levelised cost of electricity (LCOE)[5] of US¢ 44.5/kWh, which by 2022 had plummeted by 89% to US¢ 4.9/kWh. This reduction made solar PV's LCOE 29% lower than the cheapest fossil fuel alternative. Concurrently, on-shore wind's LCOE in 2010 was US¢ 10.7/kWh, decreasing by 71% to US¢ 3.3/kWh in 2022 – making it 52% cheaper than the least-expensive fossil fuel option (IRENA, 2023c). These significant reductions underscore the growing cost-competitiveness of renewable energies against traditional fossil fuels (Figure 2.9).

[5] *Assuming a weighted average cost of capital of 7.5% in the countries of the Organisation for Economic Co-operation and Development and China and 10% elsewhere. See IRENA (2018) for further details of the assumptions behind the LCOE calculations and of the IRENA Renewable Cost Database.*

Figure 2.9 Change in competitiveness of solar and wind based on global weighted average LCOE, 2010-2022



Source: (IRENA 2023c).

Note: This figure shows that the percentage the global weighted-average LCOE for each renewable power source was above or below the cheapest LCOE of the new fossil-fuel-fired electricity option globally in 2010 (US¢ 5.6/kWh) and 2022 (US¢ 6.9/kWh).

Table 2.2 Results of selected auctions in GCC countries

	Auction name	Volume (MW)	Technology	Auction award date	Average price US¢/kWh	Status
Bahrain	100 MW Solar Tender	100	Solar PV	2019	3.89	Cancelled
	72 MW Solar Tender	72	Solar PV	2023	3.9	Awarded
	100 MW Solar Tender	100	Solar PV	n.a.		Bids opened
Oman	Ibri II Solar PV project	500	Solar PV	2019		Commissioned 2022
	Amin Solar PV farm	100	Solar PV	2019		Commissioned 2020
	Manah Solar II PV project	500	Solar PV	2023		Awarded
	Manah Solar I PV project	500	Solar PV	2023		Awarded
Qatar	Al Kharsaah solar PV park	800	Solar PV	2020	1.45	Commissioned 2022
Saudi Arabia	Sakaka solar PV project	300	Solar PV	2018	2.34	Commissioned 2019
	Dumat Al Jandal wind project	400	On-shore wind	2019	2.13* (1.99)	Commissioned 2021
	NREP Round Three (1 200 MW PV)	91	Solar PV	2022	2.99	Not available
		120	Solar PV	2022		Not available
		700	Solar PV	2022	1.49	Not available
		300	Solar PV	2022	1.48	Not Available
	NREP Round Two (Shuaiba)	600	Solar PV	2023	1.04	Not available
United Arab Emirates	MBRAM Solar Park, Phase II	200	Solar PV	2015	5.84	Commissioned 2017
	MBRAM Solar Park, Phase III	800	Solar PV	2016	2.99	Commissioned 2020
	MBRAM Solar Park, Phase IV	700	Solar CSP	2017	7.3	Commissioned 2021
		250	Solar PV	2017	2.4	Commissioned 2021
	Noor (Abu Dhabi) PV plant	1 200	Solar PV	2017	2.42	Commissioned 2019
	Al Dhafra (Abu Dhabi) PV plant	2 000	Solar PV	2020	1.32	Commissioned 2022
	MBRAM Solar Park, Phase V	900	Solar PV	2020		Commissioned 2023
	MBRAM Solar Park, Phase VI	1800	Solar PV	2023	1.62	Awarded
	Al Ajban (Abu Dhabi) PV plant	1500	Solar PV	n.a.		Not awarded yet

Source: IRENA (2023f)

Note: MBRAM Solar Park = Mohammed bin Rashid Al Maktoum Solar Park; The price for the Dumat Al Jandal wind project was reduced to US¢ 1.99/kWh at financial close. CSP = concentrated solar power; MW = megawatt; PV = photovoltaic; UAE = United Arab Emirates; US¢/kWh = US cents per kilowatt hour; n.a. = not available.

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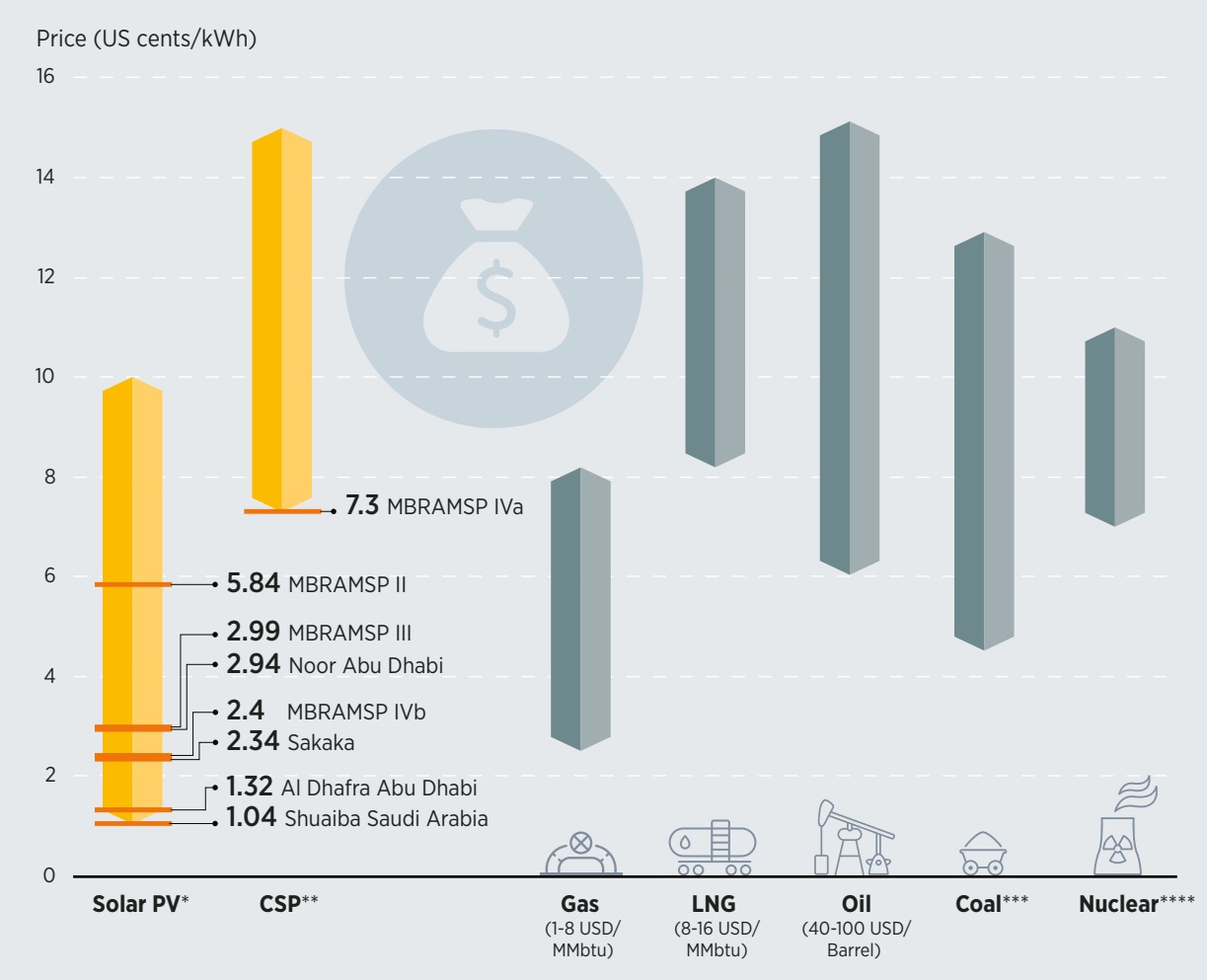
Figure 2.10 Price of utility-scale electricity generation technologies in the GCC region, 2015-2023



Sources: Renewables (Zawya 2021; Apostoleris et al. 2018; ACWA Power 2020; Dipaola 2018; Carvalho 2011); non-renewables (Zywietz 2023; Sabga 2020; Mills 2017; Channell et al. 2015; Manaar 2014; Scribbler 2015).

* *Low = price for Shuhaiba solar PV; High = conservative assumption based on expert opinion.*

** *Low = price for 700 MW MBRAMSP IV in Dubai; High = price for Morocco's Noor II.*

*** *Low = price for the Hassyan Clean Coal Power Plant; High = estimate for coal with CCS.*

**** *Estimated range for nuclear power based on (Mills 2012; Sabga 2020; Scribbler 2015).*

Notes: Shaded bars show ranges of prices for projects. The prices are primarily based on projects from 2015 to 2023. Levelised cost of electricity (LCOE) and auction/PPA prices represent one way to examine cost-competitiveness in a static analysis. These estimates are not a substitute for detailed nodal modelling, system cost tracking or analysis of factors such as backup generation requirements or demand side management. Moreover, care should be taken in comparing LCOE, auction/power purchase agreement prices and feed-in tariff levels, as they can be very different cost metrics. MBRAMSP = Mohammed bin Rashid Al Maktoum Solar Park; USD cent/kWh = US dollar cent per kilowatt-hour; PV = photovoltaic; CSP = concentrated solar power; LNG = liquefied natural gas; MMbtu = million British thermal units.

While renewables, in particular solar PV, are becoming competitive, it should be noted that the principal factors deciding the costs of renewable energy (*e.g.* energy resources, scale, installation costs and costs of capital) vary substantially by country, project and technology, which makes comparisons difficult (Ritchie, 2018). Importantly, low LCOE does not directly result in lower overall system costs; several other factors such the requirements for integration, transmission, distribution and system flexibility must also be considered in comparative analyses of power generation technologies (Elshurafa, 2023).

Prices[6] at which projects are awarded in GCC countries are consistent with global patterns. Dubai made headlines with a record-breaking US¢ 5.98/kWh bid (later reduced to US¢ 5.84/kWh) in late 2014 for the 200 MW Phase II of the Mohammed bin Rashid Al Maktoum Solar Park, which was commissioned in 2017 (Table 2.2). Shortly after, Dubai set another record with a remarkable US¢ 2.99/kWh bid for the 800 MW Phase III of the Mohammed bin Rashid Al Maktoum Solar Park, which was commissioned in 2020. The bids for the 300 MW Sakaka project in Saudi Arabia and the 250 MW Phase IV of Dubai's Mohammed bin Rashid Al Maktoum Solar Park feature even lower prices. In 2020, Abu Dhabi's 2 GW Al Dhafra solar PV plant was awarded for US¢ 1.3/kWh whereas Saudi Arabia's 600 MW Shuaiba was awarded in 2021 to ACWA Power for just US¢ 1.04/kWh (Table 2.2) (Energy & Utilities, 2021). The 400 MW Dumat Al Jandal wind project in Saudi Arabia was awarded for US¢ 2.13 cents/kWh, which was later reduced to US¢ 1.99/kWh at financial close (National Renewable Energy Program, 2019).

CSP emerged with an unprecedented bid of US¢ 7.3/kWh for the 700 MW Phase IV of the Mohammed bin Rashid Al Maktoum Solar Park. Executing similar projects in places like Oman or Saudi Arabia, with better DNI resources, could potentially result in more competitive pricing. However, prices in these locations could be influenced by several other factors such as distance from grid, land costs and financing costs, which have increased since the bid for Dubai's Phase IV was submitted.

Competitiveness with fossil fuels

Renewables are increasingly the cheapest sources of new electricity generation in GCC. As Figure 2.10 shows, solar PV, at less than US¢ 2/kWh, emerges as the lowest-cost option for power production, outpacing natural gas, liquefied natural gas (LNG), oil, coal and nuclear. CSP and wind could also be competitive in certain settings.

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[6] *The discussion uses a combination of LCOE and auction/PPA prices to discuss the cost-competitiveness of renewable energy technologies. As explained in detail in a past IRENA report (IRENA 2018), care is needed when comparing LCOE, auction/PPA prices and feed-in tariffs, which are very different cost metrics and may not be directly comparable.*

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Competitiveness with gas

Large-scale solar PV–generated electricity is now much cheaper than power derived from locally sourced natural gas or imported LNG, as indicated by bid prices in US cents/kilowatt hour (Figure 2.10). The US¢ 1.32/kWh bid for Al Dhafra is much lower than the lowest gas-based generation costs, estimated at US¢ 3/kWh assuming a gas price of USD 2 per million British thermal units (MMbtu) (Graves, 2017). Dispatchable CSP with storage is also competitive with gas-fired electricity generation. CSP, at US¢ 7.3/kWh, is equivalent to gas-fired power generation using gas at USD 5-6/MMBtu, which is lower than the opportunity cost of gas in most GCC countries (Mills, 2017; Sgouridis *et al.*, 2016). Since the costs of non-associated gas in the region are likely higher than USD 6/MMBtu, there is a strong case for solar PV and CSP. Historically, gas prices in GCC countries were below USD 3/MMBtu. However, newer wells face higher extraction costs, elevating the marginal production cost for some fields to over USD 6/MMBtu. While imported gas through the Dolphin pipeline was once affordable for Oman and the UAE at around USD 1.5/MMBtu in 2008, current prices for additional regional gas needs are expected to be higher. For example, an "interruptible supply" was sold to Sharjah at USD 5/MMBtu, and in 2011, Dolphin Energy resold Qatari gas in the UAE for USD 7-10/MMBtu (Darwish, Abdulrahim and Hassan, 2015; Krane and Wright, 2014). LNG spot prices were reported to be higher than USD 11/MMBtu in 2023 (Carpenter, 2023). Both Solar PV and CSP prove to be competitive alternatives for electricity generation when compared to virtually all these gas sources.

Although solar PV projects offer the advantage of conserving natural gas and oil, they fall short of providing firm capacity during evening peak demand due to their non-dispatchable nature. In contrast, CSP with storage serves as a dispatchable renewable energy source, often regarded by utilities as firm capacity. When combined, as seen in the Mohammed bin Rashid Al Maktoum Solar Park, solar PV and CSP offer a robust alternative to gas-based generation. This blend leverages the cost-effectiveness of solar PV with the storage capabilities of CSP to deliver a comprehensive energy solution (Padmanathan, 2018). However, CSP in the UAE, and in some other locations in the GCC region, could suffer from poor DNI (section 2.1).

Cost-competitiveness with oil, nuclear and coal

Renewable technologies like solar PV and wind are cheaper alternatives to oil-based electricity generation (prevalent in Saudi Arabia and Kuwait, see section 1.3), even with oil as low as USD 40 per barrel (Figure 2.10). For example, the US¢ 2.99/kWh cost of the 200 MW Phase III of Dubai's Mohammed bin Rashid Al Maktoum Solar Park is akin to electricity, from USD 23/barrel oil (Mills, 2016). With crude oil hovering above USD 90 per barrel in October 2023 (OPEC, 2023), integrating more solar PV and wind into Kuwait's and Saudi Arabia's oil-based power sectors is compelling.

Solar PV in the region is cost-competitive with nuclear energy and coal. The estimated price of nuclear power in the UAE could range from US¢ 7-11/kWh (Mills, 2012; Sabga, 2020; Scribbler, 2015), which is much higher than solar PV. Dubai's Hassyan coal was estimated to generate electricity at US¢ 4.5/kWh (DEWA, 2016a). This is higher than the price for recent solar PV projects in the region. However, it should be noted that the price of coal-based electricity is contingent on coal prices, which are prone to significant fluctuations. The Hassayan coal project is expected to be converted to natural gas under the climate strategies of Dubai and the UAE (Arab News, 2022a).

Key factors for renewables price reductions

Auctions in GCC countries have resulted in some of the world's lowest prices for solar PV. Several pivotal factors contribute to this: (1) excellent solar resources; (2) auction designs that are designed to achieve the lowest prices; (3) accessible financing and (4) technological advancements. It is crucial to note that this enumeration is not exhaustive; various other elements influencing regional prices might encompass investor confidence, minimal taxes, reduced land prices, low labour costs and grid connection (IRENA, 2017).

Auctions designed to achieve low prices

Renewable energy auctions have been central to large-scale renewable energy deployment in members of the GCC. Since 2015, auctions have been used to award more than 9 000 MW of renewable energy projects in the region, almost all of which were for solar PV, with only two major projects going to CSP and wind. While the UAE has been the leader, auctions in Oman, Qatar and Saudi Arabia have also picked up recently, and more activity is expected in all GCC countries in the coming years.

Renewable energy auctions in the GCC consistently draw attention from a substantial number of both local and international firms. For example, the auction for the Sakaka 300 MW solar PV received qualification statements from 128 entities. Similarly, 95 companies expressed interest in the 800 MW Phase III of DEWA's Mohammed bin Rashid Al Maktoum Solar Park (Whitlock, 2016), while the 2 GW Al Dhafra project attracted 48 bidders, with 24 shortlisted and eventually 5 consortiums submitting bids (Kenning, 2019). The extensive competition between these companies plays a crucial role in encouraging lower bids.

Administrative requirements for bidder qualifications can influence the cost of projects. Pre-requisites include environmental licenses, resource assessments and grid-access permits. In Saudi Arabia and the UAE, the government has taken on some of these responsibilities, effectively lowering entry barriers and costs for bidders (IRENA, 2017). For instance, for 300 MW solar PV and 400 MW wind projects in Saudi Arabia, the Renewable Energy Project Development Office (REPDO) handled resource assessments, site preparation, soil testing, environmental and social impact assessments, permitting and licensing with support from Aramco (Jacobs Zate, 2018). This approach not only minimised costs for bidders but also standardised the assumptions utilised by project developers.

While intense competition can drive down prices, it also poses a risk of underbidding, which could lead to delays or even abandonment of projects. However, auctions in GCC countries are designed to mitigate the likelihood of underbidding by imposing rigorous financial and technical prerequisites during the prequalification and evaluation phases. For instance, the auction conducted by DEWA for Phase III of the Sheikh Mohammed Bin Rashid Al Maktoum Solar Park set forth particularly stringent technical and financial criteria at the prequalification stage. Given these demanding requirements and the substantial project size of 800 MW, only 20 companies entered the prequalification phase. This is significantly fewer than the 49 companies that applied for the smaller 200 MW Phase II (Clover, 2015).

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In Saudi Arabia's Sakaka solar PV project, REPDO implemented rigorous prequalification criteria, allowing only firms with substantial financial and technical credibility to participate. Out of 128 companies that submitted qualification statements, 27 were shortlisted, with only 8 ultimately presenting their final bids. More recently, in the fourth round of the renewable energy procurement program, 15 developers were enlisted for 1500 MW of solar projects and 18 for 1800 MW wind projects. In June 2023, a pair of projects in the solar PV component (1100 MW and 400 MW each) attracted three bids, respectively. The winning bids were then shortlisted in September (Nada, 2017; REPDO, 2017a; SaudiGulf Projects, 2023). Some experts, such as Bkayrat (2023), have suggested that factors such as declining bid prices and rising costs of financing are limiting the number of developers in regional auctions, as they instead seek markets offering higher returns.

Utilities in some GCC countries have designed auctions to incentivise power production that complements existing generation capabilities. The Abu Dhabi Water and Electricity Company designed an auction for the 1177 MW Noor Abu Dhabi solar PV project to incentivise maximum generation during the summer months. The energy delivered during the peak summer season (June to September) is remunerated at 1.6 times as much as the energy delivered during the remaining portion of the year. The design led to a winning bid of US¢ 2.42/kWh, which is the price for non-peak months (US¢ 2.94/kWh is the average price) (IRENA, 2017). Discussions with experts such as Smith (2023) suggest that future auctions in Abu Dhabi may include design elements to incentivise ancillary services such as frequency regulation. In Dubai, DEWA used an auction for the 700 MW CSP Phase IV of the Sheikh Mohammed Bin Rashid Al Maktoum Solar Park for electricity generation from 4 pm to 10 am – thus complementing production from solar PV (Padmanathan, 2018).

Auctions in Saudi Arabia strategically encourage job creation and cultivate local expertise through domestic content requirements. For instance, the technical specifications for the 300 MW solar PV and 400 MW wind tenders incorporated a mandate for 30% local content, a percentage anticipated to rise incrementally in subsequent rounds. This gradual increase aims to stimulate the development of a resilient renewable energy supply chain within the country (REPDO, 2017b). In the second and third rounds of the National Renewable Energy Program, local content requirements were set at 17% and 18%, respectively. In Round 2, consortium members falling short of an audited 11.5% final local content score could face a three-year exclusion from participation in future rounds. The computation of the local content score integrates four key elements: (1) employee compensation, (2) investment in training Saudis and developing in-Kingdom value chains, (3) depreciation allocated for assets used within the Kingdom,[7] and (4) procurement of local goods and services (Von Hammerstein and Baş, 2020).

Favourable financing conditions enable low prices for large-scale projects

The region's large renewable energy projects enjoy favourable financing conditions, contributing to their record low prices. These conditions include low interest rates, extended loan durations and high debt-to-equity ratios, making the financial landscape for sizable projects particularly enticing (smaller-scale projects often face financing challenges, however).

Large-scale renewable initiatives in the GCC countries readily secure funding, given that commercial banks offer loans with extended tenures and reasonable interest rates amid well-crafted enabling frameworks. As the market matures and banks in the region acquire more experience with renewable projects, the terms of debt financing are becoming increasingly favourable. Projects that secure long-term PPAs with public sector off-takers – be they utilities or special purpose entities – easily attract financing under advantageous terms.

Table 2.3 illustrates that loans for regional renewable projects typically have long tenures (over 20 years) and low interest rates (120-200 basis points over LIBOR[8]). In addition, high debt-to-equity ratios (between 70% and 86%) make financing terms competitive on a global scale (Apostoleris *et al.*, 2018). For context, the global average debt-to-equity ratio for solar PV projects ranged from 60% to 70% between 2015 and 2016 (IRENA and CPI, 2020). Cost of debt (interest rate) is usually lower than the cost of equity, and therefore higher debt-to-equity ratios can lower a project's weighted average cost of capital.

[7] *Depreciation in the value of the assets which will be used in the Kingdom for the project is considered as local content. If the asset was manufactured in the Kingdom, the depreciation has a higher weightage, than if the asset was not locally manufactured.*

[8] *1 bps (basis point) is equal to 0.01%. 120 bps above LIBOR means 1.2% above the London Inter-Bank Offered Rate, which is an interest rate average calculated from estimates submitted by the leading banks in London.*

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Table 2.3 Financing details of large-scale solar projects

Project	Developer	Off-taker	Financiers	Investment	Conditions
Shams 1100 MW CSP, UAE	Masdar (UAE), Total (France), Abengoa (Spain)	ADWEC (25-year PPA)	UNB, NBAD (UAE); Natixis, Société Générale (France); Mizuho, Bank of Tokyo, Mitsubishi, Sumitomo (Japan); WestLB, KfW (Germany)	USD 153 million equity (USD 612 million loan)	22 years, 80% debt-equity ratio
MBRAMSP II, 200 MW PV, UAE	ACWA (Saudi Arabia), TSK (Spain)	DEWA (25-year PPA)	First Gulf Bank (UAE), National Commercial Bank, Samba Financial Group (Saudi Arabia)	USD 326 million	27 years, 86% debt fraction, Avg. 180 bps over Libor
MBRAMSP III, 800 MW PV, UAE	Masdar (UAE), ALJ (Saudi Arabia), EDF (France)	DEWA	UNB (UAE), IDB, APICORP (Middle East); Natixis (France), Siemens Financial (Germany), Korea Development Bank, EDC (Canada)	USD 940 million (USD 650 million loan)	70% debt-equity ratio, soft mini-perm, start 175 bps over Libor
MBRAMSP IV, 700 MW CSP 250 MW PV, UAE	ACWA (Saudi Arabia), Shanghai Electric (China)	DEWA (35-year PPA for CSP)	ICBC, Bank of China, Agricultural Bank of China, China Minsheng Bank, Silk Road Fund (China)	USD 4.36 billion (USD 1.5 billion debt)	70% debt-equity ratio
MBRAMSP V, 900 MW PV, UAE	ACWA (Saudi Arabia), Shanghai Electric (China)	DEWA (25-year PPA)	UAE: ADIB, Emirates NBD, Commercial Bank of Dubai, Mashreq bank, CBI; Region: APICORP, SAMBA Financial, Standard Chartered; Others: Industrial & Commercial Bank of China, Natixis.	USD 564 million	27 years, soft mini-perm
Noor Abu Dhabi, 1177 MW PV, UAE	Marubeni (Japan), Jinko Solar (China)	ADWEC (25-year PPA)	Natixis, CA-CIB, BNPP (France); MUFG, MUTB, Norinchukin Bank, SMBC (Japan); First Abu Dhabi Bank	USD 870 million (USD 648 million loan)	26 years, 75% debt-equity ratio, soft mini-perm, Start 120 bps over Libor
Sakaka, 300 MW PV, Saudi Arabia	ACWA (Saudi Arabia)	SPPC (25-year PPA)	Natixis (France)	USD 320 million	Not applicable
Sudair Solar, 1500 MW, Saudi Arabia	ACWA, Saudi Aramco Power Co, Badeel (Saudi Arabia), Larsen & Toubro (India)	SPPC (25-Year PPA)	Mizuho Bank, Riyad Bank, Korea Development Bank, APICORP, Al Rajhi Banking & Investment, Standard Chartered Bank	USD 906 million (USD 616 million finance)	Soft mini perm, 28 years

Sources: Shams 1 (Carvalho, 2011; Ratcliffe, 2013); MBRAMSP II (ACWA Power, 2017; Apostoleris et al., 2018; Reuters, 2015); MBRAMSP III (Apostoleris et al., 2018; Dipaola, 2018; IPPJournal, 2017); MBRAMSP IV (Lilliestam and Pitz-Paal, 2018; Santamarta, 2018); MBRAMSP V (ACWA Power, 2020) Noor Abu Dhabi (Apostoleris et al., 2018; Natixis, 2017); Sakaka (APICORP, 2018; Kenning, 2018); Sudair Solar (Zawya, 2021).

Notes: ADWEC has been replaced by Emirates Water and Electricity Company (EWEC). bps = basis point; CSP = concentrated solar power; MBRAMSP = Mohammed bin Rashid Al Maktoum Solar Park; MW = megawatt; PPA = power purchase agreement; PV = photovoltaic; SPPC = Saudi Power Procurement Company; UAE = United Arab Emirates.

Several factors contribute to the attractiveness of financing for well-structured projects in the region:

- **Reliable off-takers.** GCC economies have dependable off-takers. Winning a PPA almost guarantees timely payments from public off-takers, reducing financing risks and costs. In the UAE, the off-taker often holds a significant stake in the project.
- **Lower currency risks.** The pegging of nearly all GCC currencies to the US dollar minimises currency risks for foreign lenders.
- **Success of independent power producers (IPPs).** IPPs have a successful track record in the region. Oman initiated the first IPP in 1996, with Abu Dhabi following suit in 2002. To financiers, renewables-focused IPPs appear as secure as their fossil-fuel-based predecessors.
- **Proven track records of bidders.** The structure of renewable energy auctions in the region, particularly at the prequalification stage, allows only experienced, technically proficient and financially stable developers to participate in final bidding rounds. Given their robust track records, these selected bidders readily attract low-cost financing from both local and international financial markets.
- **Participation of local and international banks.** Local banks have historically been at the forefront of financing renewable energy initiatives within the region. However, with the market expanding, international financiers are increasingly joining the fray, particularly in the funding of multi-billion-dollar projects. For instance, Phase II of the Mohammed bin Rashid Al Maktoum Solar PV project necessitated around USD 300 million in financing, which was efficiently provided by a group of local banks. In contrast, subsequent phases – Phase III (800 MW PV), Phase IV (950 MW CSP and PV), Phase V (900 MW), the Noor Abu Dhabi project (1177 MW PV) and Sudair Solar in Saudi Arabia (1500 MW) – are substantially larger ventures, demanding USD 940 million, USD 4 360 million, USD 564 million, USD 870 million and USD 906 million, respectively. These sizable financial requirements have been met through a coalition of both local and international banking entities, with notable capital influxes from lenders based in the developers' countries of origin (Table 2.3) (Apostoleris *et al.*, 2018; Zawya, 2021).

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Financing small-scale renewable energy projects

Securing financing for small-scale solar PV projects presents a formidable challenge due to several factors: the reluctance of banks to provide loans – stemming from the higher per unit costs associated with smaller initiatives, extended payback periods and the absence of guaranteed off-taker agreements. Consequently, developers and customers are compelled to turn to expensive financing arrangements. These pricier solutions inflate the overall costs of projects, thereby impeding their swift adoption and proliferation in the market (Zywietz, 2023).

Leasing plans are starting to emerge under the Shams Dubai net-metering programme. Yellow Door Energy offers leasing arrangements for rooftop installations by which building owners pay monthly bills depending on the solar energy consumed. The arrangements include a clause allowing the ownership of the installations to be transferred to the building owner. Developers and solar lease providers such as Yellow Door, Sirajpower, Cleanmax and Alternative Energy Power Co of Kuwait are also providing turnkey leasing solutions that include project financing, development, construction and operation. These developers rely on a number of sources for financing. Siraj Power, for instance, draws financial backing from Corys Environment, which is the environmental investment arm of Green Coast Enterprises.

Standardisation and aggregation are also viable options to make small-scale projects worth the investment of time and capital, especially for larger investors. Greater standardisation allows smaller projects to be aggregated, opening the doors to securitisation via listed or unlisted vehicles. An example of a successful aggregation is Jordan's "seven sisters". The International Finance Corporation acted as the lead arranger and lender of record for seven solar projects in Jordan, engaging a common team of legal, technical, financial and insurance advisors to serve all projects. This led to a USD 247 million investment in 102 MW installed capacity (IRENA, 2016b). Yellow Door has developed a significant portfolio of distributed solar projects across the region. By aggregating these projects, Yellow Door manages to attract financing from banks and other financial institutions (Provenzani, 2023).

Another growing and potentially significant way to raise capital for renewable energy projects is via crowdfunding platforms which bypass traditional intermediaries such as commercial banks and allow for faster collection of relatively small amounts of capital from a large number of individuals or legal entities (IRENA, 2019b). Individuals (high-net-worth individuals, families or households) invested an average of USD 20 million per year in off-grid renewables during 2015-2021, primarily through dedicated crowdfunding platforms (IRENA and CPI, 2023). In the GCC region, Enerwhere, a solar PV developer in the UAE, has raised more than USD 2 million from crowdfunding platforms in the form of equity (on eureeca.com) and debt (on beehive). However, transaction costs tend to be high and project sizes remain small, as online crowdfunding platforms have built-in limits on funding volumes (Zywietz, 2023, 2018).

Mechanisms that allow for direct PPAs between utilities and developers might provide necessary off-taker guarantees, thus unlocking cheap bank finance for developers of small-scale solar PV. One potential solution is the so-called solar partners model (Kuldeep, Saji and Chawla, 2018) in which utilities aggregate rooftop owners in a selected area, auction the combined capacity and sign PPAs directly with the successful bidders. This lowers the financing risk by signing direct PPAs with developers and has the added benefit of bringing costs down through auctions. This approach could benefit rooftop solar deployment in other GCC countries as well.

Other financing mechanisms, that may be effective for small as well as large projects, are outlined as follows.

Soft mini-perms. The growing financial requirements of renewable energy initiatives in the region necessitate that lenders adopt inventive financing mechanisms. The process includes incentivising project developers to explore alternative funding sources. One such mechanism is the so-called soft mini-perm.[9] This is a long-term loan with a provision that interest rates rise after a predetermined period. Such a design encourages developers to pursue refinancing options for their projects. This approach reduces the risk for lenders and facilitates a reduction in the initial interest rate, potentially leading to a decrease in the bid price. However, this mechanism introduces a level of refinancing risk for developers. If refinancing is not achieved, the developers may have to default on their payments (Keenan, 2012). As Table 2.3 shows, five large projects (MBRAMSP Phase III, IV and V, Noor Abu Dhabi PV and Sudair Solar) employ soft mini-perm structures. In the specific case of Noor Abu Dhabi PV, the interest rate is reported to increase from 120 bps[10] over Libor to 190 bps over Libor five years past the financial closure (eventually rising to 250 bps). This encourages the project developer to refinance the project within five years to avoid an increase in the interest rate (IJGlobal, 2017; Natixis, 2017; MESIA, 2018). Phase III of the MBRAM solar park (800 MW PV), which also involved a soft mini-perm (Table 2.3), was refinanced in 2022 with eight lenders providing commercial and Islamic finance (Synergy Consulting, 2022).

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[9] *A soft mini-perm structure typically involves a long tenor. However, the sponsors have an incentive to refinance the loan by an earlier date. If the sponsors fail to refinance the loan by a specified time, the margins increase, making the cost of borrowing more expensive, and the lenders are entitled to a cash sweep.*

[10] *1 bps (basis point) is equal to 0.01%. 120 bps above LIBOR means 1.2% above the London Inter-Bank Offered Rate, which is an interest rate average calculated from estimates submitted by the leading banks in London.*

02

Green bonds. These constitute an innovative financing mechanism that could be used for large-scale project financing, as well as for refinancing. Green bonds have been used to finance renewable energy projects by MASEN of Morocco and the City of Johannesburg in South Africa (GIZ, 2017). Such bonds offer an increasingly attractive vehicle for large investors, such as institutional investors, to invest in renewable energy projects via capital markets securities. They provide issuers with large-scale long-term non-bank capital (IRENA, 2020b). Global issuance of green bonds increased from about USD 800 million in 2007 to about USD 545 billion in 2021 (IRENA and CPI, 2023).

In the GCC region, the green bonds market is beginning to see a surge. Green and sustainable bond and sukuk issuances in 2022 were estimated at USD 8.5 billion from 15 deals, marking a substantial increase from just USD 605 million garnered from six deals in 2021. Saudi Arabia emerged as the principal issuer, contributing more than half the total; the UAE accounted for the rest. Notably, in October, Saudi Arabia's PIF made its inaugural USD 3 billion green bond listing on the London Stock Exchange, attracting immense interest with orders surpassing USD 24 billion. Furthermore, Dubai Islamic Bank and a collaboration between Taqa and EWEC made noteworthy contributions to the market by respectively raising USD 750 million and USD 701 million through their debut sustainable sukuk and green bond, aiding in diversifying funds for sustainable project financing (Benny 2023). In July 2023, Masdar issued green bonds worth USD 750 million, with the proceeds to be used to fund projects in solar, wind, transmission and distribution infrastructure, and battery storage (Lee, 2023). Earlier, the National Bank of Abu Dhabi (now First Abu Dhabi Bank, following a merger with the First Gulf Bank in 2017), had issued the first green bond in the Middle East valued at USD 587 million in 2017 (FAB, 2018).


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Some prominent investors, including institutional investors, might lack either the internal capabilities or the inclination to allocate funds directly into renewable energy ventures. Engaging these investors typically requires the utilisation of investment instruments and securities that are not only listed but also overseen by esteemed asset managers, with ratings being an ideal addition. Such instruments include green bonds, green equity listings, green indices and listed renewable energy funds. The latter category includes structures akin to yieldcos – listed entities in possession of operational renewable energy assets –among other similar investment vehicles (IRENA, 2020a).

Improving technology lowers prices

The costs of renewable power generation are undergoing a notable decline due to technological advancements, economies of scale, accumulated learning, refined manufacturing processes and heightened competition throughout the supply chain. Technological refinements influence the cost of renewable energy in various ways. First, streamlined production processes, innovative designs and manufacturing economies of scale lead to a reduction in equipment manufacturing costs, such as those for solar modules and wind blades. Second, advancements in project development, construction and civil engineering help diminish installation costs. Third, greater technological efficiency increases the energy yield from renewable resources, thereby reducing the cost per unit of generation. For instance, with the rise in solar PV module efficiencies, there is a decrease in the area and materials needed for equivalent power capacity, ensuring cost-effectiveness.

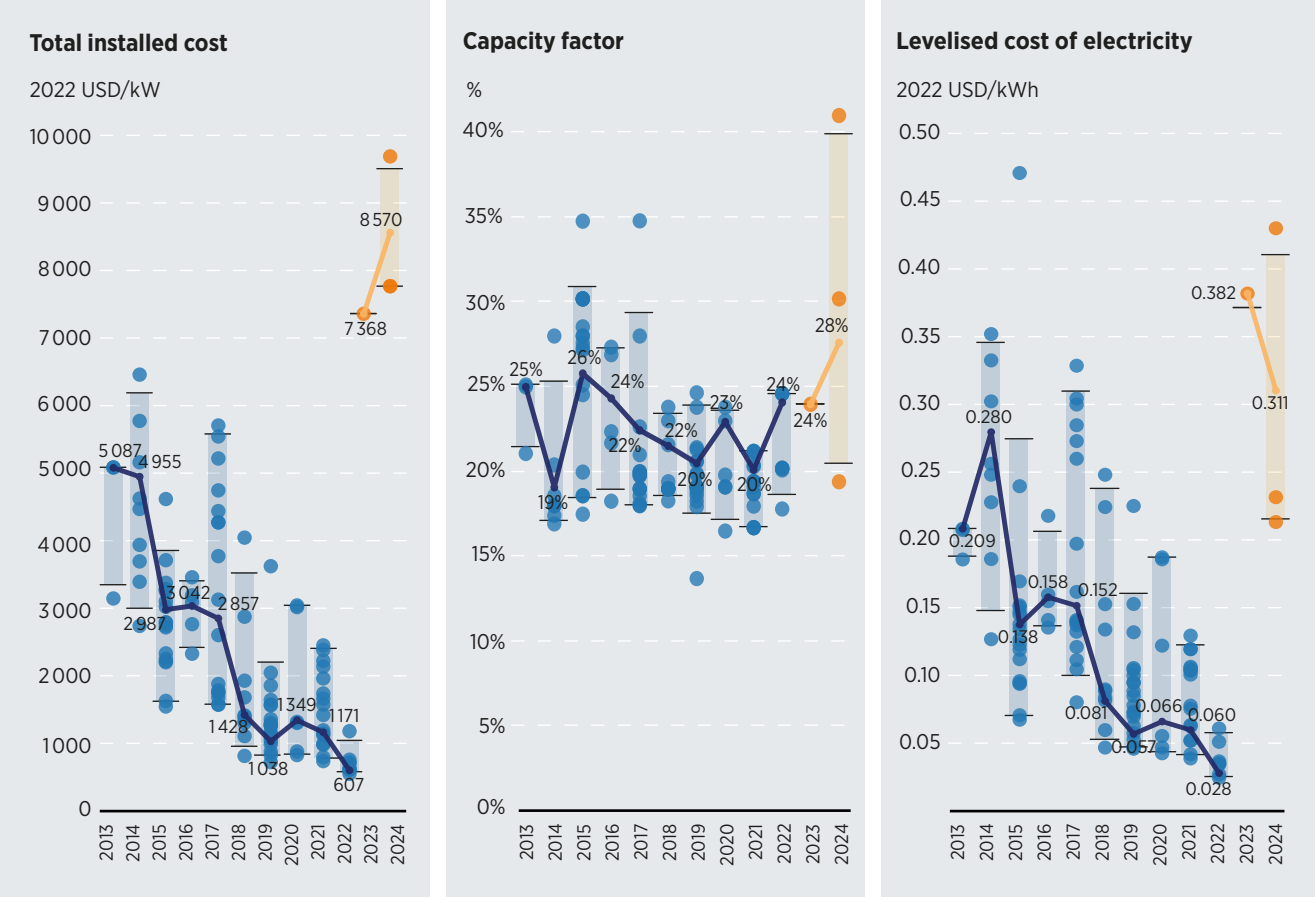
Solar PV continues to benefit from continued technology improvements in cell and module technologies, leading to higher average module efficiencies that in turn reduce module prices.[11] Manufacturing improvements have reduced materials' use in cells (*e.g.* thinner cells and diamond wire sawing that reduces waste) and the labour required. Increased manufacturing and economies of scale have also played a key role in driving down costs. The rate at which the cost of electricity from solar and wind power has fallen is quite remarkable. This has largely been driven by reductions in total installed costs. Globally, the weighted average total installed cost for utility-scale solar PV decreased from USD 5 124/kW in 2010 to USD 876/kW in 2022. In the same period, solar PV capacity factors increased from 14% on average to 16%, but this trend is affected as much by locational shifts in deployment (to more or less sunny countries) as by technology drivers. Combined, these factors ensured that the LCOE of solar PV fell by 89% between 2010 and 2012 (IRENA, 2023c).

[11] *Increases in solar PV module efficiencies reduce the surface area (and hence materials use) for a given electrical capacity, reducing the cost of the module. They also reduce the cost of components related to surface area, such as installation, racking and mounting, foundations, cabling, land costs and maintenance, etc.*

02

While data on solar PV projects in the GCC countries are limited, a look at the larger Middle East region reveals that costs are declining amid continued technological improvement. The total installed costs for projects commissioned in the years 2013 and 2014 in the Middle East region averaged about USD 5 000/kW. The weighted average total installed cost for the region fell rapidly to between USD 1 038/kW and USD 1 349/kW in 2019-2021. The year 2022 saw a steep reduction, to USD 607/kW (an 88% reduction compared with 2013/2014), as very competitive projects were commissioned in Oman, Saudi Arabia and the UAE. Inputs from experts, such as Zywietz (2023), suggest that installation costs as low as USD 500/kW were achieved in mid-2023. The calculated LCOE (capacity weighted average) of solar PV fell by 86%-90% between 2013-2014 and 2022, to reach just USD 0.028/kWh for newly commissioned projects in 2022 (Figure 2.11).

Figure 2.11 Costs and performance indicators for solar PV and CSP in MENA, 2013-2022



Source: IRENA, 2023g

Note: Blue line and blue dots are for solar PV and the orange line and dots indicate concentrated solar power. The lines show the capacity weighted average. Shaded area shows 5th and 95th percentile range.

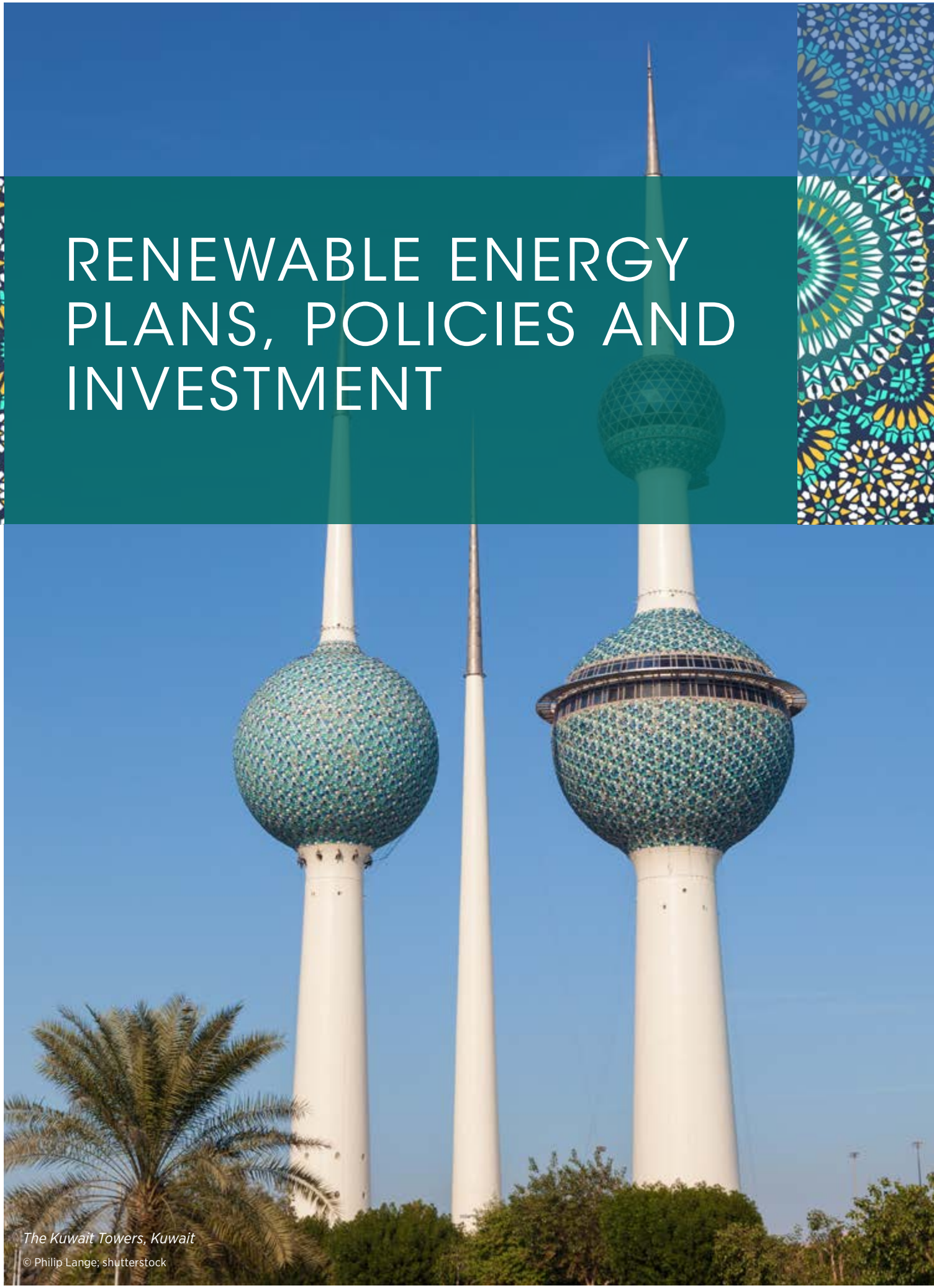
The installed costs of **CSP** projects in MENA have increased over time. This increase is primarily due to the increasing thermal storage and larger solar field – the 100 MW Shams CSP in Abu Dhabi has no storage but the 750 MW Phase IV of the Mohammed bin Rashid Al Maktoum Solar Park has 15 hours of molten salt-based thermal storage, allowing it to generate during night hours. In other projects, delays have meant that technology costs were locked in earlier and are higher than would otherwise be expected. The performance of CSP in the region has improved, with the weighted average capacity factor rising from 24% in 2013 to 28% in 2019, but is expected to leap with the commissioning of Phase IV of the Mohammed bin Rashid Al Maktoum Solar Park over 2023. The estimated weighted average LCOE of CSP projects in MENA, for which IRENA has data, declined by 29%, from USD 0.382/kWh in 2013 to USD 0.311/kWh in 2022 (Figure 2.11). Such projects' LCOE could fall into the USD 0.07-0.09 range with the commercial operation of Phase IV of the Mohammed bin Rashid Al Maktoum Solar Park in 2023.

Looking at **on-shore wind**, governments in the broader MENA region are capitalising on cost reductions and performance improvements stemming from wind turbine technology improvements and more competitive supply chains and larger-scale manufacturing. Wind speeds are unevenly distributed in the region, however; areas with strong wind resources are particularly attractive, but not the norm. The total installed costs of wind projects have been very volatile in MENA, given the few projects commissioned. Between 2014 and 2022, such costs varied from a low of USD 1 085/kW in 2017 to a high of USD 3 291/kW in 2015. In 2022, the commissioning of the Dumat al Jandal wind farm in Saudi Arabia, resulted in competitive installed costs of USD 1 338/kW.

Capacity factors have been similarly volatile, ranging between 29% and 40% when outliers are removed. The capacity weighted average LCOE ranged between USD 0.102 and USD 0.138/kWh between 2015 and 2018, but fell to between USD 0.074 and USD 0.095/kWh in 2019-2021, before dropping to USD 0.039/kWh for the Dumat al Jandal wind farm commissioned in 2022.

GCC stakeholders have actively invested in both the renewable energy value chain and associated projects to address the region's rising energy demand sustainably. This investment strategy not only aids in meeting energy needs but also spurs economic growth and job creation, playing a crucial role in economic diversification and industrial development initiatives.

RENEWABLE ENERGY PLANS, POLICIES AND INVESTMENT



The Kuwait Towers, Kuwait

03

This chapter outlines renewable energy plans, targets and policies in the Gulf Cooperation Council (GCC) countries (section 3.1.), along with investment trends (section 3.2.). Plans and policies discussed go beyond the power sector, and include those for desalination, manufacturing, transport and urban governance.

3.1 PLANS AND POLICIES

Renewable energy policies have evolved in recent years. All GCC countries now have renewable energy targets, and five out of six also have net-zero targets for the period of 2050-2060. Ambitions differ across countries, as do market size and readiness, but the overall picture is one of a dynamic region with much potential. The United Arab Emirates (UAE) and several other GCC countries have also incorporated their renewable energy targets into their Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC), as explored in Chapter 4. Targets figure in official state visions and announcements from high-ranking members of government. More announcements for new targets and ambitions are expected in the coming years.

Bahrain

Bahrain's **Vision 2030** outlines measures to protect the natural environment, reduce carbon emissions, minimise pollution and promote sustainable energy, though it makes no specific reference to renewable energy (Government of the Kingdom of Bahrain, 2008). The country's initial renewable energy target of 10% of peak capacity – approximately 710 megawatts (MW) according to Oxford Business Group (2022a) – by 2035 was adopted in 2017 as part of Bahrain's **National Renewable Energy Action Plan** (Sustainable Energy Unit, Kingdom of Bahrain, 2017). In May 2023, Bahrain announced it would double its renewable energy target to achieve 20% of the total energy mix by 2035, according to its Minister of Electricity and Water Affairs, and to reach net zero by 2060 (Kingdom of Bahrain, 2023). Bahrain's last NDC from 2021 (Kingdom of Bahrain, Supreme Council for Environment, 2021) does not reflect this target.

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In 2022, Bahrain had some 12.4 MW renewables-based electricity generation capacity, which is less than 1% of its total generation capacity of 8 580 MW (IRENA, 2023b). The National Renewable Energy Action Plan in 2017 identified several areas for possible regulatory reform of Bahrain's electricity market, including changes to allow private operation of renewable energy plants, the export of excess power to the grid and the option for private green electricity producers to sell the power produced from renewable sources to the grid (Oxford Business Group, 2022a). The government also announced that it would adopt a scheme providing a long-term purchase guarantee of electricity produced from renewable sources at a predetermined price (Oxford Business Group, 2022a). These plans have not yet materialised.

In 2019, Bahrain established the **Sustainable Energy Authority,** intended to oversee the country's renewable energy deployment by proposing strategies, policies and procedures, and to pool sustainable energy planning in the country (BNA, 2019). In 2022, the Sustainable Energy Authority's tasks were transferred to the **Ministry of Electricity and Water Affairs** (BNA, 2022). The **Supreme Council for Environment** similarly supports renewable energy policy, including through its Green Policy Committee and Government Initiative Committee, both of which have been established by the Ministry of Finance; and the Alternative Energy Committee, which is tasked with encouraging the use of alternative energy in the Kingdom (SCE, n.d.). The Supreme Council for Environment has also overseen parallel efforts to curb energy consumption, for instance, through its compact fluorescent lamps project, and to implement renewables-based pilot projects, such as solar-powered street lighting and the construction of wind turbines as part of the development of the Bahrain World Trade Centre (SCE, n.d.).

Kuwait

Kuwait has been slower than some of its neighbours in deploying renewable energy. Renewables-based electricity generation capacity in 2022 stood at 97 MW, 90% of which was solar based, though the country has some 12 MW wind power capacity, which accounts for around 1% of the country's electricity mix (IRENA, 2023b). The country's targeted share of 15% renewable energy in the electricity supply by 2030, announced in 2012, was later moved to 2035 as part of the country's **New Vision 2035** (Kuwait Times, 2018). Kuwait's most important renewable energy project is the Shagaya Renewable Energy Park, which is eventually aimed to reach 4 400 MW through Phases II and IIII (Ministry of Electricity, Water and Renewable Energy, 2023). In 2022, 2 000 MW wind and solar capacity were tendered out under a public-private partnership (PPP) by the Kuwait Authority for Partnership Projects as part of Shagaya (Brunel, 2023; Gnana, 2022b).

Anson Fernandez Dionisio; shutterstock

Renewable energy projects can either be developed directly by the **Ministry of Electricity, Water and Renewable Energy** (MEWRE), which is also in charge of renewable energy policy at large, or through a PPP. PPPs allow private companies or consortia to hold between 26-44% of shares in a jointly developed renewable energy plant; 50% of shares are allocated to Kuwaiti citizens, and between 6-24% to Kuwait's government (Government of Kuwait, 2015). The agreement is for 25-30 years, after which the project either is extended, or ownership returns in full to the government (Government of Kuwait, 2015).

According to MEWRE, the government is studying the establishment of renewable energy projects on the islands of Failaka and Bobyan; and the possibility to allow electricity consumers to purchase renewable energy from third parties (Ministry of Electricity, Water and Renewable Energy, 2023). Kuwait is also looking into buying renewables-based electricity from neighbouring countries (Ministry of Electricity, Water and Renewable Energy, 2023). Kuwait has a net-zero emissions target for 2060, although the foreign minister announced at the 2022 United Nations Climate Change Conference (COP27) that the government was committing to deliver net-zero carbon emissions in its critical oil and gas sector a decade earlier, by 2050 (Itayim, 2022).

Kuwait's institutional landscape for renewable energy is clearly structured. MEWRE, previously the Ministry of Electricity and Water, is in charge of renewable energy, while the **Kuwait Environment Authority** formulates environmental and climate policy, and also functions as a regulator. While the former is a ministry, the latter is a regulatory body directly under the **Council of Ministers**. The **Kuwait Authority for Partnership Projects**, established in 2014, is the main body responsible for PPP projects' implementation. Unlike some other GCC countries, in Kuwait, renewable energy and climate policy remain completely outside the realm of the Ministry of Oil and state oil companies, Kuwait Petroleum Corporation and Kuwait Oil Company.

Oman

In 2017, Oman announced a renewable energy target of up to 10% of electricity consumption by 2025 (Prabhu, 2017). **Oman Vision 2040** raises this target to 20% by 2030, and 35-39% by 2040 (Sultanate of Oman, 2021). These targets are reflected in Oman's second NDC of July 2021, and its **National Energy Strategy**, which is expected to be revised again in 2024.

In 2022, the government launched its **National Strategy for an Orderly Transition to Net Zero**, a green transition pathway to Oman reaching net-zero emissions by 2050 (Ministry of Energy and Minerals, 2022b). The strategy lays out both a pathway to achieve its goals, through a combination of energy and resource efficiency, electrification and renewables, battery electric technology, sustainable hydrogen, carbon capture and storage (CCS) and negative-emission solutions; and a strategy to "optimize the economic impact arising from the transition", including by minimising economic costs to Omani citizens and industries, encouraging job creation and ensuring a secure energy supply (Ministry of Energy and Minerals, 2022a; 2022b).

Planning and regulation for renewable energy and climate policy in Oman has moved across various institutions over the past years. The country's first NDC containing emissions targets and renewable energy plans was prepared by the **Ministry of Environment and Climate Change**, which was later turned into the **Authority for Environment** and the **Authority for Civil Aviation**, with the latter in charge of Oman's second NDC.

03

Renewable energy policy moved for a while to the **Authority for Electricity and Regulation**, now renamed the **Authority for Public Services Regulation**, with renewable energy originally being considered a primary electricity sector policy area. In February 2023, Oman's zero carbon programme moved to the **Ministry of Energy and Minerals**, which is now also in charge of all of Oman's renewable energy policy as well as hydrogen and CCS (ONA, 2023). In 2022, the government created the new **Oman Sustainability Centre**, tasked with supervising and ensuring the implementation of the country's net-zero plans (Ministry of Energy and Minerals, 2022c; Oman Observer, 2022).

Under the Ministry of Energy and Minerals's umbrella, hydrogen policy has been shifted to the **Directorate General of Renewable Energy and Hydrogen**, and, in 2022, **Hydrogen Oman (HYDROM)**, a subsidiary of **Energy Development Oman**, to manage hydrogen projects (HYDROM, 2023). Royal Decree 10/2023 allocates land to the development of renewable energy and hydrogen projects to the Oman Hydrogen Company (HYDROM, 2023). Hydrogen plays a large role in Oman's future energy plans, with the government aiming to build a hydrogen-centric economy by 2040, and plans to produce 1 million tonnes of green hydrogen per year by 2030 (Green Hydrogen Organisation, n.d.). Oman's hydrogen plans are discussed in more detail in chapter 4.

Oman has been active in deploying renewable energy for a variety of uses beyond utility-scale projects. In 2018, Oman launched its SAHIM II programme to install small-scale 2-4 kWp photovoltaic (PV) systems in residential areas, with the goal of eventually covering 10-30% of households (IEA, 2018; Prabhu, 2019). The programme also includes a second phase, wherein PV systems could be offered as an opportunity to investors, who would recover their investments at an agreed, competitive rate of return from payments aligned to PV system output (IEA, 2018). In addition, Oman has also been using solar-assisted steam generation developed by Glasspoint Solar for enhanced oil recovery for many years, starting with a 7 megawatt thermal (MW_{th}) pilot project in 2013, and inaugurating a 1 021 MW_{th} solar thermal facility called Mirah in 2018 (Power Technology, 2018).[12] As of 2022, the installed capacity of the project stood at 330 MW_{th} and there were no public plans for expansion. Glasspoint solar had signed a memorandum of understanding with Saudi Arabia's state-owned mining company Ma'aden to develop a 1.5 gigawatt thermal (GW_{th}) solar steam generation project in Saudi Arabia, where the steam would be used to refine bauxite ore into alumina (Epp, 2022).

Qatar

Qatar had been slower than its neighbours in adopting renewable energy targets, until it increased its renewable energy capacity rapidly in recent years. Qatar's **Vision 2030**, the basis of the country's development strategy, emphasises the role of fossil gas as a source of clean energy, dating back to 2008 with no revision since (General Secretariat for Development Planning, 2008). Initial targets were 200 MW of renewable electricity generation capacity by 2020, and 500 MW after (Planning and Statistics Authority, 2021).

In 2021, **QatarEnergy**, the country's national energy corporation, formerly known as Qatar Petroleum, launched its own **Sustainability Strategy**, which largely focuses on reducing emissions from its operations, but also includes a target of 2 000 to 4 000 MW of renewable energy by 2030 (QatarEnergy, 2021). In the same year, Qatar submitted its first NDC, which highlights the government's plans to promote decentralised renewable energy (State of Qatar, 2021). In March 2022, QatarEnergy announced a new, more ambitious target of 5 000 MW – about half of its current electricity generation capacity in 2021 – solar energy generation capacity by 2035, along with CCS technology targets and the elimination of routine methane flaring by then (Ugal, 2022).

[12] *The facility offers off-grid electricity to Oman's gas industry and therefore is not counted towards Oman's grid-base renewables supply.*

Qatar's renewable energy targets are, as evident from its historical background, set by its national energy corporation. This differentiates Qatar from its GCC neighbours, where target setting typically falls into the realm of states ministries.

Qatar's Minister for Energy Affairs announced two new major solar projects in August 2022. Aimed at supplying the country's gas field operations at Mesaieed and Ras Laffan, the two projects are expected to increase Qatar's solar output to 1.67 GW by the end of 2024, more than doubling the country's output from renewable energy within two years to support the country's expansion in fossil gas production (AFP, 2022).

Saudi Arabia

Saudi Arabia launched a comprehensive long-term strategy to transform its country and its economy in 2016, **Vision 2030**. Sustainability is a key pillar of the strategy, which is meant to rid the country of its "addiction" to oil (Nakhoul, Maclean and Rashad, 2016). Under Vision 2030, the **National Renewable Energy Program**, launched in 2019, set the goal to build a competitive renewable energy sector, as well as to localise a significant portion of the renewable energy value chain (Kingdom of Saudi Arabia, 2022a). Part of Vision 2030 are also "liveable, green cities", including its flagship urban project, NEOM, a new city to be built over the coming years, powered by 100% renewable energy (Kingdom of Saudi Arabia, 2022a).

In 2019, Saudi Arabia announced a new target for renewable energy's share of the overall energy mix to rise from less than 1% that year to 50% by 2030, though it is unclear whether this is based on capacity or generated power (Kingdom of Saudi Arabia, 2022a). This level of growth would entail a thorough transformation of the Saudi electricity mix, along with the electricity sector as a whole, including raising the electricity generation capacity from solar and wind energy from less than 500 MW in 2021 to approximately 58 000 MW by the end of this decade (Al-Atrush and England, 2022). The country also has a net-zero target for 2060 (Kingdom of Saudi Arabia, 2022a).

In 2019, Saudi Arabia's **Renewable Energy Project Development Office** completed a study stating that 13 000 MW of renewable energy could be integrated without major grid upgrades (Climate Action Tracker, 2021). Beyond this, and to achieve the renewable energy targets the government has set for 2030, large-scale investment in grid infrastructure will be necessary (Climate Action Tracker, 2021). Saudi Arabia is moving ahead with grid interconnection plans with neighbouring countries, which could facilitate future uptake and integration of renewables. In August 2020, Saudi Arabia and Jordan signed an agreement to connect the two countries with a 164 kilometre grid interconnection, planned to go live in 2025 (Arab News, 2022c), and Egypt and Saudi Arabia already are in the process of linking their grids, with contracts for the construction of the 3 000 MW interconnector awarded in 2021 and construction under way (MEED, 2021; Ministry of Energy, 2023).

Saudi Arabia is also interested in the supply chain of renewable energy technologies. In 2010, the **King Abdulaziz City for Science and Technology (KACST)** established the Solar PV Cell & Module Manufacturing Plant and PV Reliability Laboratory to produce solar panels and cells. The project aims to transfer solar energy technologies and develop commercial-grade equipment suitable for severe heat and sandstorms. KACST has also established the first internationally accredited laboratory to examine the efficiency and reliability of solar panels and develop standards that suit the Kingdom's environment. The facilities have an annual production capacity of 100 MW for solar PV module manufacturing, and another 100 MW for solar PV cell manufacturing (Kingdom of Saudi Arabia, 2022c).

03

United Arab Emirates

The UAE has one of the GCC region's most ambitious renewable energy programmes to date. Published in 2017, the country's federal **Energy Strategy 2050** initially aimed to increase the contribution of clean energy to the total energy mix, from less than 1% in 2017 to 50% by 2050; to reduce the carbon footprint of power generation over the same period by 70 percent; and to reach net-zero emissions by 2050 (Government of the United Arab Emirates, 2023a, 2023b; Wilson, 2023). Part of the 50% clean energy by 2050 is nuclear power, which is targeted to supply 6% of the country's electricity needs, implying a share of 44% renewable energy by 2050 (Government of the United Arab Emirates, 2023b). In late 2023, the government further updated the strategy, and now aims to triple the contribution of renewable energy and to invest AED 150-200 billion by 2030 to meet the country's net-zero target (Government of the United Arab Emirates, 2023b). The UAE's **Second NDC** to the UNFCCC and its 2023 update confirm the initial target (United Arab Emirates Ministry of Climate Change & Environment, 2022; United Arab Emirates Ministry of Climate Change & Environment, 2023).

The emirate of Dubai has set its own targets under the **Dubai Clean Energy Strategy**, launched in 2015, which aims to produce 25% of the emirate's electricity from clean sources by 2030, and 75% by 2050, and to make Dubai a global centre of clean energy and green economy (DEWA, 2020). The **Dubai Net Zero Emissions Strategy 2050** sets an even more ambitious target, for Dubai to provide 100% of its energy production capacity from clean energy sources by 2050 (DEWA, 2023).

Abu Dhabi is building a 2 100 MW solar plant in the Al Dhafra region, while Mohammed bin Rashid Solar Park in Dubai, which, with a current capacity of some 2 000 MW, is already one of the largest single-site solar plants in the world, is targeted to reach 5 000 MW capacity by 2030 (DEWA, 2023; Rahman, 2023). In May 2022, a third solar PV project entered the tendering process. Once completed, the Al Ajban solar PV plant will add 1 500 MW of capacity (Climate Action Tracker, 2023). The Climate Action Tracker concludes that with its current and planned renewable energy developments, the UAE is expected to reach 9 000 MW of renewable power by 2030 (Climate Action Tracker, 2023). Meanwhile, a more recent and ambitious target to triple the UAE's renewable energy generation capacity by 2030 would imply a total of 14 300 MW by the end of the decade (WAM, 2023).

To maximise the socio-economic benefits of the energy transition for its economy, the UAE launched the **UAE's Green Agenda 2030**, a long-term plan which combines objectives and policy initiatives across a range of portfolios, including the creation of a competitive knowledge economy, social development, sustainable environment, clean energy and climate action. The plan outlines programmes to support national, green innovation and diversification, investment in green infrastructure and a workforce trained in the necessary fields to support these aims. Special attention is also paid to water, energy efficiency, waste and transport (Government of the United Arab Emirates, n.d.).

In 2021, the UAE launched its **Operation 300 Billion** strategy, which aims to create a conducive environment for industries of the future, including hydrogen. The strategy seeks to develop the country's industrial sector, raising its contribution to the GDP to AED 300 billion (USD 81.7 billion)[13] by 2031. As part of the initiative, the Emirates Development Bank has allocated a portfolio of AED 30 billion (USD 8.2 billion) to support priority industrial sectors over a period of five years, including renewable energy equipment and technology, energy infrastructure, water desalination and agriculture (UAE Ministry of Climate Change & Environment, 2022).

[13] *Conversion as per UAE's Second NDC.*

The country is also leveraging artificial intelligence (AI) for use in its renewable energy sector. In 2018, the UAE government set up the Artificial Intelligence Laboratory in collaboration with Khalifa University. The laboratory uses AI to optimise the use of renewables in the UAE by mapping prime solar power locations across the country, in addition to tracking air pollutants and monitoring water quality (United Arab Emirates Ministry of Climate Change & Environment, 2022). In 2020, the **Dubai Electricity & Water Authority (DEWA)** launched **Digital DEWA**, its digital arm, to become the world's first digital utility with autonomous renewable energy storage systems featuring the integration of AI. The **UAE Strategy for Artificial Intelligence 2031**, which covers a number of economic sectors, supports renewable energy through utility management and smart consumption (Government of Dubai, 2020).

In 2022, Dubai launched its **Integrated Waste Management Strategy 2021-2041**, with a budget of AED 74.5 billion. The strategy seeks to encourage innovation in waste management, recycling and energy conversion, providing a potential starting point for waste-to-energy in Dubai (WAM, 2022).

The UAE is also the GCC region's first country to make investment in renewable energy – both at home, and overseas – an investment strategy (see section 3.2). In December 2021, Abu Dhabi's National Oil Company (ADNOC) announced a partnership with the Abu Dhabi National Energy Company PJSC (TAQA) and Mubadala Investment Company under the Abu Dhabi Future Energy Company (Masdar), to consolidate investment efforts in renewable energy and green hydrogen. The partnership has a combined committed capacity of over 23 000 MW of renewable energy, with the expectation of reaching over 100 000 MW by 2030, and the aim of turning Masdar into one of the largest clean energy companies of its kind in the world (ADNOC, n.d.; Reuters, 2021a).

Meanwhile, the UAE has proactively set relevant standards and technological specifications. In 2019, Dubai's Regulatory and Supervisory Bureau issued the Middle East region's first formal allowance of distributed renewable energy generation. Its standards define requirements for connection to the Dubai transmission and distribution systems and set up a common framework for grid connection agreements (IEA, 2022a; RSB Dubai, 2019). Dubai is further supporting the use of distributed renewable resources generators such as solar rooftop and solar water heating systems, having issued a first set of standards in 2016 (DEWA, 2016b). Since 2012, for all new villas and labour accommodations in Dubai, a solar water heating system must be installed to provide 75% of domestic hot water requirements (Dubai Municipality 2012).

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3.2. INVESTMENT

The investments in renewable energy in the GCC may be divided into two broad categories: investments in renewable energy projects and value chains in the region, and investments abroad.

Investment in renewable energy projects

The investment pattern observed in the GCC countries reflects their status as relatively new markets for renewable energy. Most of the investment is driven by large projects, implying considerable year-on-year fluctuations in investment volumes. Investment trends in renewable energy in the GCC region between 2013 and 2022 are shown in Figure 3.1. So far, investments are concentrated in the UAE, with the country accounting for close to 70% of the investments in the 2013-2022 period. As deployment picks up, annual investment flows will likely become more consistent, and increase across all countries.

Investments peaked in 2019 (Figure 3.1), mainly as three large-scale solar projects in the UAE reached financial close that year. In Dubai's Mohammed Bin Rashid Al Maktoum Solar Park, the 800 MW solar PV Phase III and the 700 MW CSP Phase IV received investments of USD 940 million and USD 3 870 million, respectively.[14] In Abu Dhabi, about USD 870 million were invested in the 1 177 MW Noor Abu Dhabi solar PV plant in Sweihan. The region's first large-scale wind farm, Saudi Arabia's 400 MW Dumat Al Jandal, valued at USD 500 million, also reached financial close in 2019.

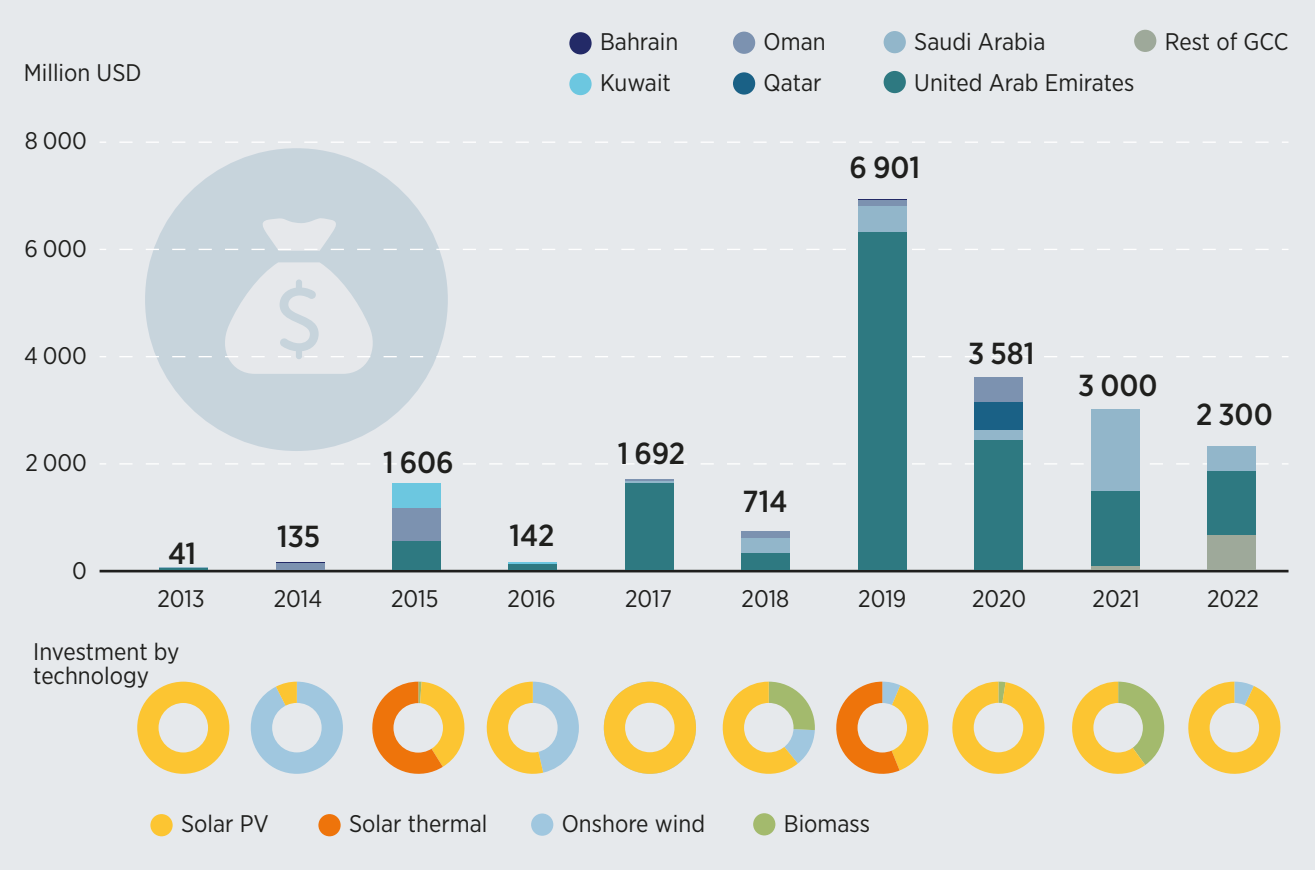
In the following years, annual investments declined gradually as the world struggled to address the onset of the COVID-19 pandemic. The financial close of Abu Dhabi's 2 GW Al Dhafra solar PV project (USD 886 million of financing) was the largest investment in 2020. Oman and Qatar also made waves with sizable investments (USD 460 million and USD 517 million) in their solar PV projects. In 2021, investments in Saudi Arabia picked up with the financial close of the 1 500 MW Sudair solar PV plant, valued at USD 924 million. Meanwhile Dubai's waste-to-energy project achieved a financial close of USD 1 200 million in the same year, marking the largest investment in waste-to-energy in the region thus far. The year 2022 was again dominated by investments in solar PV in the UAE and Saudi Arabia.

Investments are expected to reach new heights in 2023 as the region prepares to host the COP28 and countries aim to achieve their renewable energy aspirations. In August 2023, two major solar PV projects in Saudi Arabia reached financial close valued at USD 2 370 million. In May 2023, the NEOM Green Hydrogen Company completed the financial close of a green hydrogen plant (4 000 MW solar and wind and 600 tonnes per day of hydrogen by 2026) valued at USD 8 400 million.

Going forward, investments are likely to step up in Saudi Arabia, as further rounds of renewable energy auctions get underway. The UAE is expected to retain its leadership through the expected deployment of 44% of renewable capacity by 2050, and the proposed tripling of renewable capacity by 2030 backed by investment of USD 54 billion in the energy sector (Arabian Business, 2023). Investments in Bahrain, Kuwait, Oman and Qatar are also set to pick up as these countries embark on their renewable energy plans.

[14] *Sources such as ACWA Power (2020) indicate that financing of USD 1 500 million (out of a total of USD 3 870 million) for the Phase IV was secured in 2018.*

Figure 3.1 Renewable energy investments in members of the GCC by country and technology



Based on: BNEF 2023.

Note: In 2021 and 2022, national level investment data were available only for Saudi Arabia and the UAE; the rest of the investments are aggregated under "Rest of GCC". All values are at current prices and exchange rates. Due to the lack of more granular data, the units were not adjusted for inflation. These figures represent "primary" financial transactions in both large- and small-scale projects that directly contribute to deployment of renewable energy, and therefore exclude secondary transactions, e.g. refinancing of existing debts or public trading in financial markets.

Sources of funding for renewable energy

Investments in renewable energy in the region are characterised by a diverse blend of public and private funds, involving both local stakeholders and financial institutions from various other regions. The public sector had a pivotal role in kick-starting investments in renewable energy. As the market evolved, a significant portion of these investments has come from private banks and financial institutions (section 2.3).

Key public sector entities, including Saudi Arabia's Public Investment Fund (PIF), the UAE's Mubadala, the Gulf Investment Corporation (GIC) and the Kuwait Investment Authority, have been instrumental in driving investments in renewable energy. Often, these public sector institutions include sovereign wealth funds (see table 3.1). Typically, investments from these entities are channelled and executed through specialised renewable energy companies.

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Notable examples include ACWA Power in Saudi Arabia and Masdar in the UAE, both of which have played pivotal roles in shaping the region's renewable energy investment landscape. Public sector funds in the region are not merely passive investors; they actively and strategically champion the development of renewables. They finance companies specialising in project development and also secure seats on the boards of these companies – allowing them to directly influence strategic decision making as prominent shareholders. For instance, Masdar operates under the joint ownership of TAQA, ADNOC and Mubadala, and includes board members from each of these entities. Similarly, ACWA Power benefits from board representation by the Saudi PIF.

The GIC is headquartered in Kuwait and equally owned by the six GCC countries. It is becoming an active investor in the GCC renewable energy projects including the 45 MW solar-assisted desalination plant in Saudi Arabia (40% share), the 500 MW Ibri 2 solar PV plant in Oman and the 900 MW solar PV phase 5 of Dubai's Mohammed bin Rashid Al Maktoum Solar Park (GIC, 2022; Tholot, 2023). In all these projects GIC has been financier with ACWA Power taking the project development role.

Saudi Arabia's PIF, holding a 50% share in ACWA Power, plays a pivotal role in the nation's renewable energy sector. The PIF has been tasked with achieving 70% of Saudi Arabia's renewable energy targets. ACWA Power is a leading developer and operator of power and water projects (Al Arabiya, 2023a). ACWA has played a crucial role in implementing renewable projects in partnership with PIF and various stakeholders within and outside Saudi Arabia, maintaining a renewable energy portfolio with a cumulative capacity of 23 000 MW (ACWA Power, 2023b).

The Kuwait Investment Authority, the oldest sovereign wealth fund in the world, has been leading Kuwait's foray into sustainable energy project development around the world through its investments and subsidiaries such as Global Power Generation (GPG – Naturgy) and EnerTech. Enertech is a part of the Green Energy Oman international consortium which was awarded Oman's first green hydrogen block with renewable capacity of 4 000 MW and hydrogen production of 150 000 metric tonnes per year.

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Box 3.1 Investments by the GCC's several sovereign wealth funds

Several sovereign wealth funds in the region are investing in several avenues of sustainable development both inside the Gulf Cooperation Council and in other regions around the world (Table 3.1). For example, the Saudi Public Investment Fund invested USD 1 billion in Lucid Motors (an electric vehicle start-up) and is partnering with Foxconn to setup Ceer Motors for electric vehicle production in Saudi Arabia (section 2.2).

Investments have increased across all segments of the value chain in the region, including in renewable energy projects, development companies, manufacturing companies and research and development ventures.

Table 3.1 Investment by several sovereign wealth funds inside and outside the region

	Fund	Deal details	Value chain segment	Host country	Value (USD)
Kuwait	KIA (SWF)	25% stake in Global Power Generation (75% is Naturgy), 3 000 MW projects (wind and solar)	Project developer, operator	Spain	NA
Oman	OIA (SWF)	Joint equity investment in Glasspoint Solar (including Royal Dutch Shell)	Project developer, operator	Oman, United States	USD 53 million
Qatar	Nebras Power	75% stake in Zon Exploitatie Nederland (developer with 96 MW capacity), 2018	Project developer, operator	Netherlands	USD 20 million
Saudi Arabia	PIF (SWF)	50% stake in ACWA Power (RE portfolio of 23 GW).	Project developer, operator	Saudi Arabia	NA
	PIF (SWF)	60% stake in Lucid EV JV with Foxconn for Ceer EV	Manufacturer	Saudi Arabia, US	USD 3.6 billion in Lucid
United Arab Emirates	ADIA (SWF)	Investment in ReNew Power Ventures for a significant minority share (5 800 MW portfolio), 2015	Project developer, operator	India	USD 200 million
	ADIA (SWF)	Joint investment with Singapore's GIC in Greenko (more than 3 200 MW renewable energy capacity) (2016-2018)	Project developer, operator	India	USD 1.5 billion (including GIC)
	Mubadala	Establishment of Masdar Energy, Masdar Institute, and Masdar City (2007)	R&D, project developer	UAE	NA
	ADQ (through TAQA)	43% share in Masdar's renewable business and 33% in green hydrogen business, 2022	R&D, project developer	UAE	USD 1 billion

Sources: (Gifford, 2015; GPG, 2018; Mubasher, 2018; Saba and Uppal, 2023; Saudi Gazette, 2020; UNEP, 2017).

Note: ADIA = Abu Dhabi Investment Authority; EV = electric vehicle; GIC = Gulf Investment Corporation; KIA = Kuwait Investment Authority; MW = megawatt; OIA = Oman Investment Authority; PIF = Public Investment Fund; R&D = research and development; SWF = sovereign wealth fund; UAE = United Arab Emirates.

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Masdar, headquartered in the UAE, is a significant contributor to the renewable energy sector within the GCC region and beyond, with a substantial presence in nearly 40 countries and contributing to over 20 GW of renewable capacity globally. The company's investment portfolio exceeds USD 30 billion spread across six continents. In its home territory, Masdar plays an important role in the development and operation of the Mohammed Bin Rashid Al Maktoum Solar Park in Dubai and the Al Dhafra solar PV plant in Abu Dhabi. Moreover, it actively participates in Saudi Arabia's renewable energy landscape and has entered preliminary discussions with other GCC nations like Bahrain and Kuwait to invest in solar and wind projects.

Investment in the value chain

Beyond direct investments in renewable energy projects, both public and private entities have invested in the development of various segments of the region's renewable energy value chain. In most cases these entities have previous experience investing in energy and seek to extend their footprint in a dynamic and promising sector and to diversify their investment portfolio beyond conventional energy. Their initiatives have involved project development, manufacturing, research and development, and specially designed funds, among others.

Public (and in some cases private) entities have used acquisitions and equity investments as a tool for establishing domestic project development companies that are now spearheading renewable energy deployment in the Middle East and North Africa region and beyond. As stated earlier, both ACWA Power and Masdar have benefitted from investments from public entities. Abdul Latif Jameel Energy acquired Spanish developer Fotowatio Renewable Ventures, including its global 3 800 MW pipeline of PV projects in 2014, to establish itself as a significant developer. Table 3.1 (in Box 3.1) highlights a number of investments into projects outside the GCC region by regional sovereign wealth funds and public investment entities such as UAE's Abu Dhabi Investment Authority, Qatar's Nebras Power, Oman's State General Reserve Fund (now renamed to the Oman Investment Authority) and the Kuwait Investment Authority.

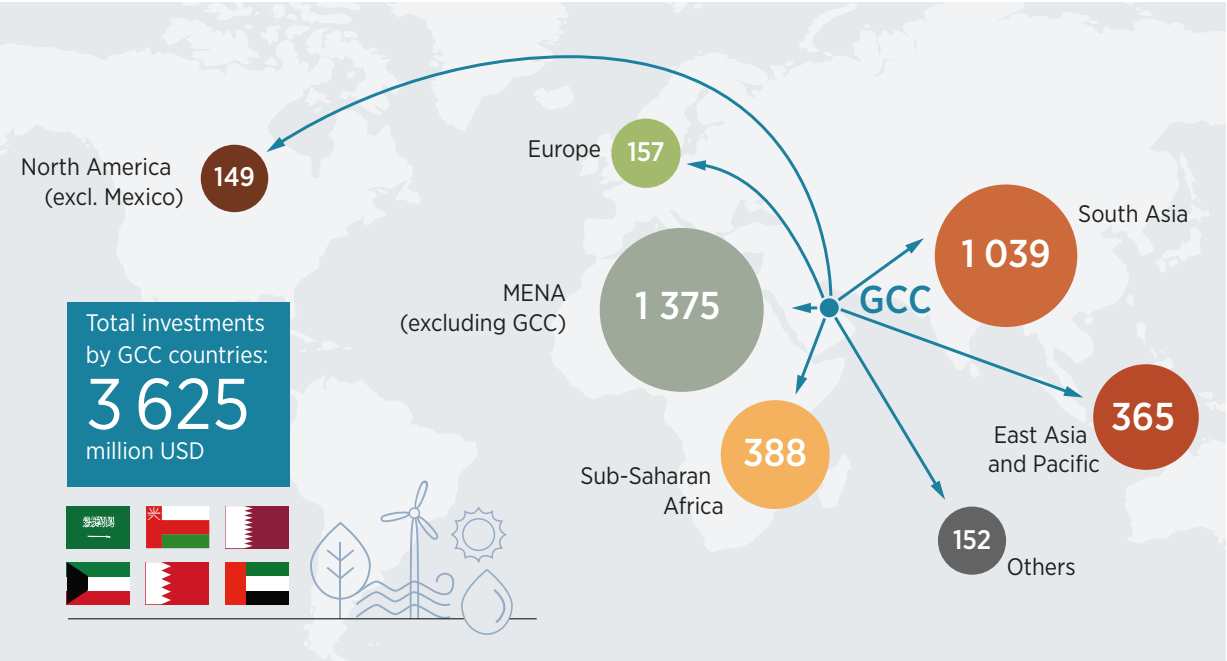
Public investments in solar PV manufacturing have had mixed results. Masdar opened a thin-film solar PV module manufacturing facility in Germany in 2009 but closed it down in 2014 amid international competition. Qatar Foundation held a sizeable stake in German SolarWorld, which stopped production in 2018 (Enkhardt, 2018).

Kuwait's EnerTech aimed to develop the manufacturing part of the solar value chain which resulted in investment in Morgan Solar (Canada) as early as in 2014. The partnership continues; however, it has likely not resulted in development of local know-how and infrastructure for solar manufacturing and assembly in Kuwait (Morgan Solar, 2014, 2022). Saudi Arabia, where local content requirements in auctions encourage domestic buying, is home to solar panel manufacturers such as the Masdar Solar by Bin Omairah holding, with annual production capacity of 600 MW, and Desert Technologies, with annual production capacity of 300 MW (Gupta, 2023; Ivanova, 2022).

Investments in the manufacturing value chain of EVs is a growing area of interest. PIF's investment in LUCID is one of many similar initiatives. PIF is also partnering with Hyundai and Foxconn on two separate EV manufacturing projects (see section 2.3). Saudi SNB capital and the Qatar Investment Authority have both invested in SK which is a Korean EV battery manufacturer (Perry, 2023; QIA, 2023)

Many GCC countries have invested in research and development to further sustainable energy technologies and their adaptation to local market and climate conditions. Examples include the Masdar Institute (now part of Khalifa University of Science and Technology), King Abdullah University of Science and Technology, and Qatar Environment and Energy Research Institute. Moreover, several institutions have set up funds to invest in sustainable energy. Masdar established the first green revolving credit facility in the GCC in collaboration with four local and international banks. The facility will provide funding for sustainable technologies and real estate projects (TradeArabia, 2018). In Dubai, DEWA is setting up the AED 100 billion (USD 27 billion) Dubai Green Fund, by raising AED 2.4 billion. The fund will be used to finance local and global renewable energy and energy efficiency projects and companies (Clowes, 2017).

Figure 3.2 Renewable energy investments by GCC countries in regions around the world, 2016-2020 (million USD)



Source: (IRENA and CPI 2023).

Note: Does not include investments in GCC. GCC = Gulf Cooperation Council; MENA = Middle East and North Africa.

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Investment by GCC entities in renewable energy projects outside the region

Wind and solar PV projects have been profitable investment opportunities in many markets around the world for the past decade. The long-term and stable cash flows provided by renewable energy projects match the long-term return horizons of some investors such as institutional investors – sovereign wealth funds, pension plans and insurance companies. Investors based in the GCC region have been keen to invest in industries that show prospects for long-term development. While return on investment is a key motive for these investments, in some cases the investments are done to support partner countries in achieving their objectives for energy access and sustainable development.

Table 3.2 Investment by GCC entities in renewable energy projects outside the region

	Fund	Investment Details	Host
Qatar	Nebras (QWEC and QH)	Multiple solar PV projects (Nebras Power, 2018): • 24% stake, 40 MW AM Solar Jordan • 35% stake, 52 MW Shams Ma'an Jordan	Jordan
Saudi Arabia	ACWA Power (Saudi PIF)	Stakes in operational wind projects (ACWA Power, 2023a): • 75% stake, Khalladi, Morocco, 120 MW • Small wind projects in Jordan, ~1.5 MW • 100, 500, 500 and 1500 MW wind projects, Uzbekistan • 250 MW wind project, Azerbaijan • 1100 MW wind project, Egypt	Morocco, Jordan, Uzbekistan, Azerbaijan, Egypt
	ACWA Power (Saudi PIF)	Stakes in operational solar projects (ACWA Power, 2023a): • 42% stake, Karadzhalovo Bulgaria, 50 MW PV • 73% stake, Noor I Morocco, 160 MW CSP • 40% stake, Bokpoort South Africa, 50 MW CSP, 9 hour storage • Benban solar PV 1, 2 and 3, 150 MW, Egypt • Kom Ombo solar PV, 200 MW, Egypt	Bulgaria, Morocco, South Africa, Egypt
United Arab Emirates	Masdar	Minority stakes in offshore wind plants (Masdar, 2023a): • 20% stake, 630 MW London Array • 35% stake, 402 MW Dudgeon • 25% stake, 30 MW Hywind	United Kingdom
	Masdar	Wind farm development around the world (Masdar, 2023a): • 158 MW Čibuk 1, Serbia • 117 MW Tafila wind farm, Jordan • 49% stake, 72 MW Krnovo wind farm, Montenegro • Stake in 149 MW Rocksprings, United States (2020) • 500 MW Wind, Uzbekistan (2020)	Serbia, Jordan, Montenegro, United States, Uzbekistan
	Masdar	Several utility-scale projects (Masdar, 2023a): • 200 MW, Baynouna PV, Jordan • 120 MW in 3 CSP projects, Torresol, Spain • 50% stake, 1600 MW portfolio EDF, United States (2020) • 100, 220, 220, 250 and 457 MW PV, Uzbekistan (2019-2023) • 230 MW PV in Gardah, Azerbaijan (2021)	Jordan, Spain, Uzbekistan Azerbaijan, United States

Source: (Nebras Power 2018; Masdar 2023a; ACWA Power 2023a).
Note: MW = megawatt; PV = photovoltaic; UAE = United Arab Emirates.

GCC countries have several strategic renewable energy investments across key regions (Figure 3.2). The Middle East and North Africa region received substantial funding amounting to USD 1.4 billion from 2016 to 2020, underlining the GCC countries' focus on strengthening renewable energy and development initiatives in that region (Figure 3.2). This includes several solar and wind projects in countries such as Jordan, Egypt and Morocco. South Asia and Sub-Saharan Africa also benefitted significantly, with investments of USD 1.039 billion and USD 388 million, respectively, contributing to the expansion of sustainable energy solutions in these areas. Details on individual investments in projects in these and other regions can be seen in later discussion (Table 3.2).

Furthermore, the GCC countries extended their renewable energy funding to East Asia and the Pacific, Europe, North America (excluding Mexico) collectively allocating USD 823 million to facilitate renewable energy development.

These direct investments in projects outside the region have primarily been initiated by public-sector-backed entities, which are often sovereign wealth funds. Masdar's investments include off-shore wind plants in the United Kingdom, wind farms in Serbia, Jordan, Montenegro, the United States and Uzbekistan, as well as utility-scale solar projects in Jordan, Spain, the United States, Uzbekistan and Azerbaijan (Table 3.2).

ACWA Power's diverse portfolio includes wind projects in Morocco, Jordan, Uzbekistan, Azerbaijan and Egypt, as well as solar projects in Bulgaria, Morocco, South Africa and Egypt (Table 3.2).

Nebras Power, a Qatar-based power company, is a joint venture between the Qatar Electricity and Water Company and Qatar Holding, the latter being founded by the Qatar Investment Authority, a sovereign wealth fund of Qatar. Nebras owns solar PV project portfolios in several countries including Jordan and Brazil. These investments have helped GCC public entities to diversify their investment portfolios. They have also helped establish Masdar and ACWA Power as key renewable energy project developers.

Several investments are also driven by the desire to advance sustainable development, increase energy access and improve livelihoods. The UAE's Abu Dhabi Fund for Development has committed USD 350 million in concessionary loans over seven funding cycles to renewable energy projects recommended by IRENA. About USD 214 million of co-financing for 21 renewable energy projects were allocated during the first five funding cycles, helping leverage an additional USD 420 million of financing from other funding sources (IRENA, 2017). In 2023, the UAE also committed to invest USD 4.5 billion in Africa, with the aim of catalysing an additional USD 12.5 billion from multilateral, public and private sources (The Cradle, 2023). The UAE has pledged USD 400 million to IRENA's Energy Transition Accelerator Financing (ETAF) platform, with additional contributions from AIIB, Masdar and Swiss Re, totalling nearly USD 1 billion at COP27. In 2023, the Organization of the Petroleum Exporting Countries Fund [15] and IDB joined as funding partners, committing USD 250 million and USD 100 million, respectively, to support renewable energy financing. IRENA oversees the ETAF platform, evaluating project submissions against eligibility criteria and managing their progress from submission to recommendations to partners (IRENA, 2022a).

Investment funds from several GCC countries, including Kuwait, Qatar, Saudi Arabia and UAE are taking part in the Sovereign Wealth Funds Initiative of the One Planet Summit and committed to invest in companies that factor climate risks into their strategies.

[15] *The OPEC Fund is a multilateral development finance institution including: Algeria, Ecuador, Gabon, Indonesia, the Islamic Republic Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, the United Arab Emirates and the Bolivarian Republic of Venezuela.*

GCC CLIMATE POLICY

Dubai, UAE: Expo 2020; COP28 venue

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Climate policy has become more visible in the GCC over the past decade. All six Gulf Cooperation Council (GCC) countries are signatories to the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement signed at the 21st Conference of the Parties (COP21) in 2015. They have all engaged proactively in the context of the UN 2030 Agenda for Sustainable Development, which includes specific goals for energy sustainability, climate action and environmental protection. For the GCC countries grappling with renewables, climate policy is now part of their sustainable development planning. The council as a whole engages with climate policy when it takes part in international forums. As host of COP28 in December 2023, the United Arab Emirates (UAE) underscores the region's attentiveness to the international climate debate. More than a decade has passed since Qatar hosted COP18 (2012), and the UAE has signalled its interest in decision making around international climate action.

This chapter provides an overview of the GCC's climate policy environment. It first explores mitigation and adaptation targets in the GCC (section 4.1), and then looks more closely at mitigation and adaptation policies (sections 4.2. and 4.3).

4.1 CLIMATE TARGETS

As of November 2023, all the GCC countries had submitted new iterations of their NDCs, offering more ambitious emission reduction targets; in fact, the UAE had in July 2023 submitted their third NDC (Table 4.1). Except for Qatar, GCC countries set net-zero targets in addition to more ambitious targets for renewable energy (Chapter 3). While the region's governments, like those of other major fossil fuel producers, have frequently stressed a continued role for oil and gas in the future energy mix, political support has intensified for international calls to "phase down" fossil fuels. Sultan Al Jaber, speaking as UAE COP28 president, called such a phase down "inevitable" and "essential" in the summer of 2023 (Harvey, 2023).

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Other GHG emissions, *i.e.* methane and nitrous oxide (N_2O), are referenced more loosely in emission reduction targets. Both gases are targeted for carbon mitigation (alongside carbon dioxide [CO_2]), or "Carbon Control Target Plan Gases," in their respective NDCs. Methane is a critical greenhouse gas (GHG) in the region, representing nearly a quarter of annual GHG emissions in the case of the UAE (Climate Action Tracker, 2023). The UAE and Saudi Arabia have reiterated their membership and active participation in the Global Methane Initiative (or Pledge) to reduce global methane emissions by 30% relative to 2020 levels, while state oil companies Abu Dhabi National Oil Company (ADNOC) and Aramco have committed to voluntary upstream methane intensity targets of their own.

ADNOC has set for itself a new upstream methane intensity target – *i.e.* the ratio of methane emissions to natural gas produced – of no more than 0.15% by 2025, the lowest in the Middle East (ADNOC, 2022), while it reports current methane intensity of 0.07%. Aramco, meanwhile, self-reports a methane intensity of 0.05% from its operating facilities and equipment (Aramco, 2022). Kuwait, Oman and Qatar all cite methane as an important gas to mitigate from their oil and gas sectors in their carbon control plans, but without providing any quantitative data or target. Bahrain does not reference methane at all.

Efforts to mitigate methane from other sources (such as landfills) are mostly limited to the UAE, where emirate-level strategies (Dubai, Sharjah and Ras al Khaimah) are pursuing methane recovery projects at landfills in addition to waste-to-energy projects and hybrid landfill gas-solar-agro projects. In Bahrain, a new methane collection system is being installed at the Askar landfill (which covers ~20% of its total area) to reduce the methane and CO_2 footprint of the landfill waste.

The UAE is the only GCC country to provide sectoral targets in its most recent NDC update, with other countries mainly indicating the sectors targeted for emission reduction. For example, Oman, under its updated NDC, is targeting emission reduction from its business-as-usual (BAU) scenario covering only *primary* industries, such as petrochemicals, mining and metals. Across all sectors, Oman's emissions rise each target year due to higher economic activity and population projections, but the rise is lower than it would be under its respective BAU scenarios.

Bahrain, Kuwait, Qatar and Saudi Arabia are also targeting emission reductions in their key sectors, aware that their circumstances, strategic visions and individual capacities might diverge, culminating eventually in starkly different planned reductions for their sectors in future NDCs/UNFCCC communications or government-released emission mitigation pathways.

Table 4.1 Mapping the GCC countries' climate change policies and targets since the Paris Agreement

Parameter	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
Updated NDC	Yes, first update to first NDC	Yes, first update to first NDC	Yes, second NDC	Yes, first update to first NDC	Yes, first update to first NDC	Yes, third update to second NDC
Update year	*October 2021*	*October 2021*	*July 2021*	*August 2021*	*October 2021*	*July 2023*
Emission reduction	30% by 2035 compared to BAU (2015)	7.4% by 2035 relative to BAU (2015)	7% reduction in total GHG emissions in 2030 relative to BAU (2019)	25% reduction in GHG emissions by 2030 relative to BAU (2019)	Remove GHG emissions by 278 $MtCO_2eq$ annually by 2030 with 2019 as base year	19% absolute reduction by 2030 with 2019 as base year
Net zero	2060	2060	2050	x	2060	2050
H_2 strategy	x	x	Yes, under development	x	Yes, under development	Yes
Renewable targets	20% of energy mix by 2035	15% of power output by 2030	20% of electricity from renewables by 2030	Add 2-4 GW of renewables by 2030	50% of electricity from renewables by 2030, as part of the Saudi Green Initiative	44% of installed power capacity by 2050
Energy efficiency targets	6% improvement by 2025 compared to BAU (2015)	Reduce energy consumption by 10% in the residential and industrial sector; improve power generation efficiency by 5%	Unspecified	Unspecified	Unspecified (programmes in place)	Reduction of final energy demand through individual and institutional consumption efficiency of 42% to 45% by 2050, compared to 2019; 40% reduction in energy use and 20% reduction in water demand for the built environment by 2050

Note: BAU = business as usual; GHG = greenhouse gas; GW = gigawatt; KSA = Kingdom of Saudi Arabia; $MtCO_2eq$ = million tonnes of carbon dioxide equivalent; NDC = Nationally Determined Contribution.

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In the UAE, the biggest reductions planned are for its power grid and the buildings sectors, with a >50% reduction for both, followed by the agriculture, industrial and transport sectors (see Table 4.2). The power sector is being targeted for major reductions due to the relative ease with which zero-carbon sources (such as renewables and nuclear) can be integrated into generation; reductions are also aided by efficiency gains in generation and the switch from thermal to reverse osmosis desalination. A steep ramping up of solar photovoltaic (PV) and nuclear (to reach 19.8 GW of clean energy capacity by 2030) will correspond to a lower grid emissions factor of 51% from 2019 levels, while meeting the expected twofold increase in total grid-delivered power demand of the country over the same period. Power sector decarbonisation will also feed into the planned emission reduction target for the buildings sector, in addition to higher energy efficiency to reduce energy demand, as well as future net zero from the construction sector.

Reductions from the industrial sector are estimated at about 5% compared with the 2019 base year level. At first glance these decreases appear modest, but they derived from the UAE's strategic aim to double industrial output by 2031. To put it another way, the UAE plans to more than halve the emissions intensity of industry. For a discussion of aligning fossil fuel production with emissions targets, see Box 5.1.

In the transport sector, the UAE expects to reduce emissions by 1% by 2030. Long lead times for ambitious public transport and electrified transport projects would bring greater reductions. It maintains that even a 1% reduction in 2030, compared to 2019, would represent a significant drop in emissions per kilometre travelled, with a decrease of 20% per passenger-kilometre travelled and 40% per freight tonne-kilometre.

The UAE has also taken a number of long lead-time decisions – for instance, a national rail network (Etihad Rail, established in June 2009) to lessen road traffic and reduce emissions. As it is powered by electro-motive diesel (Etihad Rail, 2023), the railcar network is not carbon neutral.

Table 4.2 UAE sectoral emissions by target years as per planned emission reductions

	Power grid emission coefficient	Industry	Transport	Waste	Buildings	Agriculture
Enhanced base year 2019	0.55 tCO_2e/MWh	103.0 $MtCO_2eq$	42.0 $MtCO_2eq$	13.0 $MtCO_2eq$	62.0 $MtCO_2eq$	6.0 $MtCO_2eq$
Target year 2030	0.27 tCO_2e/MWh	98.0 $MtCO_2eq$	42.0 $MtCO_2eq$	14.0 $MtCO_2eq$	27.0 $MtCO_2eq$	4.0 $MtCO_2eq$

Source: United Arab Emirates Ministry of Climate Change & Environment, 2023.
Note: $MtCO_2eq$ = million tonnes of carbon dioxide equivalent; tCO_2e/MWh = tonnes of carbon dioxide equivalent per megawatt hour.

4.2 MITIGATION POLICIES

Several policy instruments support climate targets in GCC countries. Because all six countries' emissions targets were introduced relatively recently, debate now centres on the policies best suited to each country's climate and development goals; some NDCs hint at the region's likely direction on climate policy. This section explores the region's likeliest policy options for emission reductions and their implementation status.

Regulatory tools

The reduction of emissions requires regulatory tools ranging from stricter energy efficiency mandates and green performance standards to the investment environment for renewable energy (Chapter 3). Applied throughout different economic sectors, such tools are often a first obligatory step for end users and/or retailers; combined with financial incentives such as initial investment subsidies, or credits for the emissions avoided or abated, such policies can support a gradual shift away from less efficient technologies. Governments can also support the price of more efficient products and technologies and increase visibility.

One example of regulation in the GCC is Abu Dhabi's dedicated Energy Tariff Incentive Programme (ETIP) for industrial companies. It offers preferential utility tariff rates to companies that pull in excellent evaluations across efficiency and economic output criteria, such as overall economic impact of their activity, improved logistics by their activity, better energy intensity levels and more efficient energy management. High scores warrant lower tariffs for companies recognized in these ways, and profits are boosted.

Because the electricity and energy feedstock for these companies is sourced from fossil fuels, however, any "green" impact is compromised. But paired with a direct/fixed subsidy for green technology investment by the producer of the energy feedstock/electricity, a "green profit" loop could be created whereby the producer provides green feedstock/electricity to the manufacturer, who then secures better tariff rates for their efficient energy management and boost to profits.

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Box 4.1 Energy pricing reform in the GCC region

Energy prices for domestic users remain heavily regulated across the Gulf Cooperation Council (GCC), a vestige from an era when energy companies and utilities were state businesses. Domestic users – whether households, businesses or industries – have thus benefited from the region's fossil fuel wealth, being supplied at or below the cost of production, including electricity. The International Energy Agency (IEA) estimates total fossil fuel subsidies in the GCC in 2021 at USD 76 billion, of which almost USD 48 billion went into subsidising oil and fossil gas, and another USD 28 billion was spent on electricity subsidies (IEA, 2022b). Despite extensive price reforms, Saudi Arabia and the United Arab Emirates continue to be the two largest subsidisers of fossil fuels in the world as of 2021, following the IEA's estimation method (IEA, 2022b).[a]

The impact on GCC economies and their domestic energy mix has been substantial, not only in absolute fiscal terms (through actual transfers) but also through the opportunity cost entailed in selling oil and fossil gas domestically at a substantial discount off their international price. Prices are essential in determining energy consumption behaviour, incentives for more energy-efficient products and technologies and fuel preference (Coady, Parry and Shang, 2018; IISD, 2017; IMF, 2015; Krane and Hung, 2016; Moerenhaut, 2018). Renewable energy has historically faced many economic hurdles in the GCC owing to the very low price of competing fossil fuels and, for many residential and commercial businesses, highly subsidised prices for grid-based electricity (Boersma and Griffiths, 2016; Fattouh and El-Katiri, 2012; IISD, 2017; IMF, 2015; Krane and Hung, 2016). This includes both grid-based electricity, and decentralised, roof-top solutions, the latter having made few inroads into the GCC despite their technical merits.

The reform of energy and utility prices across the GCC over the past decade has supported the economic case for renewable energy, in addition to the corresponding drop in costs for technologies such as wind and solar energy (see Chapter 3 for more details). Saudi Arabia and Oman have increased prices for fossil fuels and electricity in the years since 2015, although they remain regulated by the government (Amann *et al.*, 2021; Boersma and Griffiths, 2016; Darandary, Mikayilov and Alatawi, 2021; Moerenhaut, 2018). Also in 2015, the United Arab Emirates, which already charged higher utility prices than its neighbours, implemented a reform of electricity prices, shielding only nationals from hikes in household utility bills. That same year, the country began to deregulate transport fuel prices, which are now linked to international prices, although based on a rolling average over a month (Government of the United Arab Emirates, 2022b).

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a. The IEA's method of calculating fossil fuel subsidies is based on the Price-Gap Method. More can be read about it at IEA (2023a). According to Hamaizia and Moerenhout (2022), GCC countries sell fuel domestically at prices above production costs but below the regional and global averages. While this practice results in high opportunity costs, it does not currently meet the WTO's trade-focused definition of subsidies.

Financial incentives for green technologies

Financial incentives in the form of subsidies for green technology can be provided, in addition to other financial instruments and market incentives. Such programmes are now limited in the GCC, albeit with heightened interest over the past half-decade. An indirect way to grow support for energy efficiency and emission reduction technologies is through continued reforms of energy, water, and electricity prices in the GCC. With energy prices largely regulated and below market cost, there are currently few market incentives for individuals and businesses to invest voluntarily in more efficient technology in the region. Prices for energy and water – which is generated through desalination, a process that itself requires energy – remain heavily subsidised across the GCC, although with regional differences in rates of subsidisation. Persistent and gradual energy price reform (Box 4.1) could galvanize emissions reductions in the region, without entailing additional costs to governments; the proceeds could be used to support select user groups in adapting, for instance, to invest in emission-reducing technology.

Research and development (R&D) technology support

Technology will likely play a major role in the GCC region's future emissions policy, owing to the critical role energy efficiency and different technologies play in the energy transition. Transition technologies also hold notable political appeal in the region because of their potential to drive knowledge-based industry growth and job creation, creating win-win solutions for both climate change and socio-economic development goals.

Several GCC countries have for several years arranged direct policy support for technology solutions to climate mitigation and adaptation. An example is the Masdar-BP joint initiative (in the UAE called Catalyst), a technology start-up accelerator focussed on sustainability and clean technology. The accelerator provides fixed cost benefits (through funding for green technology), access to the land and warehouses at the Masdar City Free Zone at preferential rates, Masdar's R&D facilities, as well as soft benefits such as training to boost investment in innovative technologies and mitigation solutions that directly contribute to the Sustainable Development Goals (SDGs). A federal innovation measure is the Mohammed Bin Rashid Innovation Fund. Part of the UAE's National Innovation Strategy, it provides a dedicated guarantee scheme for financing solutions with flexible repayment periods at low cost to encourage clean technology and sustainability solutions across its major emitting sectors.

Other innovation funds in the region are lower profile. Saudi Arabia's King Abdullah University of Science and Technology (KAUST) Innovation Fund supports high-profile international technology companies willing to establish a presence in Saudi Arabia; this support mainly involves accessing KAUST research facilities and activities. Saudi Aramco's Sustainability Fund, with USD 1.5 billion, and Aramco's Wa'ed Ventures, with USD 500 million, invest in local tech-based start-ups. Other Saudi entities active in the area of research and R&D are King Abdullah City for Atomic and Renewable Energy (KACARE), King Abdullah Petroleum Studies and Research Center (KAPSARC) and King Abdulaziz City for Science and Technology (KACST).

Qatar has an Innovation Coupon provided by the Qatar Foundation and Qatar Research, Development and Innovation Council for a value of up to USD 100 000 but only if technology providers are not representing any state company. Oman, meanwhile, plans to launch a USD 5.2 billion Oman Future Fund to reduce its reliance on oil and gas and support sustainable economic growth and Vision 2040. Originally planned to launch in 2023, the fund now aims to provide funding for innovative technologies and sustainable solutions that have so far been the purview of the Omani Technology Fund (Oman Daily Observer, 2023).

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Carbon markets and carbon pricing

Market-based solutions have received more interest from policy makers in the GCC, not least because these solutions give fossil fuel producers an option to "remove" emissions, augmenting the "reduce, reuse and recycle" principle. Another recent, high-profile solution is voluntary carbon markets. Abu Dhabi Global Market announced plans in 2022 with AirCarbon Exchange to develop the world's first "fully regulated" voluntary carbon trading exchange and carbon clearinghouse (ADGM, 2022); no further updates have been provided since then. Also, Saudi Arabia's Public Investment Fund (PIF) and the Saudi Stock Exchange, Tadāwul, announced in 2021 a joint plan for a voluntary carbon exchange in Riyadh by 2023 for the trading of carbon credit certificates (Reuters, 2021d), and the launch of a regional voluntary carbon market company in 2022 (Reuters, 2022).

Carbon pricing and compliance carbon markets have received less attention than voluntary carbon markets. This is probably because they require operating on a more mandatory basis, compelling participating organisations to meet certain nationally set carbon reduction targets, which requires (1) the right regulatory framework and policy mechanisms and (2) the right transparency mechanisms.

The UAE is designing a policy package around carbon capture, utilisation and storage (CCUS), which includes plans to introduce contracts for capture-to-pay for the difference between the carbon price and actual abatement costs (United Arab Emirates Ministry of Climate Change & Environment, 2023); these plans remain at a conceptual stage and "options remain open". Carbon taxation or cap-and-trade systems are often touted as an enabler for the region but depend on the right regulatory design. The Abu Dhabi Department of Energy and the World Green Economy Organisation/Dubai Carbon Centre of Excellence (DCCE) have begun issuing i-RECs in 2017, standard certificates that ease the transparent tracking of carbon certificates, though most of them have been based on nuclear power so far. Abu Dhabi's Emirates Water and Electricity Company (EWEC) holds regular auctions of Clean Energy Certificates (issued by the Abu Dhabi Department of Energy and accredited by i-REC standard). The most recent auction was in September 2023 (iREC Standard, 2023).

Table 4.3 Strategy shifts in the GCC national oil companies and investment funds

	Strategies	
National oil companies	Integrate technologies	Integrating oil and gas operations with low-carbon technologies to keep costs low while expanding resource base and exploiting new commercial opportunities (*e.g.* CCUS for EOR) Integrate renewable generation and EOR, synthetic fuels, direct CO_2 capture, electricity marketing to battery vehicles into core business
	Commercial restructuring	Adoption of dual strategy by restructuring operations: decarbonise traditional operations while securing a dominant position in emerging energy sources (*e.g.* hydrogen)
	Downstream focus	Integrating domestic and international refineries with petrochemical plants to secure offtake for future; create new oil and gas markets by geography (Asia) and sector (downstream)
	Internationalisation	Has some overlap with downstream focus, but includes a broader scope: JVs with refineries, petrochemical plants and storage terminals
Investment funds	Divestment	Managed divestment of hydrocarbon assets
	State-backed policies for energy diversification	Investment into clean tech and low-carbon energy sources, domestically and/or internationally through sovereign wealth funds

Note: CCUS = carbon capture, utilisation and storage; CO_2 = carbon dioxide; EOR = enhanced oil recovery; JV = joint venture.

Accountability and business model shifts in the fossil fuel sector

Greater accountability and transparency in GCC have roots in the region's commitment to global climate and sustainability, like the Paris Agreement and the 2030 Agenda, to which they are signatories. They are also exposed to scrutiny from the international community (including through climate change action trackers), exposure that has caused the region's energy producers to shift strategies and business models (Table 4.3). With the advent of corporate/company-focussed climate ambition trackers, such as the Climate Action 100+ Net Zero Company Benchmark, GCC oil and gas companies have begun to provide more voluntary disclosures of their emissions, emissions mitigation strategies, progress to date towards mitigation (across all scopes) and progress towards internal net-zero targets. Other factors that have contributed to greater disclosure of environmental performance include public market listings since 2019 by Saudi Aramco and several ADNOC subsidiaries, albeit only on local exchanges; the sale of stakes in strategic infrastructure such as gas pipelines; raising finance through international bonds and the marketing of "carbon-neutral" liquefied natural gas (LNG) cargoes (Bloomberg, 2021).

While greater transparency is not tantamount to climate action, transparency does encourage internal changes in GCC oil and gas companies – which are some of the world's largest – around the issues of environmental impacts and emissions. All six state-owned oil and gas companies – *i.e.* BAPCO (Nogaholding), Kuwait Petroleum Corporation, Petroleum Development Oman (PDO), QatarEnergy, Saudi Aramco and ADNOC – have recently adopted measures or plans that respond to changing markets for hydrocarbon products. The aim is to future-proof their oil and gas companies in the face of intensifying international climate action. Plans include the introduction of low-carbon technologies such as CCUS in enhanced oil recovery (EOR), commercial restructuring, electrification of operations and internationalisation of business opportunities. The region's sovereign wealth funds (SWFs) and other investment funds have likewise moved towards greater divestments of hydrocarbon assets and more active investment in clean energy technologies both domestically and abroad.

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BAPCO, and to an extent QatarEnergy and Aramco, pursues strategies that limit gas flaring at oilfields (methane capture). The practice boosts power generation and efficiency – although not always for natural gas over crude/diesel, as occurs in Saudi Arabia – and augments renewables capacity. QatarEnergy recently committed to a mid-term target of generating 5 GW of solar power by 2035, a goal that will help secure its sustainability strategy with the acquisition of a 49% interest in Siraj Energy, which owns and operates the 800 megawatts (MW) Al-Kharsaa Solar PV, Qatar's first independent power producer. Aramco, meanwhile, is planning to invest in 12 GW of solar PV and wind projects to reduce its upstream carbon intensity by 15% by 2035. A notable trend is evident, as well, of integrating renewable energy generation with EOR practices, for example, with PDO's Miraah Solar Project, which utilises steam produced from solar power for injection into oilfields. Direct air capture and bioenergy with carbon capture and storage[16] are also growing in tandem with more traditional low-carbon energy forms but are currently limited to an R&D phase, mainly in the UAE and Saudi Arabia.

Aramco (as well as PDO and ADNOC) has also embarked on a dual strategy of decarbonising traditional operations while securing a dominant position in emerging energy sources. This is evident in the strategies it has developed for hydrogen and for expanding carbon capture. The UAE's ADNOC in 2021 launched a USD 3.6 billion electrification project linked to the country's 2050 net-zero target (Evans, 2021), expanding its own decarbonisation efforts along its value-chain. Its stake in Masdar's green hydrogen business, together with Mubadala and Taqa, marks a shift towards greater involvement in low-carbon energy development (Gnana, 2022a).

ADNOC, Aramco, and to a certain extent, Kuwait Oil (via the upstream subsidiary and some downstream ventures) have all three entered high-profile joint ventures and partnerships with refineries and petrochemical firms in Asia to expand their international footprint and secure future markets for their hydrocarbon businesses. Domestic refining and petrochemicals are also a keen focus for these companies. ADNOC is exploring future synthetic crude and e-fuels production from its existing refining base to leverage strong hydrogen production capabilities with anticipated high future demand of low-carbon fuels to meet aviation and road transport demand. QatarEnergy has several upstream foreign interests, but its strategic international investments focus on supporting its LNG business (such as stakes in LNG-receiving terminals).

Investment through SWFs is more prominently illustrated by the UAE, which has initiated new low-carbon projects (CCUS, nuclear, renewable desalination and hydrogen) through investment arms like Mubadala and its subsidiary Masdar, and ADQ. The country has also made major progress in low-cost solar power batteries (through Masdar) and established a regional Electrical Energy Storage Solution Hub. International investment arms of these SWFs have restructured the national energy and utility companies, such as EWEC and TAQA, to be more climate action–oriented. Saudi Arabia's PIF and Qatar's Investment Authority also followed suit, but so far to a lesser degree. PIF does own a 50% stake in leading regional utility developer ACWA Power. SWFs from the region have also been engaging in international initiatives; four out of the six founding members of the *One Planet Sovereign Wealth Funds* are from the GCC: ADIA, Kuwait Investment Authority, PIF and Qatar Investment Authority (One Planet Sovereign Wealth Funds, 2023).

[16] *Based on CCUS on waste-to-energy plants, therefore a mix of carbon of fossil and biological origin.*

4.3 ADAPTATION

Adaptation will play an increasingly critical role in the GCC. Rising temperatures and sea levels, along with more sustained drought in an already highly arid region, are bound to impose growing challenges over the coming decades. GCC countries have voiced their alarm over the issue and adopted adaptation strategies (Table 4.4), many of which are reflected in their national development goals. Development goals are usually referred to as the sustainable development goals of each country and are now used interchangeably with the 2030 UN Sustainability Agenda's official 17 SDGs. Among the 17 SDGs, SDG7 (access to affordable, reliable, sustainable and modern energy for all) and SDG13 (climate action) are the most proactively pursued for climate action due to interlinkages with the Paris Agreement, followed by SGDs 11 (sustainable cities and communities), 14 (life below water) and 15 (life on land). While not originally framed as climate change adaptations, the strategies in the region come in many forms, among them policies and projects that centre on the region's historical challenge of adapting to a rough climate and measures that boost the GCC states' capacity for climate change adaptation.

Urban planning and design

Across the GCC region extreme heat is already a massive challenge, and the future holds yet higher, longer-duration and more extreme temperatures for the region, making adaptation essential (Motamedi, 2023). In the UAE, the cooling of buildings accounts for most of the country's electricity consumption (ADNOC, 2023), a trend that also applies in other parts of the GCC. Efficient space cooling is hence a major priority for the region. **District cooling** is a critical technology that reduces the energy, carbon and water footprints of space cooling in the GCC, and there are a number of examples that already demonstrate how the technology works and of policies to support its greater adoption (Strategy&, 2019).

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Table 4.4 Summary of GCC countries' voluntary national reviews for tracking progress on the SDGs

Parameter	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
Signatory to the UN 2030 Agenda for Sustainable Development	✔	✔	✔	✔	✔	✔
Signatory to the 2015 UNFCCC Paris Agreement	✔	✔	✔	✔	✔	✔
Latest VNR submitted	July 2023	June 2023	Jan 2019	2021	July 2023	July 2022
VNR report	Second	Second	First	Third	Second	Second
Key concepts presented in VNRs	Economic Recovery Plan	Kuwait Vision 2035; 7 Pillars of New Kuwait	Oman Vision 2040	Qatar National Vision 2030	Saudi Green Initiative; Circular Carbon Economy	Principles of the 50; Centennial 2071 Plan; SDG ADAA System
Linked to quantified target	-	●	●	●●	●	●●
Linked to PA 1.5°C limit	-	-	●	●	●	●

Note: KSA = Kingdom of Saudi Arabia; PA = Paris Agreement; SDG = Sustainable Development Goal; UAE = United Arab Emirates; UN = United Nations; VNR = voluntary national review; SDG ADAA = An electronic performance management system, known as "ADAA", is used to manage the strategic plans of federal government agencies.

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GCC countries have already been deploying district cooling and standalone air or water chillers (the base technology in district cooling), representing 15% to 25% of the total installed cooling capacity, compared with only 2% globally (Strategy&, 2019). This high adoption rate stems from two factors: recent real estate development, and the need to minimise the cooling load on hot summer days, when that load could represent up to 70 percent of peak electricity demand in some countries (Strategy&, 2019). Abu Dhabi was the first in the Middle East and North Africa to establish a comprehensive regulatory framework for district cooling (Department of Energy, 2021). In Qatar, district cooling services consume up to 40% less energy than conventional cooling systems, resulting in estimated emissions savings of 927 875 metric tonnes of GHGs in 2022 (The Peninsula, 2022).

The UAE in 2023 announced a new landmark project that will use geothermal energy to decarbonise the cooling of buildings. Under the project, hot water produced from local wells would use an absorption process to produce chilled water. Tabreed's district cooling network at Masdar City would use the chilled water for 10% of its cooling needs (ADNOC, 2023). The project is driven by ADNOC, which uses its knowledge of the oil and gas sector to develop the country's geothermal (ADNOC, 2023). The emirate of Dubai in mid-2023 signed an agreement to increase its solar PV capacity within one of its district cooling plants, highlighting the feasibility of a combined system for renewable energy and district cooling (International District Energy Association, 2023).

Part and parcel of adapting cities to extreme summer heat in the GCC has also been to render cities more heat resilient with **urban design**. For instance, the Louvre Abu Dhabi features a dome that shades outdoor and indoor areas, while a patterned roof allows sunlight into interior spaces while blocking heat; surrounding water features add cooling elements. The King Abdullah Petroleum Studies and Research Centre in Riyadh employs a honeycomb structure that minimises energy use. It features modular, expandable design, roof cut-outs for ventilation, and entrances to encourage cooling breezes. Wind catchers circulate air. The building realized a 45% reduction in energy use and utilised construction materials sourced from within 800 kilometres, including recycled content (Clarke, 2021; Peters, 2021).

The GCC also already boasts several sustainable urban pilot projects that put such design options at scale. **Masdar City** in Abu Dhabi was the region's first flagship project of this kind, announced in 2006 at the cost of USD 22 billion to become the world's first carbon-neutral, zero-waste city, aimed to demonstrate state-of-the-art sustainable city design (Griffiths and Sovacool, 2020). While the scale of the ambition behind Masdar City has since been curtailed, the project demonstrates that the region's zero-carbon ambitions predate current global net-zero target trends.

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The design of the area hosting the World Expo in 2020/21 in Dubai, UAE, now called **Expo City** and the location of COP28, designed and built deliberately to deliver one of the most sustainable World Expos to date, with a focus on recycling and natural materials. A total of 5.5 MW of solar PV rooftop panels are distributed across the site's permanent buildings, and more than 120 buildings received Leadership in Energy and Environmental Design (LEED) certifications. Terra, the Sustainability Pavilion, alone has 12 000 square metres of PV panels. Fifty percent of the landscape plants used during Expo 2020, and 95% after the event, were native and adaptive species. Expo City's sustainability target is to ensure that 95% of the landscaped area is free of chemical pesticides, herbicides or fertilisers (Expo 2020 Dubai, 2020, 2022).

More recently, Saudi Arabia announced its own sustainable megaproject **NEOM**, in a region in the country's more temperate northwest. It aims to become a hub for sustainable industries, work and living, eventually powered by 100% clean energy (Chetwynd, 2023; NEOM, 2023). It is also clear that the development of land and coastal areas can be detrimental to natural ecosystems and habitats. Balancing the GCC countries' ambitions for large-scale projects will necessarily involve trade-offs between development, even if it tries to be sustainable, and impacts on a regional ecosystems and landscapes that were once pristine.

Water desalination

The GCC is one of the most arid, and water-stressed, regions in the world (FAO, 2021; Reig, Maddocks and Gassert, 2013) – and as it happens one of the world's biggest consumers of water; Saudi Arabia is now the world's third-largest water consumer on a per capita basis, requiring sustainable solutions to supply water to its domestic market sufficiently and cost-effectively (Chibani, 2023). With demand for water far exceeding its freshwater resources, the GCC now produces about 40% of the world's desalinated water, and Saudi Arabia alone is responsible for around a fifth of the world's production of desalinated water (Webster, 2020). Conventional technologies for desalination are not only energy intensive: they take a sizable share of the total fuel consumed in the power and water sector. Renewable energy has vast potential as a reliable, cost-effective and environmentally sustainable energy source to power desalination in the long term.

Abundant renewable energy resources can provide for the energy needs of the region's desalination infrastructure in the long term and decouple water production and supply from fossil fuel availability and price volatility. This includes the use of CSP technology for thermal desalination, and PV and wind technology for membrane desalination (IRENA, 2016a). Another option is for renewables to use electrolysis to produce hydrogen during the day and use the hydrogen to power desalination plants by night. Hydrogen could help resolve the high cost of storage technology for intermittent renewables-based electricity production, giving desalination plants 24/7 clean electricity supply (Bardsley, 2022).

Saudi Arabia already has a pilot 45 MW solar-assisted desalination plant in Jubail and is planning another 110 MW solar plant at the same location (NS Energy, 2023; PV magazine International, 2022). Oman and the UAE, too, have plans for solar-powered desalination (TotalEnergies, 2023; Prabhu, 2023; Hilotin, 2023).

Groundwater and coastal management

Among the GCC countries, Bahrain is among the most vulnerable to rising sea levels and coastal loss, with an annual sea-level rise of 1.6–3.4 millimetres since 1976 (Arab News, 2023). Rising sea levels are already causing flooding, coastal threats and the infiltration of Bahrain's limited groundwater with saltwater. By 2050, sea levels could increase by at least 0.5 metres, as per the United Nations' Intergovernmental Panel on Climate Change, though some experts consider this estimate conservative. Bahrain has invested in expanding beaches, constructing rock walls in certain areas and reclaiming land along the shore, with plans to fund such projects well into the 2030s (Arab News, 2023).

The UAE has also begun to consider a series of dam and water canal projects as part of policies to develop the country's infrastructure and strategic facilities. Projects include the construction of a dam in Wadi Naqab, Ras Al Khaimah, to control the flow of water to residential neighbourhoods and improve groundwater storage in agricultural areas; also in the works are the construction of water channels as well as lakes and protection works in areas off the eastern coast (Middle East Construction News, 2020).

Reforestation, blue carbon and natural solutions

While climate policy seeks to mitigate emissions, a host of instruments to incentivise and commercialise solutions are under active consideration and development in the region. Still, environmental policy continues to focus largely on conservation. The protection and restoration of the region's valuable mangrove forests received recent, lavish policy attention after mangrove forests were devastated by land and coastal developments. The UAE and Oman are taking on a particularly proactive role (Ahmed, 2023; Al Daheri, 2023; Times of Oman, 2021). The concept of "blue carbon" has also begun attracting attention in parts of the GCC, being still relatively nascent in the region, with interest in mangrove forests and other coastal ecosystems as natural carbon sinks increasing.

In the future, incorporating coastal wetlands and mangroves into the national mitigation strategies (and into carbon markets) could help create stronger incentives for restoration and conservation projects, which would entail important and positive second-order effects for corals, algae and marine biodiversity which were so adversely impacted in the GCC from land reclamation. Other benefits include the buffering ability of coastal ecosystems and mangrove forests in the face of pollution, coastal storms and extreme events, and how they support adaptation overall (Song *et al.*, 2023; UNEP, 2023).

The Government of Dubai in 2022 launched a new entity called *Blue Carbon* to advance investments in coastal ecosystems and mangroves in the UAE and overseas – ecosystems able to store 3 to 5 times more carbon than terrestrial forests. (Blue Carbon, 2022). Bahrain, too, has recognised the role of its mangrove forests in climate change mitigation, and now has a National Plan for Afforestation (2022-2035) that aims to raise the tree count from 1.8 million to 3.6 million by 2035, by planting 270 000 trees yearly (United Nations, 2023).

Ras Sanad Mangrove Forest-Bahrain
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GREEN HYDROGEN IN THE GCC

Muscat, Oman

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Green hydrogen is hydrogen produced from renewable electricity via electrolysers (see Box 5.1 below) has in recent years received increased, global attention, being a crucial and in some cases primary solution to help drive the decarbonization in hard-to-abate industries such as chemical and steel manufacturing, long-haul aviation and shipping (IRENA, 2022e). The Gulf Cooperation Council (GCC holds particular potential to produce green hydrogen, given record-low prices for solar photovoltaic (PV) in the region, and plans to expand renewable energy deployment over the coming years as well as domestic industries that would benefit from clean hydrogen inputs for their exports, including green products.

The region already produces hydrogen from natural gas, with no carbon capture ("grey" hydrogen, see Box 5.1) thus contributing to the region's greenhouse gas (GHG) emissions profile. The potential low cost of green hydrogen production in the region holds the potential to expand greenfield investments in the industrial sector to achieve economic diversification as well as to diversify its traditional energy exports. The governments of Oman, Saudi Arabia and the United Arab Emirates (UAE) have all announced plans for hydrogen exports, and all three have prospects to become producers of green hydrogen. This chapter explores the potential, role, barriers to and policies for green hydrogen in the GCC region.

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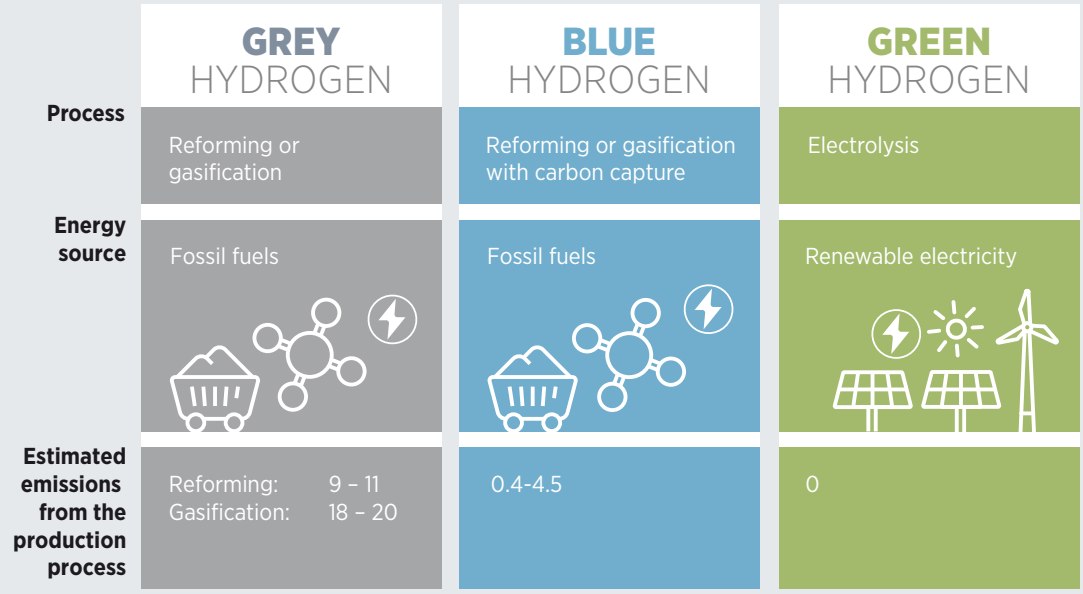
Box 5.1 A brief background to hydrogen

Hydrogen is an energy carrier that can be produced with multiple processes and energy sources; a colour-code nomenclature facilitating discussion is used in this report.[17] The most relevant types of hydrogen are outlined below in Figure 5.1, though they are not exhaustive.

In 2022, global hydrogen production stood at around 95 million tonnes (Mt), primarily derived from fossil gas and coal ("grey" hydrogen). Notably, hydrogen usage for activities like crude oil refining, ammonia and methanol synthesis accounts for nearly 93% of total hydrogen consumption (IEA, 2023c).

IRENA's *World Energy Transitions Outlook* outlines a major role for green hydrogen in driving greenhouse gas emission reduction and facilitating the energy transition. As per the roadmap, green hydrogen will play an expanded role by 2050, with its global production scaling up to approximately 492 million tonnes. Concurrently, a remaining quantity of blue hydrogen (31.5 million tonnes) would continue to be utilised (IRENA, 2023d).

Figure 5.1 Scheme of selected shades of hydrogen technologies



[17] *However, policy makers tend prefer the use of objective measures of impact based on greenhouse gas emissions and technology. This is some cases do not fall under just one "colour" (e.g. mixed hydrogen sources, such as electrolysis with grid electricity).*

5.1 HYDROGEN IN THE GCC: USE, POTENTIAL AND PRODUCTION

In GCC countries, as in many parts of the world, grey hydrogen is both produced and consumed: in 2022, the GCC is estimated to have produced around 7.8 Mt of grey hydrogen for use in refineries, chemical centers to produce ammonia and methanol and in the metallurgical sector to produce steel. Production of grey hydrogen in the GCC causes around 80 Mt of GHG emissions, assuming an average of 10 kilogrammes of carbon dioxide per kilogramme of hydrogen (kg CO_2/kg hydrogen). The only direct production pathway in the GCC is steam methane reforming, producing grey hydrogen, and the main demand for hydrogen centres on four sectors (see also Figure 5.2), listed below:

- **Oil refining,** which relies on hydrogen for hydrocracking and hydrotreating processes. Oil companies extract hydrogen as a by-product. With around 3.6 Mt of grey hydrogen produced by this activity, refining is main consumer of hydrogen in the GCC today. The largest producers of hydrogen for refining are Saudi Arabia and the UAE, with refineries controlled almost exclusively by the large national oil companies (Saudi Aramco and Abu Dhabi National Oil Company [ADNOC], respectively).
- **Ammonia** production, which is based on hydrogen and nitrogen synthesis. Eighty-five percent of the ammonia produced in the world is used to make fertiliser. The GCC manufactures 2.6 Mt of grey hydrogen for ammonia production. The agricultural sector benefits most from it, and a decarbonisation of this sector would have long-standing benefits. The production of ammonia is concentrated in Qatar, Saudi Arabia and the UAE.
- **Methanol** production, with methanol being used to synthesise heavier alcohols, gasoline and many other complex chemicals. In the GCC, 1.1 Mt of hydrogen is produced for this purpose. The production is mostly for local end use; Chemanol, in Saudi Arabia, is its biggest single producer.
- Finally, hydrogen can be used for **steel production,** acting as a reducing agent in direct reduction of iron (DRI). 0.5 Mt of hydrogen is used in the DRI-electric arc furnace plants, mostly in the UAE and Saudi Arabia.

The GCC region has significant potential of becoming a production hotspot for green hydrogen, mainly in larger countries that allows the deployment of renewable energy. Swathes of low-cost land (already a great advantage in renewable energy deployment in the region), existing industrial clusters (which could use green hydrogen directly to serve export markets with green products),[18] excellent solar resources, financial resources and proximity to growth markets all contribute to the region's potential.

Oman, Saudi Arabia and the UAE have the greatest potential and have all announced, or kick-started, large-scale projects to produce green hydrogen. As of end-2023, these three countries have among the world's lowest potential levelised cost of hydrogen (LCOH) figures (Figure 5.3), giving them a tremendous competitive advantage over green steel and chemicals producers worldwide.

[18] *Across this report, "green materials" refers to steel, ammonia and methanol produced using green hydrogen. "Green goods" refers to goods (cars, fertilisers, etc.) produced using green materials. "Green products" refers to both when appropriate.*

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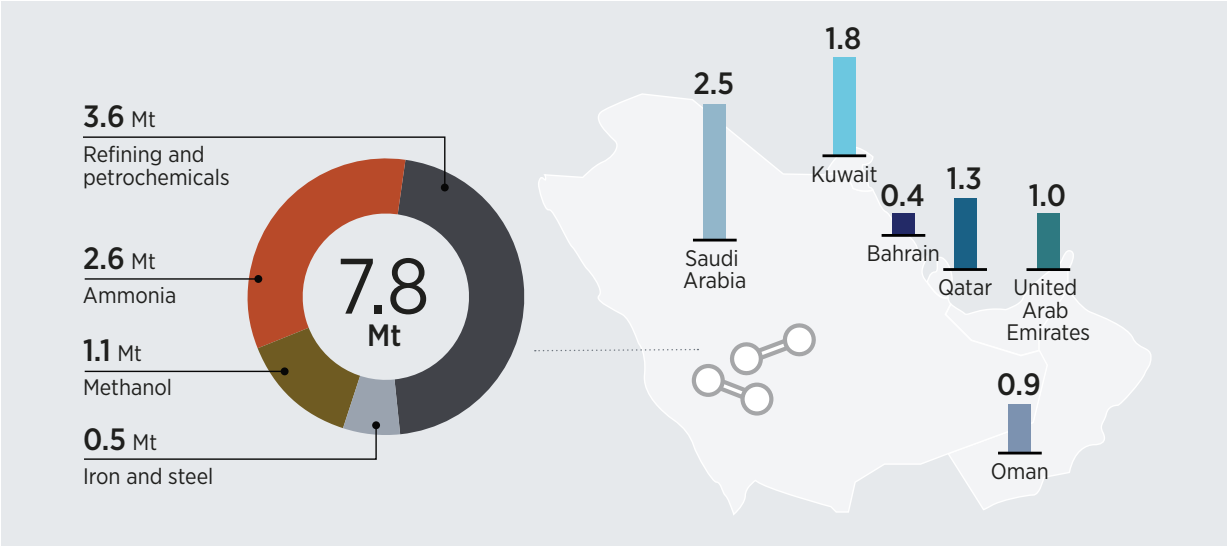
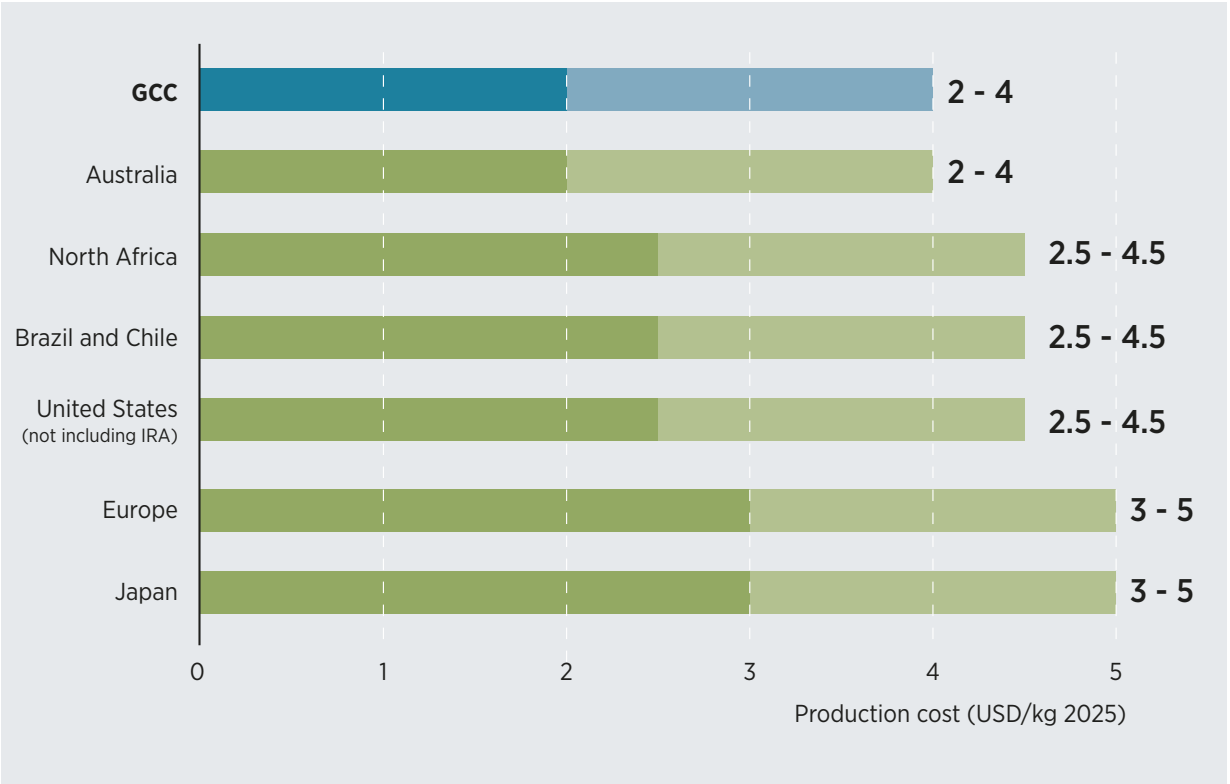
Figure 5.2 Hydrogen market by application (left) and by country (right)



Source: Authors' analysis.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Figure 5.3 Levelised cost of hydrogen production in selected markets, 2025 forecast



5.2 ENABLERS AND CONSTRAINTS FOR GREEN HYDROGEN IN THE GCC

While green hydrogen has become an appealing future technology solution to many industrial decarbonisation challenges, the degree to which the GCC region will be able to produce green hydrogen at industrial scale depends on a few country- and market-specific factors: land and renewable energy availability, water requirements, low-cost finance, domestic industry demand along with international demand for green hydrogen.

Land and renewable energy availability and policy priorities

Green hydrogen projects are land- and electricity-intensive. Assuming a plant efficiency of 70%, around 47 kilowatt hours of renewable electricity are needed to produce 1 kilogramme of hydrogen. In other terms, to fully replace the 7.8 Mt of hydrogen production in the GCC (equivalent to around 260 terawatt hours), it would require around 232 500 megawatts (MW) of dedicated capacity of solar PV (considering an average capacity factor of 18%, in line with the region) (IRENA, 2021b). Considering 75 MW per square kilometre (km^2), this 232 500 MW solar PV system would occupy around 3 100 km^2 of desertic areas (or around 0.1% of the entire Arabian Peninsula). The land occupation factor, meaning the space required for the installation a power plant, is likely to improve as solar PV panels are becoming more efficient. In addition, more efficient electrolysers would require less input capacity.

Saudi Arabia, Oman and the UAE, by order of land size, have the largest potential land areas for new projects and possess the greatest interest in producing green hydrogen in the region. Land available for such large-scale renewable energy plants, and the subsequently generated electricity, would then need to be allocated for the rival demands of the green hydrogen sector and domestic utility supply. Given the dependence of GCC electricity systems on fossil fuels, a relevant policy trade-off would be how much renewable energy production should be allocated to green hydrogen and industries – as well as, potentially, exports – over and above decarbonising domestic electricity supply first.

For this reason, investments in green hydrogen should be considered additional to the targets for the decarbonisation of the energy sector, to avoid diverting investments from sectors that can be more easily decarbonised with renewable electricity (power, light duty transport, cooling, *etc.*) (IRENA, 2022e).

Water requirements

Water is used both as an input for electrolysis and for cooling. Water for electrolysis is consumed and transformed into hydrogen and oxygen and needs to be purified before the process. Cooling water is withdrawn, and, depending on the cooling technology, a portion of it is returned to the source water body.[19] Desalinated and purified seawater is needed for the electrolysis, and normal seawater for cooling. Given the aridity of the region and the lack of availability of other sources of groundwater, seawater is the only option for hydrogen production.

It should be noted that seawater is already used to produce grey hydrogen. Seawater withdrawals for cooling needed for current hydrogen production in GCC countries is about 6 billion cubic metres (m3) each year. The annual desalinated water demand for hydrogen-producing processes is 136 million m3, accounting for about 1.1% of the total desalination demand in GCC countries (IRENA and Bluerisk, 2023).

Electrolysis can be more water efficient in both hydrogen production and cooling compared to the production of blue hydrogen, thus reducing the proportional amount of water needs for clean hydrogen production (see Table 5.1).

[19] *Air cooling is also an option for electrolysis but as a technology is still unexplored.*

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Table 5.1 Water withdrawal and consumption intensities by hydrogen production technology[20]

Type		Water withdrawal intensity (L/kg)			Water consumption intensity (L/kg)		
		Average	Maximum	Minimum	Average	Maximum	Minimum
Grey	Natural gas-SMR	20.01	25.16	16.40	17.54	19.80	15.80
Blue	Natural gas-SMR-CCUS	36.69	47.79	29.81	32.18	38.96	24.15
Green	Electrolysis-Alkaline	32.24	34.61	29.88	22.28	23.59	20.96
	Electrolysis-PEM	25.70	26.46	24.94	17.52	18.04	17.00

Grey Hydrogen *Green Hydrogen* *Blue Hydrogen*

Source: (IRENA and Bluerisk 2023).

Note: These numbers do not account for the water needed for solar PV energy production or gas extractions. However, in this case also, water requirements for renewable energy production are limited compared to the fossil fuel options (IRENA, 2015). CCUS = carbon capture, utilisation and storage; L/kg = litre per kilogramme; PEM = proton exchange membrane; SMR = steam methane reforming.

Low-cost finance

Green hydrogen has specific financing needs, requiring, like all transition technologies, access to dedicated financing. Hydrogen production entails several processes requiring local supplies of both water and renewable energy and potentially transport/distribution infrastructure. Existing hydrogen transportation infrastructure in the GCC is limited, particularly in the context of potential export of green hydrogen; shipping hydrogen involves constructing plants for conversion and subsequent re-conversion at the destination, with the notable exception of ammonia shipping (see dedicated section). All the other options, such as liquefied hydrogen, liquid organic hydrogen carriers (LOHC) and clean methanol, have low Technology Readiness Levels (TRL) and will take years to be commercially feasible and bankable (IRENA, 2022d). Finally, there is no financial market for trading hydrogen or hydrogen derivatives, so producers cannot take out futures contracts to guarantee a price for their hydrogen.

All this means developers have difficulties offering banks any confidence about the size of future revenue, even once hydrogen generation does begin, unless the buyer agrees to a price in advance (offtake agreement). Countries with access to low-cost financing through government initiatives and national funds are inherently better able to tackle the intricate challenges of green hydrogen projects. This type of financial support goes beyond mere funding; it serves as a powerful catalyst that addresses the uncertainties inherent in pioneering technologies.

[20] *"Water withdrawal" is the quantity of water withdrawn from a source (e.g. river, lake, groundwater) for use. Water consumption is the quantity of withdrawn water that is not returned to the source.*

The GCC countries are in this context well placed, although the development of successful financial markets for green hydrogen industries will likely take both time and policy commitments. By offering financial incentives, grants, concessional loans or direct investments, governments create an environment of reduced risk and enhanced predictability for both investors and developers (see next sections). GCC countries have a robust financial capability, with considerable sovereign wealth funds and resources to direct towards green initiatives. Sovereign wealth funds can play a pivotal role. These funds have the potential to act as significant financial backers of green technology projects, including those related to green hydrogen production, infrastructure development and research.

Green hydrogen for domestic industries

Kick-starting a robust green hydrogen value chain requires the actual presence of stakeholders able to pick up the challenge. These stakeholders, particularly in the early stages, may have experience in the renewable energy or fossil fuel sectors, particularly in the supply side of the value chain; downstream, they are usually the hard-to-abate industries looking to decarbonise their own processes in line with the energy transition. Box 5.2 presents some key potential stakeholders in the GCC.

Box 5.2 Relevant national stakeholders in hydrogen production in the GCC

Upstream stakeholders

The upstream part of the value chain refers to the production and potential conversion of hydrogen. In the UAE the main players currently operating in the upstream hydrogen value chain are Masdar (focusing on green hydrogen) and Abu Dhabi National Oil Company (ADNOC) (producing blue hydrogen). In Oman, hydrogen production is controlled mostly by OQ (Oman Oil Company); various local and international developers signed agreements with HYDROM in June 2023 to produce green hydrogen. In Saudi Arabia, instead, several players are involved – NEOM has set up its own fully owned entity, ENOWA, which will focus on renewable energy production, including green hydrogen, and has entered joint venture agreements with ACWA Power and Air Power. Saudi Aramco is active in the production of blue hydrogen and blue ammonia. In addition, the Public Investment Fund has signed memoranda of understanding with several international players to develop a green hydrogen champion in Saudi Arabia.

Midstream stakeholders

The midstream part of the value chain refers to the transmission and distribution of hydrogen. Currently, this part of the value chain is still evolving from the niche applications worldwide. In the UAE, ADNOC is the main stakeholder present in distribution, while Masdar is also present but with a much smaller footprint. In Oman, Hydrom is leading an initiative to develop a 2 000 km pipeline network, which is aligned with the plans to produce up to 1.25 Mt of green hydrogen by 2030.

Downstream stakeholders

The downstream part of the value chain refers to the consumption of hydrogen. Refineries, and chemical and steel producers, are the main downstream stakeholders. GCC downstream players are mostly the large, established oil and chemical companies in these markets. ADNOC in the UAE, OQ in Oman, and Saudi Aramco and Sabic in Saudi Arabia. However, as the market applications of green hydrogen develop, more stakeholders may join, most notably from the hard-to-abate heavy industries.

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Ammonia export infrastructure

Ammonia can be used as a hydrogen carrier, and its current industry already produces, stores and trades millions of tonnes of ammonia every year, which means the infrastructure already exists in certain countries to kick-start a local green hydrogen economy. For those countries already exporting ammonia, a trading infrastructure would not need to be created from scratch, lowering the initial cost of the green hydrogen transition of a country. In addition, the existence of an ammonia trade relationship may make it easier to find international off-takers. In the GCC, Saudi Arabia (USD 1.26 billion of trade in 2021), Qatar (USD 235 million), Bahrain (USD 188 million) and the UAE (USD 27.3 million) are already ammonia exporters, for a 16% market share in the international ammonia trade (Growth Lab, 2023).

International demand

With growing global interest, there is much potential for a worldwide market for green hydrogen. Climate policies and new international climate agreements will likely influence demand for clean hydrogen – both green and blue. Demand will, in turn, affect prices, and thus the attractiveness for producers of green hydrogen to increase production and to export. It should also be noted that, according to IRENA's modelling, three-quarters of the green hydrogen will be produced within the same region of consumption, and intercontinental trading will prioritise trading through pipelines when physically possible (IRENA, 2022c).

There are now two potential demand centres for clean hydrogen: Europe and East Asia and GCC countries would be uniquely positioned, geographically, to serve both markets, much as they export their fossil fuels.

The European Union already established an ambitious hydrogen strategy in 2020, which requires both substantial hydrogen deployment and imports from regional and international markets. The REPowerEU package, published in 2022, sets a target of 10 Mt of clean hydrogen produced within its borders by 2030 and another 10 Mt imported from international producers. For EU policy makers, green hydrogen is considered an essential tool to decarbonise the industry and transport as Europe seeks to achieve a net-zero carbon economy by 2050. A cluster of European governments – including Germany, Italy, France, the Netherlands, Belgium, Spain, Portugal and Austria – published their hydrogen strategies stating that green rather than blue hydrogen should be the predominant part of supply, certainly in the longer term. The definitions of green hydrogen include strict additionality requirements that impose a time and locational overlap between renewable energy generation and hydrogen production, in addition to technological additionality (*i.e.* power plants need to be built for that specific use and must prove it) (EU, 2022).

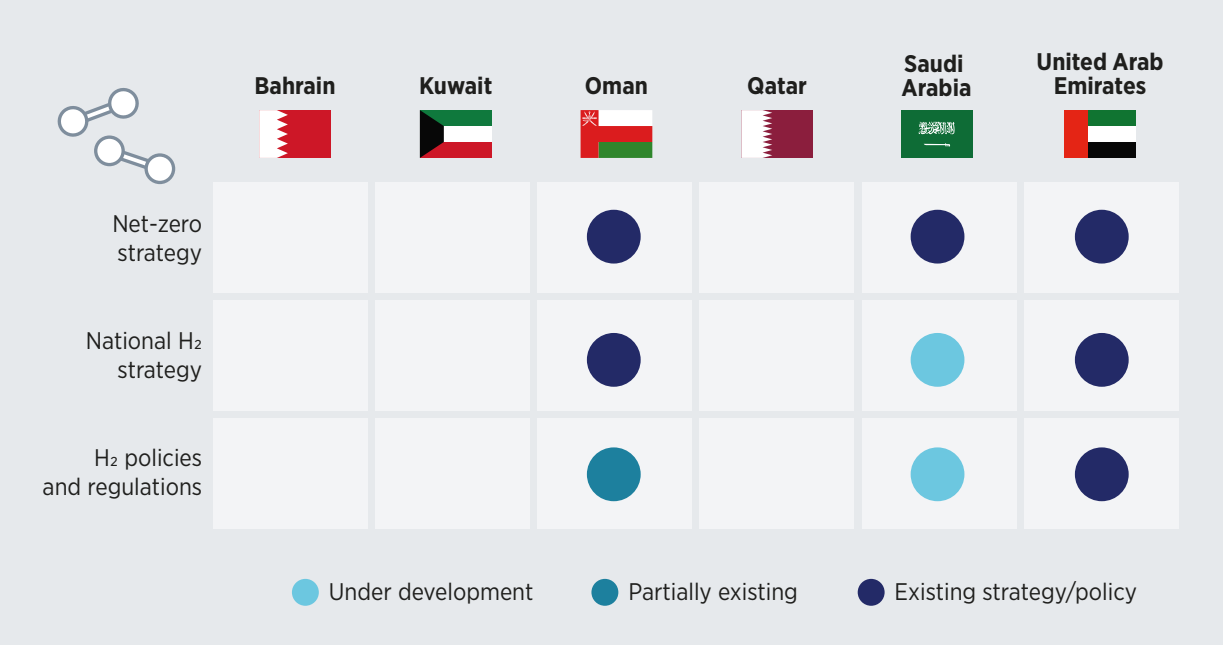
In addition, the European Union is adopting the Carbon Border Adjustment Mechanism (CBAM). It is a tool established to tackle carbon leakage (where carbon-intensive industries shift production to regions with laxer climate regulations). The CBAM enforces a carbon cost on select imported goods entering the EU market, equivalent to the emissions generated during their production. This aims at ensuring equitable pricing between domestic and imported products, curbing leakage and promoting cleaner global industry practices. The CBAM's phased implementation begins with emissions-intensive goods like cement, steel and hydrogen, expanding to cover more than half of emissions within EU-regulated sectors. Importers must report emissions during a transition period, with certificates linked to the EU Emissions Trading System allowances dictating the carbon price (EU, 2023).

East Asia's market for hydrogen notably works differently from Europe. Japan was the first country to develop a nationwide hydrogen strategy in 2017 and Republic of Korea enacted the world's first hydrogen law in 2021. According to its latest plans, Japan aims to secure 3.5 Mt a year of hydrogen by 2030 and 20 Mt by 2050 from import and local production; for the Republic of Korea, the figures are 4 and 28 Mt (Agency for Natural Resources and Energy, 2023; MOTIE, 2019). In lockstep, Japanese and South Korean corporations are touting clean hydrogen plans. What is missing from the discussion is scrutiny of the sustainability of the hydrogen import. Japan and the Republic of Korea, lack established definitions of clean hydrogen. This enables the import of blue hydrogen or of other forms of hydrogen and derivatives with no certainty over their long-term sustainability (Agency for Natural Resources and Energy, 2023).

At the same time, exports are expected to come not only from regions with substantial renewable energy production potential, such as the GCC countries, but also Australia, Chile and North Africa. The vast potential in these regions means that hydrogen trade flows are unlikely to become cartelised and that a competition more intense than the one for fossil fuel export will arise.

The evolution of trade dynamics will greatly depend on the engagement of governments and national decision makers in green hydrogen initiatives. For GCC countries to attain a prominent position in the global hydrogen market, it is important to set out a plan for export that focuses on the best option for the region domestically, and it allows a steady growth over time notwithstanding geopolitical changes.

Figure 5.4 Status of green hydrogen policies in the GCC



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5.3 POLICY FRAMEWORKS FOR GREEN HYDROGEN

Five out of the six GCC countries have net-zero targets, and three – Oman, Saudi Arabia and the UAE – have formulated net-zero strategies, outlining objectives and targets that should guide investment decisions. Two countries – Oman and the UAE – have dedicated hydrogen strategies, and one – the UAE – has hydrogen policies in place (Figure 5.4). With much of the region's hydrogen potential untapped, and strategies in preparation, the region has the potential to move forward in the coming years as more concrete action and policy follow targets.

Oman

Oman is developing its capabilities for hydrogen export. The National Hydrogen Alliance "Hy-Fly", formed in 2021, brings together 15 public and private entities to support renewable hydrogen production, transport and use. In 2022, Oman revealed its green hydrogen strategy, aiming for 1-1.25 Mt by 2030, 3.25-3.75 Mt by 2040 and 7.5-8.5 Mt by 2050, requiring an estimated USD 140 billion investment by 2050 (Ministry of Energy and Minerals, 2022b).

Three coastal regions – Duqm, Dhofar and Al-Jazir – have been chosen for renewable hydrogen production across 50 000 km^2, yielding as much as 25 Mt annually from 500 000 MW of renewable capacity. This hydrogen would fulfill domestic needs and be exported, mainly to Europe and Asia. Hydrogen Oman (Hydrom), an autonomous subsidiary of Energy Development Oman, oversees strategy execution, project structuring, land allocation and infrastructure development, overseeing project execution and fostering connected industries.

Oman's first round of public auction was announced and launched in November 2022. In June 2023, Hydrom announced the awarding of five green hydrogen projects as part of its first auction round. The projects will cover 1600 km^2 of land in Duqm, with 18.5 GW of renewable energy capacity and an expected production of 750 kilotonnes. The agreements span 47 years and allocate 7 years for project development and construction and the following 40 for operations (Ministry of Energy and Minerals, 2022c).

Saudi Arabia

Saudi Arabia is the largest of the GCC countries in land size and is strategically positioning itself in the hydrogen sector to leverage its resources, technology and global partnerships for a prominent role in hydrogen production and supply. In 2021, Saudi Arabia announced aims to reach a production of 4 Mt by 2030, based on both green and blue hydrogen (SGI Initiatives, 2023). Its first green hydrogen project, at Neom in the country's northwest, is targeted produce 240 kt of hydrogen and 1.2 Mt of ammonia by 2026 with Neom also functioning as a regional centre for green hydrogen development (Acwa Power, 2023c) (see Box 5.3). The country also has an interest in blue ammonia. Production of blue ammonia is centred in the east of the country, utilising existing CCUS assets and natural gas resources.

UAE

The UAE is one of two GCC countries with a national Hydrogen Strategy (Government of the United Arab Emirates, 2023d). The objectives of the strategy include establishing a robust hydrogen economy able to support national decarbonisation and to foster foreign direct investment alongside job creation and workforce upskilling. The target is to position the UAE as a leading global producer and exporter of clean hydrogen, and developing a resilient hydrogen supply chain for domestic industry growth. The UAE plans to produce 1.4 Mt of hydrogen by 2031 (1 Mt green and 0.4 Mt blue hydrogen), 7.5 Mt by 2040 and 15 Mt by 2050. The strategy gives equal footing to green and blue hydrogen, recognising there may be roles for other hydrogen pathways (electrolysis from nuclear energy or "pink hydrogen", pyrolysis of natural gas, or "turquoise hydrogen", and hydrogen from the gasification of waste or "dark-green hydrogen").

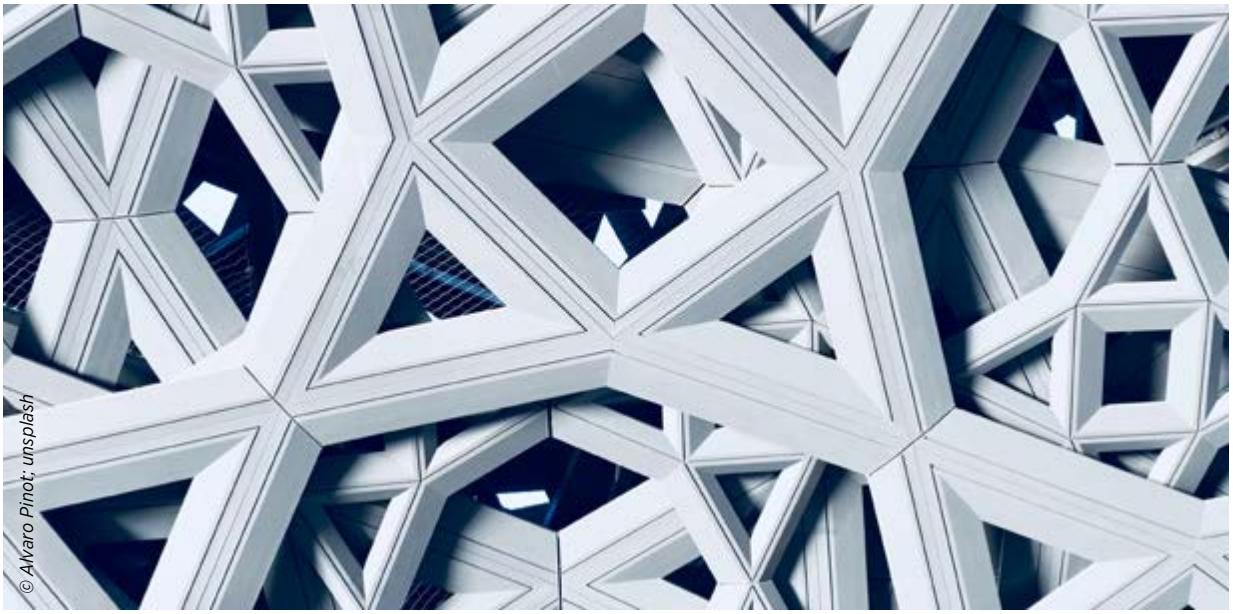
To achieve these objectives, the UAE recognizes that establishing policies, regulations and standards that foster investor confidence and activate the UAE's hydrogen market is a priority. The UAE also recognises the importance of a clear regulatory framework for all supply chain components, from production to end uses. The UAE considers as a positional advantage the concurrent presence of large natural resources, including solar radiance and gas reserves, existing industry expertise and established trade connections.

The UAE aims to address sectoral demand in industries like aluminium, steel, aviation and shipping. These factors uniquely position the UAE to capitalise on the emerging hydrogen market and to contribute to global decarbonisation. The UAE anticipates demand growth in sectors like aluminium, steel and aviation, which present ample opportunities for the UAE to scale up its hydrogen production. The local demand would work as anchor demand for more than 10 Mt by 2050, while export opportunities vary between 4.8 and 9.6 Mt by 2050, according to the strategy. However, it is noted that the export market will primarily involve chemicals and industrial products like ammonia, synthetic fuels and green steel. The country also has several memoranda of understanding (MoUs) for future hydrogen exports.

5.4 CURRENT PROJECTS

Most green and blue hydrogen projects worldwide are small-capacity plants, for example, with an electrolysis capacity below 10 MW. This is not surprising, given the early stage of knowledge on these technologies and the need to test them. Most of the projects are pilots in Europe, East Asia and Australia; as much as 50% of 1600 MW of planned or installed capacity of electrolysers of pilot-project size occurs in just four countries: China Germany, Spain and Australia (in order of capacity planned) (IEA, IRENA and UN-CCHLC, 2023).

In the GCC the largest low-carbon hydrogen projects are in Oman, Saudi Arabia, the UAE and Qatar (Table 5.2). The UAE's 1.25 MW green hydrogen plant of the Mohammed Bin Rashid Al Maktoum Solar Park in Dubai is the only green hydrogen project already operational as of 2023, but many of the next projects in the pipeline near the gigawatt scale.



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The presence of this multitude of projects showcases the keen interest in green hydrogen in GCC markets. Developers see the opportunity to become green hydrogen producers both for local demand and export opportunities. It should be noted, however, that these projects are still in the analysis/announcement phases and are expected to reach the Final Investment Decision (FID) stage. The Helios-NEOM project in Saudi Arabia is a notable case in point, achieving FID (see Box 5.3).

Table 5.2 Overview of selected announced green and blue hydrogen giga projects in the GCC

Project name	Country	Lead developer	Other partners	Capacity (MW)	Product. (Ktpa)	Renew. techno-logy	Conversion	Status
● **Green Energy Oman**	**Oman**	OQ, Inter-continental Energy, Enertech, Shell	n.a.	4 700	809	Solar PV + Wind	Ammonia	Feasibility Study
● **Helios-NEOM Green H_2 Plant**	**Saudi Arabia**	ACWA Power, Neom, Air Products	Thyssen-Krupp, Haldor Topsoe	4 000	650	Solar PV + Wind	Ammonia	Construc-tion
● **TAQA-ADPorts project**	**United Arab Emirates**	TAQA Group, Abu Dhabi Ports	n.a.	2 000	n.a.	Solar PV	Ammonia	Feasibility Study
● **Helios industry project**	**United Arab Emirates**	Helios industry	Abu Dhabi Ports, Thyssen-Krupp, Petrolyn Chemie, KEPCO, Samsung C&T, KWP[2]	800	40 (phase 2)	Solar PV	Ammonia	Develop-ment
● **Ammonia-7 project**	**Qatar**	QatarEnergy, Industries Qatar QSC, Qatar Fertiliser Co.	Thyssen-Krupp AG, Consolidated Contractors Co.	n.a.	n.a.	n.a.	Ammonia	MoU
● **Sustainable Energy Authority project**	**Bahrain**	Sustainable Energy Authority (SEA)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

● *Green Hydrogen* ● *Blue Hydrogen*

Note: GW = gigawatt; H_2 = hydrogen; ktpa = kilotonnes per annum; MoU = memorandum of understanding; PV = photovoltaic; UAE = United Arab Emirates; n.a. = not available.

Box 5.3 Green hydrogen production in NEOM, Saudi Arabia

Saudi Arabia has designated NEOM in the northwestern part of the country as a sustainable development hub, including its development as a centre for green hydrogen production. The project is expected to produce up to 600 tonnes per day of green hydrogen by the end of 2026, and this will provide demand for 4 000 megawatts of wind, solar and batteries, using more than 2.2 gigawatts of hydrogen electrolysis (Chetwynd, 2023).

In January 2023, the Saudi Ministry of Industry and Mineral Resources granted the project an industrial operating license, and subsequent investor approval was obtained in March for construction to start. In June, the project reached the Final Investment Decision stage. The partnership, called NEOM Green Hydrogen company, includes Air Products, a US industrial gases firm (which secured the engineering, procurement and construction contract) alongside Saudi entities NEOM and ACWA Power, formalised funding with 23 local, regional and international lenders, amounting to USD 8.4 billion. This, in fact, marks the world's first gigawatt-scale hydrogen project to reach this stage (Polly, 2023).

A key aspect that differentiates this project from others, it that it has an exclusive long term off-take agreement secured with co-developer Air Products. The signed offtake agreement is an important step for hydrogen projects, as they can attract investments and secure debt with a reduced risk profile. The developers plan to distribute the produced ammonia to global demand centres, with a specific emphasis on northern Europe, catering to both mobility and industrial sectors.

MoUs and early shipments

The UAE, Oman and Saudi Arabia already have MoUs and partnerships in place to export blue or green ammonia to partner countries (Figure 5.5). While MoUs typically lack detailed obligations, they establish a framework for future joint action, signal interest to investors, and define interaction formats, co-ordination methods, responsible parties and other essential aspects. Signing an MoU endorses a foundation for future co-operation. Although not strictly necessary for initiating physical hydrogen or technology trading, MoUs facilitate co-operation. Germany and Japan have been the most active foreign partners of (potential) GCC producers, but other countries are also exploring such partnerships.

In addition, both the UAE and Saudi Arabia have made their first ammonia shipments; Saudi Arabia shipped an inaugural 40 tonnes of ammonia as fuel to Japan in 2020. The Saudi-Japan ammonia-supply demonstration spanned the full value chain, up to the usage in power generation in Japan; however, the 50 tonnes of CO_2 captured during the process were used in methanol production and for Enhanced Oil Recovery at Aramco's Uthmaniyah field: it is important to note that no regulation is in place (as in the European Union, United Kingdom and United States) would allow such ammonia to be considered low carbon or blue, since the carbon captured is used again (Aramco, 2020; Brown, 2020; IRENA, 2023a).

In addition, both the UAE and Saudi Arabia have made their first ammonia shipments Saudi Arabia shipped 40 tons of ammonia as a fuel to Japan in 2020, marking the inaugural instance of such a shipment. The Saudi-Japan ammonia-supply demonstration spanned the full value chain, up to the usage in power generation in Japan; however, the 50 tonnes of CO_2 captured during the process were used in methanol production and for Enhanced Oil Recovery at Aramco's Uthmaniyah field. A complexity arises because the CO_2 captured is not truly sequestered. In the case of CCS used for enhanced oil recovery, the CO_2 that is initially captured likely results in similar levels of carbon emissions due to the oil subsequently extracted. Similarly, in the production of methanol, the CO_2 captured is expected to be released back into the atmosphere when the methanol is used as fuel. (Aramco, 2020; Brown, 2020).

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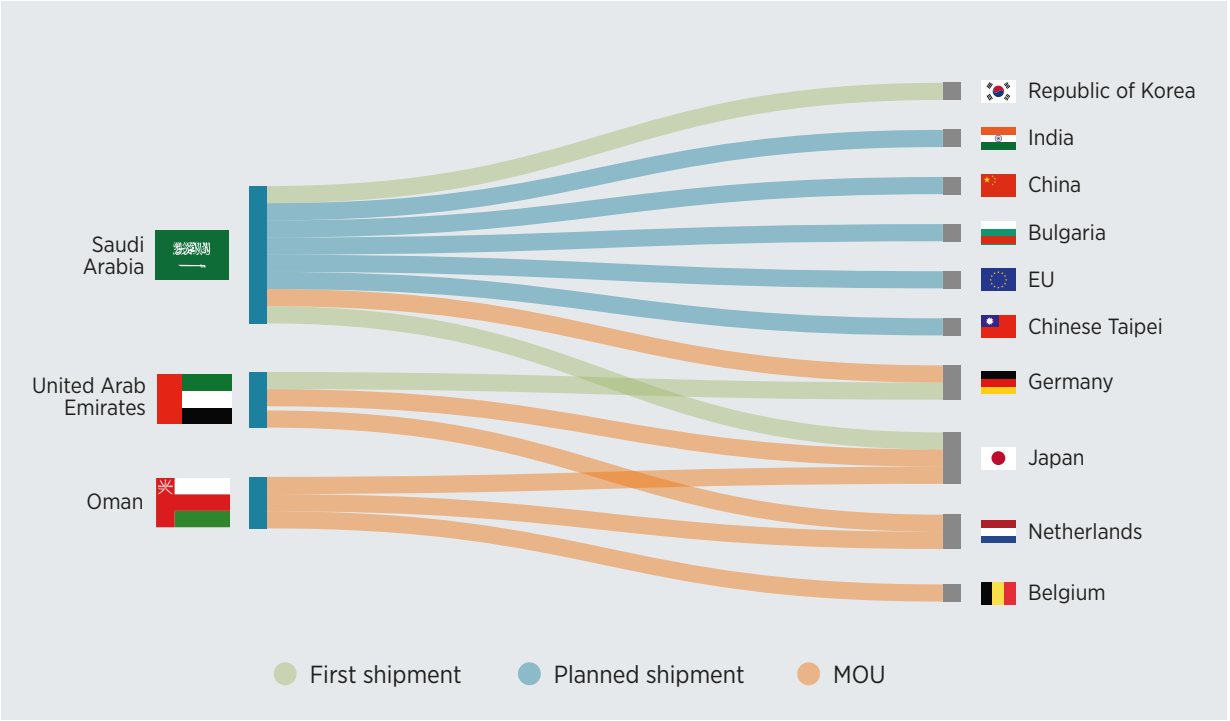
Figure 5.5 Trade MoUs and early shipment of ammonia from GCC countries as of October 2023



Similar shipments from UAE were exported to Germany and from Saudi Arabia to the Republic of Korea. It should be noted, however, that ammonia shipments are not novel. Ammonia is globally shipped, with a total trade of USD 10.4 billion in 2021; Saudi Arabia is the third-leading exporter in the world, with 15% of the total trade (USD 1.47 billion) (OEC, 2023). The breakthrough will occur when large quantities of green ammonia are shipped as grey ammonia is today.

5.5 TOWARDS A GREEN HYDROGEN MARKET IN THE GCC

The market for green hydrogen is in its infancy, in the GCC as well as internationally. GCC countries have vast potential to become a major regional growth sector. Comprehensive assessments of policies that support green hydrogen can be found in IRENA's green hydrogen guide series (2021b, 2022e). The following policies are particularly relevant for the GCC context:

Overcoming the price gap between grey and green hydrogen and products

Despite any cost competitiveness GCC green hydrogen might have relative to the rest of the world, green hydrogen is not yet cost competitive with grey hydrogen. First, the production of green hydrogen and materials demands major investments in new technologies and renovated infrastructures; such investments would incur higher operational and raw material costs than grey hydrogen, in addition to delivery costs (IRENA, 2022b, 2022d). Second, fossil fuels are priced at very low rates to domestic industries across the GCC. Taken together, these realities might curb investor interest, especially regarding capital-intensive and low-margin materials like steel and chemicals, where economies of scale and low resource costs play vital roles.

Accurate analysis therefore becomes a crucial enabler for each project, co-ordinating and centralising fiscal, economic and administrative efforts. Policy will also play a critical role in creating a market for green hydrogen in the GCC, involving mandates for certain industries, and perhaps fiscal incentives. Any reform of domestic energy prices of fossil fuels used in industries, an emissions cap for industries or a carbon price would all be suitable tools to help deploy green hydrogen in the region.

Additionally, large swathes of open land and the unique geography of GCC countries – with their high levels of solar radiation – give them a unique competitive advantage in cost minimisation. Their access to finance can, in addition, be leveraged with public funds available through subsidies and direct investments. Taken together, these advantages lower the cost of capital overall and make the GCC ever more appealing for foreign private investment.

Improving market certainty for producers

In addition to their worries over cost gaps, potential producers of green hydrogen in the GCC face deep uncertainty about future markets for green hydrogen, both domestically and abroad. Lack of clarity on the future of this technology – tied as it is to the region's export orientation to hydrogen, which relies on some narrow markets and industries – only intensifies the region's economic uncertainty. This dependency makes the region vulnerable to global market fluctuations and oligopsony. Surmounting such hurdles will rely on transparent assessments of project costs as well as clear government strategies and targets for the sector along with policies to support deployment. Domestically, for instance, a mandated target for green hydrogen in industries' total hydrogen use – an upper carbon limit and sustainable procurement mechanisms requiring industry investment in clean supply chains – would be clear signals to industries to invest in new technology. These would need to be communicated transparently and well in advance. Similarly, export agreements for green hydrogen are promoters of deployment.

Adopting and implementing increasingly ambitious policy

Ambitious policy is a critical enabler of green hydrogen development. With the region's existing price gaps between fossil fuels and green energy, ambitious policy can help overcome missing market signals to producers. Credible net-zero targets, supported with active dialogue between policy makers and industries, can be key. Dialogue should also be used to assess the potential cost incurred by industries in using green hydrogen, together with the implementation of effective, well-timed policies to support fuel transitioning inside GCC industries. In the GCC context, direct state investment is also an option to support the industry.

Promoting R&D and human capital

The production of green hydrogen and materials requires technological know-how and a qualified workforce with the skills needed to transform industries in the GCC. The GCC already has know-how in the hydrogen sectors. The region could pivot this workforce toward ongoing efforts to diversify their economies, build knowledge economies and offer high-quality jobs in meaningful fields to the young generation of GCC nationals. The green hydrogen sector and its development could become integral to the resolve of GCC countries to support clean energy transition–related education and research in the region and to build new technology centres and offer (re)training opportunities for workers already employed in the energy sector. Pilot projects developed by research institutions, assisted financially by governments and by initiatives such as Clean Hydrogen Mission,[21] could be used to promote the technology in the GCC.

[21] *Mission Innovation is a global initiative of 23 countries and the European Commission, catalysing a decade of action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all. Mission Innovation formed public-private alliances, called Missions, between countries, corporations, investors and research institutes, with specific goals to make sure more innovation happens, more rapidly. The Clean Hydrogen Mission has the goal to increase the cost competitiveness of clean hydrogen by reducing end-to-end costs to a tipping point of USD 2/kg by 2030. The initiative's goal is to facilitate the delivery of 100 large-scale integrated hydrogen valleys worldwide by 2030 (IEA, IRENA and UN-CCHLC, 2023).*

CONCLUSIONS

Doha, Qatar

A half-century after their creation as the states they are known as today, the countries of the Gulf Cooperation Council (GCC) are among the Middle East's fastest growing and wealthiest economies. Energy has been at the heart of their transformation, with the lion's share of the region's modern-day wealth derived from its fossil fuel endowments. Renewable energy is a recent entrant into the region's energy mix, as is the region's proactive engagement in global climate debates and forums.

While the region's past has been shaped by fossil fuels, the GCC countries' future may be similarly shaped by renewables. The enormous resource potential, especially for solar energy, coupled with a conducive climate for renewable energy investment, has already led to record-breaking auction prices for solar photovoltaic (PV) and concentrated solar power, making solar PV cost-competitive with all other energy technologies in the region. The United Arab Emirates, Saudi Arabia and Oman, among others in the region, have demonstrated that political commitment to renewable energy can drive deployment in a region where the energy mix was based 100% on fossil fuels a mere decade ago.

Renewable energy investments in the GCC are poised for significant growth as countries intensify their ambitions to combat climate change. Public sector entities, including sovereign wealth funds and investment authorities, are at the forefront of the movement. By making strategic investments in projects and companies across the renewable energy value chains, they are catalysing the sector's development. Banks and other financial institutions, both within the region and globally, have also shown a willingness to finance renewables, especially large-scale solar PV, with the result that the technology is now cost-competitive for the generation of electricity. Additionally, entities from within the GCC region, both public and private, are investing in renewables beyond regional boundaries, driven by profit motives and the aim to foster development in partner countries. These initiatives include not just project development, but also ventures into manufacturing, research, and development.

CLIMATE POLICY OPPORTUNITIES

GCC countries have also seen an evolution of national climate policy and policy commitments in recent years. As climate issues have become more visible, climate policy has commanded more attention in national energy and environmental policy throughout the region, with increasingly ambitious commitments, both in national development plans and strategies and at the level of the United Nations Framework Convention on

Climate Change. Recent efforts of some of the GCC countries to move towards a more diversified, low-carbon, knowledge-based and resource-efficient model can be chalked up to rising awareness of trends in demand for oil and gas, economic resourcefulness, and ambitious national visions. Initiatives within the region envision win-win outcomes through technology and innovation and recognise the value of forging alliances in new areas, such as hydrogen and carbon trading.

That COP28 is being held in the United Arab Emirates in December 2023 exemplifies the increased interest of some of the region's countries to position themselves not only as conventional fossil fuel producers, but also as hosts for negotiations around emerging international climate action frameworks. What remains to be seen is whether the region will move from targets to implementation, including in core areas such as emissions of greenhouse gases, energy efficiency, and deployment of renewable energy.

Energetic development of holistic and harmonised programmes, policies, initiatives and collaborations with major climate action–oriented countries at COP28 could place the GCC region in a prime position to address climate change. A cohesive "GCC Climate Framework", for example, would not only tackle climate issues at national and regional scale; but it would also support the global energy transition by adding the region's own insights, research, and technologies, thereby keeping the Paris Agreement's 1.5°C temperature limit within reach. As they deal with extreme summer temperatures and arid climates, the GCC countries are vulnerable to climate change, but they also have highly relevant expertise in climate adaptation. Bringing more of that experience into international negotiations could add to the value the region clearly brings to international climate agreements.

THE GREEN HYDROGEN OPPORTUNITY

Green hydrogen is a major opportunity for the GCC region, particularly in Oman, Saudi Arabia and the United Arab Emirates, which have available land and a demonstrated interest in the technology. Their strategic decisions today will profoundly shape the future of their hydrogen sectors for decades to come. Among these choices, the first pertains to the selection of the preferred route: Will it be blue hydrogen or green hydrogen? Blue (or low-carbon) hydrogen is produced from fossil fuels accompanied by carbon capture and storage. Green hydrogen is produced from renewable sources.

Green hydrogen production is aligned with the region's net zero plans. The region has a substantial cost advantage vis-à-vis virtually all other parts of the world for green hydrogen use in domestic industries, giving it the potential to become a first mover for the production of green ammonia, green fertiliser, green steel and derivatives. The opportunity will grow as more markets implement policies similar to the European Union's Carbon Border Adjustment Mechanism, which make the carbon footprint of imported products increasingly important.

In view of some GCC countries' existing agreements for the export of hydrogen, and global discussions of future international trade in clean hydrogen, one central question is whether the GCC states wish to prioritise exports or local consumption of green hydrogen. This question presents a multifaceted dilemma, because green hydrogen production will compete with domestic utilities for renewable energy. With the GCC region as a whole continuing to rely on fossil fuels for 99% of its energy and electricity mix, the initial priority would likely be to increase renewable energy deployment, given the benefits that expanded renewable capacity could bring in decarbonising the region's utilities and economies.

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