Middle East Institute

MENA'S EMERGENCE AS A HUB FOR RENEWABLE ENERGY SUPPLY CHAINS

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Key Points

- Within the next 25 years, the Middle East and North Africa will be a global leader in renewable energy production and a hub for international renewable energy supply chains.
- Morocco, the United Arab Emirates, and Jordan are spearheading the regional trend to develop green energy ecosystems in which renewable energy is used, in part or entirely, to power the manufacture of intermediate and finished goods for export. Egypt and Saudi Arabia have also made progress in this direction. There have also been some positive trends in several other MENA nations, but they will need to develop their own green energy ecosystems and/or integrate into those being developed elsewhere to expand capacity and participate in international supply chains.
- Barring a paradigm-shifting technological breakthrough, green ammonia and fertilizer production will play a central role in catalyzing the development of new renewable power generation capacity in MENA.
- Green metals processing, especially of aluminum, steel, and electric vehicle battery metals, holds great promise across MENA as an on-ramp to industrial manufacturing powered by renewable energy.
- Dedicated renewable power generation facilities increase the likelihood of the construction of undersea electricity interconnections for the export of MENA-produced renewable energy to Europe or India.

Introduction

The Middle East and North Africa will become one of the world's foremost renewable energy producing regions and a hub for international renewable energy supply chains within the next 25 years. Morocco, the United Arab Emirates, and Jordan are spearheading the trend in the region through the development of their respective green energy ecosystems. Egypt and Saudi Arabia have taken some initial steps toward their own green energy ecosystems. While there have also been some positive trends in several other MENA nations, they will need to develop their own green energy ecosystems and/or integrate into those already being developed by their neighbors to expand capacity and participate in international supply chains.

Green Energy Ecosystems and International Renewable Energy Supply Chains

The formation of green energy ecosystems has started to catalyze the widespread adoption of renewable energy in the MENA region. A green

energy ecosystem arises when the development of utility-scale renewable energy infrastructure is anchored to the coordinated development of diverse offtake markets and corresponding storage and transportation mechanisms. Beyond just direct exports of electricity generated from renewable sources, a multi-faceted green energy ecosystem gives rise to international renewable energy supply chains based on the country's production and export of green hydrogen, in the form of green ammonia, and of minerals and metals, fertilizers, agri-food products, and industrially manufactured goods — the production of which is increasingly powered, in part or entirely, using renewable energy resources. Private sector investment and the construction of dedicated renewable power generation capacity are key elements of a green energy ecosystem. More amenable to international private sector participation, green energy ecosystems critically shift the financing for construction of renewable power generation capacity to foreign direct investment (FDI) and joint venture partnerships, lessening the reliance on foreign development aid and international loans that increase national debt burdens.

Green Energy Ecosystems and Energy Carriers for Export: Electricity and Green Ammonia

Cross-border electricity interconnections form an offtake mechanism for renewable energy exports but are insufficient for creating robust renewable energy supply chains. The general lack of progress in the development of trans-Mediterranean interconnection for MENA renewable power exports to the wider European Union market stems from the lack of deliberate coordination between renewable power generation capacity and the construction of interconnections as offtake mechanisms. The $20 billion Morocco-to-UK Xlinks interconnector is the outlier that proves the point. During 2024, the Indian state-run electricity grid operator began advanced discussions with the UAE, Saudi Arabia, and Oman to establish a 2.5 GW electricity interconnector across the Arabian Sea that could transport renewable energy to India, a market opportunity for the Gulf countries on a similar scale to that of the EU. Dedicated solar and wind power infrastructure, along the lines of the Xlinks model, would facilitate the realization of an Arabian Peninsula-to-India interconnection.

Transporting renewable energy on demand as seaborne green ammonia exports greatly expands the scope of opportunities for developing a diverse array of renewable energy supply chains. A versatile energy carrier, the most cost-effective way to store and transport green hydrogen is in the form of its derivative green ammonia. Since ammonia is one of the basic inputs for fertilizer manufacturing — currently accounting for about 70% of global consumption — there is already offtake demand. Green ammonia can easily use existing storage and transportation infrastructure for conventional, natural gas-derived ammonia ("gray ammonia").

Since the 2023 inauguration of steel manufacturing using green hydrogen in Sweden, major green steel production projects are underway across Europe — including in Spain, France, and Germany — as well as in South Korea and Japan. European and Asian green steel production and other green metals processing will expand the export markets of MENA-produced green hydrogen, encouraging increased foreign investment in renewable energy infrastructure in the region. Additionally, the growing use of fuel ammonia in East Asia to replace coal has started to increase East Asian demand for and interest in investing in MENA green ammonia. By 2050, MENA is forecast to earn $130 billion annually from clean hydrogen exports.

More than interconnection projects, green ammonia production plants deliberately coordinate the construction of renewable power generation capacity with offtake storage and transportation mechanisms. This coordination can be seen in several major projects under way in Morocco, which has been at the forefront of green ammonia development in the MENA region.

North Africa

Morocco

Morocco boasts North Africa's most advanced green energy ecosystem and is on track to reach its 2030 target of

Photo above: Protective covers sit on the wing mirrors of a line of new Dacia Sandero automobiles after being shipped from Morocco, at the Port of Marseille, on November 17, 2019. Photo by Balint Porneczi/Bloomberg via Getty Images.

generating 52% of its power from renewable energy sources. Morocco's green energy ecosystem is rooted in the food-water-energy nexus, with renewable energy increasingly used for fertilizer production and water desalination for the agricultural sector, which consumes about 89% of the national water supply. Since the agricultural sector accounts for around 21% of national exports, the greening of its agri-food production will establish new international renewable energy supply chains through food exports.

Taking advantage of Morocco's control of 73% of global phosphate reserves, Moroccan phosphate and fertilizer manufacturing giant OCP is the world's fourth largest fertilizer exporter and is in the process of replacing all its natural gas-derived ammonia inputs with domestically produced green ammonia. The company is working to achieve carbon neutrality across all its operations by 2040 through the construction of dedicated renewable power generation infrastructure. In addition to exporting renewable energy globally in the form of low carbon fertilizers, Morocco anticipates exporting 1-3 million tons of green ammonia annually.

The major industrial pillar in Morocco's green energy ecosystem is the manufacture of electric vehicles (EV) and EV batteries as well as associated mining and metals processing. Morocco's impressive automotive industry now accounts for about 25% of the kingdom's GDP. Renewable energy will be used in the production of EVs, starting with phosphate and phosphoric acid for the manufacture of lithium iron phosphate (LFP) batteries. Additionally, the recycling of EV batteries to obtain lithium and other metals that is underway will eventually be powered by renewable sources as well.

Beyond battery metals, Morocco is developing other green metal production. In December 2022, the kingdom produced its first consignment of green steel with 100% of the material recycled in Morocco and 85% of the processing powered by renewable energy. While Morocco has not yet produced green aluminum, it inaugurated an aluminum waste recovery plant in 2024. These green metals could also be used for automotive components and car bodies as well as in aviation components exports.

Photo above: The Egyptian flag flies over solar panels during the inauguration ceremony for the first stage of the Infinity 50 Solar Park near Aswan, southern Egypt, on March 13, 2018. Photo by Oliver Weiken/picture alliance via Getty Images.

Egypt

Egypt's renewable energy development stands at a crossroads, after almost a decade of progress. By developing natural gas in conjunction with new renewable power generation capacity between 2016 and 2022, Egypt turned an electricity generation capacity deficit into a surplus. Cairo then adopted its Integrated Sustainable Energy Strategy that calls for renewable power to comprise 42% of Egypt's installed power generation capacity by 2035, constituting a 10-fold increase. Cairo envisioned spurring investment in additional renewable power generation capacity with the prospect of electricity exports via interconnection, but following an economic crisis in 2023-24 was compelled to import natural gas for power generation and introduce rolling power cuts. Egypt's lack of an electricity surplus has deterred investment and placed further renewable power development at an impasse.

Egypt's development of a green energy ecosystem that more deliberately connects renewable energy production to a diversity of dedicated offtake mechanisms could help provide a solution. Among the world's top 10 gray ammonia producers, Egypt can utilize its existing ammonia storage and transportation infrastructure for green ammonia to achieve both value-added export revenues and import replacement. The realization of significant green hydrogen projects under exploration in Egypt by international firms could bring the country's green ammonia capacity up to more than half of its conventional ammonia production and help Cairo reach its target of capturing 5-8% of the global market. Beyond direct green ammonia exports, Egypt holds the potential to diversify its international renewable energy supply chains through the export of minerals and metals, fertilizers, and appliance manufacturing powered by renewable energy.

Sudan

Sudan possesses renewable energy resources similar to Morocco and Egypt, but they are almost entirely undeveloped in the war-torn country. Green ammonia production for export or to power mining and cement manufacturing could

incentivize foreign investment in solar and wind power infrastructure development. With its Red Sea ports, Sudan could also supply Asian and European markets.

Algeria

Algeria's renewable power generation capacity is woefully underdeveloped. The 2030 target set by Algeria's Renewable Energy and Energy Efficiency Development Plan of 22 GW of installed renewable power generation capacity would require more than a 2,700% increase in overall capacity within five years. As Africa's largest natural gas producer, Algeria has prioritized gaining market share for so-called blue hydrogen, whose production from natural gas involves the use of a carbon capture mechanism. Algeria and its European partners seek to transport hydrogen via the undersea natural gas pipeline interconnection between Tunisia and Italy, although the technical and commercial viability of such transport remains suspect. In the absence of green hydrogen or the manufacture of Algerian export products manufactured using renewable energy, trans-Mediterranean electricity interconnection via Tunisia will be Algeria's only export offtake option and is unlikely to incentivize significant foreign investment in its renewable energy production.

Tunisia

Tunisia set a 2030 target for renewable power to comprise 35% of its total power generation capacity, representing an almost 900% increase. The 18 small projects tendered in 2023 are insufficient to create a green energy ecosystem or international renewable energy supply chains, but they could provide a vital foundation for the development of both. Tunisia's revision of its legal framework to attract FDI in renewable energy projects and progress on solar and green ammonia production projects offer some reason for optimism.

Tunisia has the potential to develop an export industry for surplus green ammonia or possibly higher-value fertilizer and automotive components manufactured using renewable power.

Trans-Mediterranean interconnection forms an important offtake mechanism for Tunisia, which is partnering with Italy to interconnect their electricity grids, and could facilitate future Tunisian renewable power exports to the wider EU electricity market.

Arabian Peninsula

The United Arab Emirates

The UAE boasts one of the most rapidly growing green energy ecosystems, with over $40 billion of cumulative investment in clean energy projects, and is on track to reach its interim goal of tripling the share of "clean energy" in the Emirati power mix by 2030 to 30% on the way to its 2050 goal of having 44% of its power generation capacity from renewable power. Of the $40 billion in cumulative investment, the UAE has invested $16.8 billion in renewable energy projects across 70 countries, with an eye toward making the UAE's own green energy ecosystem a central organizing hub for inter-regional, renewable energy supply chains.

The UAE's Updated National Energy Strategy aims to make the country a leading producer and exporter of low-carbon hydrogen, with the goal of capturing a 25% market share in European and Asian markets. By 2030, the UAE expects to produce a combined total of 1 million tons of green hydrogen and derivatives from its various operations across the MENA region. With a forecast annual green hydrogen demand of 200,000 tons, the remaining 300,000 tons produced locally and the 500,000 tons produced at Emirati-owned plants outside the UAE are slated for international export. In 2022, the UAE took its first steps in establishing international clean hydrogen supply for metals processing. A year earlier, in 2021, it began its own green energy metals processing, establishing the world's first green aluminum production powered by the UAE's solar power generation infrastructure. Looking to leverage its green aluminum production to aid in leapfrogging directly into EV manufacturing, the UAE opened its first electric car manufacturing plant and is taking steps toward the EV battery manufacturing sector by developing a battery metals recycling industry that will likely be powered by renewable energy.

Saudi Arabia

Saudi Arabia is MENA's largest producer of electric power and needs energy transition to develop a 21st century diversified economy. The kingdom aims for 50% of domestic power to be produced from renewable sources by 2030, requiring total renewable power production about 20 times greater than its 2023 capacity. While the target seems unreachable, the long-term prospects remain strong due to the green energy ecosystem approach that Riyadh has adopted, which includes the development of blue and green ammonia production capacity.

Saudi Arabia's mining and processing of minerals and metals will form a central pillar of its green energy ecosystem. Riyadh has also begun the development of steel and EV battery metals manufacturing plants to supply the development of a domestic EV manufacturing sector.

Qatar

Qatar, the world's third largest liquefied natural gas (LNG) exporter, is looking to use renewable energy to reduce the carbon footprint of its LNG production. Qatar is on track to achieve its original 2030 target of generating 20% of the country's power from renewable energy sources and has revised the target upward to 30%. Despite this achievement, Doha has prioritized capturing a share of the global hydrogen market through blue ammonia and has not made any significant investments in a parallel development track for green hydrogen.

Oman

Oman has proposed ambitious plans to develop a hydrogen-centric economy through building over $45 billion of green hydrogen and green ammonia projects. If Muscat follows the program outlined in a 2023 IEA report, Oman would be able to produce over 1 million tons of green hydrogen by 2030 and 3.75 million tons in 2040 on the way to a 2050 annual output of 8.5 million tons. Although Oman's ports are geographically well suited for green ammonia exports to both Asia and Europe, the sultanate does not have a large conventional ammonia industry to leverage in the transition, and would need an export infrastructure buildout equivalent to 20 times the present capacity.

Kuwait

Despite investing in the development of renewable energy abroad, Kuwait has no utility-scale, renewable power infrastructure. In January 2024, the country restarted its renewable energy development by issuing a new tender for the construction of a moribund solar plant. Kuwait's path to developing a green energy ecosystem could emerge from using renewable energy to reduce the carbon footprint of its upstream oil production. Kuwait's long-term role in renewable energy supply chains remains obscure and may mostly depend on continued smart investments in green energy ecosystems in other MENA countries.

The Levant

Jordan

The Kingdom of Jordan is the sole Levant country with enough available land to accommodate the distributed nature of utility-scale renewable power generation infrastructure, which may enable Jordan to become the anchor of cross-border supply chains within and beyond the sub-region. By the end of 2023, renewable power accounted for 27% of Jordan's total installed capacity, prompting Amman to raise its 2030 generation target from 30% to 50%. The kingdom must upgrade and expand the national power grid to become a renewable energy supply chain hub via international electricity interconnection.

Jordan is also developing its green hydrogen sector as an alternative offtake mechanism, aiming for an initial annual production capacity of 500,000-600,000 tons during the present decade. Based on the 13 memorandums of understanding (MoU) Jordan signed in 2023, the kingdom could produce up to 2.35 million tons of green hydrogen or its green ammonia equivalent, upon the completion of the intended projects.

The potential hydrogen utilization capacity by Jordanian industries is 57,000 tons per year. Jordan can replace its

Photo above: Visitors inspect Saudi Aramco's H_2 hydrogen-powered racing truck, developed by Gaussin, during the Dakar Rally in Riyadh, on January 8, 2022. Photo by Tasneem Alsultan/Bloomberg via Getty Images.

entire consumption of gray hydrogen with green hydrogen with almost 10 times the amount of green hydrogen remaining for domestic power consumption or export to major European and Asian markets.

To address the kingdom's water crisis, Jordan is building a solar-powered water desalination plant in Aqaba and entered into a UAE-brokered water-for-energy deal with Israel in 2021, but Jordan backed out two weeks prior to the signing date over Israel's conduct in the Gaza war. Jordan has also been looking at alternative geographies for renewable energy supply chains, including electricity transmission deals with Iraq and Lebanon. Regional cooperation in the Levant is essential for the establishment of renewable energy supply chains to the European electricity market, particularly given the recent progress in advancing an Israel-based electricity interconnector to Europe.

Moving MENA Forward: Green Energy Ecosystems and Renewable Energy Supply Chains

Barring paradigm-shifting new technologies in energy storage and transport, the versatility of green hydrogen exports in the form of seaborne green ammonia will play a prominent role over the next five years in shaping the map of renewable energy supply chains across the MENA region. With exception of interconnectors such as the $20 billion Xlinks project running from Morocco to the UK, green ammonia projects are proving themselves more amenable to deliberate coupling of renewable energy infrastructure development with international offtake markets. The UAE and Saudi Arabia could play increasingly formative roles in organizing the seaborne flows of MENA-produced green ammonia to European and Asian markets, with Morocco forming a distribution hub to Europe and Egypt or Oman possibly playing a similar role for both and especially Asian markets.

The map of MENA-centered renewable energy supply chains will be shaped by the diversity and robustness of green energy ecosystems within the MENA nations themselves. Beyond renewable energy exports via electricity interconnection and seaborne green ammonia, MENA nations — through the development of renewable energy-powered manufacturing and agri-food production — will be shipping renewable energy in the form of higher-value-added products.

One of the first of these high-value-added products will be green fertilizers produced from green ammonia. Morocco will be the main producer of green fertilizers in the MENA region. The UAE's green ammonia facilities at home and in Egypt could be engaged in the production of green fertilizers. Saudi Arabia and Jordan also possess strong potential for production in the near term, while the development production capacity remains both possible and desirable for Algeria, Tunisia, and Oman.

The development of minerals and metals processing with renewable energy will increasingly shape the map of regional-based renewable energy supply chains over the next five years. The UAE has already pioneered the production and export of green aluminum. Morocco has initiated the production of green steel and is poised to initiate the processing of green EV battery metals. Saudi Arabia could emerge as the region's main green metals processor. Egypt, Algeria, Tunisia, Jordan, and Sudan could also become green metals exporters of varying scales.

Green mobility is shaping up as the premier sector in the MENA region for the use of renewable energy in industrial manufacturing. Morocco is the region's undisputed leader in overall EV manufacturing, with the UAE and Saudi Arabia recently launching their first embryonic ventures. All three will leverage their comparative advantages in green metals processing of aluminum, steel, and EV battery metals to expand market share. The manufacture and export of products from cement to home appliances could establish new renewable energy supply chains for countries such as Egypt, Jordan, and Oman.

Recommendations

To support the formation of green energy ecosystems, transition to use of renewable energy, and emergence of the MENA region as a hub for international renewable energy supply chains, the following steps should be taken:

- Create a MENA regional platform for the export of green ammonia beyond the region;
- Construct dedicated power plants for undersea electricity interconnectors between MENA and the European Union and the Arab Gulf states and India;
- Promote private sector investment in green fertilizer production in Oman, Egypt, Algeria, Tunisia, Jordan, and Sudan;
- Promote private sector investment in green mining and metals processing in Egypt, Algeria, Tunisia, Jordan, and Sudan; and
- Promote private sector investment in green industrial manufacturing of inputs and finished goods in already existing manufacturing sectors among the MENA nations (e.g. appliance manufacturing in Egypt).

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Main photo: Aluminium from Dubai produced using solar energy at the opening of a new electric car motor housing production line at the BMW Landshut factory on October 25, 2024 in Ergolding, Germany. Photo by Leonhard Simon/Getty Images.