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Emerging Technologies, Innovations, and Policy Gaps in the Green Energy Transition:

Opportunities for the acceleration of NDC implementation in Arab States

United Nations Development Programme

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This publication has been developed with contributions from the MENA Clean Energy Business Council (CEBC) under a partnership between UNDP's Regional Bureau for Arab States and CEBC that aims to strengthen collaboration and cooperation on climate change, sustainable energy, and the energy-water nexus.

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List of acronyms

BAU	Business as Usual
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture, Utilization, and Storage
CFL	Compact Fluorescent Lamp
COP	Conference of the Parties
CSP	Concentrated Solar Power
DSM	Demand-Side Management
EPC	Engineering, Procurement and Construction
ESCO	Energy Service Company
EU	European Union
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
JREEEF	Jordan Renewable Energy and Energy Efficiency Fund
LAS	League of Arab States
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MENA	Middle East and North Africa
MSW	Municipal Solid Waste
NDC	Nationally Determined Contribution
NEOM	A planned cross-border city in the Tabuk Province of northwestern Saudi Arabia, significant for its green hydrogen production and sustainable technology initiatives.
O&M	Operations and Maintenance
OPEC	Organization of the Petroleum Exporting Countries
PV	Photovoltaic
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RE	Renewable Energy
R&D	Research and Development
SEEC	Saudi Energy Efficiency Company
T&D	Transmission and Distribution
TCFD	Task Force on Climate-related Financial Disclosures
TSO	Transmission System Operator
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
V2G	Vehicle to Grid
W2E	Waste to Energy

Executive summary

The Arab States region has demonstrated a deep political commitment to the 2030 Agenda for Sustainable Development and the Paris Agreement, with many countries setting clean energy transition targets to be achieved by 2030-2035 and net-zero emissions commitments by 2060 or earlier.

To date, almost all Arab States have submitted a Nationally Determined Contribution (NDC), outlining their commitments to mitigate and adapt to climate change, while 17 countries have submitted updated or new NDCs since 2016, reflecting the ratcheting of their commitments. This policy brief examines technologies, innovations and policy gaps in renewables, energy efficiency and hydrogen across 17 Arab States, grouped into four distinct categories, and presents recommendations for practical steps to advance the green energy transition.

Collaboration between the private and public sectors will be critical to achieving decarbonization and clean energy targets. The region is home to tremendous renewable energy resources, including potential for generating electricity and green hydrogen from solar and wind power technologies. Renewable energy investments are becoming more attractive, aided by a 58 percent fall in the IEA's index of clean energy equipment costs between 2014 and 2020.[1] However, the progress in deploying clean energy technologies is uneven across the region and energy demand will only continue to grow. Energy demand in the Middle East and North Africa (MENA) region is expected to increase at an annual rate of 3 percent and electricity demand at 6 percent over the 2010-2030 period.[2] Energy efficiency measures on the demand and supply side will be critical to ensuring that renewable energy additions are not outpaced by growing energy demand.

Opportunities for the private sector emerge across the value chain. In solar Photovoltaic (PV), concentrated solar power (CSP) and wind, localization opportunities depend on the existing availability of technology, finance and human capital. In countries with readily accessible finance, investment in the manufacturing of solar cells or thermal storage components is possible. Countries with a skilled workforce have the potential to localize the assembly of solar modules and all countries with an industrial base have been capable of localising the engineering, procurement and construction (EPC) segment of the value chain. In the area of energy efficiency, energy services companies (ESCOs) represent a substantial opportunity to generate value for local economies by relying on local materials and the domestic workforce for decarbonization measures. Lastly, in the emerging hydrogen economy, localization opportunities lie in the production, transport (via ships, trucks or pipelines) and storage of hydrogen, transformation (into synthetic fuels or green ammonia) and end use (in industry, transport and energy storage).

Policy and regulation will be key factors enabling the transition to a green energy economy. The most suitable policy tools will vary depending on country-specific conditions, including the current state of energy infrastructure, access to finance, administrative capacity and the current energy mix. Broadly, the recommended policies can be grouped into fiscal measures (e.g. subsidies and rebates for deployment of renewable power generation, energy-efficient appliances and retrofits), enabling environment measures (e.g. establishing markets for services incentivising modernisation of the grid, facilitating establishment of ESCOs, etc.) and the development of infrastructure (direct role of governments in building grids, storage capacity, interconnections, etc.).

Access to finance is a critical factor that will allow countries to meet their energy transition goals and NDC commitments. Arab States should continue to pursue measures that create enabling environments for channelling finance toward sustainable investments, such as developing a harmonized green finance taxonomy and promoting climate-related financial disclosures. Additionally, available financial mechanisms should be used, including issuing green bonds and green sukuk, developing regional carbon markets and leveraging the investment power of sovereign wealth funds.

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1 World Bank Group. (2023). Global Solar Atlas 2.0.

2 European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.


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1. Introduction

The objective of this policy brief is to inform the public and private sectors about effective and innovative policies that can be used to deploy low-carbon efficient technologies and accelerate the green energy transition in Arab States.

This policy brief is guided by the technological priorities identified by each Arab State in their national climate pledge, or Nationally Determined Contribution (NDC), submitted to the United Nations Framework Convention on Climate Change (UNFCCC).

In 2015, at COP21, world leaders collectively adopted the Paris Agreement and committed to limit global temperature rise to 1.5° to 2.0°C above pre-industrial levels. For the world to realize the Paris Agreement goals and avert catastrophic climate change, there is an urgent need to pivot towards decarbonization. According to the IPCC, this requires achieving net-zero emissions by 2050.[3] At COP27 in Sharm el-Sheikh, a mitigation work programme was launched to urgently scale up mitigation ambition and implementation.

For Arab States, climate change impacts are going to affect the energy sector in multiple ways. Decreasing rainfall and increasing incidents of drought will have negative impacts on water-cooled thermal power plants, reduce efficiency of power generation (thermal, solar PV and wind) and threaten hydropower availability, especially in the Mediterranean basin.[4] The number of cooling degree-days is also increasing and will push up peak electricity demand in the summer.[5]

Within this context, the Arab States region has demonstrated a deep political commitment to the 2030 Agenda for Sustainable Development and the Paris Agreement and has catalysed various mitigation-related measures in response to the current level of regional and global emissions. To date, almost all Arab States have submitted an NDC, outlining their commitments to mitigate and adapt to climate change, while 17 countries have submitted updated or enhanced NDCs since 2016, reflecting the ratcheting of their ambition and commitments.

All countries in the Arab States region have established clean energy transition targets to be achieved by 2030-2035. Additionally, at least five Arab States[6] pledged or presented policy documents committing to net-zero emissions by 2060 or earlier. It will be difficult, however, for the public sector alone to achieve those targets without the private sector.[7] The private sector brings

3 IPCC. (2018). The Special Report on Global Warming of 1.5°C.

4 International Energy Agency. (2023). Climate Resilience Is Key to Energy Transitions in the Middle East and North Africa.

5 Ibid.

6 Bahrain, Kuwait, Oman, Saudi Arabia and The United Arab Emirates.

7 Vera Songwe, Nicholas Stern and Amar Bhattacharya. (2022). Finance for climate action: Scaling up investment for climate and development - Report of the Independent High-Level Expert Group on Climate Finance.

agility, capital, innovation and skills that are critical to designing, financing and building low-carbon solutions.

The region is home to the highest levels of solar irradiance in the world and it has strong onshore wind resources across Northern and Eastern Africa and throughout the Gulf.[8] Returns on investment for renewable energy are aided by a 58 percent fall in the International Energy Agency's (IEA) index of clean energy equipment costs between 2014 and 2020, although higher input costs have recently nudged prices up.[9] The synergy between strong renewable resources and low costs has resulted in some of the world's largest and cheapest solar photovoltaic (PV) and concentrated solar power (CSP) projects developed in the Arab States (e.g. Saudi Arabia, the UAE).[10]

However, the progress in deploying clean energy technologies is uneven across the region and demand will only continue to grow. Energy demand in the MENA region is expected to increase at an annual rate of 3 percent and electricity demand at 6 percent over the 2010-2030 period.[11] In the face of this growing demand, ensuring access to, and use of, clean energy technologies will be paramount to decarbonization efforts.

The private sector shoulders significant responsibility for the successful and timely implementation of clean energy transition projects. A major impediment in the region is the heavy dependence on imported products and critical technological elements related to accelerating the clean energy transition. The past few years have demonstrated the fragility and ability of global supply chains to rapidly increase in cost as they are impacted by international conflicts and pandemics. From initial experiences of clean energy project implementation, it is important to consider the need for both regional technology transfer and supply chain diversification to enhance regional and national energy security. Reducing policy barriers and perceived risks to potential investors will further promote the creation of high-skill green jobs.


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8 IEA. (2023). World Energy Investment 2023; Technical University of Denmark (DTU). (2023). Global Wind Atlas.

9 World Bank Group. (2023). Global Solar Atlas 2.0.

10 Energy & Utilities. (2021). Saudi Arabia achieves two new world record solar tariffs.; Emirates Water and Electricity Company. (2020). Abu Dhabi Power Corporation Announces Lowest Tariff for Solar Power in the World.; NREL. (2023). Concentrating Solar Power Projects by Country.

11 European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.

2. Regional focus

This policy brief discusses emerging technologies, innovations, and policy opportunities for the green energy transition in the 17 Arab States where UNDP is currently operating.

These countries and territories include Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, the State of Palestine, Saudi Arabia, Somalia, Sudan, Syria, Tunisia and Yemen. Additionally, the brief will explore case studies from the UAE and Oman to showcase policy success and the potential for private-sector investment.

The countries targeted by this work are located along the coasts of the Mediterranean Sea, Red Sea, and the Arabian Gulf. Most of the population in these countries lives in areas with relatively high ambient temperatures and low levels of precipitation. The economic and political circumstances of these countries are very different, however, ranging from high-income countries of the Gulf Cooperation Council (GCC) to fragile economies of Libya, Somalia, Sudan, Syria and Yemen that have suffered from armed conflicts over the past decade. The wide range of gross domestic product (GDP) per capita in these countries is shown in Figure 1 (overleaf). Apart from Sudan with hydropower capacity of 1,928 MW, fossil fuels are the main source of electricity by a wide margin, as shown in Figure 2 (overleaf). In this brief, countries are separated into three groups, based on similar opportunities and challenges, and relevant recommendations are presented for each group.

Group 1: Djibouti, Lebanon, Somalia, Sudan, Syria and Yemen

Group 1 comprises low-income and lower-middle-income countries that have low levels of primary energy consumption (see Figure 1) and fall short of universal electricity access (except for Lebanon) (see Figure 2). Over the past decades, they have faced political and economic instability that jeopardised the investment landscape, resulting in a high cost of capital exceeding 20 percent (see Figure 2). Within the group, Sudan has considerable renewable energy penetration at 52 percent of total installed power generation capacity and Yemen, Syria and Lebanon have emerging renewable energy sectors (see Figure 3, overleaf). While Sudan, Syria and Yemen are net oil exporters, the role of the oil sector is limited in these economies. Heavy reliance on oil for power generation is a distinguishing factor of this group and ranges between 30-100 percent.[12]

Group 2: Egypt, Jordan, Morocco, the State of Palestine and Tunisia

Group 2 represents a set of middle-income countries with universal access to electricity that have made significant strides in creating an enabling environment for energy transition. Egypt, Jordan, Morocco and Tunisia are the top four highest-scoring countries in the

12 Hannah Ritchie and Max Roser. (2022). Our World in Data. Electricity Mix.

Arab Future Energy Index.[13] Their energy consumption remains relatively low (see Figure 1), with imported fossil fuels serving as the primary source of electricity generation in this group (mainly natural gas and in Morocco, coal),[14] given that these countries do not have significant hydrocarbon reserves. Egypt, Jordan, Morocco and the State of Palestine have emerging renewable power generation capacities based on variable sources.

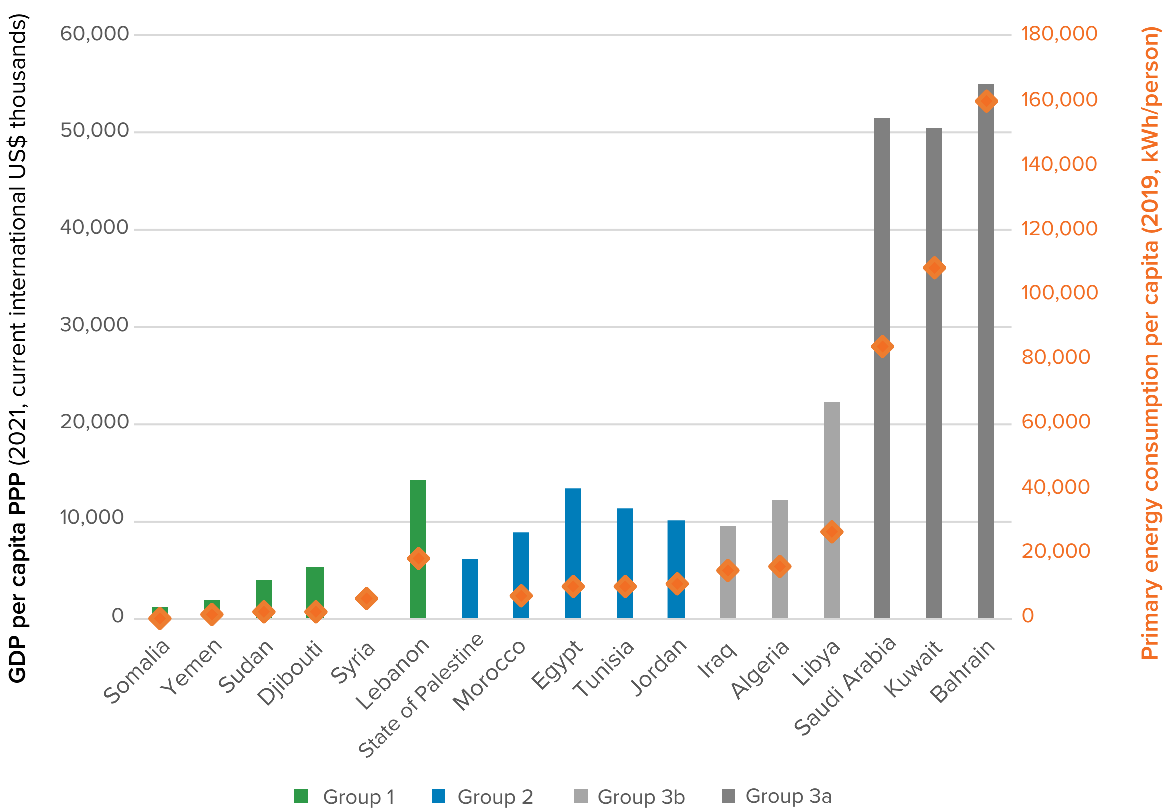
Group 3: a) Bahrain, Kuwait, Saudi Arabia; b) Algeria, Iraq, Libya

Group 3 is composed of six countries that are major fossil fuel exporters. Within this group, two subgroups can be identified: (3a) high-income: Bahrain, Kuwait and Saudi Arabia; and (3b) middle-income: Algeria, Iraq and Libya.

These countries have nascent renewable energy sectors, with virtually all power coming from natural gas and oil (see Figure 3). While the high-income countries all enjoy universal electricity access, a low cost of capital (see Figure 2) and have announced net-zero emissions targets by 2060, the middle-income countries face some economic, political and technological challenges. In Libya, only 70 percent of the population has electricity access and in Iraq, the cost of capital exceeds 15 percent (see Figure 2). The Gulf states have the highest scores for energy equity in the world due to the high level of subsidies provided by those governments.[15]

The United Arab Emirates and Oman don't have an operational UNDP programme, but they are part of the GCC and offer relevant insights to this study. They would fall into Group 3a and will be referenced in this report as appropriate.

Figure 1. GDP per capita and primary energy consumption per capita in Arab States



Source: The World Bank. (2022). GDP per capita, PPP.; Energy Institute. (2023). Our World in Data. Energy use per person.

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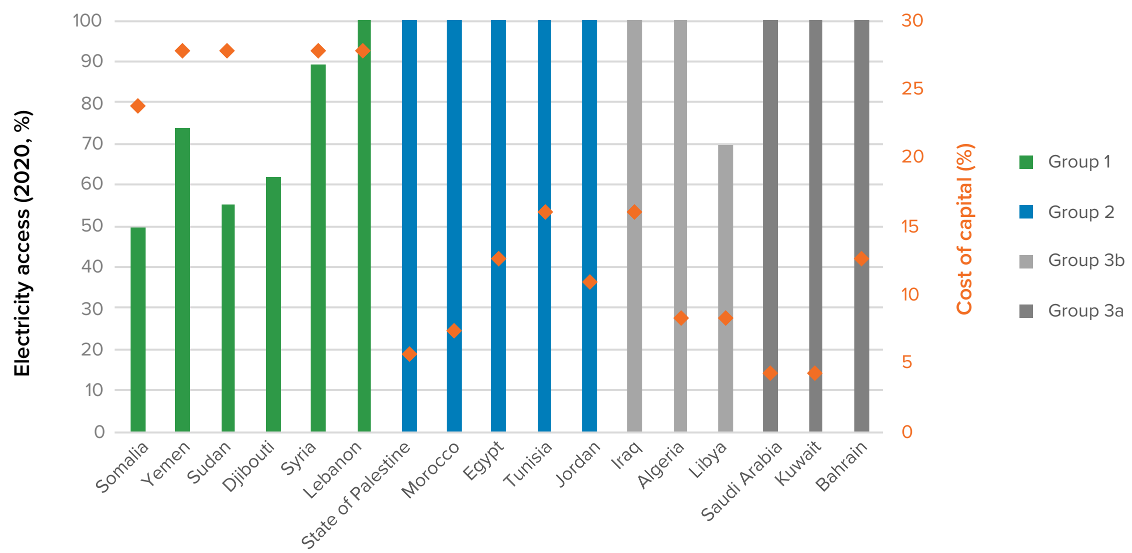
13 Arab Future Energy Index 2023, ranks 20 Arab countries under more than 50 indicators that illustrate key energy market aspects including policies, institutional and technical capacities, strategies, socio-economic data and investments.

14 Hannah Ritchie and Max Roser. (2022). Our World in Data. Electricity Mix.

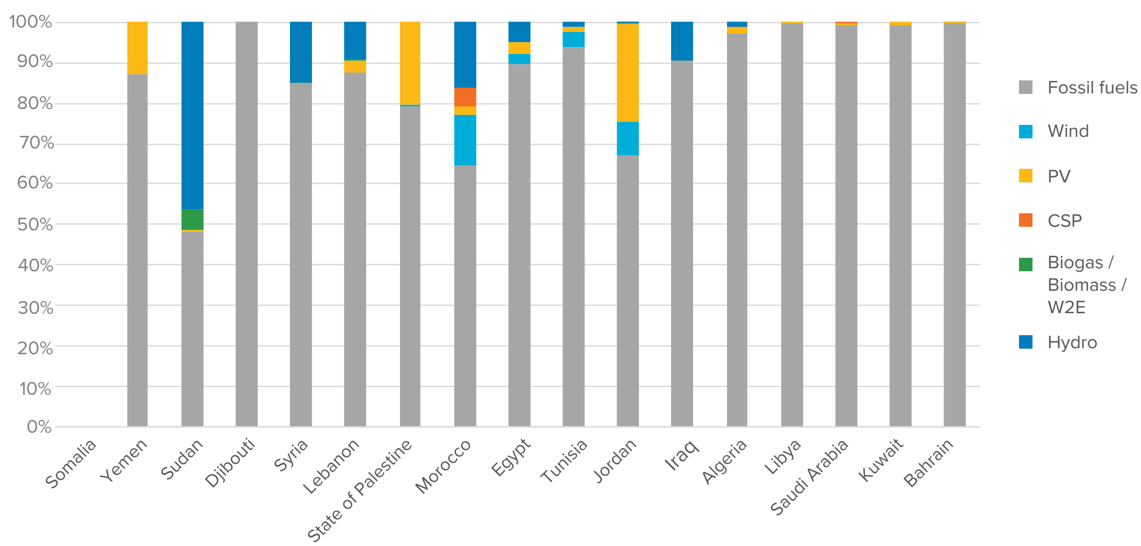
15 World Energy Council. (2022). World Energy Trilemma Index 2022.

Figure 2. Electricity access and cost of capital in Arab States



Source: The World Bank. (2023). Our World in Data. Electricity access.; Aswath Damodaran. (2023). Country Default Spreads and Risk Premiums.

Figure 3. Types of installed power generation capacity in Arab States



Source: Ali Habib, et al. (2023). Arab Future Energy Index 2023. RCREEE, UNDP, Government of Sweden, SDG Climate Facility.

2.1. NDC orientation

NDCs are voluntary pledges of mitigation and adaptation targets and actions that countries make to limit and reduce their greenhouse gas emissions and build resilience to climate change. Out of 17 countries in the scope of this brief, 12 countries have submitted enhanced NDCs that were updated since their submission in 2016 (Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Morocco, Saudi Arabia, Somalia, State of Palestine, Sudan and Tunisia). Among the other five countries (all in Groups 1 and 3b), Libya never submitted an NDC, Yemen only submitted an Intended NDC (INDC) and Algeria, Djibouti and Syria only submitted their initial NDC and did not update.

NDCs provide guidance about priority sectors and actions that each country aims to take, including how they will pursue their energy transition. Understanding the target technologies for each country provides insight into emerging market opportunities. However, NDCs do not provide a complete picture of the national energy transition plans as they:

- Are often not intended to provide an extensive technological roadmap and are complemented by more detailed climate and sector strategies, domestic energy strategies and/or net-zero strategies;
- Are updated every five years and may not capture more recent priorities[16]; and
- Summarize public sector priorities in the area of climate action and energy transition, potentially missing opportunities being independently pursued by the private sector.

NDCs of the Arab States were reviewed and four technology focus areas emerged:

1. Renewable energy (including solar, wind, waste-to-energy and other sources, such as geothermal, hydro, ocean);
2. Demand-side efficiency (including appliances, buildings and cities, and industry [covers Carbon Capture, Utilization and Storage (CCUS)]);
3. Supply-side efficiency (including power generation efficiency and grid); and
4. Hydrogen.

A summary of the coverage of these technologies in the NDCs is shown in Table 1. Broad coverage of these technologies across countries highlights their popularity. Renewable energy technologies, in particular, wind and solar, and demand-side efficiency are the most common measures. Among the groups, countries in Group 2 exhibit the most robust NDCs (in particular, Egypt, Jordan and Morocco). This is coherent with the findings of the Arab Future Energy Index, which placed Egypt, Jordan, Morocco and Tunisia as four-top scoring countries.[17]

Table 1. Review of technologies covered in Arab States NDCs

	RE	Solar	Wind	W2E	Other	Demand-side efficiency	Appliances	Buildings and cities	Industry	Supply-side efficiency	Power generation efficiency	Grid	Hydrogen
Somalia	x	x	x			x	x			x		x	
Yemen*	x	x	x	x	x	x	x	x	x	x	x		
Sudan	x	x	x	x	x	x	x			x		x	
Djibouti*	x	x	x	x	x	x	x	x					
Syria*	x	x		x		x		x	x				
Lebanon	x					x		x	x				
The State of Palestine	x	x		x		x		x	x	x		x	
Morocco	x	x	x		x	x	x	x	x	x	x	x	
Egypt	x	x	x	x		x	x	x	x	x	x	x	x
Tunisia	x	x		x		x			x	x	x	x	
Jordan	x	x	x	x		x	x	x	x	x		x	x
Iraq	x	x	x	x	x	x	x	x	x	x	x	x	
Algeria*	x					x	x	x	x	x	x		
Libya**													
Saudi Arabia	x	x	x	x	x	x	x	x	x	x	x	x	x
Kuwait	x					x	x	x	x	x	x	x	
Bahrain	x	x	x	x		x							

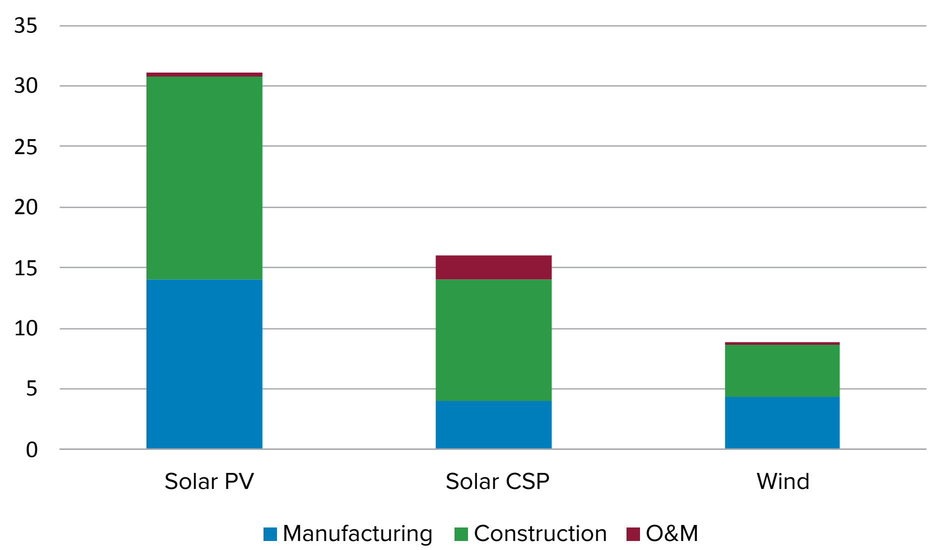
To note: * = INDC or one NDC; ** = no NDC/INDC
Source: UNFCCC. (2023). NDC Registry.

16 Aside from Egypt and Sudan, the NDCs explored in this brief are from October 2021 or earlier.
17 Ali Habib, et al. (2023). Arab Future Energy Index 2023. RCREEE, UNDP, Government of Sweden, SDG Climate Facility.

2.2. Localization

Localization of manufacturing and services is an increasingly popular strategy driven by the desire to reduce exposure of supply chains to geopolitical risks.[18] This trend also impacts the implementation of NDCs, as countries aim to capture long-term economic value of the green transition by localizing clean technology manufacturing and services. Localization of supply chains, including the processing of raw materials and manufacturing, has the potential to develop new high value-add industries, improve energy security and create jobs. This will be achieved through technology transfer, for example, by establishing joint ventures between local companies or investors and international companies. Data on job creation potential in renewable energy industries is shown in Figure 4.

Figure 4. Job creation in renewable energy industries in full-time equivalent jobs (FTE) per MW of installed capacity



Source: European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.

There are many references to localization in NDCs. For example, Saudi Arabia aims "to diversify local energy sources, stimulate economic development and establish the local renewable energy supply chain and industry."[19] Similarly, according to its NDC, Iraq "is considered a promising area for the localization of [renewable energy] technology."[20] Localization will also reduce dependency on imported technologies and improve resilience to the fragility of global supply chains that may be disrupted by geopolitical tensions, trade disputes, pandemics and conflict.

Broader economic trends point to the importance of localization, including many campaigns launched in recent years in the region, such as the 'Make in the Emirates' and 'Made in Saudi' initiatives. Countries pursue these efforts through local content policies, reforms encouraging foreign direct investment and improvements to the physical and digital infrastructure.[21] However, there are constraints to localization, including the availability of a skilled workforce, market integration and maintaining a friendly business environment.[22] A comparative summary of pros and cons for localization of the solar energy value chain is shown in Table 2 (overleaf).

18 Goldberg, P. & Reed, T. (2023). Brookings Papers on Economic Activity. Is the Global Economy Deglobalizing? And if so, why? And what is next?

19 Kingdom of Saudi Arabia. (2021). Updated First Nationally Determined Contribution.

20 Republic of Iraq. (2021). Summary of First Nationally Determined Contribution (in Arabic).

21 The Economist Intelligence Unit. (2021). The power of proximity: Localising supply chains in the Middle East.

22 Ibid.

Table 2. Advantages and disadvantages of localizing the solar energy value chain

Pros of localization	Cons of localization
◆ Jobs creation and reduced unemployment in manufacturing, installation, maintenance, and research and development. ◆ Reduced dependency on international supply chains, making them more resilient to shocks and disruptions. ◆ Technology transfer fosters collaboration between local stakeholders, leading to innovation. ◆ Reduced transportation costs associated with importing solar panels and components. ◆ Higher efficiency thanks to better customization of solar technology to local conditions, including climate, grid requirements and building designs. ◆ Nurturing competitive domestic industry that can increase exports.	◆ Significant upfront investment costs for manufacturing facilities that may result in higher initial costs for solar projects. ◆ At the onset, potentially lower quality and higher costs of manufacturing, which should be addressed by the government through standardization for products and services. ◆ Local manufacturers are unable to obtain the economies of scale that international companies benefit from. ◆ Basing localization of manufacturing on governmental support makes the industry vulnerable to political changes. ◆ Localization of a value chain is a time-consuming process.

The value chain of green energy technologies spreads across equipment manufacturing, EPC, and operations and maintenance (O&M). Gradual localization that prioritizes action in areas with existing capacities allows countries to reap the benefits of localization while avoiding potential disadvantages. Therefore, governments should focus on increasing local contributions in parts of the value chain where products or services can be provided efficiently, affordably, and at high quality. Table 3 shows the breakdown of the value chain for the main renewable energy technologies. While localization of component manufacturing would generate benefits to the local community, there are robust opportunities across the EPC and O&M segments.

Table 3. Renewables value chain breakdown

Technology	Major equipment components	Engineering, procurement, and construction (EPC)	Operations and maintenance (O&M)
Onshore wind	**57%** ◆ Turbine ◆ Blades ◆ Tower	**22%** ◆ Civil works (44%) ◆ Balance of system (31%) ◆ Other costs (25%)	**21%** ◆ Routine inspection ◆ Preventive maintenance ◆ Corrective maintenance
Solar PV > 1 MW	**54%** ◆ PV module	**36%** ◆ Civil works (57%) ◆ Balance of system (29%) ◆ Other costs (14%)	**10%** ◆ Routine inspection ◆ Preventive maintenance ◆ Corrective maintenance
Solar PV < 1 MW	**45%** ◆ PV module	**46%** ◆ Civil works (57%) ◆ Balance of system (29%) ◆ Other costs (14%)	**9%** ◆ Routine inspection ◆ Preventative maintenance ◆ Corrective maintenance
Solar CSP	**36%** ◆ Solar field (80%) ◆ Thermal storage system (20%)	**55%** ◆ Civil works (35%) ◆ Balance of system (30%) ◆ Other costs (35%)	**9%** ◆ Routine inspection ◆ Preventative maintenance ◆ Corrective maintenance

Source: infoDev. (2014). Building Competitive Green Industries: The Climate and Clean Technology Opportunity for Developing Countries. Washington, DC: World Bank.

The selection of technologies to be prioritized for localization also depends on the characteristics of the national economy and its labour market. Governments in countries with higher unemployment and smaller GDP, such as Group 1 and 3b, may prefer to focus on technologies that are more labour-intensive, such as energy efficiency measures, or less sophisticated, such as manufacturing and building electricity transmission towers or lines, rather than capital-intensive technologies like hydrogen. Countries with smaller populations, lower costs of capital and strong domestic technological prowess, such as Group 3a, may prioritize capital-intensive technologies like CCUS or hydrogen.

In between, there are countries that have existing technological capacity but continue to lack capital for scale-up of advanced manufacturing, such as Group 2. Their opportunity lies in technology assembly and EPC activities (such as solar PV module assembly) with continued imports of components from countries with unbeatable economies of scale (such as solar PV wafers from China). Specific technologies with strong regional appeal but limited international applicability may be sensibly localized too since they could get a strong international competitive advantage, for example, CSP.

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3. Technologies, investment opportunities and scale-up enablers

The objective of this section is to provide a regional and subregional overview of priority areas for low carbon technology deployment and the potential for localization of these technologies with the aim of accelerating NDC implementation.

Each of the four subsections is dedicated to a different technological area: renewable power generation, demand-side efficiency, supply-side efficiency and hydrogen. Each subsection includes: (i) the priority technologies identified in NDCs, (ii) opportunities for private sector participation in the scale-up of these technologies, and (iii) relevant policy suggestions to accelerate uptake across the three country groups. This is supported by case studies that demonstrate how public and private sector actors in the region and beyond have successfully implemented similar interventions.

3.1. Renewable power generation

3.1.1. NDC priority areas

Renewable power generation will be the backbone of a low-carbon energy system, especially as the industrial and transportation sectors are electrified. As shown previously in Table 1, renewable energy is covered in all existing NDCs. Solar and wind are widely recognised as the two key renewable energy technologies. Countries across all groups have set ambitious renewable energy goals. For example, Djibouti aims for 100 percent of electricity generation coming from renewables by 2035[23] while Saudi Arabia aims to provide 50 percent of the energy mix from renewables by 2030.[24]

Access to finance will be critical: Lebanon aims to supply 18 percent of power demand from renewables by 2030 but up to 30 percent share could be achieved upon

23 Republic of Djibouti. Vision Djibouti 2035.

24 Kingdom of Saudi Arabia. (2021). Updated First Nationally Determined Contribution.

availability of concessional financing.[25] While solar and wind power are present in almost all NDCs and most countries also aim to pursue waste-to-energy, many countries focus on specific technology classes, sectors or scales in their NDCs:

Solar PV:

- Utility-scale solar PV (Sudan, Djibouti, Morocco, the State of Palestine, Jordan, Saudi Arabia)
- Utility-scale CSP plants (Morocco, Egypt, Jordan – 300 MW, Saudi Arabia).
- Rooftop solar PV
  - Domestic (Yemen – 110,000 households with a total capacity of 5.5 MW by 2025, Morocco – 1 GW by 2030, Egypt, Iraq)
  - Commercial (Djibouti, Morocco – 1.5 GW by 2030)
- Solar water heaters (Yemen, Morocco – installation of 40,000 m^2/year)

Wind:

- Utility-scale (Sudan, Yemen – 400 MW, Djibouti – 390 MW, Morocco – 2.18 GW by 2030, Jordan, Iraq)

Waste-to-energy:

- Landfill gas and municipal solid waste-based power generation (Yemen – landfill gas, Djibouti – MSW, the State of Palestine – 80 MW by 2030, Egypt – 300 MW by 2026 through incineration, pyrolysis and other technologies, Tunisia, Jordan, Iraq)
- Sludge and sewage-based power generation (Sudan, Tunisia, Jordan, Iraq)
- Agricultural waste-based power generation (Tunisia)

Hydro:

- Utility-scale (Sudan, Morocco – 1 GW by 2030)

Geothermal:

- Utility-scale (Yemen – 160 MW, Djibouti – 1.2 GW by 2030, Saudi Arabia)

In many countries, the deployment of variable renewable energy sources is constrained by grid capacity. For example, in Morocco, rooftop solar PV projects on industrial sites are developed in self-consumption mode while awaiting authorization to inject into the medium voltage network.[26] At the same time, solar and wind power will play a critical role in ensuring energy access in areas without grid. For example, in Iraq, renewable energy will be used "in the agricultural sector to operate irrigation pumps and use efficient irrigation systems" and mobile plants for on-site organic waste treatment will produce biogas in rural areas.[27]

Localization of renewable energy value chains will strengthen the self-sufficiency of the countries, especially those that are net importers of fossil fuels, to power the current energy system. Jordan explicitly aims to "increase self-sufficiency through the utilization of domestic natural and renewable resources."[28]

3.1.2. Private sector participation opportunities

Given the deployment targets for the respective renewable energy technologies, solar PV, solar CSP and wind present the greatest market opportunity for private sector participation. For hydropower and geothermal, there are several large projects in the pipeline, but they are constrained by hydrology/geology and there is no market for the long-term expansion of these technologies. The waste-to-energy market is still nascent and planned projects in most of the countries do not exceed 100 MW.

Solar PV: An overview of the solar PV value chain is shown in Figure 5 (overleaf). The value chain segments can be broken down into a few categories. Firstly, there is highly specialised and automated wafer and PV cells manufacturing that requires large capital investment which may be suitable for higher income countries like Saudi Arabia and Kuwait, but are less suitable for Group 1, 2 and 3b countries due to lacking economies of scale, large capex requirements and their higher costs of capital. If sufficiently large investment prospects in the region emerge, establishing manufacturing could be profitable through joint ventures with PV cells manufacturers and wafer manufacturers. Secondly, there are manufacturing segments (solar module and solar panel assembly) that can be reasonably scaled-up in countries with sufficient capital and available labour, such as countries in Group 2 and potentially 3a and 3b. Lastly, there are segments with strong overlap in terms of skills and technology with existing industries, such as extraction and processing of some raw materials (except silicon, which is highly specialised), construction and O&M.

25 Republic of Lebanon. (2020). Lebanon's Nationally Determined Contribution.

26 Kingdom of Morocco. (2021). Summary of Updated First Nationally Determined Contribution.

27 Republic of Iraq. (2021). Summary of First Nationally Determined Contribution.

28 Hashemite Kingdom of Jordan. (2021). Updated Submission of Jordan's 1st Nationally Determined Contribution.

Figure 5. Solar PV value chain

	Design & development	• Land claims • Survey reports • Design & engineering • Financial and economical analysis • Permission process • Grid integration
	Raw material	• Silicon • Crystalline • Multicrystalline • Thin film • Copper and aluminum • Steel • Cement • Concrete
Solar module manufacturing	**Wafer manufacturing**	• Ingot • Slurry • Ingot mounting adhesives • Acids • Doping to create n-type and p-type wafers • Saws
Solar module manufacturing	**Cells manufacturing**	• Wafer • Metallization paste • Ammonia • Chemicals • Silane • Acids • Hydroxide • Screens
Solar module manufacturing	**Solar module assembly**	• Cells • Ribbon • Glass surface • Encapsulates • Back sheet • Cables • Junction boxes • Connector • Frame
	Solar panel assembly	• Solar module • Inverter, trackers • Balance of system (control, switch gear, cabling,...)
	Construction	• Engineering & procurement • Infrastructure • Foundations • Steel support structure • Transformers, electrical cabinets • Metering devices • Computer systems, logistics • Fencing and observation • Trucks, cars, cranes, lifts • EHS
	Operation & maintenance	• Operation of the plant • Scheduled and unscheduled maintenance

Figure 6. Solar CSP value chain

	Design & development	• Land claims • Survey reports • Design & engineering • Financial and economical analysis • Permission process • Grid integration
	Raw material	• Steel (raw & galvanized), reinforcement, plates, pipes, etc. • Low iron sand, flat glass • Silver, film, primers, coatings • Concrete, solar salt • Mineral/glass wool • Chemicals, mineral, synthetic oils • Water, natural gas/diesel
Component manufacturing	**Solar field**	• Mirrors (flat or curvet) • Support structure • Receiver, ball joints, bearings, • HTF and piping, trackers, • Cables, junction boxes
Component manufacturing	**Thermal storage**	• Storage vessels • Storage material (salt) • Heat exchanger • Pumps, valves, motors • Hydraulic and pneumatic components, steel structure, • Nitrogen, isolation, foundation
Component manufacturing	**Balance of plant & power block**	• Steam boiler, steam turbine • Generator, condenser • Control system • Transformers, switch gears • Cables. junction boxes • Inverters, UPS, overhead lines, • Pumps, valves, motors • Vessels/tanks, isolation • Hydraulic and pneumatic components, compressors • Auxiliary boilers, chemicals/acide
	Solar site assembly	• Assembly of mirror structures • Infrastructure • Foundation, civil construction • Support structure, assembly-/process construction • Metering devices • Electrical cabinets • Computer systems • Logistics • Fencing and observation • EHS, Trucks, cars, cranes, lifts • Machinery for cutting, rolling, welding, bending, etc.
	Operation & maintenance	• Operation of the plant • Trucks, cars, cranes, lifts • Scheduled and unscheduled maintenance • Further optimization of power block

Source: European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.

Solar CSP: The value chain of solar CSP is shown in Figure 6. Overall, CSP offers greater short- to medium-term localization opportunities compared to solar PV. The high-investment value chain segments are mirror production, storage systems and the power block. In particular, curved mirrors, the power train and storage salt are mostly likely to be procured internationally or could be manufactured as a joint venture in countries in Group 3a, given the high research and development (R&D) costs. Supply of raw materials, piping, electronic components, structural systems, grid connection and EPC services largely exists locally across countries in all groups and could be channelled towards CSP.

Wind power: The value chain of wind power is shown in Figure 7. The structure of the onshore wind value chain is similar to CSP where production of specific components (generator and blades) is highly concentrated due to high investment costs and engineering quality requirements. Production of wind turbines is strongly integrated and most of the market share is controlled by a few companies (Vestas, Goldwind, Gamesa). However, strong local capacity exists in Arab States for construction, electronics and wind tower (all country groups). Countries may also be able to produce blades and provide raw materials, depending on presence of existing industries (Groups 2 and 3a).

Figure 7. Wind power value chain

	Design & development	• Land claims • Survey reports • Design & engineering • Financial and economical analysis • Permission process • Grid integration
	Raw material	• Steel for towers • Reinforcement steel • Cement • Concrete • Balsa wood • Fiber class or carbon fiber • Epoxy resin • Primer • Final coating • Mineral/ synthetic oils • Copper/ aluminium • Greases
Wind mill manufacturing	**Machinery suppliers**	• Machinery forcutting, rolling, welding, bending, etc. • Cranes • Transport equipment
Wind mill manufacturing	**Component suppliers**	• Gearboxes • Bearing • Tower • Generators • Blades • Transformers • Cables • UPS • Junction boxes • Switch yards • Frequency converters • Hydraulic and pneumatic components • Electronics
Wind mill manufacturing	**Wind turbine company**	• Design of components • Interfaces • Project management
	Construction	• Engineering & procurement (EPC) • Infrastructure • Construction companies • Electrical cabinets • Metering devices • Motors • Pumps • Valves • Computer systems • Logistics • Fencing and observation • EHS
	Operation & maintenance	• Operation of the plant • Scheduled and unscheduled maintenance

Source: European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.

3.1.3. Policy recommendations

Financial incentives and subsidies

While they are sometimes costly to the government, financial incentives, such as feed-in tariffs, exemptions, contracts for difference, and carbon taxes are important policy tools with a proven track record of accelerating the deployment of renewable energy technologies, development of local value chain capacity (EPC and O&M services), attracting international investment and lowering carbon emissions. Feed-in tariffs are best suited for projects below 50 MW capacity[29] and have been implemented by Jordan[30] and Algeria.[31] The least-cost approach to incentivising renewable energy is removing subsidies for fossil fuels.

Enabling measures for the power market

Continued uptake of renewables is contingent on favourable power market design, which depends on net metering, procurement methods and auction design. However, these approaches require governments to implement robust policy and technological frameworks. For example, net metering is contingent on the capacity of the utility to measure all generation and consumption at a household unit level. In terms of project procurement methods, IRENA suggests auctions and competitive bidding by independent power producers for projects on a scale of several hundred MW and direct proposal submission for GW-scale projects.[32] Additionally, wheeling directives would allow generation companies to direct power to specific customers and drive expansion of corporate power procurement. This has been implemented by the UAE,[33] Algeria[34] and others.

Ecosystem support for renewable energy supply chains

Developing a domestic renewable energy industry requires a systemic approach that entails establishing research centres, support programs for small- and medium-sized enterprises, policies that set local content requirements and favourable import tariffs. Appropriate use of tariff exceptions can foster specific segments of the value chain. For example, by waiving tariffs on solar cells but not on PV modules encourages developers to seek local capacity for assembling the modules to minimise the cost. However, applying tariff exemptions is preferred for segments with relative competitive advantage to avoid excessive costs of localization. In terms of technology development, creating regional centres would improve economies of scale of the research work and improve exchange of best practices and standards. There is an opportunity for the higher-income Arab States to take a lead on this initiative for the benefit of all.

Table 4. Summary of policy recommendations for renewable power generation

	Group 1	Group 2	Group 3a	Group 3b
Facilitate auctions, competitive bidding by Independent Power Producers and direct proposal submission	X	X	X	X
Remove fossil fuel subsidies; introduce carbon taxes	X	X	X	X
Exempt renewable energy components and machinery from tariffs	X	X	X	X
Incubate the market with feed-in tariffs		X	X	
Implement net metering		X	X	
Establish shared research centres			X	

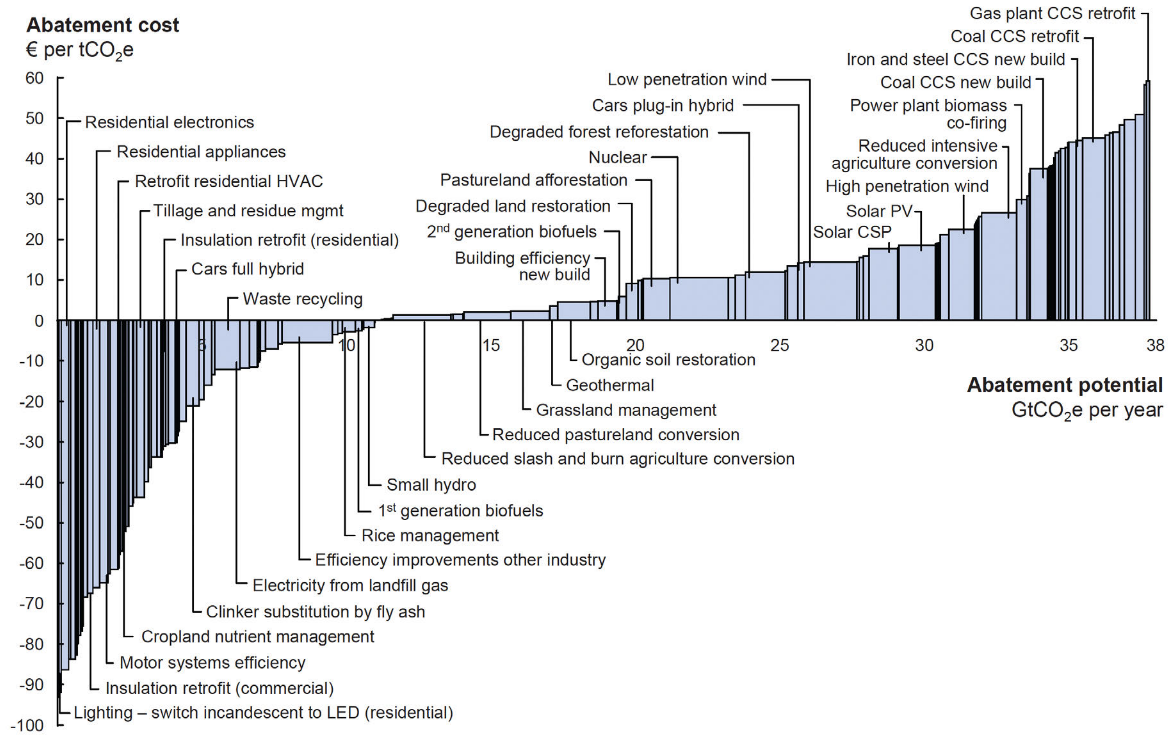
3.2. Demand-side energy efficiency

3.2.1. NDC priority areas

Energy efficiency is a cost-effective way to reduce emissions and facilitate renewable energy targets. Despite the rapidly growing deployment of renewable energy technologies globally, the share of fossil fuels in final energy consumption has remained relatively constant because of the increase in energy demand. Energy efficiency helps to decouple energy consumption and economic growth. Efficiency measures also make it easier to achieve renewable energy targets since smaller energy systems require fewer renewables to decarbonize. Figure 8 (overleaf) shows that efficiency is among the most cost-effective ways to reduce emissions, and typically saves more money that it costs to deploy.

29 IRENA. (2016). Renewable Energy in the Arab Region.
30 IRENA. (2018). Evaluating Renewable Energy Manufacturing Potential in the Arab Region: Jordan, Lebanon, United Arab Emirates.
31 Jones Day. (2015). Newly Updated Renewable Energy Program in Algeria.
32 IRENA. (2016). Renewable Energy in the Arab Region.
33 PV Magazine. (2023). UAE utility opens bidding for 1.5 GW of solar.
34 EQ. (2023). Algeria accepts 77 bids in 2-GW solar auction – EQ Mag.

Figure 8. Abatement cost and abatement potential for renewable energy and energy efficiency measures



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: McKinsey & Company. (2009). Pathways to a Low-Carbon Economy - Version 2 of the Global Greenhouse Gas Abatement Cost Curve.

As shown previously in Table 1, demand-side efficiency measures are as popular in NDCs as renewable energy production. Some countries have set specific energy efficiency goals: for example, Lebanon aims for 3 percent power demand reduction (or 10 percent conditional on finance access) by 2030 through energy efficiency measures[35] and the State of Palestine targets 20 percent energy efficiency improvements across all sectors by 2030 compared to business as usual (BAU).[36] Some countries target specific sectors for energy efficiency measures (for industry, Morocco set 17 percent energy consumption reduction goal by 2030[37] and Tunisia, 38 percent by 2030[38]).

The demand-side energy efficiency measures in the NDCs have been identified across four scopes:

Appliances:

- Efficient light bulbs (LEDs and other) (Somalia, Djibouti – 5 million installations each year, Morocco – 40 million CFLs and 40 million LEDs by 2030, Egypt, Iraq, Algeria)
- Labelling (Yemen, Egypt, Iraq)
- Minimum energy performance standards for air-conditioning units (Djibouti – 3,000 installations each year, Morocco, Kuwait)
- Minimum energy performance standards for refrigerators (Djibouti – 4500 installations each year, Morocco)
- Minimum energy performance standards for other appliances (Egypt, Saudi Arabia, Kuwait – including import bans on devices that do not meet criteria)
- Use of climate-friendly refrigerants and efficient cooling technologies (Jordan, Yemen, Egypt, Tunisia)
- Solar water heaters (Egypt, Jordan – 90,000 houses, Morocco, Iraq)

35 Republic of Lebanon. (2020). Lebanon's Nationally Determined Contribution.

36 State of Palestine. (2021). The State of Palestine's First Nationally Determined Contributions (NDCs) Updated Submission.

37 Kingdom of Morocco. (2021). Summary of Updated First Nationally Determined Contribution.

38 Republic of Tunisia. (2021). Summary of Updated First Nationally Determined Contribution.

Buildings:

- Green building codes (Yemen, Morocco, Egypt, Jordan, Iraq, Saudi Arabia, Kuwait)
- Renovation of existing stock (Djibouti – 3,000 buildings each year, Egypt, Jordan, Iraq, Algeria, Saudi Arabia, Lebanon)
- Energy audits (Djibouti)
- Smart meters (Iraq)

Cities:

- Energy efficient programs in public lighting (Morocco, Iraq, Egypt, Iraq)
- Energy efficiency programs in public buildings (Jordan, Kuwait)
- Urban planning approaches (Jordan – "compact city" for Amman, Iraq)
- Distribution networks for low-carbon fuels (Jordan – natural gas grid in Amman, Zarqa and Aqaba)

Industry:

- Minimum energy performance standards for motors (Morocco, Jordan)
- Thermal energy efficiency improvements (Egypt – 10 percent energy consumption reduction for iron and steel, fertilizers, and ceramic tiles industries)
- Transfer and development of more efficient practices and technologies (Jordan, Iraq)
- Reducing methane emissions in oil and gas sector (Saudi Arabia, Egypt, Iraq, Algeria)
- Switching to less carbon-intense feedstock
  - In cement industry (Syria – natural gas, the State of Palestine – 30 percent municipal solid waste by 2040, Morocco – fly ash, Egypt – MSW with specific energy consumption reduction from 3,710 to 3,540 MJ/tonne cement, Tunisia, Jordan – fly ash, Iraq – MSW)
  - Iron and steel (Iraq, Saudi Arabia – blue hydrogen)
- CCUS for industrial processes (Morocco – applied to phosphoric stacks, Iraq, Saudi Arabia – applied to petroleum sector to produce blue hydrogen)

While technological energy efficiency measures are the focus of this section, behaviour change fostered through education and information campaigns will play an important role in reducing the energy demand (recognised by NDCs, including Jordan[39] and Iraq[40]). Energy efficiency measures can also be encouraged through voluntary guidelines or financial incentives, as in Egypt.[41]

The low-hanging fruit for energy efficiency measures are demand loads controlled by the government. For example, Saudi Arabia established the Saudi Energy Efficiency Company (SEEC) with aim to rationalize and increase energy efficiency in production and consumption,[42] as well as the National Energy Services Company (Tarshid) to incentivize energy efficiency in government buildings with "plans to retrofit the entire pool of public and governmental assets and facilities which include 2 million streetlights, 110,000 government buildings, 35,000 public schools, 100,000 mosques, 2,500 hospitals and clinics."[43] Jordan and Kuwait also have retrofit plans for public sector buildings.

3.2.2. Private sector participation opportunities

Energy efficiency is a labour-intensive sector that requires on-the-ground service providers to perform energy efficiency audits, recommend cost-effective solutions and then source local suppliers and installation companies to implement these recommendations. By its nature, energy efficiency services tend to result in significant local job creation and provide secondary opportunities to the local economy.

Energy service companies (ESCOs) represent a major opportunity to implement energy efficiency measures effectively and efficiently. Typically, in the ESCO model, the ESCO signs an energy services contract with a building owner, where the ESCO assumes the building's energy bill, uses its technical expertise and arranges financing to make energy efficiency improvements, and shares a portion of the resulting savings with the building owner. Given the significant capital expenditure required, ESCOs require engagement of financial institutions to finance the operations. ESCO services are inherently local and draw on local supply chains to source equipment and materials for retrofits.

3.2.3. Policy recommendations

Energy performance labelling

Informing energy consumers – both households and industrial users – about the energy requirements for the use of appliances, machinery and vehicles is the easiest way to induce greater awareness about energy consumption and a shift to more energy efficient devices. This measure can be enacted through legislation by countries in all groups with implementation of labelling done by manufacturers.

39 Hashemite Kingdom of Jordan. (2021). Updated Submission of Jordan's 1st Nationally Determined Contribution.

40 Republic of Iraq. (2021). Summary of First Nationally Determined Contribution.

41 Arab Republic of Egypt. (2023). Egypt's Second Updated Nationally Determined Contribution.

42 Kingdom of Saudi Arabia. (2023). Saudi Energy Efficiency Program.

43 Kingdom of Saudi Arabia. (2021). Updated First Nationally Determined Contribution.

Minimum performance standards

The next step for improvement of demand-side energy efficiency beyond labelling is implementation of minimum performance standards that require manufacturers of devices, such as air-conditioning units, refrigerators or motors to implement measures that reduce energy use per unit of output. This action results in research and development costs on the side of industry, which are going to be passed down to consumers, but results in lower operating costs in the long-term.

Subsidies and rebates for energy-efficient appliances and retrofits

Energy efficiency measures can be further incentivised by providing subsidies and/or rebates. These can take the form of direct subsidies for purchasing energy efficient appliances, such as recently implemented heat pump subsidies in the European Union[44], or for energy-efficient refurbishment of residential buildings. Subsidies are an expensive measure more suitable for upper-middle or high-income countries in Groups 2 and 3a. An alternative approach is tax rebates on energy efficient measures, for example, being able to claim tax returns on retrofits. This policy tool is available to all countries.

Table 5. Summary of policy recommendations for demand-side energy efficiency

	Group 1	Group 2	Group 3a	Group 3b
Energy performance labelling	X	X	X	X
Minimum performance standards		X	X	X
Subsidies and rebates for energy efficiency appliances		X (rebates)	X (subsidies)	X (rebates)

3.3. Supply-side energy efficiency

3.3.1. NDC priority areas

Supply-side energy efficiency measures refer to interventions that reduce losses in power generation, transmission and distribution. Additionally, in the context of NDCs, supply-side measures include fuel switching from more carbon-intense feedstock, such as coal or fuel oil, to a less carbon-intensive one, such as natural gas. Supply-side energy efficiency measures are slightly less popular than interventions on the demand-side, but they are still noted in the majority of NDCs (see Table 1). Most of the countries do not have standalone energy efficiency targets for the supply side, with a few exceptions, including Yemen (15 percent energy efficiency gains in the power sector by 2025[45]). The two areas of interventions considered in this section are:

Power generation:

- Cogeneration (combined heat and power, does not include thermal desalination) (Yemen, Morocco, Tunisia)
- Fuel switching (Yemen, Morocco – from fossil fuels to waste, Iraq – fuel oil to liquified petroleum gas (LPG), Algeria – to natural gas. Saudi Arabia – to natural gas, Kuwait – fuel oil to natural gas)
- Retrofitting of power plants, deployment/conversion to combined-cycle gas turbine (Egypt, Iraq, Saudi Arabia, Kuwait – 250 MW in 2024, Saudi Arabia)

Grid (transmission and distribution):

- Upgrades of grids (Sudan, the State of Palestine, Morocco, Saudi Arabia, Egypt, Tunisia, Jordan, Iraq, Kuwait)
- Connections for wind and solar (Sudan, Morocco)
- Digitalisation of the grid, including smart meters (Egypt, Iraq)
- Regional interconnections (Egypt)
- Energy storage (Jordan)
- Minigrids and microgrids (Sudan, Egypt, Iraq)

As noted in section 3.1.1, electric grid modernisation means not only to reduce transmission and distribution losses and enable implementation of smart grids, but it is also necessary to incorporate variable loads of renewable energy sources. As such, modernisation of the grids is a low-regret strategy that will have catalytic impact on further transformation of the energy sector.

Upgrading power sector infrastructure will play a role not only in climate change mitigation but also in adaptation. As temperatures increase and extreme weather events become more frequent, power generation and transmission and distribution (T&D) systems will have to withstand new types of shocks, such as shortage of cooling water or extremely high temperatures that

44 EHPA. (2023). Subsidies for residential heat pumps in Europe.

45 Republic of Yemen. (2015). Intended Nationally Determined Contribution (INDC) Under the UNFCCC.

put strain on functioning of machinery and cables. This has been recognised in Iraq's NDC that aims to change "the specifications of electrical equipment used in the electricity sector in line with the increase in temperatures."[46]

3.3.2. Policy recommendations

Develop flexible power systems and smart grids

Grid connection bottlenecks are one of the leading barriers for increasing the share of renewables and generation of renewable electricity. Annual global investment in grids of US$ 600 billion is required to stay on track with decarbonization goals.[47] Deployment of smart, flexible grids will be one of the key enablers in this process. Due to its capital-intensive nature, it can be most easily implemented in high-income countries of Groups 3a and 3b but it will be relevant in all jurisdictions. Jordan has a streamlined process of grid expansion, where the project developer evaluates transmission congestion constraints and informs the relevant authority so that capacity expansion and transmission expansion happen side-by-side.[48] Upgrading grid infrastructure is a capital-intensive undertaking that requires long-term stability from policy makers to ensure return on investment for grid operators.[49]

As the frequency of climate-induced extreme weather events increases, grids will need to become more resilient. Smart grids will also facilitate better demand response. Planning and implementing grid expansion needs to be based on robust datasets and modelling of future loads.[50] Regulators should promote use of connected data platforms for enhanced forecasting and flexible operations[51] and grid codes need to be adapted to enable integration of higher levels of variability.

Expand energy storage capacity

Energy storage will be critical to ensuring reliable power supply as the share of renewable energy technologies in the electricity mix increases. While wind and solar PV are intermittent, storage provides dispatchable power and so complements renewables on all timescales.[52]

Currently, many large-scale energy storage technologies remain expensive and hence, they are most likely to be implemented in countries in Groups 2 and 3a. The policy recommendation is to develop markets that make energy storage commercially viable and incentivise expansion of capacity: time-of-use pricing, development of flexibility markets and ancillary service markets. Beyond the conventional power system, policies that facilitate vehicle-to-grid services and regulations for all electric vehicle chargers to have a two-way function (G2V and V2G) enable deployment of mass distributed storage in the long run.

Improve cross-border grid interconnectedness

Developing transmission networks, including ultra-high voltage lines, between countries provides an opportunity to further manage the geographic variability of renewable power generation and reduce curtailment.[53] Furthermore, opening national electricity sectors to neighbouring power producers would introduce competition and cross-border efficiencies[54] and interconnection would also provide balancing services and in extreme cases, provide emergency services. Currently, there are some existing interconnections between groups of Arab States, and with Europe (see Figure 9), however, there is potential for closer integration. In particular, regulators should enable transmission system operators to buy and sell power across borders in places where it is currently restricted, as many interconnections are limited to providing back-up in the case of blackouts. The Pan-Arab Regional Electricity Market would have 280 GW of capacity and could be realised by 2038.[55] Implementing it would require general agreement from Member States, market agreement from asset owners and an Arab grid code developed by Transmission System Operators (TSOs). Recent announcements about interconnection of Arab States to neighbouring regions include the subsea power link between Egypt and Greece[56] and Saudi Arabia and India.[57]

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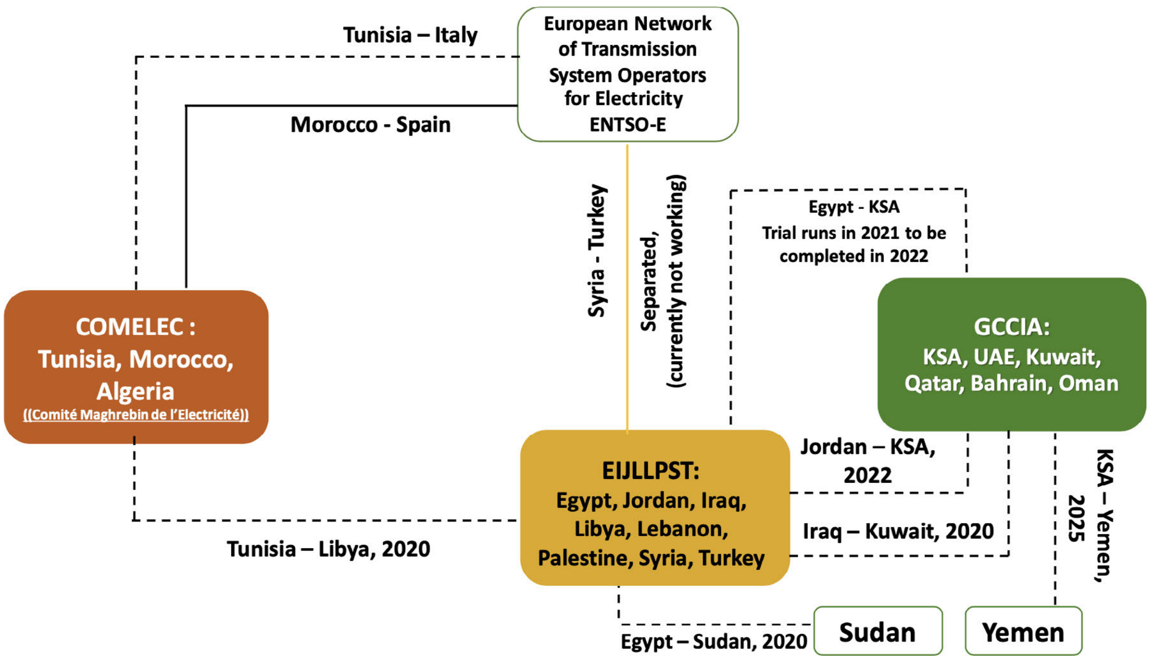
46 Republic of Iraq. (2021). Summary of First Nationally Determined Contribution.
47 IEA. (2023). Electricity Grids and Secure Energy Transitions.
48 IRENA. (2019). Power sector planning in Arab countries.
49 EURELECTRIC. (2011). 10 Steps to smart grids.
50 IRENA. (2019). Power sector planning in Arab countries.
51 The Green Powered Future Mission coalition. (2022). Action plan 2022-2024, Green Powered Future Mission.
52 IRENA. (2019). Power sector planning in Arab countries.
53 Ibid.
54 European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.
55 The Arab League. (2020). The Pan-Arab Electricity Market: Creating Regional Momentum for Energy Trade.
56 Reuters. (2021). Greece, Egypt sign deal for first subsea power link between Europe and Africa.
57 The National News. (2023). Saudi Arabia and India join hands to co-operate on electrical grid interconnection.

Figure 9. Scheme of interconnection between grids in Arab States



Source: The Arab League. (2020). The Pan-Arab Electricity Market: Creating Regional Momentum for Energy Trade.

Deploy minigrids and microgrids

Minigrids and microgrids will play a critical role in ensuring last-mile electricity access, especially in remote and rural areas where grid expansion would be costly and time-consuming. This solution is particularly suitable for countries with limited access to capital, such as Groups 1 and 3b. As small-scale renewable energy generation and energy storage become cheaper, microgrids and minigrids will become more feasible. To ensure long-term viability of minigrids, regulation should both protect the capital invested in minigrids when the national grid eventually reaches the spot powered by the minigrids and ensure common standards so minigrids assets can be utilised by the national grid.

In the industrial context, minigrids in industrial parks with self-generation help to manage the huge industrial loads with their own dedicated systems, reducing pressure on the national power system.

Consider whole-of-economy approach for planning flexibility

The presence and functioning of various heavy industries can be an opportunity or a challenge for ensuring responsiveness to variability to RE and should be addressed accordingly. For example, Qatar's must-run cogeneration units pose risk to curtailment as the share of RE increases and the issue needs to be addressed by deploying more flexible desalination technologies.[58] On the other hand, in Saudi Arabia, aluminium smelters provide flexibility to curtail their demand if needed and they have indeed previously covered for failures of the grid.[59] Demand response will be critical in the coming years and policy makers could create a regulatory 'sandbox' in which demand-response programs can be trialled, and then pilot them with large industrial and commercial users so they can provide flexibility to the grid at a lower cost than peaking plants during times of high demand. This assures that these services can be used and helps with price discovery. The open electricity market should allow aggregators and large individual consumers to offer demand-side management services in the same way that independent power producers can, where the breadth of Demand-Side Management (DSM) functions includes all relevant ancillary services to the grid (e.g. capacity markets, fast frequency response, balancing and others).

58 IRENA. (2019). Power sector planning in Arab countries.

59 Ibid.

Table 6. Summary of policy recommendations for supply-side energy efficiency

	Group 1	Group 2	Group 3a	Group 3b
Develop flexible power systems and smart grids		X	X	
Expand energy storage capacity		X	X	
Improve cross-border interconnections	X	X	X	X
Deploy minigrids and microgrids	X	X		X
Consider whole-of-economy approach for planning flexibility		X	X	

3.4. Hydrogen

3.4.1. NDCs priority areas

Wind and solar are expected to be the key drivers of decarbonization in the power sector. However, there are many sectors where electricity does not sufficiently replace fossil fuels, especially in terms of energy density (heavy industry), energy storage (transportation) or molecular inputs (chemicals and iron and steel). In the search of potential energy carriers, hydrogen emerges as a highly potent solution, and it is likely to play a key role in the net-zero energy mix. Many countries in MENA are global champions and trailblazers in the use of hydrogen, especially Saudi Arabia,[60] Egypt,[61] Morocco,[62] and the UAE.[63] Importantly, hydrogen production is a promising export-oriented emerging industry. The anticipated market for clean hydrogen and its derivatives is $400-$700 billion and GCC alone could gain revenue of $70-$200 billion.[64]

The new export will be important for countries that currently rely on sales of hydrocarbons, given the projected global oil demand to peak by 2030, according to the IEA.[65] This projection is contested by some analyses, including OPEC.[66]

While hydrogen is recognised as a key contributor to net zero by leading authorities including the IEA and IRENA, it is only mentioned in three NDCs. This is likely because most NDCs are from October 2021 or earlier, just when hydrogen's prominence was starting to grow. Nonetheless, the priority areas for hydrogen are:

- Blue hydrogen production (Saudi Arabia)
- Green hydrogen production (Jordan, Egypt, Morocco, Saudi Arabia – 650 tonnes per day in NEOM)
- Use of green hydrogen for ammonia, including fertilisers (Egypt, Saudi Arabia – 1.2 million tonnes per year in NEOM)

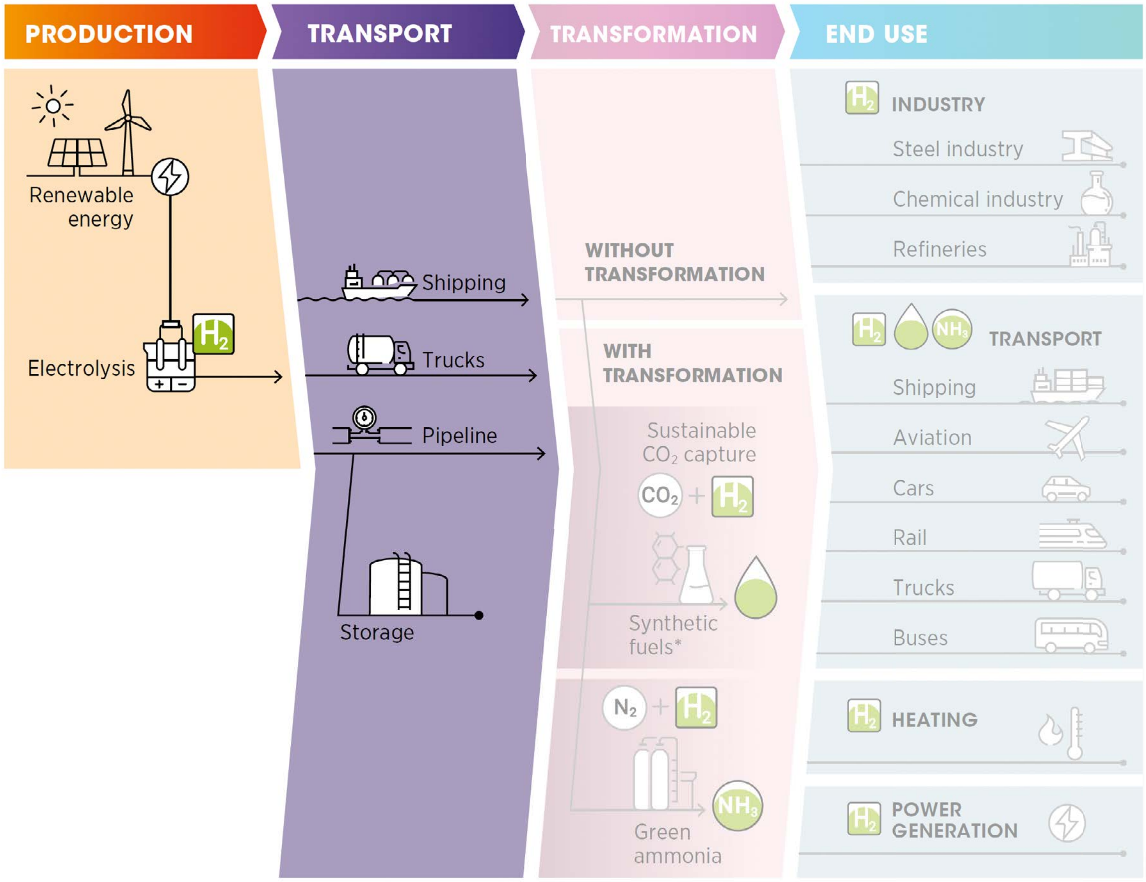
The nomenclature of hydrogen types is quite robust and depends on the type of energy that is used to produce this energy carrier. Green hydrogen refers to production using renewable energy to power the electrolysis of water, while blue refers to production from natural gas using CCS-equipped steam methane reforming.

3.4.2. Private sector participation opportunities

The green hydrogen economy will be strongly integrated with the emerging energy system based on renewables, as shown in Figure 10 (overleaf). Renewable power generation will be at the core of the upstream part of the hydrogen value chain where the power is used to produce hydrogen. Downstream segments of the supply chain include transport (via ships, trucks or pipelines) and storage of hydrogen, transformation (into synthetic fuels or green ammonia) and end use (in industry, transport, heating and power generation).

60 Kingdom of Saudi Arabia. (n.d). Vision 2030.
61 Arab Republic of Egypt. (2023). National Green Hydrogen Council Approves Green Hydrogen Strategy.
62 Kingdom of Morroco. (2021). National Green Hydrogen Strategy.
63 UAE. (2023). National Hydrogen Strategy.
64 Carnegie Endowment for International Peace. (2023). The Hurdles of Energy Transitions in Arab States.
65 Reuters. (2023). World oil, gas, coal demand to peak by 2030, IEA says.
66 OPEC. (2023). OPEC Statement on peak fossil fuel demand.

Figure 10. Hydrogen value chain



Source: IRENA. (2021). Green Hydrogen Supply: A Guide to Policy Making.

While the hydrogen economy offers a promising opportunity for diversification of exports (for renewables-rich fossil fuels exporters) and energy supply (for fossil fuels importers), participation of countries in the hydrogen economy of the future will vary. Developing hydrogen infrastructure is very capital intensive, so it is not likely to be a major feature of countries with high costs of capital. Furthermore, shipping is a challenge that is likely to reduce participation of landlocked countries. Domestic uses of hydrogen will be focused on heavy industry, heavy transport, and chemicals so countries with small industrial base are unlikely to consider hydrogen a strong opportunity for domestic decarbonization.

3.4.3. Policy recommendations

Setting targets and objectives

Setting long-term targets provides certainty for the private sector about the needed pipeline of projects to meet national targets. For example, the National Hydrogen Strategy of Morocco anticipates deployment of 1 GW of projects in the mid-term (2020-2030).[67] Fiscal incentives for supporting the national targets provide further encouragement for the private sector to engage in development of the national hydrogen economy.

Derisking investment by developing infrastructure

Developing a hydrogen economy is a capital-intensive process and by investing in infrastructure that would support operations of private sector companies, governments can encourage development and deployment of technologies.[68] In particular, pipeline transmission networks and import and export facilities will be critical for enabling cross-border hydrogen trade and leveraging the export potential in countries with abundant renewable energy potential, such as many Arab States.

67 Royal Kingdom of Morocco. (2021). Feuille De Route Hydrogène Vert Vecteur de Transition Énergétique et de Croissance Durable.
68 Wilhelm Schmundt, et al. (2023). Building the Green Hydrogen Economy, Infrastructure Strategy, 2023.

Creating a single portal for energy auctions and procurement

Hydrom is an example of a pioneering entity established in Oman which serves as a single portal for energy auction and procurement. Such a one-stop-shop solution provides an opportunity to maximise the use of resources available in the country and allocate them to developers in a manner that benefits from economies of scale. Effective and efficient use of centralised data centres allows all stakeholders to develop a connected industry ecosystem.

Table 7. Summary of policy recommendations for hydrogen

	Group 1	Group 2	Group 3a	Group 3b
Setting targets and objectives	X	X	X	X
Derisking investment by developing infrastructure		X	X	
Creating a single portal for energy auctions and procurement		X	X	

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4. Mobilizing private sector finance

For the world to reach the goals of the Paris Agreement and achieve net-zero emissions by 2050, global annual investment of $4 trillion is required.[69]

However, even though developing and emerging economies, including Arab States, account for two-thirds of the world's population, they receive only one-fifth of investment in clean energy.[70] Specifically, investment of $2.4 trillion annually by 2030 for developing and emerging economies (excluding China) is necessary, with $1.4 trillion being able to be met with domestic sources and the other $1 trillion requiring international capital markets. This points to the role of private sector finance. Instruments such as green bonds have emerged in recent years to address these gaps and there are prominent examples of their use in the region, including issuance of $5.5 billion of green bonds by Saudi Arabia's Public Investment Fund.[71]

Currently, the cost of capital among Arab States ranges significantly between country Groups (see Figure 2). While high-income countries in Group 3a average 7.1 percent, the average in the low-income Group 1 is 27 percent. Reported data from utility-scale solar PV projects in Morocco, Tunisia, Egypt, Jordan and Yemen between 2019-2021 shows that average cost of capital in the MENA region is higher than in all other regions across the Americas, Europe, Africa and Asia.[72] The cost of capital is influenced by project- and country-specific factors. In many Arab States, renewable energy projects have suffered from an unfavourable macroeconomic environment, resulting from political uncertainties, high interest rates and supply chain disruptions.

Providing the necessary finance for capital-intensive renewable power generation technologies, grids, efficiency measures and hydrogen production will require accessing large funds on concessionary terms. To achieve this, governments will have to ensure (i) enabling environments, and (ii) deploy financial and economic tools.[73] The enabling environment creates the conditions that affect the viability of sustainable investments, while financial and economic tools are needed to raise and deploy capital and manage risks.

The key recommended interventions to support enabling environments and financial mechanisms are explored below.

69 IEA. (2021). Net Zero by 2050.
70 IEA. (2021). Financing clean energy transitions in emerging and developing economies.
71 Yousef Saba and Yoruk Bahceli. (2023). Saudi wealth fund to raise $5.5 billion with second green bond sale.
72 IRENA. (2023). The cost of financing for renewable power.
73 Jeffrey Beyer and Moustafa Bayoumi. (2022). Financing a Green Transition in the Middle East.

4.1. Enabling environments

Develop green finance taxonomy

Given the commitments of countries to green energy transition, unified definitions of what investments are aligned with decarbonization goals would provide certainty to investors, strengthen regional collaboration, and prevent greenwashing.[74] A regional collaboration platform, such as RCREEE, would be best suited to develop the taxonomy and national adoption of the policy should follow. While this is a regional recommendation, it should be prioritized in countries with strong existing financial systems in Groups 2 and 3a.

Map out a bankable pipeline of projects

National strategies, such as the NDC and national renewable energy action plans, present country-level plans for energy transition. Translating these targets into specific, costed projects would provide a basis for a financing strategy that matches priority projects with appropriate funding sources. This is a low-regrets strategy that is recommended across all country groups.

Establish climate-related disclosure standards

Compliance disclosure regulations are increasingly being implemented in leading markets, including the EU's Sustainable Finance Disclosure Regulation.[75] To maintain inflow of foreign investments, stakeholders in the Arab States should consider compliance with standards such as Taskforce for Climate-related Financial Disclosures (TCFD). This policy is recommended for countries with strong administrative capacities in Groups 2 and 3a.

Direct central banks to support sustainability projects

Central banks have the capacity to steer the financial system to diversify away from carbon intensive projects and increase investment in green energy. It is already happening in Lebanon where the central bank provides loans with subsidised interest rates for industrial projects.[76] Central banks should also be encouraged to join the Central Banks and Supervisors Network for Greening the Financial System. This recommendation is relevant to all countries because the task of the central bank is to protect macroeconomic stability by pursuing a diversified, resilient and future-oriented economy.

Tax exemptions

Favourable tax regulations, combined with the introduction of carbon taxes, can further attract private investors and also be applied to reduce the cost of low-carbon products and equipment. Tax exemptions can be wide-ranging, such as low corporate tax rate (in the UAE[77]), or support specific objectives such as, property tax exemption on industrial projects (in Jordan and Lebanon[78]) or tariff exemptions on energy efficient products or machinery and raw materials for manufacturing of components in renewable energy technologies.

4.2. Financial mechanisms

Develop a regional carbon market

Market mechanisms, such as cap-and-trade systems, serve reducing emissions at the most optimal total cost.[79] By expanding the scope of high-integrity carbon markets, it is possible to facilitate cost-effective solutions more efficiently within the region. With support from more fiscally resourced governments in Groups 2 and 3a, a regional approach could be adopted from the beginning across the studied countries.

Leverage sovereign wealth funds

With some of the world's largest sovereign wealth funds in countries in Group 3a, the governments could provide substantial capital for clean energy industries.[80] Mubadala of the UAE through Masdar and the Public Investment Fund of Saudi Arabia are leading the way in investments in renewable energy. The funds could be further used to de-risk emerging technologies and projects.

Issue green bonds or green sukuk

Green bonds are an important tool to raise money for sustainable investments. For countries with a good credit rating, especially in Groups 2 and 3a, green bonds would help to raise the necessary finance for green investments.

74 World Bank. (2020). How to Develop a National Green Taxonomy for Emerging Markets - A New World Bank Guide.
75 EU. (2021). Sustainable finance.
76 IRENA. (2018). Evaluating Renewable Energy Manufacturing Potential in the Arab Region: Jordan, Lebanon, United Arab Emirates.
77 Ibid.
78 Ibid.
79 OECD. (2021). Carbon markets.
80 Global SWF. (2021). 2021 GSR Scorecard.

Secure risk insurance

Some countries in the region, especially in Groups 1 and 3b, continue to suffer from limited interest of private investors because of high perceived risk due to economic and political instability. Securing guarantees and risk insurances from the World Bank, the International Monetary Fund or other multilateral development banks would encourage private capital to flow to these markets. An example is the MENA CSP Scale-up Investment Plan led by the World Bank and the African Development Bank to accelerate concessional financing for CSP projects in Algeria, Egypt, Jordan, Morocco and Tunisia.[81]

Regulate subsidies in the energy sector

If funding is available, subsidies are a powerful tool to spur investment in selected areas of the economy. These programs could range from incentivizing energy efficiency improvements among end users to promoting localization of segments of renewable energy technology value chains, as successfully illustrated in Jordan by the Jordanian Renewable Energy and Energy Efficiency Fund (JREEEF), which supports renewables deployment and energy efficiency measures across the project development stages, and the Chamber of Industry's Factories Support Program, which provides grants to support small industrial enterprises with the installation of solar PV or solar water heaters.[82] On the flip side, phasing out inefficient subsidies for fossil fuels is viable across all country groups and would improve competitiveness of clean technologies.

For many of the initiatives listed above, pooling them across countries into regional frameworks would further reduce the cost of initiating them resulting in decreased cost of capital and increased attractiveness to investors.[83]

Table 8. Summary of policy recommendations for mobilising private sector finance

	Group 1	Group 2	Group 3a	Group 3b
Enabling environments				
Map out a bankable pipeline of projects	X	X	X	X
Develop green finance taxonomy		X	X	
Establish climate-related disclosure standards		X	X	
Direct central banks to support sustainability projects	X	X	X	X
Financial mechanisms				
Develop a regional carbon market	X	X	X	X
Secure risk insurance	X			X
Regulate subsidies in the energy sector	X	X	X	X
Issue green bonds or green sukuk		X	X	
Leverage sovereign wealth funds			X	

81 European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.
82 IRENA. (2018). Evaluating Renewable Energy Manufacturing Potential in the Arab Region: Jordan, Lebanon, United Arab Emirates.
83 European Investment Bank. (2015). Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries.

Appendix

Key energy and economic statistics for Arab States

Country	Income classification[a]	GDP per capita PPP (2021, current international $)[b]	Primary energy consumption per capita (2019, kWh/person)[c]	Electricity access (2020, %)[d]	Renewable energy penetration (2021, %)[e]	WACC (%)[f]	Net zero target[g]
Group 1							
Somalia	Low-income	$1,254	228	50%	10%	23.8%	No
Yemen	Low-income	$1,924[h]	1,477	74%	17%	27.8%	No
Sudan	Low-income	$4,084	2,337	55%	64%	27.8%	No
Djibouti	Lower-middle-income	$5,421	2,355	62%	0%	#N/A	No
Syria	Low-income	#N/A	6,221	89%	5%	27.8%	No
Lebanon	Lower-middle-income	$14,331	18,513	100%	5%	27.8%	2050
Libya	Upper-middle-income	$22,371	26,684	70%	0%	8.3%	No
Group 2							
The State of Palestine	Upper-middle-income	$6,225	4,050	100%	23%	5.6%	No
Morocco	Lower-middle-income	$8,892	7,257	100%	20%	7.4%	No
Egypt	Lower-middle-income	$13,441	9,920	100%	11%	12.6%	No
Tunisia	Lower-middle-income	$11,471	10,128	100%	5%	16.0%	2050
Jordan	Lower-middle-income	$10,155	10,843	100%	24%	10.9%	No
Iraq	Upper-middle-income	$9,696	14,871	100%	5%	16.0%	No
Algeria	Lower-middle-income	$12,170	16,272	100%	1%	8.3%	No
Group 3							
Saudi Arabia	High-income	$51,407	83,663	100%	0%	4.3%	2060
Kuwait	High-income	$50,375	107,970	100%	0%	4.3%	2060
Bahrain	High-income	$54,902	159,475	100%	0%	12.6%	2060

Sources:

a: World Bank. (2022). New World Bank country classifications by income level, 2022-2023.

b: World Bank. (2022). GDP per capita, PPP.

c: Our World in Data. (2022). Primary Energy Consumption per capita.

d: Our World in Data. (2022). Share of the population with access to electricity.

e: Our World in Data. (2022). Share of electricity generated by renewables.

f: *Methodology*: Egli, F., Steffen, B. & Schmidt, T.S. (2019). Bias in energy system models with uniform cost of capital assumption.; *Data*: NYU Stern School of Business. (2024). Country Default Spreads and Risk Premiums.

g: Net Zero Tracker. (2024). Data Explorer.

h: International Monetary Fund. (2021). World Economic Outlook Database.

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