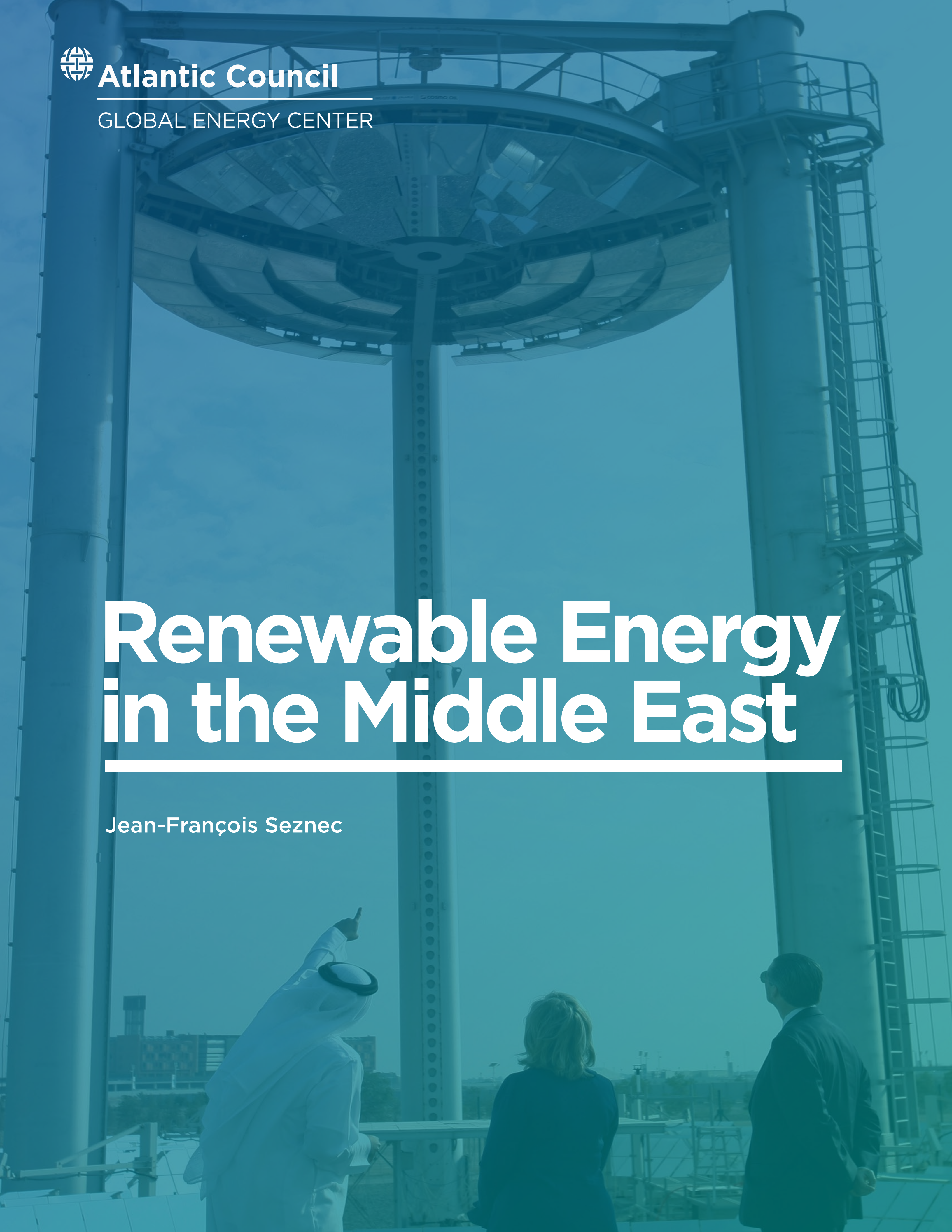

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GLOBAL ENERGY CENTER

Renewable Energy in the Middle East

Jean-François Seznec

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Cover photo: Jumana El-Heloueh/Reuters. Former US Secretary of State Hillary Clinton speaks to Masdar CEO Sultan Ahmed Al-Jaber as US Ambassador to the United Arab Emirates Richard Olson looks on, during her tour of the "Beam Down" solar project in Masdar City, approximately 11 miles from Abu Dhabi, in January 2011.

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INTRODUCTION

The Middle East may be politically fractured, but there is one issue on which the countries in the region seem to agree. They all seek to fulfill their growing domestic energy demand with renewable sources instead of their traditional hydrocarbon reserves. The region's demand for energy is booming, a trend that is expected to continue. Economic growth combined with significant population increases have driven demand for cars, air conditioning, water, and functioning infrastructure. This in turn has translated into annual increases of 7 and 8 percent in electricity demand.[1]

In the Gulf countries in particular, the growth in energy demand stems from their holding the largest reservoirs of crude oil and natural gas in the world. It is common sense for these governments to use cheap domestic energy to provide the benefits and conveniences of modernity. This system likely contributed to the Gulf population having a sense of entitlement to the region's hydrocarbons, and thus the presumption that they can use them as they wish at virtually no cost. Subsidies have also been employed by Gulf governments to keep these prices low. Gasoline has traditionally been sold at the very low cost of production, while desalinated water and electricity produced with local natural gas and heavy fuel oil were provided at some of the lowest prices in the world.

Local demand for energy boomed to the point, however, that it started to take a toll on the volume of oil and gas exports, particularly in the Gulf states. For example, Saudi Arabia consumes two to three million barrels per day (mbd) of oil domestically. This has increased pollution substantially, making the Gulf states the largest emitters of carbon dioxide (CO_2) per capita in the world, as described in table 1.[2]

Hence, the Gulf countries have realized they can reduce their carbon footprint while increasing their ability to generate cash from exports of crude oil and natural gas if they can establish a sizable local supply of renewable energy. Since the Gulf states and North Africa have an abundance of strong sunlight, much of this effort has concentrated on solar energy. Some areas, especially in North Africa, also have steady wind, and thus have started developing their wind power. Finally, there have been efforts to develop a nuclear energy system, especially in the United Arab Emirates (UAE), to help meet the growing electricity demand without dipping into their exports of crude oil, while improving their CO_2 footprint. Nuclear energy in the Gulf and Egypt will also help these countries develop renewables without having to back them up with oil and gas turbines that have heavy CO_2 footprints.

The detailed and impressive work of the International Renewable Energy Agency (IRENA)—the international body based in Abu Dhabi that studies renewable energy—provides comprehensive information on the latest renewable energy developments, particularly in the Middle East and the Gulf. This report repeats some of the findings of IRENA, but will place their research in a slightly more critical form.

Table 1.

COUNTRY	CO_2 EMISSIONS PER CAPITA (TONNES PER CAPITA) (2014)	WORLD RANK
Qatar	35.73	1
Kuwait	22.94	3
Bahrain	21.80	4
UAE	19.31	5
Saudi Arabia	16.40	7
Oman	14.14	12

For reference:
CO_2 emissions in tons per capita

United States	16.22
OECD average	9.36
China	6.66

Source: IEA, "Key world energy statistics," 2016.

1 "The GCC in 2020: Resources for the future," Economist Intelligence Unit, 2010, p. 4.

2 International Energy Agency, *Key world energy statistics*, 2016, https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf.

Amogdoul Wind Farm in Essaouira, Morocco, a country which leads the region in wind power capacity and production.
Photo credit: Sqala/Wikimedia.

Today, large national oil companies like Saudi Aramco are no longer dependent on foreign companies to get their oil and gas out of the ground. They do buy services from the likes of Halliburton, Brown and Root, or Schlumberger; by and large, they manage their own activities and are considered to be both as technologically advanced and as competent, if not more so, as most international oil companies. In a role reversal, while Asia and the Western world were dependent on oil from the Gulf states, switching to renewable energy will make the Gulf states dependent on technology suppliers in Asia and the West. Of course, Middle Eastern countries will, and do already, seek to develop their own renewable technologies, but just as it took some years to become leaders in hydrocarbon technologies, it will take some time to become leaders in renewables.

Renewable projects are undeniable public relations opportunities for Gulf countries to tout their efforts, and many Gulf countries present solar and wind projects to the public in glowing terms, accompanied by sleek presentations, as illustrated by the Masdar city plan or the newly unveiled Saudi plan for a megacity called NEOM. However, irrespective of the public relations advantages, the long-term development of renewables only makes sense if the production of electricity is sufficiently economical to replace the use of natural gas, heavy fuel oil, and in some cases crude oil. In other words, long-term development of renewables will only happen if the benefits warrant the expense, regardless of the opinions and pressures of international and environmental constituencies. Reducing or removing subsidies is a difficult policy move in any country. However, the promotion of renewables that can compete with hydrocarbons over the long term in the Gulf requires removing subsidies on the use of the latter, so that renewables can compete. Fortunately, there is already evidence this is happening, including bids by developers in the Gulf to sell renewable power at $0.0179 per kilowatt hour (KWh) in 2017, a price competitive with natural gas and coal-fired generation.[3]

3 “Moroccan Solar Shines as Costs Tumble,” *Middle East Economic Survey*, last updated April 14, 2017, http://archives.mees.com/issues/1690/articles/54765.

Additionally, the adoption and use of renewables will accelerate if it is done with the support and participation of local citizens. For instance, the widespread use of solar roofs will likely be more popular if people can link them to battery systems or other energy storage devices and go off the grid altogether. Tesla's newly developed concept to cheaply build aesthetically pleasing roofs and link them to flat batteries set in the walls of houses could be used extensively in the Middle East, if adapted for the region.

This paper argues that Middle Eastern countries will have the most success adopting renewables if they develop their own technologies, as is being done by several research institutes in the Gulf, or alternatively (even concurrently) acquiring global technology companies in this industry. If the present trends in the use of renewables worldwide continue, the world could witness, albeit in several years, a decline in the demand for hydrocarbons. Thus, Middle Eastern oil and gas producers may find that locally developed renewables products and technology would help limit the impact of the decline in hydrocarbon consumption both at home and abroad. Similarly, non-oil producers like Morocco or Jordan may build on their development of renewables to become not only less dependent on imports of hydrocarbon, but also suppliers of electricity and technology to neighbors and beyond.

SURVEY OF EXISTING RENEWABLES
Track Records in the Middle East and North Africa (MENA)

SECTOR-WIDE

The International Energy Agency's (IEA) Renewables 2017 report forecasts growth in renewable electric capacity of 43 percent (922 GW) over 2017–2022, driven by strong policy support and cost reductions primarily for solar photovoltaics (PV) and wind. This projection represents a 12 percent increase over the IEA's 2016 growth projection of 36 percent due to an improved solar forecast in India and China. Though optimistic for renewables in the MENA region, the IEA says market barriers, weak grid infrastructure, and difficulties in securing affordable financing could limit potential growth.[4]

The main renewables technologies used in the Middle East are:

Wind turbines

Wind turbines and mills are used where wind resources are quite stable, and provide alternative current. Currently, large-scale wind farms are the lowest cost renewables production option.[5] At the time of writing, wind turbines in the Middle East are being used mainly in Morocco. Most wind farms are placed in areas where winds are quite constant, but nevertheless, there can be periods of unexpected calm. Thus, wind power will have to have some back up, either in the form of large energy storage or links to hydrocarbon generation.

4 "IEA Highlights Barriers to Mena Renewables Growth," *Middle East Economic Survey*, November 4, 2016, http://archives.mees.com/issues/1668/articles/54356; International Energy Agency, *Renewable Energy Medium-Term Market Report 2016*, October 25, 2016, https://www.iea.org/newsroom/news/2016/october/medium-term-renewable-energy-market-report-2016.html; International Energy Agency, *Renewables 2017*, October 4, 2017, https://www.iea.org/publications/renewables2017/.

5 Fatih Birol et. al., "World Energy Outlook 2017," International Energy Agency, November 14, 2017, 269.

Table 2.

COUNTRY	DRIVERS	CHALLENGES
Morocco	Excellent resources. New capacity and diversification needs. Long-term government targets supported by auctions with power purchase agreements (PPAs). Third party sales for independent power producers allowed.	Grid integration for large-scale renewables. Limited access to grid for distributed solar PV. Limited access to commercial financing.
Egypt	Excellent resources, fast growing demand and strong need for power sector diversification. Feed-in-tariffs (FITs) and competitive auctions.	Cost and availability of financing. Unclear support scheme procedures. Lengthy administrative barriers.
Jordan	Small fossil fuel resources and strong need for power sector diversification. Solar PV contracted prices competitive for new generation, net metering available.	Policy uncertainty over continuation of current scheme. Grid integration challenges for new capacity cause delays. Land constraints. Lengthy permitting for distributed PV.
UAE	Fast-growing power demand. Competitive auctions, net metering for distributed. Low solar PV contracted prices make it cost-effective versus new conventional generation.	Non-economic barriers to IPPs can present investment challenges to new entrants outside of the tendering framework. Limited visibility over auction schedule. Subsidized end-user tariffs.
Saudi Arabia	Excellent resources, fast growing demand, and strong need for power sector diversification.	Vertically integrated power sector. Lack of clear policy support mechanism. Uncertainty over timing and implementation of targets.

Sources: IEA, *Renewable Energy Medium-Term Market Report* (2016), p. 93; IEA, *Renewables 2017* (2017), p. 87.

Photovoltaic (PV) Panels

These panels generate direct current, which needs to be changed into alternative current. PV technology today has the lowest capital cost at $1,300 per kW to $1,450 per kW at utility scale.[6] On the other hand, PVs are intermittent as they do not produce electricity after sundown unless linked to expensive battery packs or intricate and expensive heat storage systems.

Concentrated Solar Power (CSP)

CSP systems consist of mirrors concentrating sun rays on tubes holding a liquid, often molten salt, that when heated turn a turbine to generate electricity. These systems are either heating tubes placed inside an array of mirrors, or they concentrate the rays on the tip of a high tower, boiling the molten salt, which is then put through a heat exchanger to make steam that turns electricity generating turbines. CSP systems can be designed to hold boiling liquids to run "after hours" and thus can continue producing for several hours after sundown. CSP's main drawback is capital cost, which runs between $4,000 and $9,000 per kW of producing and storage capacity.[7]

Hydropower

Dams are, of course, built on rivers with relatively constant and significant flows; in terms of Middle East energy, they are limited primarily to the MENA regions of Morocco, Iraq, and Egypt. The dams, which depend on reliable rain upstream and can be costly and environmentally disruptive, are used for irrigation and electricity production. However, once built, they last for very long periods of time and provide quite low-cost power. Aswan, Egypt's dam on the Nile and the most well-known hydroelectric dam in the region, has a capacity of 2.1 GW and produces approximately 15,000 GWh of electricity annually in addition to controlling irrigation and river flow.[8] Hydropower capacity in Morocco is approximately 1.3 GW, while Iraq has around 2.3 GW, and Syria also has 1.6 GW.[9]

RENEWABLE ENERGY IN THE GULF COOPERATION COUNCIL (GCC) COUNTRIES

Based on the IRENA database, current renewable (excluding nuclear) capacity in the GCC countries and the growth trajectory over the past five years is outlined in table 3.[10] The breakdown by GCC country is listed in table 4 (all figures MW).

While the Gulf region is very long on projects for renewables, it is thus far quite short on producing plants. The emphasis on renewables is quite new and, in the case of oil and gas producers, has developed as countries began to realize that the 8 percent annual electricity demand growth is eating into the use of their main export commodities, crude oil and natural gas. There were even alarmist reports that Saudi Arabia would become an oil importer by 2030, given the exponential increase in domestic fuel consumption.[11]

6 "Capital Cost Comparison," Lazard's Levelized Cost of Energy Analysis–Version 10.0, *Lazard Freres & Co.*, December 2016, 11 https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf.

7 "Morocco Qualifies Bidders For First Phase Of $2.2bn Hybrid Solar Project," *Middle East Economic Survey*, June 23, 2017, Volume: 60 Issue: 25.

8 Hossein Rosazi et. al., *The Arab Republic of Egypt: Power Sector Brief 2010*, African Development Bank, 2010, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/ENERGY%20mpa%20ENG%20Power%20Sector%20Emer.pdf.

9 Capacity figures sourced from Irena's public database, http://resourceirena.irena.org/gateway/dashboard/.

10 All figures sourced from Irena's public database: http://resourceirena.irena.org/gateway/dashboard/.

11 Glada Lahn and Paul Stevens, *Burning Oil to Keep Cool: The Hidden Energy Crisis in Saudi Arabia*, Chatham House, December 1, 2011, https://www.chathamhouse.org/publications/papers/view/180825; Yukari Hino, *Saudi Arabia field report: Another potential oil crisis in the Middle East*, Brookings Institution, July 2, 2015, https://www.brookings.edu/blog/markaz/2015/07/02/saudi-arabia-field-report-another-potential-oil-crisis-in-the-middle-east/.

Table 3. Total GCC Capacity (MW)

	2011	2012	2013	2014	2015	2016
Solar PV	11.1	35.6	52.3	77.7	94.0	128.4
Solar CSP	—	—	100.0	100.0	100.0	100.0
Onshore Wind	0.7	0.7	1.5	1.5	1.5	11.5
Biomass	30.0	30.0	30.0	30.0	30.0	30.0
Biogas	8.0	8.0	8.0	8.0	8.0	8.0
Total GCC Capacity	49.8	74.3	191.8	217.3	233.5	277.9

Source: Irena database.

These warnings have proven overblown. Indeed, the growth rate in local usage has declined, driven by the expansion of gas-fired generation and pricing and subsidy reforms that encourage diversion of crude oil toward export and value-added activities. In Saudi Arabia, domestic crude demand has fallen back to 2013 levels,[12] and in fact much of the growth was due to large refineries coming online. Saudi Arabia currently refines 2.6 million b/d, a 30 percent increase from 2014, and this is set to increase to 3.3 million b/d within a year. In addition to refining, the Kingdom exports 6.7 million b/d of its 10 million b/d of production and burns 0.7 million b/d of crude to generate electricity. However, about 1 million b/d of the refined crude is exported as gasoline, diesel, or naphtha. Nevertheless, the Kingdom will benefit from being able to export more of its crude oil and products if it can build and operate sizable renewables plants.

12 El Gamal, "Burning less oil at home."

Table 4.

KUWAIT	2011	2012	2013	2014	2015	2016
Solar PV	—	—	—	2.1	3.2	30.5
Onshore Wind	—	—	—	—	—	10.0
Total	—	—	—	2.1	3.2	40.5

SAUDI ARABIA	2011	2012	2013	2014	2015	2016
Solar PV	—	19.0	25.0	36.0	48.0	48.0
Total	—	19.0	25.0	36.0	48.0	48.0

OMAN	2011	2012	2013	2014	2015	2016
Solar PV	—	—	0.7	0.7	0.7	0.7
Total	—	—	0.7	0.7	0.7	0.7

UAE	2011	2012	2013	2014	2015	2016
Solar PV	11.0	13.3	23.3	29.0	32.0	38.0
CSP	—	—	100.0	100.0	100.0	100.0
Onshore Wind	—	—	0.9	0.9	0.9	0.9
Biogas	—	—	1.0	1.0	1.0	1.0
Total	11.0	13.3	125.2	130.9	133.9	139.9

QATAR	2011	2012	2013	2014	2015	2016
Solar PV	—	3.2	3.2	4.9	4.9	6.0
Biomass	30.0	30.0	30.0	30.0	30.0	30.0
Biogas	8.0	8.0	8.0	8.0	8.0	8.0
Total	38.0	41.2	41.2	42.9	42.9	44.0

BAHRAIN	2011	2012	2013	2014	2015	2016
Onshore Wind	0.7	0.7	0.7	0.7	0.7	0.7
Solar PV	0.1	0.1	0.1	5.1	5.2	5.2
Total	0.8	0.8	0.8	5.8	5.9	5.9

Source: Irena

The existing plants and the main projects in the Gulf are listed below. Unless otherwise footnoted, these projects are included in the IRENA research.[13]

Saudi Arabia

Saudi Arabia, the world's largest oil producer, also has big plans for renewables. In 2013, the King Abdullah City for Atomic and Renewable Energy (Kacare) announced plans to build 54 GW of renewables capacity by 2032, which it has since scaled back to a more manageable level in line with Vision 2030. Today, Saudi Arabia has a National Renewable Energy Plan (NREP), which aims for 9.5 GW of renewable energy by 2023, with an interim goal of 3.45 GW of installed capacity by 2020.[14]

Saudi Arabia has a PV capacity of 48 megawatts (MW). In terms of wind, Saudi Arabia only has one wind turbine of 2.75 MW. However, the country's Renewable Energy Project Development Office (Repdo) and the Ministry of Energy has issued a request for proposals for a 4,000 MW wind farm to be built at Dumat al-Jandal in the norther Al-Jawf region—the same location as the Kingdom's first utility scale solar PV project. This is the second of two tenders in round one of the NREP, the first of which is a 300 MW solar PV plant to be built at Sakaka also in Al-Jawf.[15]

UAE

The UAE is the leading Gulf country when it comes to renewables. The UAE's current renewable capacity is 139.9 MW, comprised of 100 MW solar CSP, 38 MW solar PV, 0.9 MW onshore wind, and 1.0 MW of biogas. Under its Energy Plan for 2050, the UAE intends that renewables will account for 44 percent of total generating capacity by 2050.[16] However, the UAE still lags behind Jordan, Egypt, and Morocco in the rest of the Middle East when it comes to installed capacity thus far.

In particular, the UAE has made major gains, and has huge plans, in solar. The 200 MW Seih al-Dalal solar PV plant, the second phase of a 5 GW solar project, came online in 2017; there were 139.9 MW of renewable capacity at end-2016, based on IRENA figures. According to the Middle East Economic Survey (MEES), the UAE is planning to build the world's largest solar PV plant—1.18 GW at Sweihan— expected to cost $3.2 billion.[17] The signing of the Sweihan contract increases the total capacity of power projects under development in the UAE to almost 13 GW, equivalent to 45 percent of the 28.8 GW of capacity currently online.[18] The 800 MW Phase 3 of Mohammed bin Rashid al Maktoum Solar Park has also been awarded and is expected to be delivered in 2020.[19]

The UAE has made strides in the industry and shown a willingness to consider new approaches. The "off the grid" plan of the new Masdar City was quite a challenge to the renewables' world and to the UAE itself. Masdar City, funded by the UAE's Mubadala Sovereign Wealth Fund, is intended to be a zero-emission city with 50,000 residents, using only solar energy. The project, estimated to ultimately cost $16.5 billion,[20] first established a campus for energy research. This campus, which currently houses students, and has classrooms and a library, is accessible by self-driving electric "pods" from the main parking lot. The existing buildings are all built with energy savings in mind. They are designed to maximize shade near windows and in the streets to protect visitors and inhabitants from sun and reduce the amount of cooling required. While the rest of the city has not yet been built, it is home to IRENA's headquarters. It is the base for the largest CSP plant in the Middle East, the 100 MW Shams 1 (operational in 2013), which displaces 175,000 tons of CO_2 annually. Masdar is also becoming a large renewables' developer in the rest of the world, with solar PV and CSP as well as wind projects both operational and planned in Europe and the Indian Ocean region in addition to projects elsewhere in the MENA region.[21]

13 IRENA, Database, last accessed December 13, 2017, http://resourceirena.irena.org/gateway/dashboard/.

14 "Saudi Invites Proposals For 400MW Wind Power Project," *Middle East Economic Survey*, September 1, 2017, http://archives.mees.com/issues/1712/articles/55135.

15 "Saudi Solar Tender: Masdar Offers Lowest Ever Power Price," *Middle East Economic Survey*, October 6, 2017, http://archives.mees.com/issues/1717/articles/55222.

16 "Dubai Breaks Solar Capacity, Power Pricing Records with CSP Project," *Middle East Economic Survey*, September 22, 2017, http://archives.mees.com/issues/1715/articles/55184.

17 "UAE Pushes Solar, Big & Small, But Leaves Room for New Gas-Fired Capacity." *Middle East Economic Survey*, June 2, 2017, http://archives.mees.com/issues/1697/articles/54898.

18 "Dubai Breaks Solar Capacity, Power Pricing Records with CSP Project," *Middle East Economic Survey.*

19 "Dubai Sets New PV Cost Benchmark In 800MW Phase Three of Solar Park," *Middle East Economic Survey*, July 1, 2016, http://archives.mees.com/issues/1643/articles/54013.

20 Tamsin Carlisle, "Masdar City clips another $2.5bn from price tag," *National*, December 1, 2010, https://www.thenational.ae/business/masdar-city-clips-another-2-5bn-from-price-tag-1.535641.

21 Masdar corporate website, accessed November 15, 2017, http://www.masdar.ae/.

Kuwait

Kuwait currently has 40.5 MW of renewable generating capacity, comprised of 30.5 MW of solar PV and 10.0 MW of onshore wind. The country aims to double its power generation capacity by 2030, when 15 percent of electricity is expected to be generated by renewable sources.[22]

In terms of projects, the 50 MW Al-Shegaya solar PV plant is under construction and expected to be operational by the end of 2017, while the Al-Dabdaba solar project, estimated capacity of 560 MW, is expected to come online by 2021.[23]

Qatar

Qatar currently has 44 MW of installed renewable capacity, comprised of 6 MW of solar PV and 38 MW of biomass/biogas. The country is reportedly exploring opportunities for increased renewable development, particularly in solar. According to PV Magazine, Qatar Petroleum and Qatar Electricity and Water Company created a joint venture to explore solar opportunities and are targeting 1 GW of solar deployment under a $500 million collaborative initiative.[24] Qatar Solar Energy also built a 300 MW solar PV panel factor in Doha's industrial zone.[25]

Bahrain

Bahrain currently has 5.9 MW of renewable capacity, predominately solar PV (5.2 MW) with 0.7 MW of onshore wind. While Bahrain's National Renewable Energy Plan (NREAP) targets 5 percent of generation by renewable in 2025 and 10 percent by 2035,[26] there is currently only one renewable project under development in the country—a 5 MW hybrid wind and solar project.

Bahrain is in an energy predicament driven by time and size, as the country is about to run out of its domestic natural gas resources. As all the country's electricity currently comes from domestic natural gas, it should have more incentive than its neighbors to develop renewables. However, Bahrain is a small country and lacks the land for PV arrays or CSP farms. Bahrain's immediate solution would be to import liquefied natural gas (LNG) and/or arrange for piped gas from Qatar or even Iran, as was contemplated in better days.

Oman

Oman currently has minimal installed renewable capacity, boasting just 0.7 MW of installed solar PV at the end of 2016. However, Oman's Rural Areas Electricity Company (Raeco) plans to develop 90 MW of wind and solar capacity by 2020. [27]

If built, this would amount to 25 percent of total generation, at an expected cost of roughly $200 million.[28] Thus far, only a 300-kW pilot solar PV plant at Mazyunah has been completed, with 7 MW more in small projects under consideration.

RENEWABLE ENERGY IN THE NON-GCC MIDDLE EAST

Jordan

Jordan has almost 700 MW of renewable capacity planned or under development. The Ministry of Energy aims to generate 10 percent of its electricity from renewables by 2020, a target that is projected to be met—and potentially surpassed—if all the planned renewables projects are developed on schedule.[29]

Renewable development is gaining momentum. In 2016 alone, Jordan brought roughly 176 MW—96 MW of wind and 80 MW of solar—online. This new capacity was based at Ma'an, with Scatec of Norway as a key developer of the solar capacity.[30] In 2017, the Ministry of Energy invited expressions of interest for 200 MW of solar PV capacity (four 50 MW projects) at Ma'an and 100 MW of wind capacity (two separate 50

22 "Kuwait Plans For 32GW Capacity, 15% Output from Renewables," *Middle East Economic Survey*, July 21, 2017, http://archives.mees.com/issues/1704/articles/55029.

23 Ibid.

24 Ian Clover, "Qatar JV plans 1 GW solar PV development," *PV Magazine*, February 23, 2016, https://www.pv-magazine.com/2016/02/23/qatar-jv-plans-1-gw-solar-pv-development_100023339/.

25 Ian Clover, "Qatar Solar Energy opens 300 MW PV factory in Qatar," *PV Magazine*, June 10, 2014, https://www.pv-magazine.com/2014/06/10/qatar-solar-energy-opens-300-mw-pv-factory-in-qatar_100015352/.

26 Emiliano Bellini, "Bahrain to introduce net metering policy for PV," *PV Magazine*, April 18, 2017, https://www.pv-magazine.com/2017/04/18/bahrain-to-introduce-net-metering-policy-for-pv/.

27 "Oman Taps Abu Dhabi For Wind Farm Cash," Middle East Economic Survey, August 25, 2017, http://archives.mees.com/issues/1711/articles/55124.

28 "Oman's Raeco Targets 25% Rural Renewables," Middle East Economic Survey, May 30, 2014, http://archives.mees.com/issues/1532/articles/51545.

29 "Jordan Keeps Up Renewables Momentum with Solar Award & New Tender," *Middle East Economic Survey*, January 20, 2017, http://archives.mees.com/issues/1678/articles/54542.

30 Ibid.

The Aswan Dam, located along the Nile River in Egypt, has a 2.1 GW capacity and is used to control irrigation and river flow.
Photo credit: Sharaf Al Deen/Wikimedia.

MW projects) in southern Jordan.[31] According to the Ministry of Energy, these projects will be developed as independent power producer (IPP) projects on a build-own-operate (BOO) basis. Battery storage options are being considered for both the solar and wind projects.[32]

ACWA of Saudi Arabia has won two solar projects in Jordan through aggressive pricing: the 61.3 MW Risha at US$0.059/kWh and the 60.3 MW Mafraq at US$0.0614/kWh.[33] Elsewhere in Jordan, Abu Dhabi's renewable energy developer Masdar reached an agreement with the International Finance Corporation (IFC) in February 2017 to oversee the funding of the Bainounah project—Jordan's largest solar project to date—under a BOO agreement with state utility Nepco.[34]

The IFC, a member of the World Bank group, has invested in eight of Jordan's commercial solar PV projects under its Seven Sisters Program, which is designed to catalyze development of renewables in Jordan through common frameworks and economies of scale. IFC is lending $76 million to Spain's Fotowatio for a 50 MW solar PV power plant at Mafraq and is considering funding the 49.5 MW Daehan wind development at Tafila by Korea's Daelim and Kosco.[35]

The IFC also supports wind in Jordan and backed Jordan's first utility scale renewables project, the 117 MW Tafila wind farm, which came online in October 2015.[36] Tafila was built by Jordan Wind

31 Ibid.

32 Ibid.

33 "Jordan Pushes Ahead with Oil Shale-Fired Power Plant, Lining Up More Solar," Middle East Economic Survey, 28 April 28, 2017, http://archives.mees.com/issues/1692/articles/54795.

34 "Jordan Power Finance," *Middle East Economic Survey*, February 10, 2017, http://archives.mees.com/issues/1681/articles/54618.

35 Ibid.

36 Ibid.

Table 5. Jordan's Renewable Capacity (end 2016; MW)

	2011	2012	2013	2014	2015	2016
Solar PV	1.3	1.4	3.0	8.7	26.0	295.0
Hydropower	12.0	12.0	12.0	12.0	12.0	12.0
Onshore Wind	1.4	1.4	1.4	1.4	118.4	184.4
Bioenergy	3.5	3.5	3.5	3.5	3.5	3.5
Total	18.2	18.3	19.9	25.6	159.9	494.9

Source: Irena.

Table 6. Jordan—Renewable and Nuclear Pipeline

STAGE	DEVELOPER	EXPECTED	LOCATION	TYPE	MW
Under Development	Enviromena/ TSK	2017	Quweira	Solar	103
Under Development	Kepco	2018	Fujeij	Wind	89
Under Development	Fotowatio	2018	Mafraq	Solar	50
Under Development	Green Watts	2019	Al Rajef	Wind	86
Planned	ACWA	2018	Mafraq	Solar	60
Planned	ACWA	2019	Risha	Solar	61
Planned	Daehan	2019	Tafila	Wind	50
Planned	Masdar	2020	Bainounah	Solar	200
Planned	Rosatom	2024	Qusayr Amra	Nuclear	2,000
Total					2,699
Total excl. nuclear					699

Source: "Jordan Keeps Up Renewables Momentum."

Project Company (JWPC)—owned in part by French investment fund InfraMed (50 percent), Masdar (31 percent) and Cyprus-based EP Global Energy (19 percent)—for $287 million. IFC invested $69 million and earmarked a further $152 million.

The European Bank for Reconstruction Development (EBRD) also supports Jordanian renewables projects, including providing $54 million of financing, split with the Netherlands Development Finance Company (FMO), for ACWA's $72 million Mafraq PV project, which will be built 80 km northwest of Amman. The EBRD, in cooperation with FMO, is also lending $65 million to the Al-Sawafi Green Energy 51 MW solar PV project northeast of Amman, developed by Spain's Fotowatio and local firm Arabia Trading and Consulting.[37] Between 2012 and 2016, IFC and EBRD arranged some $564 million renewables-related investment in Jordan.[38]

Egypt

Egypt is making a major effort to develop its non-hydrocarbon resources. Egypt already operates one of the largest hydropower dams in the world at Aswan, and has developed large wind farms and CSP and solar plants in the desert. From this baseline, Egypt plans to triple its non-hydrocarbon and non-hydropower assets.

Egypt is also endowed with substantial reserves of natural gas, mainly onshore and offshore of the Nile Delta. However, these reserves have declined so that instead of being an exporter of natural gas by

37 "Jordan EBRD Solar Loan," *Middle East Economic Survey*, September 22, 2017, http://archives.mees.com/issues/1715/articles/55186.
38 "Jordan Power Finance."

Table 7. Egypt's Renewable Capacity (end 2016; MW)

	2011	2012	2013	2014	2015	2016
Solar PV	15.0	15.0	15.0	15.0	25.0	39.0
Solar CSP	20.0	20.0	20.0	20.0	20.0	20.0
Hydropower	2,890.8	2,890.8	2,890.8	2,890.8	2,890.8	2,890.8
Onshore Wind	550.0	550.0	550.0	550.0	750.0	750.0
Total	3,475.8	3,475.8	3,475.8	3,475.8	3,685.8	3,699.8

Source: Irena.

Table 8. Egypt—IFC Solar projects

PROJECT	MW	DEVELOPER(S)	PROJECT COST ($M)
Arc	50	SECI/Enerray/Desert Technologies	75-80
Phoenix Power	50	Phoenix Power/Infinity Solar/ib vogt	75-80
Taqa Arabia Solar	50	Taqa Arabia	75-80
SP Energy Egypt	50	Shapoorji Pallonji	76
Al Subh Solar	50	Acciona/Enara	70-75
Acciona Benban 2	50	Acciona/Enara/TBEA	70-75
Acciona Benban 3	50	Acciona/Enara/TBEA	70-75
Alcazar Solar	50	Alcazar/Enerpal	70-75
Delta Solar	50	Alcazar/Nile Capital	70-75
Arinna	20-30	Al Bilal/SECI/Enerray/Desert Techn.	48
Winnergy	20-30	Tawakol/Enerray/Desert/Spectrum Intl.	48
Total	490—510		$747-$787

Source: "Egypt's Largest Solar Investor Ties Up Finance for Benban Projects," *Middle East Economic Survey*, November 3, 2017, http://archives.mees.com/issues/1721/articles/55303.

Table 9. Egypt—EBRD Solar projects

PROJECT	MW	DEVELOPER(S)	PROJECT COST ($M)
Scatec Benban 1-6	300	Scatec/Norfund	471.0
ACWA Benban Solar PV 1-3	120	ACWA/Hassan Allam	187.7
Infinity/ib vogt Solar PV 1 &2	80	Infinity Solar/ib vogt	115.7
Access/EREN Benban PV 1 &2	100	Access/EREN	154.6
Alfa Solar Benban PV	50	Al Fanar	74.0
Elsewedy Benban PV	50	Elsewedy	72.0
EDF EN Benban PV	50	EDF/Elsewedy	72.0
Total	750		1,147.0

Source: "EBRD Kick-Starts Egypt Solar with $500mn Investment In 16 PV Projects," *Middle East Economic Survey*, June 16, 2017, http://archives.mees.com/issues/1699/articles/54934.

Table 10. Morocco's Existing Renewable Capacity (end 2016; in MW)

	2011	2012	2013	2014	2015	2016
Solar PV	14.2	15.2	15.2	19.6	19.8	21.9
Solar CSP	20.0	20.0	20.0	20.0	180.0	180.0
Hydropower	1,305.6	1,305.6	1,305.6	1,305.6	1,305.6	1,305.6
Pumped Storage	464.0	464.0	464.0	464.0	464.0	464.0
Onshore Wind	291.9	291.9	532.0	834.0	834.0	934.0
Biogas	—	0.9	0.9	0.9	2.1	2.1
Total	2,095.6	2,097.5	2,337.6	2,644.0	2,805.4	2,907.5

Source: Irena.

pipeline to Israel, Jordan, and Syria and a producer and exporter of LNG, Egypt no longer exports piped gas or produces LNG, and has even become a net LNG importer. Fortunately, Italian oil company ENI discovered large gas reserves in the offshore Mediterranean Zohr field in 2015, which is expected to come online in early 2018 and produce enough to fully meet Egypt's domestic needs. Nevertheless, with a rapidly increasing population and a rebounding economy, growing energy needs require Egypt to look beyond hydrocarbons.

Egypt, thus, also has important plans for nuclear, solar, and wind developments. Egypt concluded negotiations and signed a preliminary agreement with Russia in 2015 for the construction of four nuclear power plants at Dabaa, 170 km west of Alexandria on Egypt's Mediterranean coast.[39] Russia will lend Egypt $25 billion to fund 85 percent of the development cost. The twenty-two-year loan with an interest rate of three percent will burden an already fiscally strained government.

The IFC has approved a plan to invest $635 million to help build, operate, and maintain up to 11 PV plants in Egypt with a combined capacity of 500 MW.[40] The IFC announcement follows an EBRD decision to back sixteen solar projects with combined capacity of 750 MW at Benban with almost $500 million in loans. Nine of the projects will have nominal capacities of 50 MW and two will have nominal capacities of 20 to 30 MW. Investment requirements are expected to range from $48 million for the smallest to $80 million. IFC is taking the lead role in financing through a combination of direct loans—ranging from $12 to $20 million—plus syndicated finance.

The recent progress in catalyzing a renewable energy sector in Egypt was nearly derailed over contract disputes.[41] Fortunately, the disagreements, which focused on tariffs and Egypt's acceptance of a Paris arbitration decision, were ironed out. Today, Egypt is lining up its 4.3 GW renewables investment program.

Outside of the EBRD- and IFC-supported solar program, Egypt is also looking to expand wind power. NREA has invited international firms to prequalify for a turnkey construction contract for a 200 MW wind farm, potentially extendable to 250 MW. Construction is scheduled to begin in early 2018 and is expected to take thirty-two months, implying a 2021 operational date.[42] At present, Egypt has 380 MW of wind capacity under development at two sites in the Gebel El Zeit area on the Gulf of Suez.

Morocco

Morocco may be the most advanced country in the Middle East when it comes to renewables deployment. The country has high solar irradiance, steady winds from both the ocean and the mountains, and some rivers that are used to produce hydropower. However, the country has almost no hydrocarbon resources and depends on oil and gas imports. Morocco also appears to have the political will to strongly develop renewables, and has obtained substantial support from European and international organizations to

39 "Egypt Advances $29bn Nuclear Plant," *Middle East Economic Survey*, August 11, 2017, http://archives.mees.com/issues/1708/articles/55084.

40 "Benban Solar Plan: Egypt PV Gets $635mn World Bank Cash," *Middle East Economic Survey,* August 4, 2017, http://archives.mees.com/issues/1706/articles/55064.

41 Ibid.

42 "Egypt Tenders Wind Project as Three Megaprojects Begin Supplying Grid," *Middle East Economic Survey*, April 7, 2017, http://archives.mees.com/issues/1689/articles/54746.

Table 11. Morocco—Key Wind Power Pipeline

PROJECTS	MW	DATE	PROJECT COST ($M)	DEVELOPER(S)
		PLANNED		
ONEE Wind Power Programme:		Ongoing	$1,080.32	Enel Green Power (EGP)
Tanger II (Tangier)	100			
Midelt (Midelt)	150			
Essaouira (Jbel Lahdid)	200			
Tiskrad (Laayoune)	300			
Boujdour (Boudjour)	100			
Total planned	850			
		IN DEVELOPMENT		
Khalladi Wind Farm	120	2018	$180	ACWA Power
Total Planned + In Development	970			
		KEY OPERATIONAL ASSETS		
Tarfaya Wind Farm	300	2014	$590	TAREC (Nareva and GDF Suez)
Taza Wind Farm	150	2012	EUR 265	EDF, Mitsui
Akhfenir	100	2016	TBD	Nareva Holding, Engie

Source: "Morocco Qualifies Bidders for First Phase Of $2.2bn Hybrid Solar Project," Middle East Economic Survey, June 23, 2017, http://archives.mees.com/issues/1700/articles/54953.

Table 12. Morocco—Key Solar Power Pipeline

PROJECT	MW	TYPE	DATE	PROJECT COST (M)
NOOR Midelt	1,000	CSP / PV Hybrid	2020	$2,200
Noor—Ouarzazate Solar Power Station Project:				
NOOR I	160	CSP	2016	$880
NOOR II	200	CSP	2017/18	$950
NOOR III	150	CSP (Tower)	2017/18	$750
NOOR IV	70	PV	2018	TBD
Masen-Led Projects:				
NOOR Laayoune	80	PV	2018	TBD
NOOR Boujdour	20	PV	2018	TBD
ONEE-Led Projects at Tata:**				
NOOR Tafilalet	100	PV	2017	EUR 158
NOOR Atlas	200	PV	2018	TBD
NOOR Argana	200	PV	2019	TBD

Note: According to MEES, the NOOR II and III projects combined will cost $1.7bn.
** ONEE is the Office Nationale d'Energie et de l'Eau, the state-owned utility company of Morocco
Sources: "Morocco Qualifies Bidders"; "Morocco Inaugurates 160MW Solar Plant, Starts on Two More," Middle East Economic Survey, February 12, 2016, http://archives.mees.com/issues/1623/articles/53594.
Mariyana Yaneva, "Morocco to add 4 GW of wind, solar capacity by 2020," Renewables Now, January 21, 2017 https://renewablesnow.com/news/overview-morocco-to-add-4-gw-of-wind-solar-capacity-by-2020-555087/. Cost estimates for Noor II and Noor III projects converted from Euros to USD at current exchange rates.

Table 13. Morocco—Finance for the NOOR Midelt Solar Project

SOURCE	COUNTRY	CONTRIBUTION ($M)
KfW	Germany	750.0
Masen	Morocco	440.0
IBRD (World Bank)	Multilateral	400.0
African Development Bank	Multilateral	260.0
European Investment Bank	Multilateral	200.0
Government of France	France	100.0
Clean Technology Fund	US	50.0
Total		2,200.0

Source: MEES.

finance its efforts. Hence, Morocco has been able to build a sizable portfolio of renewables, which it plans to expand, aiming to increase its use of renewables to 52 percent of total electricity supply by 2030.[43]

Morocco operates Noor 1, a 160 MW CSP plant in Ouarzazate close to the Sahara Desert in the south, and is building the 190 MW Noor 2, expected to open next year. The plant was built and is operated by Saudi Arabia's ACWA in partnership with Spain's Sener, Acciona, and TSK on behalf of MASEN, Morocco's state renewable energy agency.[44]

Morocco has 709 MW of installed wind capacity, including the 300 MW Tarfaya farm,[45] the largest wind farm in Africa according to the Middle East Economic Survey.[46] There is also 970 MW of onshore wind power capacity in the pipeline: the ONEE wind power program is targeting 850 MW at five sites, the Khalladi Wind Farm near Tangiers, developed by the ACWA of Saudi Arabia.

Morocco is also looking for developers for the first phase of its $2.2 billion hybrid solar project.[47] The Noor Midelt project will be Morocco's first hybrid PV/CSP plants. There is roughly 2,180 MW of solar in the pipeline across four separate project portfolios: NOOR Midelt and Ouarzarate, Masen at Laayoune (80 MW) and Boujdour (20 MW), and the three ONEE-led projects at Tata (500 MW). Masen, Morocco's state renewables agency, is aiming to install 1 GW of PV and CSP capacity in two phases, each developed on an IPP basis with a twenty-five-year PPA. Masen says that its Noor solar program is expected to add a total 2 GW of generating capacity by 2020 and will incorporate projects at Ouarzazate, Laayoune, and Boujdour as well as at Midelt.

Algeria

In 2011, Algeria introduced a program, updated in 2015, to develop 22 GW in renewables energy capacity by 2030, including 13.6 GW of solar PV, 2 GW of concentrated solar power, 5 GW of wind power, and 1.4 GW from other sources (see table).[48] Algeria has plans to develop an initial 4 GW of solar capacity, with the energy ministry planning to solicit bids for three separate projects including a local manufacturing element.[49]

The government has established a renewable and energy efficiency fund, the Fond National pour la Maitrise de l'Energie, pour les Energies Renouvelables et la Cogeneration (FNMEERC), to support renewable energy projects. The fund receives 1 percent of royalties from hydrocarbons contracts annually, 55 percent of

43 Celeste Hicks, "Morocco lights the way for Africa on renewable energy," *Guardian*, November 17, 2016, https://www.theguardian.com/global-development/2016/nov/17/cop22-host-morocco-lights-way-africa-renewable-energy-2020.

44 "Morocco Qualifies Bidders For First Phase Of $2.2bn Hybrid Solar Project," *Middle East Economic Survey*, June 23, 2017, Volume: 60 Issue: 25.

45 "Morocco Wind Farm Award," *Middle East Economic Survey,* August 12, 2016, http://archives.mees.com/issues/1649/articles/54127.

46 Ibid.

47 "Morocco Qualifies Bidders for First Phase Of $2.2bn Hybrid Solar Project," *Middle East Economic Survey,* June 23, 2017, http://archives.mees.com/issues/1700/articles/54953.

48 "Algiers Aims for The Sun; Is Its Head in The Clouds?," Middle East Economic Survey, April 28, 2017, http://archives.mees.com/issues/1692/articles/54796.

49 "Algeria Plots Unlikely Power Capacity Boost Whilst Rejecting Foreign Funding," Middle East Economic Survey, September 15, 2017, http://archives.mees.com/issues/1714/articles/55167.

Table 14. Algeria's Existing Renewable Capacity (end 2016; in MW)

	2011	2012	2013	2014	2015	2016
Solar PV	—	—	—	1.0	49.1	219.1
Solar CSP	25.0	25.0	25.0	25.0	25.0	25.0
Hydropower	227.6	227.6	227.6	227.6	227.6	227.6
Onshore Wind	—	—	—	10.2	10.2	10.2
Total	252.6	252.6	252.6	263.8	311.9	481.9

Source: Irena.

Table 15. Algeria Renewables Targets (2015—2030)

	PHASE 1 (MW)	PHASE 2 (MW)	TOTAL (MW)
Technology	2015—2020	2021—2030	2015—2030
Solar PV	3,000	10,575	13,575
Wind	1,010	4,000	5,010
Solar CSP	—	2,000	2,000
Biomass	360	640	1,000
Cogeneration	150	250	400
Geothermal	5	10	15
Total	4,525	17,475	22,000

Source: "Algiers Aims for The Sun."

revenue from taxes on gas flaring, and (as of the 2017 budget) 10 percent of revenue from value-added taxes on energy-consuming goods and appliances.[50]

However, despite plans to develop 22 GW in renewable capacity by 2030 and the existence of a fund to finance their development, the Algerian government does not seem prioritize renewables. The Middle East Economic Survey casts doubts on whether Algeria can achieve its targets, saying:

"If the government is to hit its objectives it will have to overcome barriers including a bloated bureaucracy, top-heavy and ponderous decision-making, a suspicion of foreign investment, high capital costs for renewables infrastructure, intermittency, grid capacity, ongoing state subsidies for electricity consumers, and security concerns."[51]

Given its large gas reserves and production, there may be less of a sense of urgency to spend large amounts of capital on renewables. However, Algeria could still achieve its goals, as it has the solar assets, a strong capital base, and an educated population that can manage and build these assets. This will also require working closely with the technology providers, including firms from the other oil producers, as has been the case in Jordan and Morocco.

50 "Algeria Plots Unlikely Power Capacity Boost."

51 "Algiers Aims for The Sun."

Table 16. Tunisia's Renewable Capacity (end 2016; in MW)

	2011	2012	2013	2014	2015	2016
Solar PV	1.5	5.3	9.0	16.5	26.5	37.8
Hydropower	65.6	65.6	65.6	65.6	65.6	65.6
Onshore Wind	53.0	173.0	200.0	233.0	240.0	245.0
Total	120.1	243.9	274.6	315.1	332.1	348.4

Source: Irena.

Tunisia

Tunisia needs to reduce its reliance on fuel imports and has set a target of 30 percent of electricity from renewables by 2030.[52] Like Egypt, Jordan, and Morocco, Tunisia seeks funding from EBRD for its renewables, and EBRD is also funding upgrades to the national power grids to enable them to incorporate renewables.[53]

However, there is little information on the actual projects in Tunisia, suggesting that the recent budgetary difficulties (exacerbated by a sharp drop in tourist revenues) may be causing delays in renewable deployment.

52 "Tunisia's STEG Awards 450MW Gas-Fired Plant," *Middle East Economic Survey*, June 30, 2017, http://archives.mees.com/issues/1701/articles/54974.

53 "Oil-Poor Arab States Get Multilateral Finance Boost for Renewables," *Middle East Economic Survey*, December 2, 2016, http://archives.mees.com/issues/1672/articles/54436.

THE MIDDLE EAST'S MOST NOTABLE INSTITUTIONS FOR DEVELOPING RENEWABLES

Across the Middle East, most of the existing renewables plants and projects are run by state-owned organizations. In the countries that have little hydrocarbon resources or income, these state-owned entities seek funding from traditional international funders, namely international organizations and multilateral development banks. In countries with substantial cash reserves, state companies lobby their own states for funding and also, as they have good credit on the international markets, can easily complement the financing with suppliers' credits from the sellers of equipment. There are even efforts to bring in private sector investors, which may be the wave of the future for renewables growth in the region.

An interesting indication of how much emphasis is now placed on the development of renewables in the region is the sheer number of non-state companies involved in the industry, as developers, installers, and manufacturers. The UAE's Masdar and Saudi Arabia's ACWA Power have become major developers of renewable projects in the region. In addition, companies such as Qatar Solar Technologies (QStec, Qatar), IDEA Polysilicon (Saudi Arabia), Gulf Solar Technologies (UAE), Enviromena Power Systems (UAE), Almaden (UAE), and Dusol (UAE) have established themselves across the solar supply chain.[54]

In Morocco, the manager of renewable energy is a government organization called Masen, and the national electricity company of Morocco, ONEE, is the operator and main customer, while Masen designs the projects and seeks financing. For instance, on the Midelt solar projects scheduled to produce 580 MW, Masen has arranged $2.2 billion of funding from Germany, the IBRD, EBRD, and France. The first phase of 160 MW is already operational, phase two is under construction, and two other phases are expected by 2020 for a total of 2 GW of production.

In the GCC, which has large amounts of available capital, entrepreneurs have been interested in taking chances on possible profits in the renewables industry, and there are numerous active firms and institutions. Notably, QStec has started production of solar films in Qatar with a capacity of 8,000 metric tons per annum, there are suppliers of inverters (AEC Saudi Arabia), and mounting structures companies. There are manufacturers of solar modules, including SOLON Group, originally from Germany, now from the UAE, and the AlMaden MENA FZE, wholly owned by Chang Zhou Almaden of China. This all suggests that the GCC is slowly but surely attracting renewable investment, as well as making (small) steps to develop a renewable industry. The Middle East Solar Industry Association[55] has over one hundred members, mostly focused on renewables in the UAE, and there are many other organizations dealing with renewables promotion. Some state organizations also deal with or promote the industry, including the Clean Energy Business Council (Dubai), Dubai Carbon Center of Excellence, Dubai Supreme Energy Council, EDAMA (Jordan), and the Emirates Environmental Group (UAE).

The Gulf is also increasingly focused on promoting renewables from a research perspective. There are research centers in the UAE, such as MASDAR and the Solar Innovation Centre—Dubai; Saudi Arabia has solar technology centers at King Abdullah University for Science and Technology (KAUST), King Abdullah Research Center for Petroleum Studies and Research Center (KAPSARC), and King Abdel Aziz City for Science and Technology (KACST).

Countries are also taking steps to establish state organizations or planning departments to focus solely on renewables. The Ministry of Energy, Industry, and Mineral Resources of Saudi Arabia has established the Saudi Renewable Energy Development Office (REPDO), tasked with directing the development of its

54 *Renewable Energy Market Analysis: The GCC Region*, IRENA, 2016, Irena, http://www.irena.org/DocumentDownloads/Publications/IRENA_Market_GCC_2016.pdf.

55 See MESIA.com for more details on the members, they include developers and manufacturers, integrators, suppliers, etc.

large renewables program.[56] It is planning to develop 10 GW of solar, wind, and nuclear by 2023.[57]

Saudi Arabia has a number of private firms developing renewable projects, including ACWA, one of the few fully operational, profit-seeking energy developers in the region, with a division specializing in renewables. ACWA is owned by several other companies, some of which are controlled by large trading families (Abunayyan, AlRajhi, AlMutlaq, AlEsayi, Al-Thouki). It also includes investments by Sanabil, the first, albeit small, sovereign wealth fund of the Kingdom and now part of the Public Investment Fund (PIF), and by the Saudi Public Pension Agency.

ACWA, which manages $8 billion in projects, 14 percent of which are renewables, seeks to develop energy and water projects using hydrocarbon based and/or renewables as needed. It will syndicate each project with outside investors, and take an important share for itself. Its portfolio of renewables includes existing projects in Oman, Jordan, Morocco, Spain, South Africa, and Bulgaria, and it has several hydrocarbon-based projects in some of the same countries, plus Egypt and Vietnam. ACWA's overall projects have a capacity of 24 GW of electricity and can produce 2.5 million cubic meters of water per day. Some of the best-known merchant family firms in the Kingdom are also expanding in the renewables field. For example, AbdelAtif Jameel has Solar PV projects in the UAE, India, Uganda, Jordan, Brazil, Uruguay, and Chile.

In the UAE, Masdar, owned by Mubadala, one of Abu Dhabi's main sovereign wealth funds, is most famous for Masdar City, mentioned above. However, Masdar is also involved in the development of numerous projects in the UAE and around the world. Among its many projects, it developed a wind farm and solar arrays in Jordan and is involved in solar development in Egypt and Spain (in a joint venture with Sener of Spain), and in wind in the United Kingdom.

Dubai aims to have 5 percent of its electricity from renewables by 2020, the development of which is coordinated by the Regulatory and Supervisory Bureau, which oversees electricity and water production companies (IWPP and DEWA). DEWA is seeking to develop production of roof top electricity in homes, which could produce enough energy for themselves and sell extra production to the grid. In fact, DEWA envisages solar panels being installed on all rooftops in the Emirate by 2030.[58] DEWA also operates the Sheikh Rashid Al Maktoum Solar Park, expected to be the largest single-site solar park in the world. A 13 MW first phase was connected to the grid in 2013, and the 200 MW second phase is expected to be completed in 2017.[59] The third phase, to be implemented by 2020, is most notable for having received bids for development at $2.99/KWh, the lowest cost per KWh in the world in 2016, driven by the giant project's economies of scale.[60] DEWA is also building the largest CSP in the world, awarded to a joint venture between ACWA of Saudi Arabia and Shanghai Electric of China, with commissioning expected to begin in 2020.

56 Emiliano Bellini, "Saudi Arabia's 300 MW solar tender may conclude with lowest bid ever," *PV Magazine*, October 4, 201, accessed November 21, 2017 https://www.pv-magazine.com/2017/10/04/saudi-arabias-300-mw-solar-tender-may-conclude-with-lowest-bid-ever/.

57 Matthew Martin, "Saudi Aramco Said to Weigh Up to $5 Billion of Renewable Deals," *Bloomberg* January 29, 2017, accessed November 21, 2017 https://www.bloomberg.com/news/articles/2017-01-29/saudi-aramco-said-to-weigh-up-to-5-billion-of-renewable-deals.

58 "Dubai Sets New PV Cost Benchmark."

59 Ibid.

60 "Saudi Solar Tender."

IMPEDIMENTS TO THE GROWTH OF RENEWABLES

CONTROL OF THE TECHNOLOGY

Renewables are not the panacea that one could expect in a region known for its huge deserts and numerous hot, sunny days, interspersed by wind storms. Renewable development is in part challenged by the Middle East—particularly the Gulf—states' natural advantage in low cost, plentiful natural gas and crude oil resources. The cost of extracting crude oil out of the ground has been as low as $1.50 per barrel in Saudi Arabia's Ghawar field, the largest in the world, and costs in many countries in the region remain below $6 per barrel even in the Gulf's offshore fields.

Until about 1980, natural gas was viewed as a curse to the easy production and shipping of crude oil, and thus mostly flared. While Western companies controlled oil production in the region prior to the 1970s, from the mid-1970s on, local states and national oil companies took over ownership of the reserves and the tools of production. Over the past forty years, the national oil and gas companies came to control, own, and actually develop the technology needed to extract, clean, refine, and export their oil, and some of these companies, like Saudi Aramco, developed into mega modern and efficient producers. Natural gas then came to be seen as a blessing to be gathered to produce electricity, desalinate water, used as feedstock for chemicals and fertilizers, and in some cases exported as LNG. Today, companies like Saudi Aramco do not normally depend on foreign technology and when they do, they either acquire the companies that own it, or lease it as is needed.

However, unlike oil and gas technologies, renewables technologies are produced elsewhere, and most of the needed equipment is imported. The largest producers of solar panels are Chinese firms, while the large CSP plants are designed and built by Western firms. Thus, the benefits of renewables often do not accrue to the local manufacturing or engineering companies, but over time local firms will build enough knowledge and experience to develop their own technology and designs. This is already happening with ACWA and Masdar, which are designing and selling their services to firms in other parts of the Middle East, like Jordan or Morocco; Qatar has a PV panel plant. Nonetheless, there is still a long way to go for most of the development of renewable technology and equipment to originate in the region.

COST OF RENEWABLES RELATIVE TO THE COST OF HYDROCARBONS

The past few years have seen a major decline in renewable energy costs in the Middle East. Increasingly, the (mainly) state buyers of energy put out requests and obtain bids for new renewable projects based on expected output costs rather than on the cost of

DESALINATION, RENEWABLES, AND THE RISK OF POLLUTION

Desalination is vital to the survival of the countries of the Gulf. Presently, most desalination comes from hydrocarbon sources, either as the firing of natural gas, heavy fuel oil, even crude oil for multi-flash systems, or in the generating of electricity for reverse osmosis plants. With the development of renewables in the region, more and more of the water produced will come from renewable energy. Unfortunately, the salt removed during the desalination process is pumped back into the Gulf, increasing the salinity of this environmentally fragile body of water. The problem needs urgent attention as the volumes are staggering. Today, the Gulf countries put back 60 million tons of brine per day at 5 percent salt content, i.e. 3 million tons of salt per day. Besides pumping it into the Gulf, there are only a few other ways to use the salt, and thus far they are only marginally efficient. For example, brine can be used to make caustic soda, which can be used in the Gulf's large aluminum industry. Brine could also be injected into producing oil fields or used to make baking soda. However, this would account for only a small percentage of the brine and would require large amounts of energy, thereby increasing the need for renewables. Hence, just like the Gulf countries need to invest in technology and supplies of renewables to prepare for a post-oil era, they will need to invest in research to limit the increase in the salinity of the Gulf.

NUCLEAR ENERGY

Even though nuclear energy is not commonly considered a renewable energy in the same vein as solar or wind power, it does contribute to reducing CO_2 emissions and a general decline in the local use of hydrocarbons.

The region is developing its nuclear portfolio. The UAE is building four reactors with a planned capacity of 5.6 GW at a cost of $20 billion expected to go online by 2020.[1] Saudi Arabia has plans to develop two plants, after scaling back its initial goal of sixteen reactors. Egypt has letters of intent to build reactors with Russia. However, Qatar, Kuwait, and Oman cancelled their plans for development of nuclear power following the 2011 Fukushima disaster in Japan.[2]

Just as they have done with oil and gas, some of the Middle East states, especially Saudi Arabia, will want to develop nuclear energy if they can control the technology. However, nuclear technology is highly controversial, extremely complex, and requires many years to acquire and develop. Saudi Arabia has founded a large research center to study nuclear technology for electricity (KACARE) and to train the hundreds of engineers it will require to build its own nuclear plants. However, the Kingdom is still many years away from such development. The UAE has successfully gotten the green light from the United States to contract four plants from South Korea, but at the cost of not having control of the technology or the reprocessing of nuclear fuel. Iran already has a Russian nuclear reactor operating at Bushehr and is seeking to build a second one. However, the technology is still controlled by Russia. Thus, for the near-and medium-term future, it would seem that nuclear will not grow to be a major source of energy for the region, except in the UAE, which will rely on Korean and US technology entirely.

1 Charlie Sorrel, "Nuclear Power Is Growing In The Gulf As The Middle East Tries To Find A Future After Oil," Fast Company, January 26, 2017, https://www.fastcompany.com/3067557/nuclear-power-is-growing-in-the-gulf-as-the-middle-east-tries-to-find-a-future-after-oil; Carole Nakhle, *Nuclear Energy's Future in the Middle East and North Africa*, Carnegie Middle East Center, January 28, 2016, http://carnegie-mec.org/2016/01/28/nuclear-energy-s-future-in-middle-east-and-north-africa-pub-62562.

2 Carole Nakhle, *Nuclear Energy's Future in the Middle East and North Africa*.

hardware and building of plants. The developers that respond are increasingly aggressive in their pricing offers. For example, and as was mentioned above, Jordan obtained bids from ACWA for two 60 plus KW PV plants at US$0.059 and $0.0614/KWh, considered the lowest price for solar anywhere in the world.[61] In the ensuing race to the lowest PV price, the Saudi Ministry of Energy's REPDO received a bid from Masdar, in joint venture with Electricité de France, at $0.0179/KWh on a 300 MW plant in 2017, a price that is even lower than the $0.0242/KWh bid received by Abu Dhabi earlier this year.[62] The Saudi auction was well attended, with three bids below $0.03/KWh, coming in very close to bids offered using non-renewable resources.

The cost of CSP is also declining, although not as quickly as PV. The cost of CSP has gone from between $0.10 to $0.12/KWh[63] for plants in the United States to about $0.063/KWh in Chile in a 2017 auction, a low price set by SolarReserve's bid.[64] CSP is also becoming increasingly competitive in the Middle East. In a 2017 DEWA call for bids on a 200 MW CSP plant, the lowest bid by ACWA of Saudi Arabia came in at $0.0945/KWh to provide energy at night using molten salt or oil to store the energy produced during daylight.

The low cost of solar has not replaced further traditional generation plants, as they are still needed for peak demand and at night. Thus, while the price for PV in particular may be declining, solar is still hampered by the need to supply energy at night, which would require PV plants to be linked to a hydrocarbon generating plant. In other words, a purely PV plant

61 "Cheap Solar Energy Plants to Spread Throughout the Middle East," *National*, July 18, 2017, https://www.thenational.ae/business/energy/cheap-solar-energy-plants-to-spread-throughout-middle-east-1.609849.

62 Anthony Dipaola, "Saudi Arabia Get Cheapest Bids for Solar Power in Auction," *Bloomberg Markets*, October 3, 2017, https://www.bloomberg.com/news/articles/2017-10-03/saudi-arabia-gets-cheapest-ever-bids-for-solar-power-in-auction.

63 Yashar Rajavi, Concentrating Solar Power, Submitted as coursework for PH240, Stanford University. http://large.stanford.edu/courses/2013/ph240/rajavi1/.

64 Susan Kraemer, "SolarReserve Bids 24-Hour Solar at 6.3 Cents in Chile," *Clean Technica*, March 13, 2017, https://cleantechnica.com/2017/03/13/solarreserve-bids-24-hour-solar-6-3-cents-chile/.

A solar enhanced oil recovery (EOR) site in Amal, Oman. *Photo credit:* GlassPoint Solar.

could incur both the cost of the plant plus the cost of a traditional hydrocarbon-based production facility.

The major decline in solar costs in the Middle East is in part due to the great decline in the cost of Chinese mass-produced PV panels, which puts competitive pressure on all the other means of renewable energy production. This cost may decline even further in the Middle East if the case brought before the United States Trade Commission in September 2017 by US solar panel manufacturers succeeds in imposing punitive tariffs on Chinese panels. Indeed, without a US market, Chinese firms will more aggressively price their products where they are welcomed, i.e. in the Middle East.

Another cause of the rapid decline in the bid pricing is that large developers are very aggressively trying to position themselves in the Middle East, especially in Gulf markets. Most developers assume that all the equipment needed in the bid requests, like mirrors, PV panels, converters, etc. are going to continue declining in price as volumes increase, thus they can take the risk of bidding low today for work that will be completed in a couple of years. Large well-capitalized developers also seem to be comfortable bidding low to make sure they get their foot in the door of a growing market. It is important for buyers of renewable facilities to ensure that the bidders, especially the lowest ones, live up to their commitments when construction starts and the hand over of the facilities takes place. It is normal procedure in the Gulf to obtain performance bonds and advanced payment guarantees for all large construction contracts. One can safely assume that these procedures are also followed for renewables bids and that the consulting engineers hired by the buyers of the facilities can ferret out whether the bidders are ultimately able to deliver at the prices offered.

By and large, in the Middle East and other areas endowed with good wind and sun, technological improvements and the economies of scale are making the cost of renewables less and less of an impediment to the growth of renewables.

CONCLUSION

The recent growth of renewables in the Middle East is remarkable. Countries have realized that they need to limit the domestic use of their hydrocarbon reserves. The local demand for energy is growing exponentially, which hurts the countries in two ways. First, the fuel used locally could instead be exported, increasing income. Second, the rapid increase in the use of oil and gas to generate electricity and desalinate water has made the region and the countries within it major carbon emitters, undermining efforts by many countries to be viewed as contributors to environmental progress. In the case of countries like Jordan and Morocco, which do not have important hydrocarbon resources, an aggressive policy to become largely independent from imported oil or natural gas is vital to providing economic growth and jobs to their people.

The growth of renewables, which helps mitigate the region's carbon footprint, also contributes to economic growth. However, growth does come at a price. In the Gulf states in particular, growth means increased demand for desalinated water, which contributes to the important and growing problem of the 60 million tons per day of brine production mostly pumped back into the Gulf. Renewables do not cause the pollution, but as their use increases, their indirect contribution to the pollution of the Gulf increases as well.

As renewables become a major part of energy use globally and in the Middle East, the need for hydrocarbon will slow, and perhaps even start declining. While this will not happen in the very near future, it will eventually impact the demand for the oil and gas that made the Middle East producers what they are today. Hence it is important for the Middle East countries to continue to increase their efforts not only to install renewables at home, but also to become experts in renewable technologies, which they in turn can export worldwide, just like they export hydrocarbon today.

Therefore, Middle Eastern countries will do well to continue in their efforts to control the technologies, engineering, and equipment associated with renewable energy. Whether done by private companies seeking to benefit from the problems associated with renewables or by state-sponsored research establishments, it will greatly benefit the region to make the growth of local producers of technology a priority. As described, there are already a number of renewables institutions based in the region. However, more efforts have to be initiated and more incentives have to be provided to ensure that the Middle East states and local firms obtain, control, and build the technology and products of renewables, just as Saudi Aramco and SABIC in the chemicals business have come to be technology leaders in their own right. Saudi Aramco and SABIC have learned technology, technical sales, and best practices through strategic joint ventures and worldwide acquisitions. In the realm of renewables, the local firms will also learn from their various joint ventures and foreign acquisitions. It will be important for the Gulf states not only to gradually take ownership of the technology, but also manufacture all components that could be competitively exported. The large, efficient industrial cities and free trade zones of the Gulf will help achieve the lowest possible cost for renewable technology and components for use in the Middle East.

The sovereign wealth funds of the Gulf, in particular Saudi Arabia's newly expanded Public Investment Fund and the UAE's large funds, like ADIA and Mubadala, may seek to fund local companies and acquire foreign ones with a view to ultimately own and control as much of the renewables supply chain as possible. For example, there could be further joint ventures with Chinese producers for PV panels and wind turbines, or US and European firms in CSP and wind turbines. Companies with interesting concepts in organizing efficient use of renewables, like Tesla[65] is doing with its roof to wall batteries concept, may become targets of investment by Middle Eastern investors, both private and public.

The pursuit of renewable energy in the Middle East will continue to be a challenge, but the countries of the region now see that they can develop their natural advantage in sunlight and wind resources. The countries with hydrocarbon resources are starting to plan for a post-oil era, and those without can become leaders in new energy production.

65 Note: the author has no financial interest in Tesla or any other renewables company.

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