

Enabling Policies for Sustainable, Digitalized Power Grid Connectivity and Cross-border Cooperation in the Arab Region

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Economic and Social Commission for Western Asia

Enabling Policies for Sustainable, Digitalized Power Grid Connectivity and Cross-border Cooperation in the Arab Region

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Acronyms and abbreviations

ADPEES	Arab Digital Power Enabling Environment Scorecard
AI	artificial intelligence
AMI	advanced metering infrastructure
CEN-CENELEC-ETSI	European Committee for Standardization, European Committee for Electrotechnical Standardization and European Telecommunications Standards Institute
CERT	computer emergency response team
DER	distributed energy resource
DEWA	Dubai Electricity and Water Authority
DSO	distribution system operator
ESCWA	Economic and Social Commission for Western Asia
GCC	Gulf Cooperation Council
GCCIA	Gulf Cooperation Council Interconnection Authority
GDP	gross domestic product
GECOL	General Electricity Company of Libya
GIS	geographic information system
GSMA	Global System for Mobile Communications Association
GW	gGigawatt
HVDC	high-voltage direct current
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
kWh	kilowatt-hour
LDC	least developed country
MENA	Middle East and North Africa
MW	Megawatt
OETC	Oman Electricity Transmission Company
OMS	outage management systems
ONEE	National Office of Electricity and Drinking Water (Morocco)

RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
RIIO	revenue = incentives + innovation + outputs
SCADA	supervisory control and data acquisition
SWOT	strength, weaknesses, opportunities, and threats
TSO	transmission system operator
VPP	virtual power plant

Introduction

Powering the Arab region's energy transformation

Energy is fundamental to economic development, human well-being and the provision of essential services across the Arab region. It powers industry, transport, water supply, digital connectivity, healthcare, education, and the broader systems that support livelihoods and economic transformation. The region possesses some of the world's most promising solar and wind resources, yet these resources, together with the infrastructure, investment capacity, institutions, and technical skills required to harness them, remain unevenly distributed across countries. This creates both challenges and opportunities, underscoring the importance of deeper regional cooperation and integration.

The Arab region's electricity systems are entering a period of significant transformation. Population growth, urbanization, economic development, rising temperatures, and the electrification of transport, industry and other end uses are increasing demand for reliable electricity. At the same time, countries are seeking to expand renewable energy and strengthen energy security. These shifts place growing demands on grids designed largely around centralized generation, traditional utility structures and one-way electricity flows. Integrating variable renewable energy, distributed generation, storage, and more active consumers will require investment in transmission and distribution infrastructure, accompanied by changes in planning, regulation, market design, and system operation.

Arab countries are entering this transformation from different starting points. Some have achieved near-universal electricity access and are investing rapidly in renewable energy and advanced grid technologies. Others face unreliable supply, deteriorating infrastructure, financial constraints, and persistent disparities affecting rural, remote and conflict-affected communities. Extreme heat, water scarcity, natural hazards, fuel-supply disruptions, and conflict further expose the vulnerability of electricity systems. Regional interconnections are expanding, and there is considerable scope to increase cross-border electricity exchanges, which remain limited relative to their technical and economic potential. The challenge is therefore to develop power systems that are reliable, affordable, sustainable, flexible, and resilient, while responding to differing national circumstances.

Significance of digitalized and interconnected power grids

Digitalization and stronger interconnection are central enablers of the transformation of energy systems. Digitalization refers to the systematic use of digital technologies and data across the electricity value chain to improve system visibility, control, coordination, and adaptability. Smart

meters, sensors, automated controls, digital substations, and data-driven forecasting can help integrate renewable energy, reduce losses, identify equipment failures, restore service more quickly, and make better use of existing assets. Stronger national and cross-border interconnections can increase flexibility, facilitate electricity trade and provide support during emergencies, while digital systems enable timely data exchange and coordinated operation across interconnected networks.

The benefits of technology and infrastructure depend on effective institutions, sustainable utility finances, coherent planning, appropriate regulation and market design, interoperable standards, cybersecurity, sound data governance, and a skilled workforce. Policies must also address risks such as cyberattacks, misuse of consumer data, dependence on proprietary technologies, and exclusion of people with limited digital access or literacy.

A people-centred approach is essential to avoid widening existing inequalities and to ensure that no one is left behind.

Key themes

The present publication examines the enabling policies needed to develop inclusive, sustainable and digitalized power grids and strengthen cross-border electricity cooperation in the Arab region. Its analysis is organized around the following five closely connected themes:

- **The regional context and differentiated power-system needs,** including electricity access and service quality, renewable energy integration, energy-transition pressures, and energy connectivity (chapter 1).
- **Power system resilience under climate stress, conflict and fragility,** and the role of digital and decentralized solutions (chapter 2).
- **Digitalized power grids,** including enabling technologies, regional deployment, opportunities, inclusion considerations, and operational risks (chapter 3).
- **Cross-border electricity connectivity and cooperation and the role of digitalization** in creating secure and functional regional electricity markets (chapter 4).
- **Governance and implementation priorities,** including regulation, data governance, cybersecurity, financing, and human capacity, and the **Arab Digital Power Enabling Environment Scorecard (ADPEES)**[1] as a diagnostic framework for assessing readiness for digital power transformation (chapter 5).
- **Policy recommendations,** outlining priority actions to advance digital-power transformation, strengthen resilience and address key governance, financing, cybersecurity, and capacity challenges (chapter 6).

Across these themes, inclusion is treated as a cross-cutting objective, encompassing access, affordability, reliability, consumer protection, and equitable opportunities for underserved communities, so that no one is left behind in a just energy transition.

1. Regional context: power systems in the Arab region

Key messages

- **Electricity access has expanded. Policy must now also focus on reliable, affordable and resilient service.** Access increased from 88.8 per cent in 2014 to 92.2 per cent in 2024. Remaining gaps are concentrated in least developed countries (LDCs), conflict-affected settings and rural areas. Further progress requires better reliability data, targeted affordability measures, and a combination of grid extension and decentralized renewable solutions.
- **Structural pressures require integrated grid modernization, not infrastructure investment alone.** Rising demand, fossil-fuel dependence, climate stress, subsidies, constrained utility finances, and uneven infrastructure readiness call for stronger planning, demand-side management, financial reform, and investment frameworks adapted to differing national and subregional circumstances.
- **Renewable energy deployment must be supported by grid readiness, digitalization and regional cooperation.** Renewable energy accounted for only 4.84 per cent of total final energy consumption in 2023. Moving from individual projects to renewable-ready systems requires updated grid codes, storage and flexibility frameworks, distributed-energy regulation, cybersecurity, interoperability, and stronger arrangements for cross-border electricity trade.

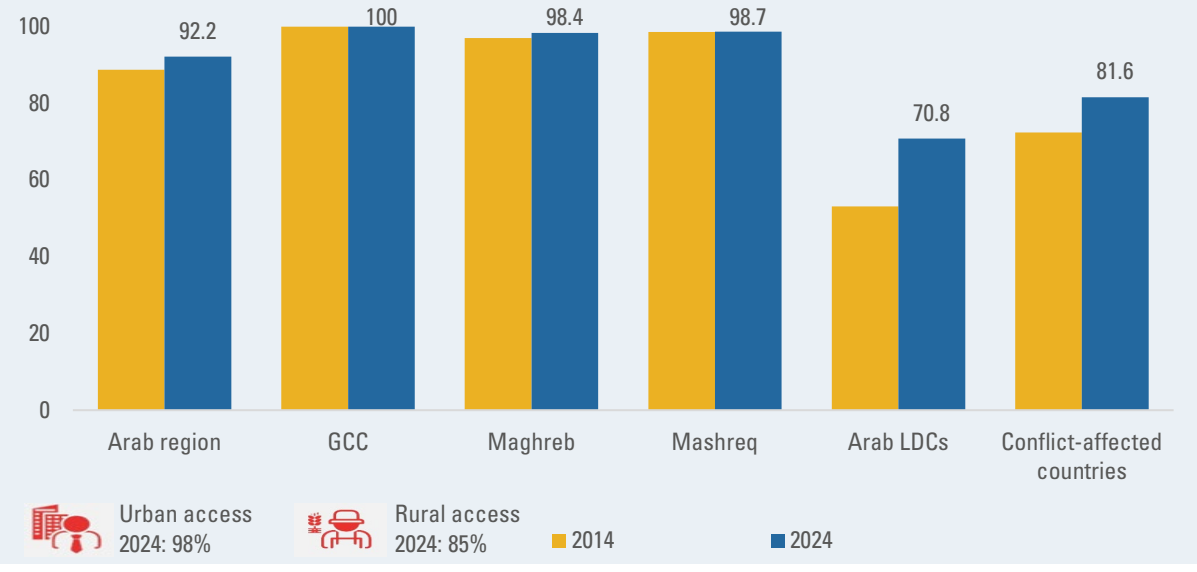
A. Electricity access, service quality and the energy transition

The Arab region has made substantial progress in expanding electricity access. The energy transition is now increasingly shifting attention from connection alone towards the quality, reliability, affordability, and resilience of electricity services. Electricity access increased from 88.8 per cent in 2014 to 92.2 per cent in 2024, and most Arab countries had achieved or approached universal access. The largest remaining shortfalls were concentrated in Djibouti, Mauritania, Somalia, the Sudan, and Yemen.[2] Urban access reached 98.1 per cent in 2024 compared with 85.3 per cent in rural areas, while rural access stood at only 62 per cent in Arab LDCs and 68 per cent in conflict-affected countries.[3]

The region's access challenge is shifting from whether a connection exists to whether electricity is sufficiently reliable, affordable and resilient to support households, public services and economic activity. Connection rates alone do not capture outages, voltage quality, cost burdens, dependence

on backup generation, or vulnerability to fuel and climate shocks. In rural, remote and underserved areas, grid extension can be complemented by mini-grids, stand-alone renewable systems and storage where these provide a more affordable or resilient option, supported by clear arrangements for tariffs, service quality, ownership, maintenance, financing, and integration with national planning.

Figure 1. Electricity access by subregion (Percentage)



Source: ESCWA, 2026a.

Progress across other dimensions of the energy transition also remains uneven. Access to clean cooking fuels and technologies plateaued at 84 per cent between 2022 and 2024, with persistent rural deficits.[4]

The next phase of the region's energy transition should prioritize utility performance, maintenance, loss reduction, affordability, and resilience, supported by better data on outages, reliability, distributed generation, and service quality, which are essential for targeting investment and tracking whether electricity services are becoming more inclusive.

B. Electricity systems as the foundation for energy transition, resilience and digitalization

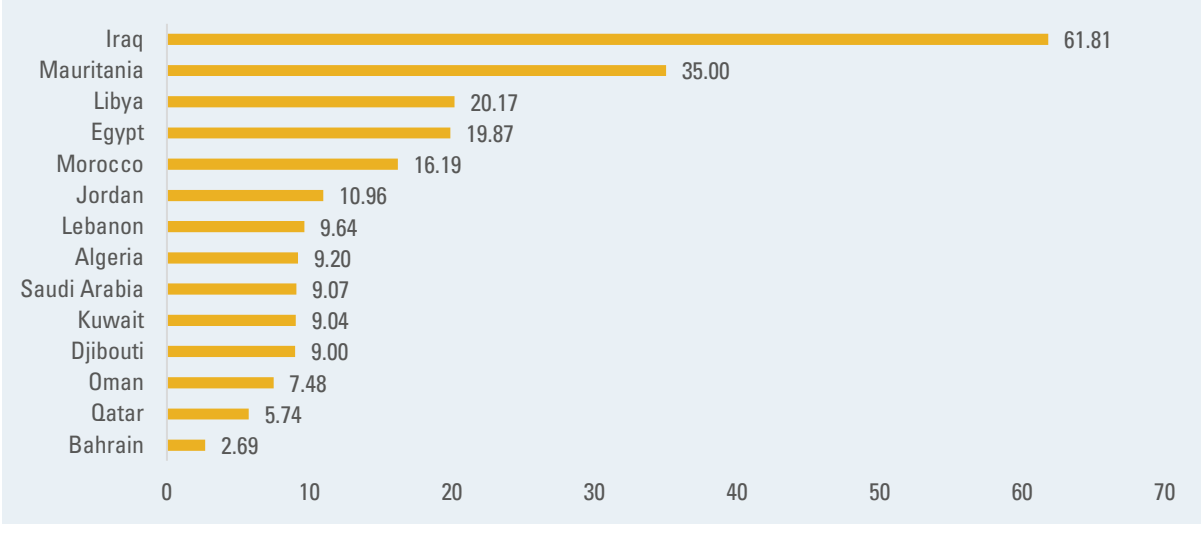
Electricity systems in the Arab region are diverse, reflecting wide differences in resource endowments, income levels, institutional capacity, geography, levels of conflict exposure, and demand patterns. Hydrocarbon-exporting countries have often benefited from stronger fiscal resources and domestic fuel availability, while energy-importing countries have faced sharper incentives to improve efficiency, diversify supplies and deploy renewable energy. LDCs and fragile contexts face a different set of challenges, including lower access levels, weaker infrastructure,

limited fiscal space and greater exposure to climate and conflict-related shocks. These differences shape countries' energy transition pathways, the resilience of their power systems to shocks and their readiness for grid digitalization.

Despite this diversity, many systems share a legacy of centralized, fossil-fuel-based generation and publicly led grid expansion. This model supported major electrification gains. It is, however, less suited to integrating variable renewable energy, distributed generation, storage, flexible demand, and two-way electricity flows. Modernization therefore requires coordinated investment in networks, planning, forecasting, and digital monitoring, supported by updated grid codes and appropriate rules for distributed resources, interoperability, data governance, and cybersecurity.

Transmission and distribution losses provide an important indication of network efficiency and commercial performance. Their wide variation across Arab countries reflects differences in infrastructure condition, maintenance, metering, billing, and institutional capacity. In countries with high losses, additional generation may not translate into more reliable or affordable service, while lost revenues constrain maintenance and further investment.

Figure 2. Transmission and distribution losses in selected Arab countries (Percentage)



Sources: World Bank, 2025a and 2026a; U4E, 2026 (values represent reported transmission and distribution losses as a percentage of electricity output. The World Bank definition includes pilferage, but the coverage of non-technical losses may vary across countries. The indicator should not be interpreted as a fully comparable measure of aggregate technical and commercial losses).
Note: Latest reported losses as a percentage of electricity output. Latest available year is 2023, except for Djibouti (2022) and Mauritania (2025). The State of Palestine is omitted because no value is reported.

The figures illustrate the scale of electricity losses in several Arab countries and reinforce the need for grid modernization and improved utility performance. Policy responses should combine network rehabilitation and better asset management with improved metering, billing and collection, stronger performance monitoring and regulatory incentives that promote service quality and operational efficiency.

Digital readiness also varies widely. Some countries are deploying advanced metering, grid automation, supervisory control, and digital asset-management systems, while others still lack basic network monitoring, outage-management, data-quality, and maintenance capabilities. Digital technologies can help manage more complex and decentralized systems, provided that governance, institutional capacity, interoperability, and cybersecurity keep pace (chapter 3).

Energy connectivity is another important dimension of this transformation. Stronger national and cross-border electricity networks can help countries manage differences in supply and demand, integrate larger shares of renewable energy, share reserves, and strengthen resilience to disruptions. Connectivity in this sense goes beyond physical interconnection: its benefits depend on compatible technical standards, coordinated system operation, functioning institutions, and the ability to exchange electricity and data securely across networks.

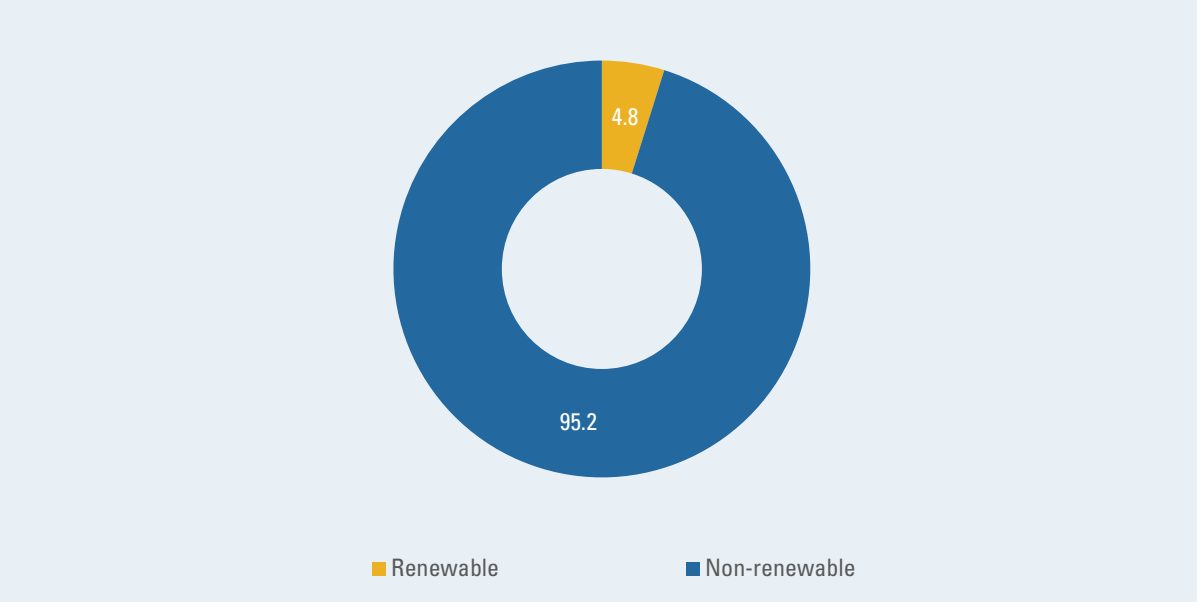
C. Renewable energy progress and the grid integration challenge

The Arab region has strong renewable energy potential, especially solar and wind, and several countries have made progress in deploying modern renewable energy. The integration challenge is increasingly shifting from project development to system readiness.

Renewable energy remains below 5 per cent of regional final energy consumption and is unevenly distributed.[5] Traditional biomass continues to dominate renewable consumption in several Arab LDCs, while modern solar and wind deployment is concentrated in a smaller group of markets. Planning should therefore distinguish clearly between traditional biomass and modern renewable energy systems. Electrification and sector coupling in buildings, cooling, clean cooking, agriculture, transport, productive uses, and parts of industry can accelerate the translation of renewable electricity growth into higher renewable shares of final consumption. Solar energy has become the most widely deployed modern renewable source across much of the region, while wind remains concentrated in fewer countries and hydropower plays a notable role only in selected cases.

Deployment is accelerating: solar and wind capacity increased from 6.3 gigawatts (GW) in 2018 to 43 GW in 2025.[6] The central challenge is increasingly becoming system integration, requiring transmission and distribution reinforcement, storage, flexibility, modern grid codes, demand response, forecasting, and operational procedures capable of managing variability. Digital monitoring, forecasting and control can support each of these, provided that data governance, interoperability and cybersecurity arrangements are in place (chapter 3).

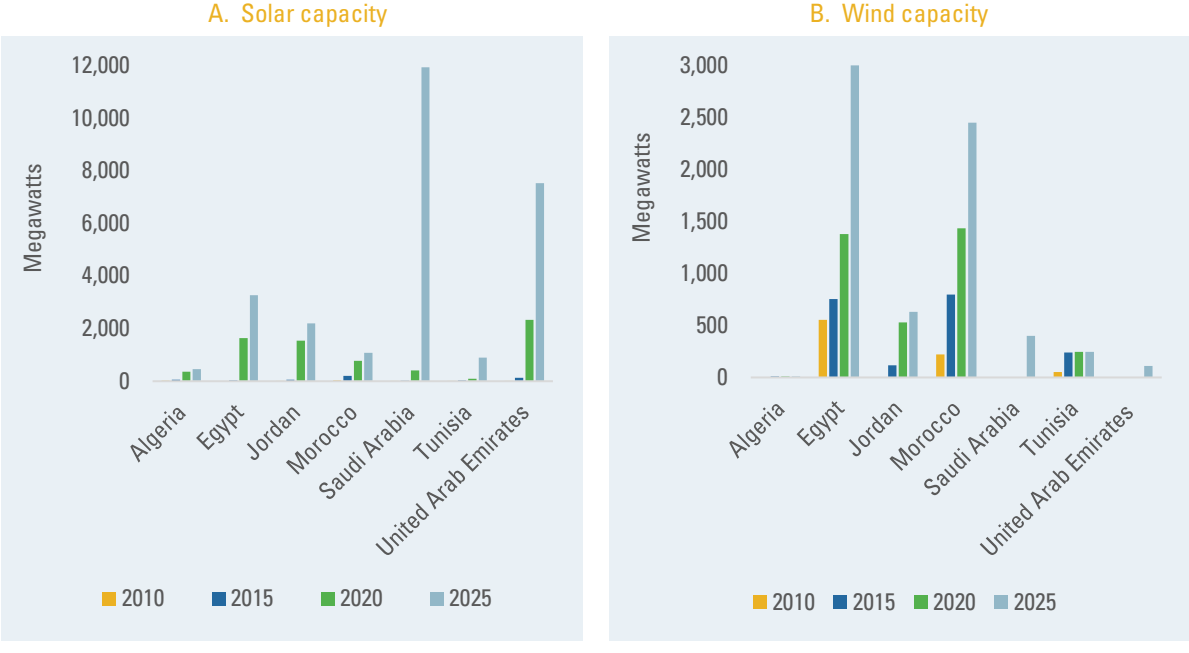
Figure 3. Share of renewable energy in total final energy consumption, 2023 (Percentage)



Source: ESCWA, 2026a.

Growth in solar and wind capacity has accelerated across parts of the Arab region. As figure 4 shows, the pace of expansion varies widely between countries.

Figure 4. Total installed solar and wind capacity (MW), 2010–2025



Source: Energy Institute, 2026.

The concentration of this growth in a limited number of countries points to significant scope to establish, or implement more consistently, frameworks that allow renewable energy to be integrated at scale. These include transparent grid-connection procedures, updated grid codes for variable renewable energy, rules for distributed generation and prosumers, storage regulations, flexibility and ancillary service mechanisms, renewable forecasting requirements, and planning processes that coordinate generation, transmission and distribution investment.

Renewable energy targets and projects therefore need to be matched by renewable-ready electricity systems, able to absorb variable generation, reduce curtailment, accommodate distributed resources, and balance supply and demand, and by the institutional capacity to operate them. Half of the participants surveyed[7] in 2024 for the ESCWA publication entitled *Investing in the Future: The Role of Human Capital in Enabling Just Energy Transitions in the Arab Region*[8] reported having no accessible learning opportunities for skills needed in emerging sustainable-energy sectors. Skills shortages in market design, renewable integration, cybersecurity, digital infrastructure, and cross-border coordination can become an additional constraint on deployment.

D. Structural pressures, market dynamics and institutional roles

Electricity systems in the Arab region are under increasing pressure from population and demand growth, climate stress, fossil-fuel dependence, subsidies, fiscal constraints, and uneven infrastructure readiness. These pressures differ by country, but together they explain why grid modernization has become a regional priority.

1. Rising and changing demand

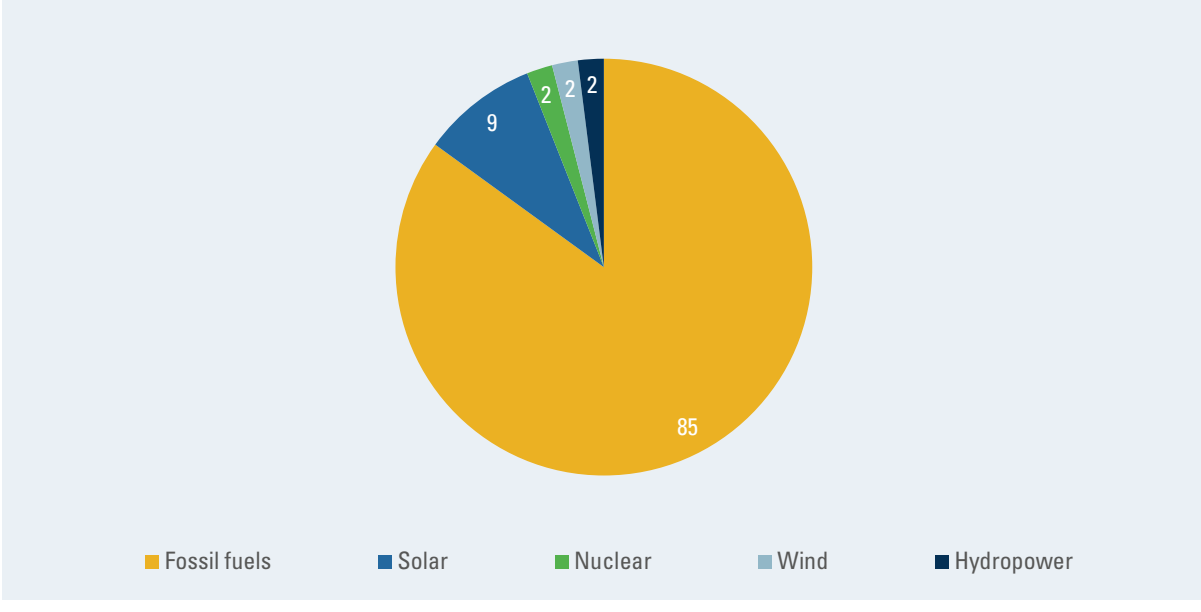
Energy consumption in the Arab region has grown significantly over recent decades, driven by economic and population growth, urbanization and rising demand for energy services. Total final energy consumption in the Arab region has expanded faster than the global average, although growth has decelerated since 2016. Industry and transport are the largest drivers of energy consumption, accounting for 24.6 and 29.4 per cent of total energy use in 2023, respectively, while the residential sector accounted for 15.6 per cent, reflecting rising heating and cooling needs.[9]

Electricity demand is also becoming more sensitive to climate conditions and water scarcity, as rising cooling needs and the growing electricity requirements of desalination, water pumping and wastewater treatment strengthen the interdependence between energy and water systems. This strengthens the case for appliance and building standards, demand response, time-sensitive tariffs, and planning that accounts for climate-driven demand peaks and water-energy interdependencies.

2. Fossil fuel dependence and energy vulnerability

The region's power systems remain deeply shaped by fossil fuels, which have played a central role in expanding electricity access, supporting economic growth and generating public revenue in exporting countries. Natural gas and oil together accounted for over 85 per cent of total electricity capacity in 2025. Of this fossil-fuel-based capacity, approximately 84 per cent is natural gas, which is the leading fuel in countries such as Algeria, Bahrain, Egypt, Oman, Qatar, Tunisia, and the United Arab Emirates. Oil accounted for the remaining 16 per cent of fossil-fuel-based capacity, particularly in major hydrocarbon-exporting economies such as Iraq, Kuwait and Saudi Arabia. Natural gas continues to play a key role in the energy transition by supporting system flexibility and replacing more carbon-intensive fuels. Nevertheless, continued dependence on hydrocarbons exposes power systems to price volatility, fuel supply disruptions, fiscal pressures, and transition risks.[10]

Figure 5. Electricity capacity by energy fuel mix, 2025 (Percentage)



Source: Data compiled by ESCWA based on IRENA, n.d.

These pressures reinforce one another: subsidies can encourage inefficient consumption, weak grids can constrain renewable integration, and conflict can damage infrastructure and institutional capacity.

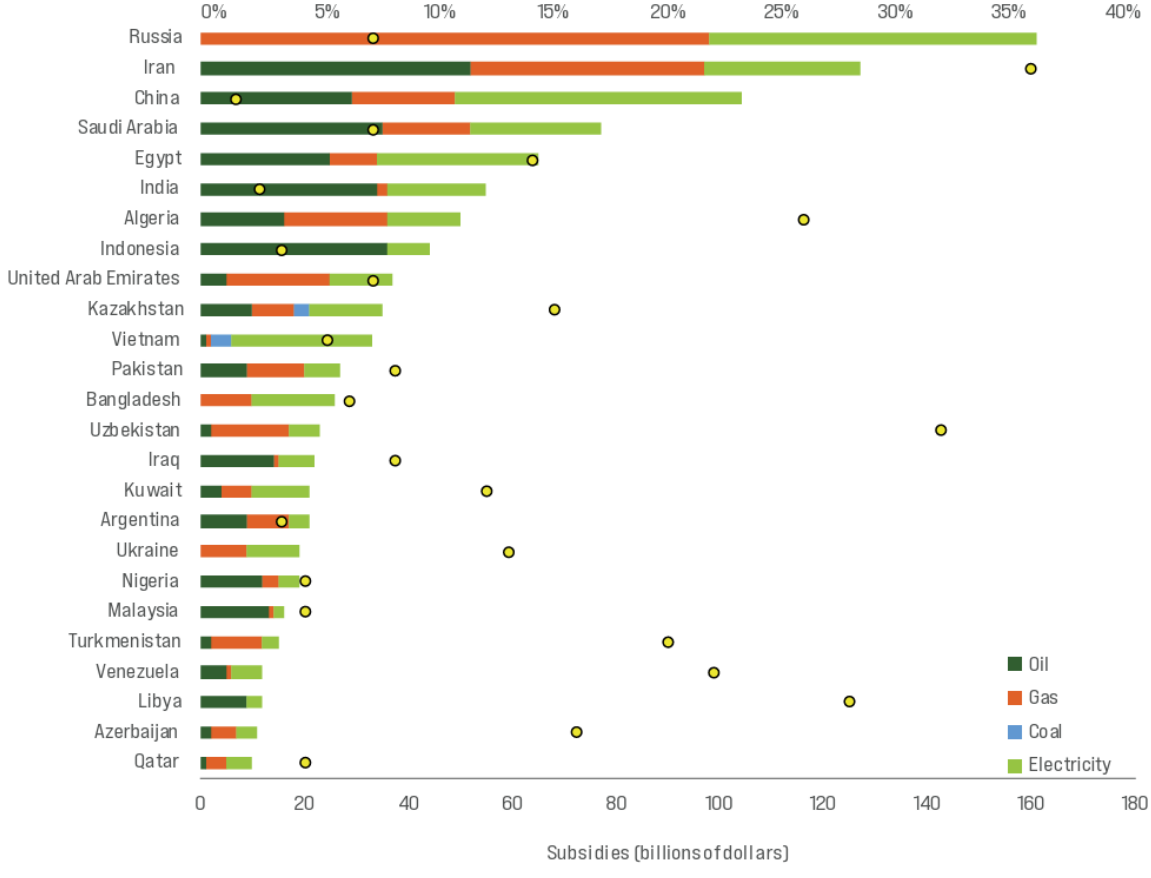
3. Subsidies, affordability and efficiency

Energy subsidies have played an important role in maintaining affordability in several countries. They have also contributed to high consumption and inefficiencies. Artificially low energy prices have significantly influenced domestic demand, particularly in electricity, transport and industrial

production. Energy subsidies in the Arab region are almost eight times greater than the global average.[11]

The policy challenge is not simply to remove subsidies, but to reform energy pricing in ways that improve efficiency, protect vulnerable households and support investment in reliable service. Well-designed reforms can create fiscal space for infrastructure, targeted social protection, energy efficiency and clean energy investment, whereas poorly designed reforms can increase energy poverty or generate social resistance. Redirecting just 1 per cent of gross domestic product (GDP) from subsidies to infrastructure investment could boost real GDP by 2 per cent and create half a million jobs over six years in the Arab region.[12]

Figure 6. Subsidies in billions of dollars versus as a share of GDP, 2022 (Percentage)



Source: ESCWA, 2025.

Efficiency is therefore also a grid-management and resilience measure: reducing inefficient consumption and managing cooling demand can lower peak loads, defer network investment, improve affordability, and reduce exposure to fuel shocks.

4. Utility finances, market dynamics and investment constraints

Grid modernization is capital intensive. It requires investment in transmission and distribution networks, substations, control systems, digital infrastructure, storage, metering, data systems, and maintenance, as well as financially viable utilities and clear regulatory frameworks that can crowd in public and private investment. Several Arab countries face fiscal constraints, high debt burdens, limited cost recovery, losses, arrears, or limited access to grants or concessional finance.

Financial performance across electricity-sector companies in the Arab region is mixed: recent financial statements show both positive net income and reported losses.[13] These results should be interpreted cautiously, as companies differ substantially in their mandates, market structures, public-service obligations, and treatment of government support and are therefore not directly comparable measures of national electricity-sector financial performance. Financial sustainability therefore needs to be reconciled with universal service through transparent compensation, targeted support, improved efficiency, and protection for vulnerable consumers. National electricity companies remain central because they operate much of the region's network infrastructure and are responsible for planning, reliability and service delivery. Sound finances and institutional capacity enable them to fund maintenance, loss reduction, renewable integration, and digital investment.

Private participation has expanded in generation and renewable energy, but remains more uneven in networks, storage, flexibility, and digital infrastructure. Investment in these areas depends on predictable regulation, transparent procurement, credible payment and cost-recovery arrangements, and risk allocation suited to national circumstances.

Distributed energy resources and digital technologies are also creating opportunities for a wider range of actors, including distributed energy providers, aggregators, energy service companies, storage operators, and "prosumers" that both produce and consume electricity. The expansion of energy service company markets in countries such as Jordan and the United Arab Emirates, alongside the growth of rooftop solar and net-metering schemes, illustrates how regulatory reforms can foster new business models while improving energy efficiency and expanding consumer participation.[14]

Realizing these opportunities requires rules governing connection, compensation, licencing, data access, consumer protection, and market participation, so that innovative business models reach beyond higher-income consumers and commercially attractive areas and help narrow, rather than widen, inequalities in access and service quality.

Clearly defined public and private roles are also essential. Governments set overall energy policy, public-service objectives and investment priorities; regulators establish tariffs, market rules, service-quality requirements, consumer protections, and data-governance frameworks, and utilities and system operators plan and operate networks, maintain reliability and integrate digital systems. Private companies can contribute capital, technologies, innovation, and specialized services, while development partners and financial institutions can reduce investment risks and strengthen institutional capacity. Across these roles, digitalization should reinforce public-service objectives by

improving utility performance and consumer service without excluding low-income, rural or digitally disadvantaged users.

E. Regional diversity and differentiated power-system needs

The diversity of Arab power systems, in income, resource endowments, demand growth, geography, access gaps, fiscal space, institutional capacity, and exposure to conflict and climate stress, requires differentiated policy approaches.

In Gulf Cooperation Council (GCC) countries, electricity access is universal, fiscal and institutional capacity is generally stronger, and major renewable energy, smart-grid and digital transformation initiatives are under way, including renewable-powered microgrid developments in Saudi Arabia and the Smart Grid Strategy of the Dubai Electricity and Water Authority (DEWA). The GCC reduced primary energy intensity from 5.73 megajoules per 2021 United States dollar of GDP at purchasing power parity in 2014 to 5.27 in 2023. It nevertheless remains the most energy-intensive subregion, with high electricity consumption and cooling loads.[15]

Electricity access is also generally high in the Mashreq and Maghreb, but power-system conditions vary widely. Some countries, including Jordan and Morocco, have developed significant renewable energy experience, while others face constraints linked to utility finances, regulatory implementation, infrastructure readiness, fossil-fuel dependence, or political instability. Conflict, displacement and migration have also placed additional pressure on electricity systems and generated informal demand in parts of the Mashreq.

Arab LDCs, including the Comoros, Somalia and the Sudan, continue to face the deepest electricity access gaps, especially in rural areas, alongside more limited fiscal space and greater exposure to climate and development constraints. Least-cost electrification strategies combining grid extension, mini-grids and stand-alone systems can play an important role when supported by sustainable business models, maintenance arrangements, targeted financing, and institutional capacity. In conflict-affected and fragile settings, priorities may instead centre on resilience, restoration and institutional recovery, including rebuilding utility, planning, regulatory, and maintenance capabilities (chapter 2).

Policy priorities must therefore reflect these different starting points. Higher-income systems may emphasize advanced grid management, storage, demand response, and flexibility markets; energy-importing countries may prioritize efficiency and renewable integration; LDCs may require decentralized electrification and concessional finance; and fragile contexts may need resilience-first planning and institutional support. Digitalization must likewise be adapted to local capacity and deployed in ways that do not deepen disparities affecting rural communities, low-income households, women, persons with disabilities, and displaced populations.

Countries will therefore follow different pathways towards digitalized power systems, which interconnection can complement through greater energy security, resilience and renewable integration (chapter 4).

F. Grid modernization and energy connectivity are regional development priorities

The regional context points to a shared need for stronger, renewable-ready and resilient grids, but also to differentiated pathways that reflect national circumstances. Grid investment will remain essential and is projected to account for close to 40 per cent of total power-sector investment over the next decade,[16] but infrastructure alone cannot address weaknesses in planning, regulation, utility performance, digital governance, and institutional capacity.

Stronger energy connectivity can complement national modernization by widening balancing areas, supporting electricity exchange, strengthening resilience to disruptions, and enabling more efficient use of renewable resources across borders. In fragile and conflict-affected settings, modernization must also support institutional recovery so that restored infrastructure is matched by the capacity to plan, operate, regulate, and sustain electricity systems over time.

The following chapters examine resilience and recovery in fragile and climate-stressed contexts, digitalization, cross-border cooperation, and the governance frameworks needed to translate investment into inclusive and sustainable power-system outcomes.

2. Resilience of power systems in contexts of conflict, fragility and climate stress

Key messages

- **Power system resilience must be treated as a core policy objective in the Arab region, not only as emergency repair after shocks.** Conflict, fragility, climate stress, fuel supply disruptions, and institutional weakness can combine to undermine electricity service, deepen energy insecurity and delay recovery.
- **Digitalization can strengthen resilience, but only when it is practical, secure and institutionally grounded.** Monitoring, forecasting, outage management, asset mapping, remote operations, and predictive maintenance can improve system visibility and recovery capacity. Gaps in cybersecurity, data governance and utility capacity can, however, create new vulnerabilities.
- **Recovery should build more resilient and inclusive power systems rather than recreate pre-crisis vulnerabilities.** Reconstruction and preparedness should protect essential services, combine grid rehabilitation with decentralized renewable solutions, strengthen utility and planning capacity, and ensure that poorer, rural and displaced communities are not left dependent on costly coping systems.

A. Why resilience matters now

Power systems across the Arab region are increasingly exposed to overlapping shocks. In several conflict-affected settings, such as southern Lebanon, Libya, the State of Palestine, the Syrian Arab Republic, and Yemen, conflict has damaged generation assets, substations, transmission lines, distribution networks, and fuel infrastructure. In others, fragility has weakened maintenance, planning, revenue collection, system operations, and investment. Across the region, climate stress, rising temperatures, growing cooling demand, water scarcity, and fuel supply disruptions are placing additional pressure on electricity systems that were often designed for more stable operating conditions.

In this context, resilience should be understood as the capacity of a power system to anticipate, prepare for and adapt to changing conditions, and to withstand, respond to and rapidly recover from disruptions through adaptable and holistic planning and technical solutions.[17] This understanding treats resilience not as a static condition but as system performance under both acute shocks and chronic stresses. It also recognizes that resilience is contextual: a system that is

resilient to one type of hazard may not be resilient to another, which matters in a region facing natural, human-caused and systemic risks at the same time.

This framing is especially relevant because electricity is no longer only a question of generation capacity or physical access to the grid. Reliable power underpins hospitals, water pumping and desalination, schools, telecommunications, food systems, public administration, small businesses, and household welfare. When electricity systems fail, the effects cascade across society and the economy.

A recent ESCWA policy brief entitled "Conflict and its shockwaves: escalating impacts and risks for energy, water and food systems in the Arab region"[18] shows how conflict-related shocks can destabilize tightly interlinked energy, water and food systems, with import-dependent and fragile economies hit first and hardest through rising inflation, higher power and fuel subsidy bills, disrupted transport and supply chains, and constrained fiscal space. These shocks underscore the need for policies that strengthen the resilience of power systems before, during and after disruption, including enabling frameworks for digitalization and cross-border connectivity, such as early warning systems, real-time monitoring, outage management, shared data systems, harmonized interconnection protocols, and diversified supply corridors. They reinforce the central argument of the present publication: digitalized and interconnected power systems are not only tools for efficiency and renewable integration, but also essential foundations for resilience and recovery.

Resilience is therefore fundamentally a planning, investment and governance challenge rather than a matter of emergency repairs alone. It requires power systems that can withstand disruptions, restore services rapidly and protect the most vulnerable users from prolonged energy insecurity.

Box 1. RICCAR: climate risks and implications for power-system resilience

The Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)[a] provides a regional evidence base on rising temperatures, heat extremes, water scarcity, and, in some areas, greater flood risk. These trends have direct implications for power systems by increasing cooling demand, placing additional stress on transmission and distribution networks, reducing the efficiency of thermal generation, and exposing substations, transmission corridors and generation assets to climate hazards. RICCAR projections indicate a substantial increase in extreme heat across the Arab region: by the end of the century, the annual number of days with maximum temperatures above 35°C could increase by up to around 80 days in parts of the southern Arabian Peninsula, while most of the region is projected to experience more very hot days above 40°C.[b]

RICCAR findings also highlight the close relationship between water and electricity: thermal power plants require water for cooling, while pumping, treatment and desalination depend on reliable power. This strengthens the case for climate-informed and digitalized planning, coordinated emergency response and cross-border connectivity that can provide flexibility when domestic systems are constrained by heat, drought or infrastructure disruption.[c]

[a] ESCWA, 2017.
[b] ESCWA, 2022.
[c] ESCWA, n.d.a.

Climate stress compounds these risks. Rising temperatures increase electricity demand for cooling, while water scarcity raises the importance of energy-intensive water services, including pumping, treatment and desalination. In the Gulf, electricity reliability is closely linked to water security: ESCWA notes that nearly 40 million people in GCC countries depend on desalinated water from the Gulf, and that damage to water or energy infrastructure, or contamination of marine resources serving desalination plants, could have severe consequences.[19] Climate-informed power-sector policies, supported by digital tools for demand forecasting, early warning, infrastructure monitoring, and outage management, as well as cross-border connectivity that can provide additional flexibility and emergency support when national systems are under stress, can help manage these risks.

B. How conflict and fragility affect power systems and shape recovery

Conflict and fragility affect power systems through several channels. The most visible is physical damage to infrastructure. Generation plants, substations, transmission corridors, distribution feeders, control rooms, fuel pipelines, storage facilities, and metering systems can be damaged, destroyed or made inaccessible. Since electricity systems operate as interconnected networks, damage in one part of the system can reduce supply, overload remaining assets, increase losses, and weaken reliability across wider areas.

The impact is not limited to direct destruction. Insecurity can prevent workers from accessing facilities, delay repairs, interrupt fuel delivery, limit procurement of spare parts, and reduce the ability of utilities to inspect and maintain assets. Over time, this shifts utilities from preventive maintenance to emergency repair. Temporary disruptions can become structural weaknesses, especially where institutions are already underfunded or fragmented. The Syrian Arab Republic illustrates these cumulative impacts: electricity-generation capacity fell from approximately 8,500 megawatts (MW) before the conflict to 3,500 MW by early 2025, largely because of damage to key power plants.[20] Reconstruction offers an opportunity to build a more resilient system by integrating modern digital monitoring, control and cybersecurity frameworks alongside investments in physical infrastructure.

Box 2. Electricity insecurity and digital planning in the State of Palestine

Electricity insecurity in the State of Palestine reflects interconnected constraints, including infrastructure damage, limited supply, import dependence, restrictions on movement and investment, institutional fragmentation, and constrained system planning. In Gaza, the war that began in 2023 has caused a severe electricity crisis, leaving much of the electricity infrastructure damaged or destroyed. Even before the war, electricity supply averaged only around 10 hours per day.[a] In May 2026, the World Bank estimated that more than 90 per cent of Gaza's electricity assets were damaged, with physical losses of about $560 million and reconstruction needs of $2.7 billion to $4.7 billion over five years.[b]

The West Bank faces different vulnerabilities, including high import dependence and major investment needs. Dependence on electricity imports declined from 97 per cent in 2019 to 88 per cent in 2025. Achieving 1.6 GW of installed solar capacity by 2030 would require $1.5 billion in generation investment and $330 million in system and network investment.[c]

Digitalization can support planning and resilience. Since 2021, a centralized solar mapping platform based on a geographic information system has helped integrate data from more than 200 distributors, covering photovoltaic systems, medium-voltage networks and substations. Such tools can support damage assessment in Gaza and guide renewable integration and network upgrades in the West Bank.[d]

[a] OCHA, n.d.
[b] World Bank, 2026a.
[c] Ibid.
[d] ESCWA, 2026c.

In conflict-affected and fragile contexts, restoring electricity is not only an energy-sector priority but a precondition for wider recovery, from health, water, sanitation, education, and telecommunications services to agriculture, local enterprise and public administration.

When electricity is unreliable, alternative systems emerge. These may include private diesel generators, informal neighbourhood networks, rooftop solar systems, batteries, and small-scale mini-grids, as in Lebanon, the Syrian Arab Republic and Yemen. Such systems provide essential relief, but they can also deepen inequality. Wealthier households, larger firms and urban users may be better able to secure backup power, while poorer households, rural communities, internally displaced persons, returnees, public institutions, and small enterprises remain more exposed to outages and high energy costs.

Fragility also changes how power systems must be planned and maintained. Demand may shift because of displacement, return movements, economic contraction, or reconstruction, while infrastructure damage may be uneven and poorly mapped, as in the Syrian Arab Republic. Emergency repairs and donor-funded interventions may not align with long-term planning, and shortages of data, skilled staff and spare parts can weaken preventive maintenance, increase losses and reduce the capacity of the system to absorb further shocks. In Yemen, years of conflict have led to a proliferation of donor-funded and community-based energy solutions, including solar microgrids and emergency electricity projects designed to restore basic services, which have been critical for maintaining access to electricity. Integrating them into a coherent long-term power-sector strategy will require addressing the fragmentation of the sector and strengthening institutional capacity, technical expertise and maintenance resources.

Conflict and fragility also increase payment, currency, political, security, and regulatory risks, making both public and private investment more difficult. Resilience therefore depends not only on rebuilding physical assets, but also on strengthening utility finances, institutional capacity, system planning, and the ability to maintain and operate infrastructure under uncertain conditions.

The scale of this challenge is evident in several fragile power systems. In Aden, Yemen, technical and commercial losses stand at 44 per cent,[21] while Iraq recorded transmission and distribution losses of 62 per cent in 2023.[22] Such losses reflect gaps in metering, billing, maintenance, system monitoring, investment planning, and utility governance, as well as technical factors.

Countries not experiencing active conflict also show how resilience can be strengthened before a crisis occurs. In Jordan, solar and energy-efficiency upgrades in schools reduced electricity bills by up to 90 per cent, while related analysis examined options for scaling sustainable energy in hospitals.[23] By reducing electricity demand and dependence on imported fuels, such measures can lessen exposure to fuel-price and supply shocks, ease pressure on public budgets and strengthen the continuity of essential services during periods of system stress.

The following section examines how digitalization can strengthen resilience while also introducing risks that must be managed.

C. Digitalization as a resilience enabler

Digitalization can strengthen resilience when it improves the ability of utilities and system operators to see, anticipate and respond to disruption. In fragile and climate-stressed contexts, the most important digital tools are often not the most advanced. Basic system visibility, accurate asset data, outage management, and secure communications may matter more than sophisticated artificial intelligence (AI) applications.

Digital tools can support resilience in five main ways.

1. **Improve system visibility.** Supervisory control and data acquisition (SCADA) systems, sensors, smart meters, geographic information systems, and digital asset registries help utilities understand the condition of generation, transmission and distribution assets. This is especially important after conflict or disaster, when the status of infrastructure may be unclear and paper records may be incomplete.
2. **Improve forecasting and preparedness.** Digital tools support demand forecasting, renewable energy forecasting, heatwave-related peak-load forecasting, and planning for fuel constraints. As climate stress increases cooling demand and renewable energy deployment expands, forecasting becomes increasingly important for maintaining system balance and anticipating system risks.
3. **Strengthen connectivity and coordination.** Real-time communication systems, data-sharing platforms and digital control technologies enable coordination across utilities, system operators and interconnected networks. This connectivity can improve emergency response, support cross-border electricity exchanges and provide additional operational flexibility when individual systems are under stress.
4. **Strengthen outage management, restoration and remote operations.** Outage management systems, fault detection, automated switching, customer-reporting platforms, and remote monitoring and control technologies help utilities locate faults, prioritize critical loads and restore service more quickly. Remote operations are particularly valuable where physical access to sites is difficult, unsafe or costly, and can support distributed renewable energy systems, mini-grids and storage assets in rural or conflict-affected areas. In fragile contexts, these tools can also facilitate the restoration of hospitals, water systems, telecommunications infrastructure, schools, and other essential services.

5. **Support predictive maintenance and asset management.** Sensors, asset data and analytics help utilities prioritize repairs, reduce equipment failures and make more effective use of limited maintenance budgets, thereby improving reliability and extending asset lifetimes.

Digitalization should therefore be treated as governance infrastructure, not only as technology procurement. Its contribution to resilience depends on standards for interoperability, data sharing and cybersecurity, clear institutional roles, and sustained technical and institutional capacity within utilities and regulators. With these in place, digitalization can enhance the ability of power systems to withstand shocks, adapt to evolving risks and recover more rapidly from disruption. Chapter 3 examines the technologies, deployment pathways, opportunities, and risks associated with digitalized power grids across the Arab region.

3. Digitalization of power grids in the Arab region

Key messages

- **Digitalization is a powerful but conditional enabler of power-system outcomes.** It can advance renewable energy integration, system resilience, operational efficiency, and more inclusive, reliable and affordable electricity services, but only where deliberate institutional, regulatory, financing, and capacity-development choices are made.
- **The promise of digitalization will only be fulfilled if no one is left behind.** Absent robust safeguards and inclusive approaches, digitalization could deepen existing disparities while exposing Governments, businesses and consumers to new cybersecurity, governance, interoperability, and consumer-protection risks.
- **There is no single pathway for grid digitalization across the Arab region.** Priorities should reflect each country's system needs and readiness, ranging from basic network visibility, metering and loss reduction to renewable forecasting, automated operations and distributed-energy-resource management.

A. Why digitalization matters for Arab power grids

Digitalization is not an end in itself, but a cross-cutting capability that can help Arab power systems integrate renewable energy, improve reliability and efficiency, strengthen resilience, and extend better services to underserved communities. Realizing these benefits requires financing, institutional capacity, cybersecurity, and effective data governance, with inclusion built into design and implementation.

The present chapter defines digitalized power grids, reviews key technologies and regional deployment, and examines their opportunities, risks and enabling policy requirements.

B. What digitalized power grids mean in practice

The terms "smart grid" and "digital grid" are frequently used interchangeably in policy and industry discourse, yet they carry different technical and institutional connotations. The present section sets out a working definition of a digitalized grid and its underlying architecture, and describes the digitalization continuum along which Arab countries approach grid modernization from different starting points and at different speeds.

1. Defining digitalized power grids

The Institute of Electrical and Electronics Engineers defines smart grids as electricity networks that use digital communication, sensing and control technologies and are characterized by the bidirectional flows of both electricity and information.[24] The International Energy Agency (IEA) defines a smart grid as an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users.[25] The focus of smart grids is automated operational control of electricity networks using predefined algorithms; key applications include self-healing networks, outage management, automated voltage control, smart metering, and demand response.

A digitalized grid is a broader concept: a power network in which sensing, communication, computation, and automated control are embedded across the entire electricity value chain. The digital transformation of the electricity sector goes beyond the smart grid and includes planning, operations, markets, asset management, and consumer services. Technologies such as cloud and edge computing, AI, digital twins, the Internet of Things and predictive analytics can support applications ranging from renewable energy forecasting and power dispatch to predictive maintenance and integrated energy platforms.

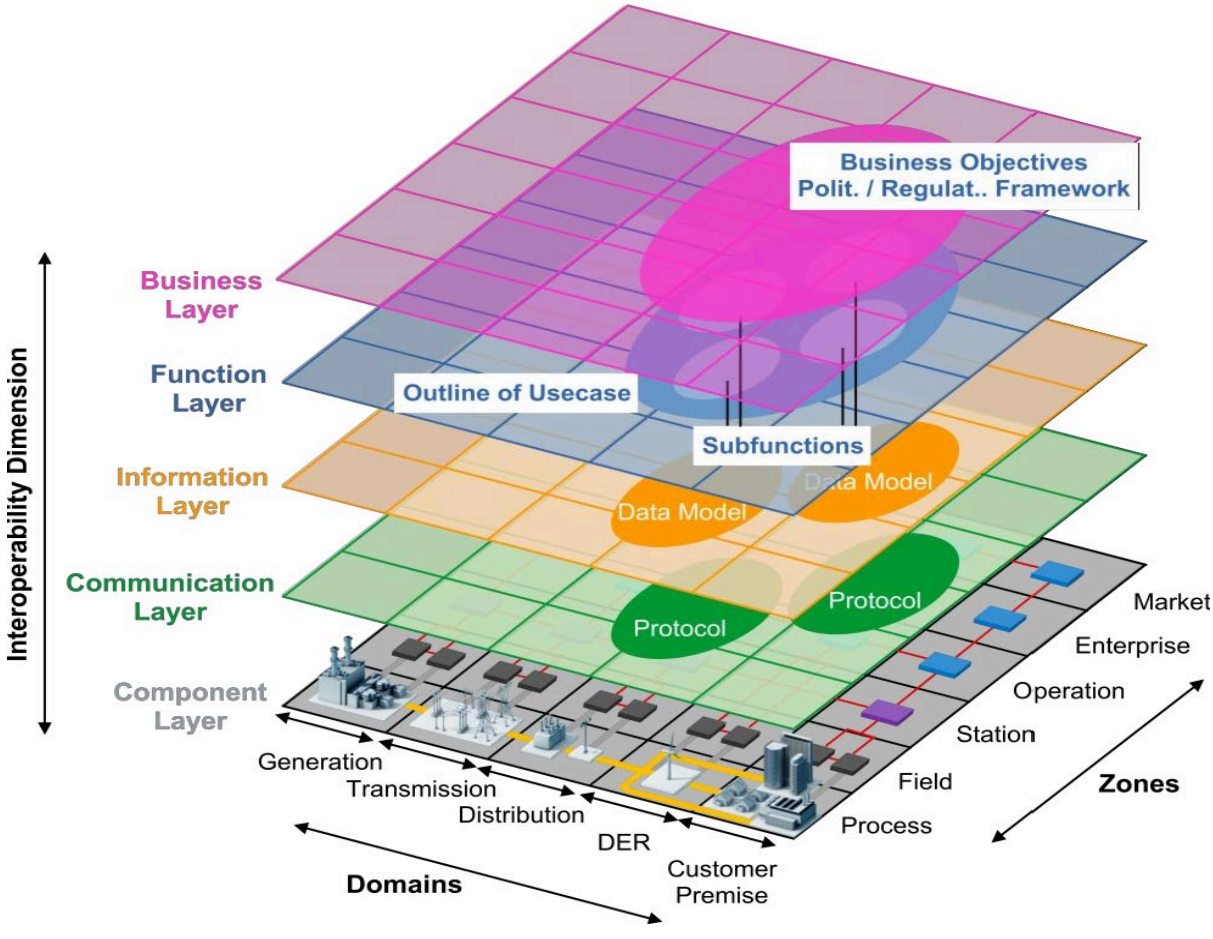
For this publication, a digitalized power grid is one in which digital technologies are systematically deployed to improve the observability, controllability and adaptability of the electricity system in support of reliability, efficiency, renewable energy integration, and inclusive access. This outcome-oriented definition recognizes that technical configurations will differ according to national and utility circumstances.

2. Five layers of smart grids

The Smart Grid Architecture Model, developed by the European Committee for Standardization, European Committee for Electrotechnical Standardization and European Telecommunications Standards Institute (CEN-CENELEC-ETSI), provides a framework for mapping smart-energy systems and identifying interoperability requirements. It distinguishes the following five layers:

- **Component layer:** physical power-system equipment, information and communications technology devices and software.
- **Communication layer:** protocols used to exchange data.
- **Information layer:** information and data models exchanged between functions and services.
- **Function layer:** functions and services required to operate the system.
- **Business layer:** objectives, processes, business models, and policy and regulatory considerations.

Figure 7. Smart grid architecture model framework



Source: CEN-CENELEC-ETSI Smart Grid Coordination Group, 2014.
Note: DER stands for distributed energy resources.

These layers extend across generation, transmission, distribution, distributed energy resources, and customer premises, and across levels of system management from field processes to operations, enterprises and markets. The framework illustrates that digitalization depends not only on installing equipment, but also on ensuring that technologies, data, operational functions, and institutional arrangements work together.

3. Digitalization continuum

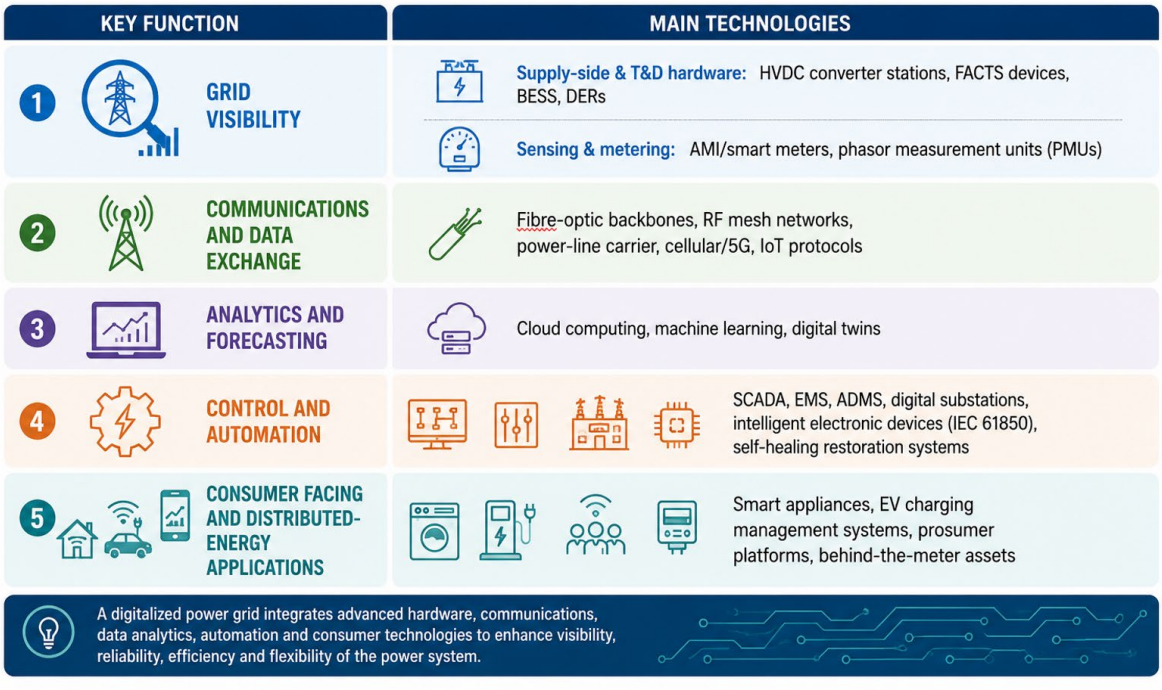
Digitalization is therefore not a binary condition but a continuum along which utilities and countries are positioned. A utility with limited automation but comprehensive advanced metering infrastructure (AMI) coverage is at a different point on this continuum from a utility with a fully digitalized control centre but minimal consumer-side metering. Given the wide variation in grid maturity, resource endowments and fiscal constraints across the Arab region, the present chapter

does not prescribe a single pathway but acknowledges that there are multiple entry points suited to different starting conditions. A country with constrained fiscal space may derive greater near-term value from targeted loss-reduction metering than from an integrated SCADA overhaul, while a more advanced system may prioritize power management platforms to accommodate rising renewable penetration.

C. Key enabling technologies for Arab power systems

Figure 8 presents the key functions of a digitalized power grid and the main technologies for delivering them, while table 1 sets out the operational value of the main technologies, along with deployment examples in the Arab region.

Figure 8. Key functions of a digitalized power grid and main technologies



Source: Compiled by ESCWA.
Note: FACTS = flexible alternating current transmission systems; BESS = battery energy storage systems; PMUs = phasor measurement units; RF = radio frequency; IoT = Internet of Things; EMS = energy management systems; ADMS = advanced distribution management systems; EV = electric vehicle; IEC = International Electrotechnical Commission; T&D = transmission and distribution.

Table 1. Operational value of main technologies and examples of digitized power grids

Key function	Operational value and examples
Grid visibility	Reduces transmission losses and increases usable transfer capacity on long-distance transmission lines. For example, the 500 kV high-voltage direct current (HVDC) link between Egypt and Saudi Arabia reduces electrical losses over its 1,300 km distance and provides 3 GW of bidirectional power exchange functionality.[a] Gives utilities granular, near real-time visibility of electricity consumption and system conditions. Over the period 2015–2020, DEWA installed more than 2 million smart meters.[b] Phasor measurement units, which provide synchronized, high-resolution voltage and current measurements, have been deployed in Jordan.[c]
Communications and data exchange	Moves data between field devices and control centres; forms the backbone enabling AMI and automation functions. For example, DEWA uses an IPv6 radio-frequency mesh network canopy for smart-meter and neighbourhood communications.[d]
Analytics and forecasting	Supports predictive maintenance, renewable-generation forecasting, optimized dispatch, and battery energy storage system scheduling. Lowers maintenance costs and raises equipment availability.
Control and automation	Enables real-time monitoring, remote switching and rapid fault isolation and restoration. As an example, DEWA implemented an Automatic Smart Grid Restoration System that locates the fault in the power network, isolates it and automatically reroutes power from an adjacent substation within milliseconds, practically eliminating grid downtime.[e]
Consumer-facing and distributed-energy applications	Enables demand-side participation and integration of distributed energy resources (DERs). Supports the accelerating adoption of electric vehicles in GCC markets and rising prosumer activity.

[a] Arab Fund for Economic and Social Development, n.d.
[b] DEWA, 2022a.
[c] Institute of Electrical and Electronics Engineers, 2021.
[d] Itron, 2017.
[e] DEWA, 2022b.

D. Status of digitalization in the Arab region

Digitalization is advancing unevenly across the Arab region. Several utilities, particularly in the GCC, have documented large-scale deployment of advanced metering, automation and data-driven grid management, while others remain focused on basic monitoring, network rehabilitation and service restoration. These differences reflect variations not only in technology deployment, but also in institutional capacity, financing and the wider enabling environment.

1. Regional maturity snapshot

In the GCC, DEWA has completed the short-term goals of its Smart Grid Strategy 2014–2035 and launched an updated strategy in 2021. The updated strategy moves from a technology-led to a value-driven approach, covering six themes: Foundational Capabilities, Grid Automation, Smart Energy Solutions and Green Mobility, Smart Water, Smart Grid AI, and Innovative Value-Added Services.[26] In Saudi Arabia, the Saudi Electricity Company had installed or replaced more than 10 million low-voltage smart meters by 2021 as part of its national distribution network modernization. In Qatar, the digitalization programme of the Qatar General Electricity and Water Corporation has achieved near-universal smart meter deployment and is now focused on grid automation, predictive operations, renewable energy integration, and enhanced system resilience through the third phase (2026–2030) of its long-term strategy under the theme "Leading practices phase".[27] Oman is building a digital, resilient and renewable-ready electricity network through smart meter deployment, grid automation, digital asset management, and integration of solar and wind power. Smart meter deployment reached 78.7 per cent by the end of 2025,[28] and a smart grid pilot has been implemented in the Wilayat of A'Seeb to integrate remote control systems and fault detection at the main control centre.[29] In July 2024, the Ministry of Electricity, Water and Renewable Energy of Kuwait signed a phase II agreement with the Kuwait Telecommunications Company to supply 500,000 smart electricity meters as part of a national push tied to Kuwait Vision 2035. These meters will help conserve energy and build a smart grid.[30]

Across the Maghreb and Mashreq, utilities are pursuing a diverse mix of initiatives. In Algeria, Sonelgaz is modernizing SCADA systems, digital control centres and network management infrastructure to improve grid reliability, operational efficiency and the integration of renewable energy sources.[31] The National Office of Electricity and Drinking Water (ONEE) of Morocco has deployed a meter data management platform to enable automated, secure use of electricity consumption data and support the national digital transformation agenda.[32] In Tunisia, the Société Tunisienne de l'Électricité et du Gaz has launched a Smart Grid Programme that includes AMI, meter data management systems, demand-side management tools, and digital customer services. Following successful pilot deployments, the programme is being scaled up nationally to strengthen network visibility, improve billing accuracy, reduce losses, and facilitate the integration of renewable energy.[33] In Egypt, digital switchgear and substation automation are expanding, though full process-bus implementation is expected to take considerably longer to reach maturity.[34] Overall, progress has been faster on metering than on full network automation and data integration.

In several Arab LDCs and conflict-affected settings, priorities centre on service restoration, network stabilization and foundational system visibility. Digital tools, where present, are more often used for humanitarian and operational monitoring, such as satellite-based assessment of damaged infrastructure in Yemen. This divergence underscores that countries in the Arab region lie at different points on the digitalization continuum and must account for fundamentally different starting conditions.

2. Notable deployments and pilots

Several deployments illustrate the range of digitalization pathways being pursued across the region.

Box 3. OETC digital and data-driven grid transformation in Oman

In 2025, the Oman Electricity Transmission Company (OETC) launched a data-driven transmission strategy integrating human capabilities, governance and digital technologies to strengthen grid reliability and financial sustainability. Supported by investments exceeding 1 billion Omani rials ($2.6 billion), OETC aims to develop a smart transmission grid by 2030, supporting the national target of 30 per cent renewable energy (9 GW). It is deploying SCADA and AI-based forecasting and assessing a digital twin solution for real-time grid monitoring, simulation and predictive analysis.[a] Digitalization has already delivered measurable benefits. Real-time asset monitoring enabled predictive maintenance, contributing to 99.9994 per cent network reliability by the end of 2025. Integrated warehouse and asset tracking eliminated inventory losses and reduced storage and supply costs by around 15 per cent. Workflow automation reduced errors and accelerated execution, while centralized data architecture consolidated information from grid stations, transmission lines and asset-management systems to improve planning, investment and maintenance decisions.

OETC's experience demonstrates that digitalization is an institutional transformation, requiring governance, workforce readiness and financing alongside technology. Its 97 per cent Omanization, leadership programmes and digital human resources tools support skills development, while its $750 million green sukuk provides financing for grid digitalization and renewable integration. These measures offer a transferable governance model for Arab transmission system operators pursuing digitalization at scale.

Source: Oman Electricity Transmission Company, 2026.
[a] MITSloan ME Editorial, 2026.

At a different level of digital maturity, Mauritania has pursued smart metering through the MOUNSIF prepaid-metering system of the *Société Mauritanienne d'Électricité,* which uses an electronic platform for remote management and monitoring.[35] The utility subsequently launched a programme envisaging the acquisition of up to 350,000 low-voltage smart meters, beginning with a pilot phase of 15,000 meters, and announced a meter-installation campaign in 2023. Efforts to develop the supporting architecture have nevertheless encountered implementation constraints: a 2026 procurement for server infrastructure to manage smart-meter data was declared unsuccessful because the compliant bids were considered too costly. The experience illustrates that advanced metering requires not only meters, but also affordable and interoperable data-management and operational systems.[36, 37, 38, 39]

Taken together, these deployments demonstrate genuine intent and ambition across the region. Capacity, however, remains fragmented. The central policy challenge is therefore to extend to other systems the institutional, financing and capacity conditions that have supported more extensive deployment in some.

Box 4. NEOM/ENOWA grid of microgrids

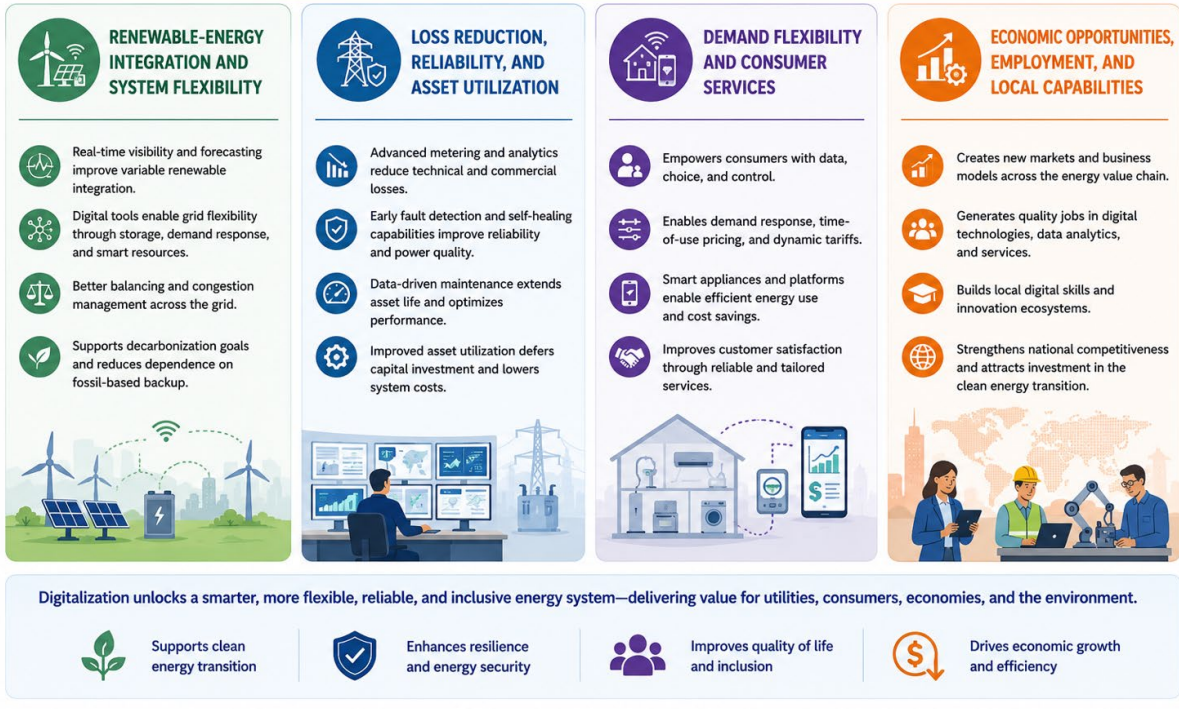
ENOWA, the energy and water subsidiary of NEOM established in Saudi Arabia in March 2022, is building a high-voltage smart grid structured as a "grid of microgrids", aiming to supply the entire NEOM region with 100 per cent renewable energy, complemented by a 1.5 GW net-zero AI data-centre campus in Oxagon ($5 billion first-phase investment, targeted for 2028).[a] AI-driven microgrid balancing across solar, wind and hydrogen systems has achieved 99.9 per cent grid reliability in pilot zones.[b] Co-locating renewable generation with data centres to power AI demand internalizes flexibility needs and provides a scalable template for balancing the region's rising data-centre demand with decarbonization goals. Purpose-built greenfield projects can serve as living-lab testbeds for the integration of distributed energy resources (DERs), interoperability and cybersecure microgrid control before lessons are scaled to incumbent grids. The "grid of microgrids" concept, which segments a large territory into interconnected, semi-autonomous microgrids, offers a resilience-oriented design option for other Arab countries with dispersed or fragile grids.

[a] Saudi Press Agency, 2025.
[b] Global Centre for Risk and Innovation, n.d.

E. Opportunities from digitalization

Building on this overview, the present section focuses on four outcome areas that digitalization makes possible for Arab power systems, as shown in figure 9.

Figure 9. Opportunities from digitalization



Source: Compiled by ESCWA.

1. Renewable energy integration and system flexibility

Renewable energy integration is digitalization's highest-impact use case for the Arab region, given the scale of utility-scale solar and wind deployment embedded in national energy targets. AI, machine learning and data analytics improve the forecasting of production and demand, reduce curtailment and enable more flexible grid operations. Advanced AI techniques such as ensemble learning and convolutional neural networks are being deployed to produce highly accurate short-term (minutes to hours ahead) forecasts for wind and solar generation.[40] Evidence from Australia, India and the United Kingdom shows that AI-based forecasting methods can be up to 45 per cent more accurate than traditional methods.[41] For Arab utilities pursuing ambitious renewable energy targets, advanced forecasting, real-time DER visibility and dynamic dispatch will increasingly determine whether installed renewable capacity translates into delivered, bankable generation.

2. Loss reduction, reliability and asset utilization

Digitalization improves the operational and financial performance of existing grid assets. Real-time network optimization, predictive maintenance and AI-driven automation reduce technical losses, detect faults, extend asset life, and enhance asset management, while advanced metering directly targets commercial losses through remote, tamper-resistant reading and near-real-time anomaly detection, thereby reducing operational costs and equipment downtime.[42] The prepaid meter rollout of the General Electricity Company of Libya (GECOL) (378,000 meters installed as at November 2024, with 2 million planned) reduced electricity demand by 210 MW through improved demand rationalization and behavioural change, and helped the utility recover revenues. GECOL also planned to launch a mobile application for services, reports and account top-ups, further demonstrating the benefits of digitalization.[43] Real-time visibility also enables automated restoration and more stable voltage and frequency management. Because these gains typically carry the shortest payback period among digital investments, loss reduction and predictive maintenance represent a natural entry point for fiscally constrained utilities beginning their digitalization journey.

Box 5. Advanced control centres and SCADA systems in the Arab region

The Gulf Cooperation Council Interconnection Authority (GCCIA) operates a main control centre in Dammam, Saudi Arabia, and a backup control centre in Ghunan, both equipped with supervisory control and data acquisition (SCADA) and energy management systems to perform day-to-day operational activities and ensure 100 per cent redundancy in case of emergencies.[a]

The high-level smart grid plan of Abu Dhabi prioritizes wide-area monitoring systems and phasor measurement units, which provide synchronized, high-frequency measurements that allow operators to assess grid stability and enhance transmission automation across large areas in real time. The plan also covers advanced digital meters that give consumers better information and automatically report outages, relays that automatically sense and recover from faults in substations, automated feeder switches that reroute power around problems, and batteries that store excess energy and make it available to the grid later to meet customer demand.[b,c]

In Saudi Arabia, it is mandatory for all transmission substations to have substation automation systems to ensure interoperable data exchange.[d] In addition, as of late 2024, Saudi Arabia had automated 32 per cent of its electricity distribution network, with a target of 40 per cent by 2025–2026 to enhance reliability and response times.[e]

[a] GCCIA, 2021.
[b] Abu Dhabi Department of Energy, 2024.
[c] GCCIA, 2024.
[d] Middle East Energy Dubai, 2023.
[e] Saudi Arabia Energy, 2024.

3. Demand flexibility and consumer services

Digitalization also expands demand-side flexibility. Demand-response programmes and dynamic pricing allow utilities to shift load away from peak periods, offering a lower-cost complement to new generation capacity. Rising electric-vehicle adoption is creating comparable demand-management needs at the distribution level. The *Tarsheed* platform in Qatar, which had connected more than 135 charging points, with roughly 1,000 stations expected by 2030, illustrates how coordinated charging management can prevent the growth of electric vehicles from undermining grid stability.[44] In Jordan, the ongoing deployment of smart meters is intended to support time-based electricity tariffs and more efficient load management, enabling consumers to respond to price signals and helping utilities reduce peak demand.[45] At the same time, consumer-facing platforms and prosumer arrangements, such as the regulation on self-production of electrical energy in Morocco, are shifting households and businesses from passive consumers towards active participants who monitor, respond to, generate, and trade electricity.[46]

Digital consumer services can also improve service delivery in fragmented and underserved electricity systems. In Somalia, the National Energy Corporation of Somalia piloted smart-metering and digital grid-management technology on its 20,000-customer distribution network. In August 2024, the technology provider reported that it had commenced a system-wide rollout, designed to enable the utility to identify losses and overloaded transformers and offer more flexible billing and payment options. This shows how modular digital tools can strengthen operational visibility, revenue management and customer service even where centralized grid institutions remain limited.[47,48]

4. Economic opportunities, employment and local capabilities

Beyond direct operational benefits, digitalization carries a broader economic value proposition relevant to the region's pronounced youth-employment challenge. Deployment of digital infrastructure generates near-term demand for installation, systems-integration and maintenance work, while sustained operation requires longer-term investment in data engineering, cybersecurity and DER planning skills. Local-content requirements embedded in recent smart-grid tenders in Saudi Arabia illustrate how digitalization procurement can be structured to support domestic industrial participation and small and medium enterprise growth, provided complementary skills and industrial policies are in place.[49]

Taken together, these four opportunity areas reinforce the key message that digitalization functions as a cross-cutting enabler rather than a stand-alone objective, simultaneously advancing renewable integration, efficiency, resilience, and economic diversification.

Box 6. Digitalization-driven industrial and skills development model of Algeria

Algeria is using electricity grid digitalization to support both industrial development and skills creation. Through Sonelgaz, investments in the local manufacture of electrical equipment and smart meters are helping strengthen domestic value chains, while specialized training programmes are building the workforce needed to operate and maintain digital electricity systems.

- **Building local industrial capabilities.** Sonelgaz, through its subsidiary SAIEG, has linked grid modernization to domestic manufacturing. Agreements with General Electric Algeria Turbines support the local production of electrical cabinets, metal structures and electricity meters, contributing to industrial integration, local subcontracting and reduced import dependence.
- **Developing technical skills.** Sonelgaz operates specialized training schools in electricity and engineering disciplines, while its transmission system operator reported training more than 3,000 staff in 2025 through internal programmes, technical schools and international partnerships.

Source: Sonelgaz, n.d.

F. Inclusion, equity and the digital-energy divide

Digitalization can help close gaps in electricity access, reliability and affordability. Inclusive design, consumer safeguards and targeted investment can ensure that its benefits reach rural and underserved communities, low-income households, women, older persons, and persons with disabilities, rather than reinforcing existing disadvantages.

1. Rural, remote and underserved communities

Digitalization can significantly accelerate energy access for rural, remote and underserved communities where central grid extension is technically challenging or economically unviable. Evidence from sub-Saharan Africa shows that remote monitoring can reduce mini-grid operating costs by up to 17 per cent, with investment payback periods as short as one year, substantially improving project viability.[50] These benefits are particularly relevant for Arab LDCs and conflict-affected contexts, where decentralized renewable energy systems, including solar mini-grids and solar home systems, have been identified as a priority solution for expanding rural electricity access, for example in Mauritania, the Sudan and Yemen.[51] Digital monitoring and smart management platforms can make these systems more reliable and less costly to operate.

2. Reliability, equity and affordability

Digital tools such as smart prepayment meters can improve utility efficiency and cost recovery by reducing arrears, improving billing accuracy and lowering non-technical losses. Their benefits are shared equitably only when supported by appropriate consumer protection measures. Evidence from New Zealand shows that prepayment systems encouraged extreme self-rationing of electricity among households in fuel poverty and can increase the risk of "self-disconnection", whereby households lose electricity access when they are unable to purchase additional credit.[52] This is relevant for countries

such as Egypt, where prepaid electricity meters have been deployed at scale as part of broader electricity sector modernization efforts.[53] As prepayment meters are often deployed among lower-income consumers, these risks can disproportionately affect vulnerable households unless accompanied by safeguards such as low-credit alerts, emergency credit, flexible payment options, and targeted social protection mechanisms. Similarly, dynamic and time-of-use tariffs can improve system efficiency by encouraging consumers to shift demand away from peak periods, but their benefits depend on households having the flexibility and technology needed to respond to price signals.

3. Ease of access for women, older persons and persons with disabilities

Digital-energy platforms are only as inclusive as the connectivity and digital literacy that underpin their use, and both remain unevenly distributed by gender across the region. According to the Global System for Mobile Communications Association (GSMA) Mobile Gender Gap Report 2024, the mobile Internet gender gap in the Middle East and North Africa (MENA) was 21 per cent in 2023, compared with only 4 per cent in Europe and Central Asia, reflecting a combination of affordability barriers, digital-literacy gaps and social and cultural constraints on women's access to technology. GSMA analysis also shows that, on average, the cost of an entry-level handset represents 24 per cent of women's monthly income in low- and middle-income countries, compared with 13 per cent of men's, highlighting the disproportionate affordability barrier faced by women.[54]

Applied to the power sector, unequal access to digital platforms has direct implications. Consumer-facing platforms, mobile billing applications and demand-response programmes that assume smartphone or Internet access risk excluding women, older persons and other underserved groups from services that are increasingly delivered by default through digital channels.

4. A compounded divide

Digitalization can amplify existing inequalities when gaps in electricity access, Internet connectivity, affordability, and digital skills overlap. Communities with unreliable electricity supply often also face limited broadband access and lower digital literacy, reducing their ability to benefit from smart metering, online services, demand-response programmes, and digital payment platforms. This is particularly relevant in LDCs and conflict-affected settings such as Somalia, the Sudan and Yemen. Bridging this compounded divide requires embedding inclusion by design across all functions of digitalized energy systems.

G. Key risks and operational constraints

Realizing the opportunities of digitalization depends on managing risks that could otherwise undermine reliability, erode public trust or leave utilities holding costly, underused digital assets. Figure 10 shows the key risks to digitalized grid operations and why they matter operationally, with some examples of the supporting evidence.

Figure 10. Risks to digitalized grid operations



Risk	Evidence and scale
Cybersecurity	In 2023, 67 per cent of energy, oil and utilities firms were hit by ransomware.[a] Ransomware attacks on the energy sector increased by 80 per cent in 2024.[b] Risk professionals in MENA rank cyberattacks and technology failure as the most feared "black swan" scenario.[c]
Data privacy and governance gaps	Most Arab data-protection regimes are only beginning to address energy-sector-specific data. Harmonized regional standards remain absent, which also constrains cross-border data flows needed for interconnection.

Risk	Evidence and scale
Interoperability and vendor lock-in	This creates dependence on single suppliers for spare parts, licensing and support, raising long-term costs and undermining the interoperability that regional power trade and shared control-room coordination require.
Human capital and skills gaps	Globally, 88 per cent of energy professionals surveyed identify workforce skills gaps as the principal barrier to accelerating digital adoption.[d] ESCWA assessments find significant mismatches in the Arab region between labour market demand and workforce capability, especially outside the GCC.[e]
Financing, cost recovery and stranded-asset risk	Weak utility balance sheets and below-cost tariffs across much of the region compound the challenge, linking financing risk directly to broader tariff and subsidy reform.

Source: Compiled by ESCWA.
[a] Sophos, 2024.
[b] Trustwave, 2025.
[c] Allianz, 2026.
[d] EY, 2025.
[e] ESCWA, 2025.

H. From digital potential to enabling policy

Digitalization is not a single technology package but a set of capabilities whose relevance depends on where countries lie on the digitalization continuum. Three broad pathways are shown in figure 11.

Figure 11. Differentiated digitalization pathways for Arab power systems



Source: Compiled by ESCWA.
Note: GIS = geographic information system; OMS = outage management systems.

Fragile and access-constrained systems benefit most from foundational tools and functionalities that restore basic operational visibility where it is currently absent. Intermediate systems are better served by capabilities that convert basic digitalization into operational reliability. Advanced systems

can extract additional value from already-digitalized infrastructure. Many utilities and countries in the region will find elements of more than one pathway relevant simultaneously, reflecting the uneven maturity of grid digitalization in the Arab region.

Positioning technology along these differentiated pathways is necessary but not sufficient. Institutional, regulatory, financing, and human-capital arrangements determine whether digital investment translates into reliable, inclusive and resilient grids; these enabling conditions are examined in the following chapters.

4. Digitalization in cross-border electricity cooperation and regional integration

Key messages

- **The Arab region has established substantial cross-border electricity infrastructure, providing a strong foundation for regional electricity trade. Most interconnections are still used mainly for system support rather than commercial trade.** Matching physical interconnections with strong institutions, digital and operational systems, and greater alignment in technical standards, market rules and data exchange can enable secure and efficient regional electricity trade.
- **Cross-border interconnections can strengthen market efficiency, power-system resilience and renewable energy integration.** They cannot, however, substitute for robust national grids. Their benefits depend on reliable domestic networks, operational readiness, reserve-sharing arrangements, coordinated dispatch, and emergency protocols.
- **Digitalization is essential for transforming physical interconnections into secure and effective regional electricity markets.** Real-time monitoring, improved forecasting, interoperable trading platforms, and secure data exchange can enhance coordination and market efficiency, provided they are supported by compatible digital systems, common standards, cybersecurity arrangements, and capable institutions.

A. From physical interconnection to regional electricity markets

Cross-border electricity cooperation in the Arab region has historically been driven by energy security, operational reliability and rising electricity demand. Existing interconnections across the Maghreb, Mashreq and GCC have demonstrated their value in providing emergency support, sharing reserves and strengthening system reliability. There is considerable scope to expand sustained commercial electricity trade, which remains limited relative to the physical infrastructure and technical potential of the region.

The priority is therefore to put in place the operational, commercial and regulatory arrangements needed for interconnections to function as regional markets. The ESCWA Committee on Energy, at its fifteenth session, accordingly emphasized strengthening the enabling environment for regional energy interconnection. Moving from occasional bilateral exchanges and emergency support towards continuous electricity trade will require coordinated system operation, transparent pricing and settlement, compatible market rules, and stronger institutional cooperation.

B. Interconnections and regional electricity cooperation in the Arab region

The integration of power systems in the Arab region began with the Maghreb grid (Algeria, Libya, Morocco, and Tunisia) initiated in the 1950s, followed by the Mashreq grid (Egypt, Iraq, Jordan, Lebanon, the Syrian Arab Republic, and others) in 1988, and the GCC grid (Bahrain, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates) in 2001.[55] The region today presents a mixed but increasingly promising landscape of interconnection initiatives, ranging from well-established subregional networks to emerging bilateral links and long-term integration ambitions anchored in the Pan-Arab Electricity Market.

1. Maghreb

The Maghreb grid enables bilateral electricity exchanges within the subregion and is complemented by links extending beyond the Arab region, most notably between Morocco and Spain through submarine cables across the Strait of Gibraltar and between Tunisia and Italy through the planned ELMED interconnection project.

2. Mashreq

The Mashreq grid, a network of bilateral and multilateral interconnections among the eight countries of the Eight Country Interconnection Project (see below), forms the backbone of regional electricity exchange in the Levant, facilitating economic electricity trade and improving power system reliability. Additional connections extend between Saudi Arabia and both Kuwait and Iraq, while major projects such as the Egypt-Saudi Arabia interconnection are under development, reflecting ongoing efforts to strengthen links between the Mashreq and the Gulf and to expand regional electricity trade. Egypt is also advancing interconnection projects with Cyprus and Greece, illustrating the potential of the region to serve as a bridge between Arab and European electricity systems.

3. Gulf Cooperation Council

The GCC grid is a synchronized regional grid operated by GCCIA that interconnects the six GCC countries. An ongoing project to interconnect the grid with Iraq is paving the way for future electricity trade between GCC countries and Iraq under the Regional and Arab Electricity Market Framework. A similar interconnection project is also underway to establish a direct connection between Oman and the GCC grid rather than relying on the existing connection via the United Arab Emirates. The GCC grid enables electricity exchanges primarily for reliability support, emergency assistance and reserve sharing, and is evolving into a dynamic marketplace that allows countries to trade surplus clean electricity as the share of renewable energy in the electricity mix rises, especially in Saudi Arabia and the United Arab Emirates.

4. Eight Country Interconnection Project

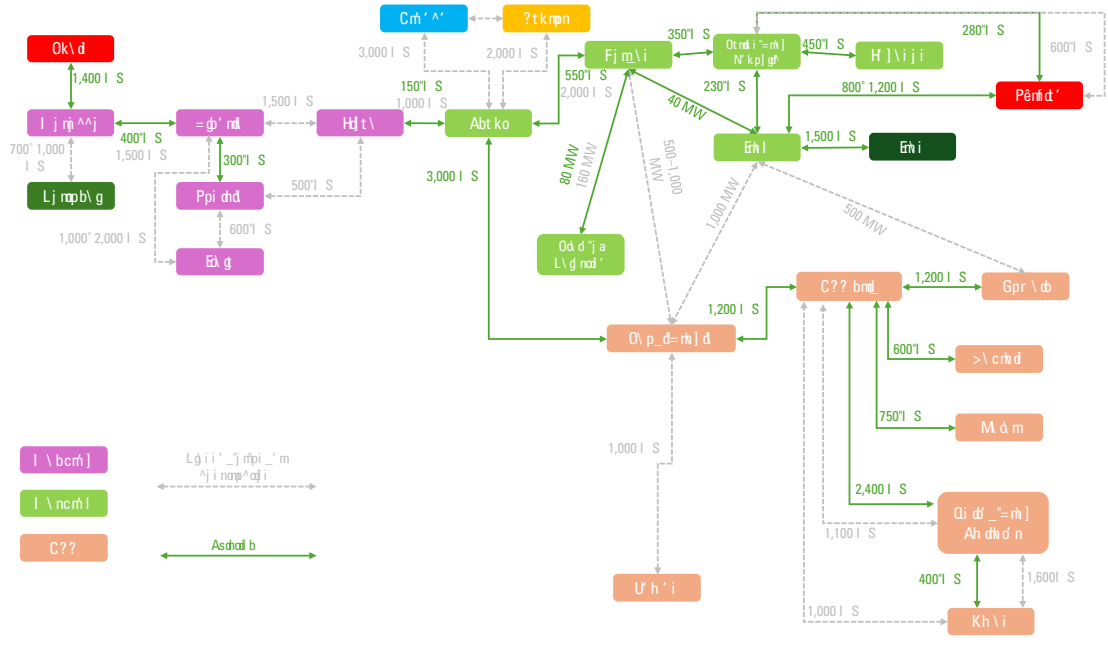
The Eight Country Interconnection Project is one of the oldest and most ambitious regional electricity integration initiatives in the Arab region. It involves interconnecting the electrical grids of Egypt, Iraq, Jordan, Lebanon, Libya, the State of Palestine, the Syrian Arab Republic, and Türkiye, creating an interconnected power system extending from North Africa to the Eastern Mediterranean and Anatolia. Several transmission links under the project have been completed. Political instability, armed conflicts and institutional and regulatory differences, especially following the conflicts in Iraq and the Syrian Arab Republic, have limited the use of these links, and exchanges still occur mainly through bilateral arrangements rather than coordinated regional trading mechanisms. The existing infrastructure nevertheless remains strategically important: recent initiatives to strengthen electricity cooperation among Egypt, Iraq and Jordan, together with proposals to expand the capacity of the Egypt-Jordan interconnection, could help revitalize parts of the network and support future regional market integration.

5. Pan-Arab Electricity Market

The Pan-Arab Electricity Market, led by the League of Arab States through its Arab Ministerial Council for Electricity, is a strategic initiative aimed at creating a unified regional electricity market across all Arab countries. Formally initiated in 2017, the Pan-Arab Electricity Market reached a major milestone in December 2024 with the signing of market and governance agreements, setting the stage for full implementation by 2038. Once fully integrated, it would become one of the largest multi-country power systems globally, with a total generation capacity exceeding 600 GW. This level of coordination is projected to save the region between $107 billion and $196 billion in system costs by 2035, while unlocking a vast reservoir of approximately 192 GW of renewable energy. The market is also expected to drive social and economic development, potentially creating millions of green energy jobs and improving regional energy security.[56]

The interconnections across the Arab region, along with their capacities, are depicted in figure 12.

Figure 12. Existing and proposed electrical interconnections by 2035



Source: IEA, 2025.

Interconnection projects that are planned or under construction across the Arab region are detailed in table 2.

Table 2. Planned or under construction interconnection projects in the Arab region

Countries and regions	Capacity (MW)	Estimated completion year
Egypt ↔ Saudi Arabia	3,000	2026
Egypt ↔ Jordan	2,000	2026
United Arab Emirates ↔ GCC	1,100	2027
Oman ↔ GCC	1,600	2027
GCC ↔ Iraq	500–1,000	2027
Oman ↔ Saudi Arabia	1,000	2027
Jordan ↔ Saudi Arabia	500–1,000	2028
Italy ↔ Tunisia	600	2028
Morocco ↔ Portugal	700–1,000	2029
Egypt ↔ Greece	up to 3,000	2030
Egypt ↔ Cyprus ↔ Greece	2,000	2030
Egypt ↔ Libya	1,000	2030
Algeria ↔ Italy	1,000–2,000	2030s
Algeria ↔ Libya	1,500	2035
Saudi Arabia ↔ Yemen	1,000	Not specified
Jordan ↔ State of Palestine	160	Not specified

Source: Compiled by ESCWA based on IEA, World Bank, GCCIA, European Commission, and STEG.

Within the GCC, electricity trading has surged since 2016, with volumes exceeding 1 million megawatt-hours in 2020 and annual growth rates of 15–20 per cent.[57] These trades have generated annual savings of approximately $200 million to $300 million, and GCCIA estimates the full potential of the market at $1 billion a year if trading opportunities were fully maximized through arbitrage and resource optimization.[58] Across the region, however, existing links are used primarily for system support and emergency exchanges, and differences in regulatory frameworks, market structures and institutional arrangements have constrained the development of an integrated and competitive regional electricity market.

Many pressures facing national power systems, including peak demand, renewable variability, reserve needs, and supply disruptions, can be managed more effectively through regional cooperation, and recent initiatives signal a shift towards deeper cooperation. According to the World Bank, by coordinating expansion plans and optimizing resources, the Pan-Arab Electricity Market can significantly reduce overall costs, allowing countries to optimize investments aimed at meeting peak national demands.[59] Complementary platforms and bilateral agreements are also expanding.

C. Cross-border electricity cooperation: strengths, weaknesses, opportunities, and threats

Cross-border interconnections can strengthen power-system resilience by diversifying supply, sharing reserves, enabling emergency imports, and creating larger balancing areas for variable renewable energy. The GCC grid demonstrates these benefits.

Realizing them depends on reliable domestic networks, coordinated dispatch, operating agreements, common technical standards, settlement and emergency protocols, cybersecurity, and trust among participating countries. Table 3 summarizes the position of the region.

Table 3. SWOT analysis

Strengths	Weaknesses
• Existing interconnection infrastructure: The interconnected subregional grids of the Maghreb, the Mashreq and the GCC provide a strong basis for regional electricity integration. • Demonstrated reliability benefits: GCCIA has prevented nearly 2,700 power disturbances since 2009,[a] highlighting the resilience benefits of interconnected systems. • Proven economic value: The GCC grid has generated approximately $2.8 billion in savings through more efficient system operation and avoided generation investments.[b]	• Most Arab interconnections remain underutilized as commercial trade platforms, functioning primarily as emergency support mechanisms rather than fully developed regional electricity markets. • Transmission and distribution losses average around 15 per cent, more than double the global average of 7 per cent, reflecting ageing infrastructure and insufficient maintenance.[c] • Differences in system standards, such as the 60 Hz frequency of Saudi Arabia versus the 50 Hz standard used by neighbouring countries, require costly HVDC conversion solutions.

Strengths	Weaknesses
• Established regional cooperation mechanisms: GCCIA provides a successful model of cross-border coordination. • Emerging electricity market experience: The digital trading platforms of GCCIA demonstrate a shift from emergency exchanges to market-based electricity trade. • Abundant renewable energy resource potential creates strong opportunities for cross-border clean energy trade.	• Common grid codes, dispatch protocols and settlement mechanisms remain largely undeveloped across the region. • Gaps in data availability, interoperability and information-sharing hinder coordinated regional planning and market development. • Wide differences in market structures, tariff systems, subsidies, and levels of market liberalization limit regional integration. • Significant gaps remain in skills related to smart grids, digital energy systems, data analytics, cybersecurity, and electricity market operations.
Opportunities	**Threats**
• The Pan-Arab Electricity Market provides an established framework for advancing regional electricity trade and market integration. • Enhanced regional integration could enable countries with abundant solar and wind resources to become major exporters of low-carbon electricity and green energy products. • Ongoing projects such as the GCC-Iraq, Saudi Arabia-Egypt and Jordan-Iraq interconnections will expand transfer capacity and create new electricity export opportunities. • Rising demand, varying peak-load profiles and diverse generation resources create strong opportunities for regional electricity trade; a power pool linking Egypt, Iraq, Jordan, and the GCC countries could reduce renewable energy curtailment by 35 per cent and avoid 8 million tonnes of CO_2 emissions annually by 2030.[d] • Wider deployment of SCADA systems, AI-based forecasting, smart-grid technologies, and digital trading platforms can improve system flexibility and market efficiency. • Multilateral development banks and climate funds offer increasing sources of concessional financing for interconnection, grid modernization and renewable energy projects.	• Political instability and conflict can disrupt infrastructure development and regional cooperation. • Governments may remain cautious about dependence on cross-border energy supplies. • Large differences in electricity tariffs and subsidy regimes complicate market integration and investment decisions. • High interconnection costs, financially stressed utilities and elevated sovereign risk in several countries may slow investment in regional infrastructure. • Rising temperatures, more frequent extreme weather events and increasing electricity demand for cooling could place additional stress on power systems and interconnections. • Greater reliance on digital platforms, smart grids and cross-border market systems increases exposure to cyberattacks and cross-border operational disruptions. • Differences in digital infrastructure and technical capabilities across countries could create unequal participation in a future regional electricity market. • Rapid growth in decentralized renewables, storage technologies and domestic generation may reduce incentives for some countries to pursue deeper regional electricity integration.

Source: Compiled by ESCWA.
[a] GCCIA, 2024.
[b] GCCIA, 2021.
[c] IEA, 2025.
[d] Petitet and others, 2025.
Note: SWOT is short for strengths, weaknesses, opportunities, and threats.

Interconnection should therefore be treated as one component of a broader resilience strategy, complementing investment in robust domestic grids, institutions and operating capacity.

D. Digitalization as an enabler for cross-border coordination

Realizing the Pan-Arab Electricity Market will depend on digital infrastructure and enabling policies as well as physical interconnections. Advanced energy-management systems, real-time monitoring, automated dispatch, and secure data exchange can improve the visibility and control of cross-border electricity flows. Their effectiveness, however, requires interoperable systems, harmonized data standards, agreed cybersecurity protocols, and institutions capable of coordinating across national boundaries.

Box 7. Supporting increased energy security and resilience through energy transition

Through the project entitled "Supporting increased energy security and resilience through energy transition", ESCWA is strengthening the digital foundations needed for deeper regional electricity cooperation, including in Iraq. As Iraq expands renewable energy and strengthens its interconnections with GCCIA, Jordan and Türkiye, priorities include secure cross-border data exchange, renewable energy forecasting, congestion management, and reserve sharing. These capabilities can improve grid flexibility, reduce curtailment and support the participation of Iraq in a more connected regional electricity market.

Source: ESCWA, n.d.b.

1. Real-time system monitoring and coordination

Cross-border electricity exchanges require continuous coordination between transmission system operators to maintain system stability, ensure secure operation and manage unexpected disturbances. Advanced digital technologies, including SCADA systems, energy management systems, phasor measurement units, and wide-area monitoring systems, provide operators with real-time information on network conditions, power flows, frequency, and system constraints.

Enhanced situational awareness improves the ability of interconnected systems to respond to disturbances, optimize dispatch decisions and coordinate balancing actions across borders. Real-time data exchange also increases transparency among system operators and reduces the risk of cascading failures, making timely, accurate and interoperable data increasingly important for reliability and security as cross-border trade expands.

2. Forecasting, flexibility and renewable energy integration

The growing deployment of solar and wind energy across the Arab region increases the need for more sophisticated forecasting and system balancing capabilities. According to the 2025 Solar Outlook Report of the Middle East Solar Industry Association, solar capacity in MENA could exceed

180 GW by 2030.[60] Improved forecasting reduces uncertainty, facilitates more efficient scheduling of generation resources and enhances the management of cross-border electricity flows.

Digital technologies also support the development of more flexible power systems capable of integrating higher shares of variable renewable energy. In 2022, sudden cloud cover reduced solar generation by approximately 500 MW in just a few minutes in two GCCIA member countries. This caused frequency disruptions, and the digital situational awareness tools of GCCIA allowed the automatic activation of high-voltage direct current under-frequency controllers, which immediately stabilized the system frequency.[61] Combined with regional coordination, advanced forecasting allows interconnected systems to benefit from geographic diversity in renewable resources and demand, transmitting surplus renewable generation to neighbouring systems, reducing curtailment and improving system utilization and reliability.

3. Digital platforms for market operation and data exchange

The digital trading platforms of GCCIA demonstrate how digitalization can support the transition from occasional bilateral exchanges towards more continuous electricity trading. Automated scheduling systems, standardized data exchange protocols, electronic market platforms and real-time settlement mechanisms increase transparency, reduce transaction costs and improve market efficiency. Common data standards, interoperable communication systems and coordinated market platforms also help harmonize operational and commercial practices among participating countries, providing an important foundation for more integrated regional electricity markets.

Over the period 2018–2021, GCCIA launched its digital energy trading platform and bilateral contracts platform. These platforms stimulate daily energy trading contracts among member countries, similar to global electricity markets, and serve as the cornerstone for operating the broader spot market for energy trade.[62] In 2022, the digital platform contributed to a 20 per cent increase in the volume of energy exchanged between member countries.[63] In 2023, the platform processed import requests totalling approximately 1.3 terawatt-hours.[64]

4. Cybersecurity and digital readiness

Greater connectivity also creates shared vulnerabilities. Cross-border data exchange and automated operation require compatible cybersecurity standards, secure information-sharing arrangements and coordinated incident-response protocols. Regional training and cooperation can help build the trust and technical capacity required for system operators to exchange sensitive operational data. Chapter 5 examines these governance and cybersecurity requirements in greater detail.

Digital readiness also supports joint system studies, transmission planning and investment assessment by allowing countries to work from compatible data and analytical tools. Matched by common rules, trusted institutions and sustained cooperation, these shared technical capabilities can deepen regional electricity integration.

5. Governance and policy frameworks for digitalized grids

Key messages

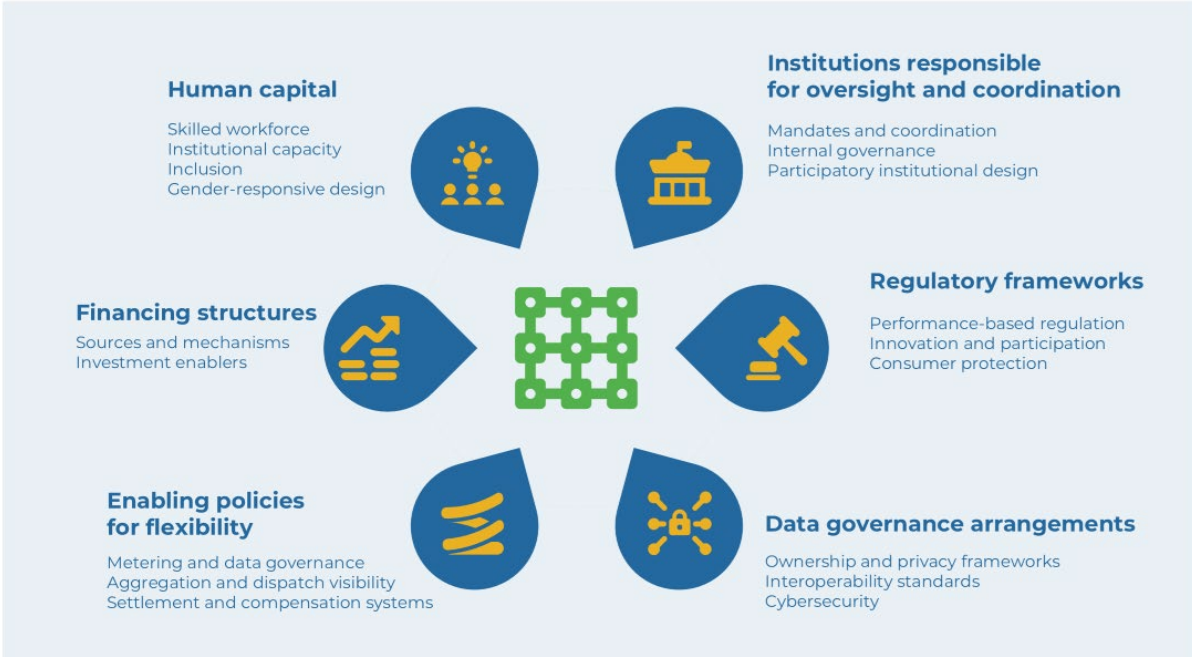
- **Governance and technology are both binding constraints.** Strengthening governance is one of the preconditions for realizing the benefits of grid digitalization in the Arab region.
- **Regional cooperation on governance and standards lowers the cost and risk of digital transformation for individual countries.** Shared cybersecurity arrangements and interoperability standards protect increasingly interconnected systems, while knowledge-exchange platforms let countries earlier on the digitalization continuum draw on governance capacity built elsewhere in the region.
- **A common framework spanning institutional architecture, regulatory design, data governance, enabling policies, financing, and human capital can help Arab countries advance digitalized grids coherently.** Foundational steps must be in place before advanced reforms can take hold, while the sequencing itself must be adapted to each country's starting point on the digitalization continuum.

A. Governance for an enabling environment

The present chapter addresses the governance conditions that determine whether the opportunities provided by digitalization are realized equitably and at scale. A coherent governance framework accelerates returns on investment, while weak institutional mandates, unclear rules or the absence of cost-recovery mechanisms can neutralize the benefits of digital infrastructure. Governance therefore needs to be an integral component of the twin green and digital transitions reshaping Arab power systems.

The chapter is organized around six interdependent pillars of digitalized grids, as shown in figure 13: the institutions responsible for oversight and coordination; the regulatory frameworks that shape investment incentives; the data governance arrangements that determine trust and interoperability; the enabling policies for flexibility; the financing structures that support deployment; and the human capital required to sustain digital transformation. These pillars reinforce one another rather than operating in sequence, and a weakness in any single pillar constrains the benefits that accrue from the others.

Figure 13. Six pillars of digitalized grids



Source: Compiled by ESCWA.

B. Institutional architecture for digitalized grids

Institutional architecture is the starting point for governance, since it determines who is accountable for translating intent into practice. Digitalization redraws the boundaries of responsibility across the power sector, drawing energy ministries, regulators, utilities, and system operators into intersecting relationships with telecommunications regulators, cybersecurity agencies and data-protection authorities. Clearly defined mandates, coordination mechanisms and implementation responsibilities help keep digitalization moving across institutional boundaries.

1. Mandates and coordination

As grids digitalize, the traditional division of responsibility between ministries, regulators, utilities, and system operators requires deliberate reconsideration. Energy ministries retain responsibility for strategic direction and policy coherence but need in-house expertise to assess technology choices and their fiscal implications. Regulators face a more fundamental shift, as their traditional focus on cost-of-service oversight and tariff approval must expand to encompass performance monitoring, data governance and incentive design. This entails moving from regulating inputs, such as approved capital expenditure, towards regulating outcomes, such as reliability metrics, loss reduction and data quality. Utilities and system operators, meanwhile, must plan for distributed

energy resources, manage cybersecurity exposure and operate increasingly automated networks, responsibilities that often exceed the technical capacity built under conventional grid operations.

The 2023 electricity-sector reform in Morocco is a successful example of a regulatory mandate helping to advance an increasingly digitalized and decentralized grid. Law No. 48–15 on the regulation of the electricity sector established the National Electricity Regulatory Authority as an independent regulator, and Law No. 40–19, adopted in 2023, expanded its mandate to include setting tariffs for system and distribution services, approving the capacity of the grid to integrate electricity generated from renewable energy sources and setting the purchase tariff for surplus electricity.[65] In 2025, the regulator issued the distribution-network access tariff for operators injecting electricity into or withdrawing it from the grid, and published rolling five-year hosting-capacity assessments, demonstrating that changes in mandates can ease planning and operations of digital grids.

These evolving mandates also need to be coordinated across government, since digitalization cuts across institutional silos in ways conventional grid governance rarely required. Decisions on smart-meter data standards, cybersecurity protocols or DER interconnection rules routinely involve energy, telecommunications, digital economy, and finance ministries simultaneously, yet most Arab governance structures are not designed for this degree of cross-sectoral coordination.

Cybersecurity agencies, data-protection authorities and digital ministries also increasingly hold authority over decisions that directly affect grid operations, although they have historically had limited engagement in energy governance. Structuring coordination at an early stage allows these emerging mandates to be aligned with power-sector needs. Durable coordination mechanisms – such as interministerial committees, joint task forces, designated digital-energy focal points, and memoranda of understanding with cybersecurity and data-protection authorities – with clear implementation responsibilities, timelines and reporting lines are therefore a prerequisite for translating digital grid strategies into operational reality.

2. Utility governance and implementation capacity

The internal governance of publicly owned utilities, which continue to dominate the electricity sector across most of the region, shapes their capacity to absorb digital transformation. Utilities with limited managerial or financial autonomy often face structural obstacles to digital investment, including constrained procurement flexibility, weak incentives for efficiency and limited ability to hire specialized technical staff. Corporatization and functional unbundling, where pursued, can strengthen governance by focusing on commercial objectives and enabling performance-based management and accountability. The pace and sequencing of such reforms vary across the region and must be adapted to national political-economy conditions.

Bahrain illustrates how governance reform and digital transformation can advance together. The Government is separating asset ownership and long-term investment planning from the day-to-day operations of the Electricity and Water Authority, forming an Electricity and Water Holding

Company in 2025 to manage State investments in energy and water facilities. This restructuring is proceeding alongside the authority's own digital-transformation initiatives, including a network control centre enabled by AI and the Internet of Things for real-time monitoring and control through a unified operating platform, demonstrating that corporatization and digitalization pursued in parallel can help a utility capture greater commercial benefits.[66]

3. Inclusive and participatory institutional design

Institutional design also has distributional consequences. Advisory boards, regulatory commissions and interministerial coordination bodies are more likely to produce policies that address affordability, accessibility and rural-urban disparities when their membership extends beyond utility representatives and technical specialists to include consumer representatives, civil-society organizations and local governments. This is particularly relevant in decentralized and rural contexts, where mini-grid and off-grid programmes are often designed and implemented with limited input from the communities they serve. Embedding structured mechanisms for stakeholder representation into institutional design helps ensure that digitalization strategies reflect the needs of diverse consumer groups from the outset.

C. Regulatory design for digital adoption

Regulatory design determines whether well-mandated institutions have the incentives to act effectively. Regulators can inadvertently discourage digital investment if tariff structures fail to recognize digital capital expenditure, if performance incentives remain tied to legacy metrics, or if the rules governing innovation and private participation have not adapted to a digital environment.

1. Cost recovery and performance-based regulation

Digital investments, such as AMI, control centre upgrades and analytics platforms, carry substantial upfront capital costs alongside recurring software, licensing and cybersecurity expenditures that conventional tariff-setting methodologies, designed around physical asset depreciation, do not readily accommodate. Where regulators have not established clear mechanisms for recovering these costs, whether through regulatory asset base adjustments, dedicated digitalization surcharges or performance-linked cost pass-through, utilities face weak incentives to invest despite the efficiency and reliability gains of digitalization. Regulators therefore need cost-recovery mechanisms that balance affordability with the long-term financial sustainability of digital transformation, neither penalizing consumers with premature tariff increases nor leaving utilities financially exposed.

Jordan illustrates how cost recovery and reform can be sequenced around metering capability and the incentive trade-off. Facing rising digital-investment costs, it introduced a monthly connection charge for self-generation consumers, with higher grid fees for commercial and industrial users, to

fund network costs, and then used the resulting metering infrastructure to roll out time-of-use tariffs, which are expected to shift load off-peak and reduce system costs.[67]

Cost recovery alone does not guarantee efficient deployment. Cost-of-service regulation reimburses approved expenditure regardless of outcomes, providing limited incentives to deploy digital technologies effectively. Performance-based regulation instead ties revenue to outcomes such as loss reduction, reliability and customer service. It requires regulators to define indicators, set baselines and verify results, capabilities that some regulators are only beginning to build. The RIIO (revenue = incentives + innovation + outputs) framework of the United Kingdom ties utility revenue to output categories such as reliability, safety and environmental performance rather than to approved expenditure alone, paired with dedicated innovation funding.[68] Cost-recovery design and performance-based regulation together determine not only whether digital investment occurs, but also whether it delivers.

2. Innovation, participation and consumer protection

Digital technologies often evolve faster than frameworks designed to govern them. Regulatory sandboxes, which allow controlled testing of new technologies, business models or tariff structures under relaxed regulatory conditions, offer a way to manage this uncertainty while generating evidence to inform subsequent full-scale regulation. For example, the Future Regulation Sandbox of the Office of Gas and Electricity Markets of Great Britain, developed through 2024, is designed to test and trial rule changes needed to accommodate innovations supporting a smarter, decarbonized energy system.[69] As no comparable dedicated energy-sector sandbox has yet been implemented in the Arab region, regulators may find it more practical to begin with targeted pilot projects to bring propositions to the market while gathering evidence to inform permanent reform.

Innovation cannot substitute for consumer trust, which depends on whether affected consumers have a voice in shaping digital-service rules. As smart metering, dynamic pricing and automated disconnection become widespread, decisions once made administratively now carry direct, sometimes immediate, consequences for household electricity access. Public consultations, consumer advisory panels and transparent tariff-setting allow affordability and inclusion concerns, particularly for vulnerable consumers, to be addressed before rules are finalized. Such mechanisms are especially important for disconnection rules, prepayment safeguards and dynamic-pricing disclosures, each of which requires deliberate design to prevent efficiency gains from becoming one-sided. Embedding the consumer voice from the outset strengthens the trust on which acceptance of smart metering and data-driven tariffs depends.

D. Data governance, interoperability, cybersecurity, and cross-border cooperation

As digitalized grids generate expanding volumes of granular operational and consumer data across an increasingly heterogeneous mix of vendors, protocols and legacy assets, Governments and

regulators face questions concerning who owns and controls these data, how systems interoperate and how the expanding attack surface is managed. Open standards and protocols for interoperability with legacy infrastructure are particularly important, since much of the existing grid equipment in the region predates current digital standards.

1. Data ownership, access and privacy frameworks

The ownership, permissible use and access conditions of detailed household and business electricity data remain only partially defined across most Arab jurisdictions. Establishing clear rules for who owns metering and grid-level data, whether the consumer, the utility or a third-party service provider, and on what terms these data may be accessed, shared or monetized, is a precondition for both consumer trust and the emergence of value-added digital services such as demand-response aggregation and energy-management applications. Several Arab countries are developing general data-protection legislation, yet sector-specific rules addressing the particular sensitivities of granular energy-consumption data, including its potential to reveal occupancy patterns and household behaviour, remain largely absent. Such rules would give utilities and regulators legal certainty as new data-driven business models emerge.

The Personal Data Protection Law of the United Arab Emirates (Federal Decree-Law No. 45 of 2021) is a comprehensive law closely aligned with international standards such as the General Data Protection Regulation of the European Union. The United Arab Emirates Data Office acts as the federal data regulator and issues guidelines for the implementation of the law.[70] Although general in scope, the law provides a foundational legal architecture on which more granular rules for energy-sector data, including grid data, metering and cross-border data transfers, could be built in the region.

2. Interoperability standards and open protocols

Fragmented procurement practices have left many Arab utilities operating metering, communication and control systems built on differing, often proprietary, protocols that constrain data integration and future upgrades. National and regional strategies that mandate open standards can prevent this fragmentation from compounding over time. As regional interconnection deepens, adopting internationally recognized protocols, such as IEC 61850 for substation automation and common information model standards for grid data exchange, allows new digital assets to interoperate with legacy infrastructure while positioning utilities to participate in cross-border data exchange. Interoperability standards therefore serve a dual function of protecting utilities from vendor lock-in domestically and establishing the technical foundation on which regional electricity cooperation ultimately depends.

3. Cybersecurity and cross-border cooperation

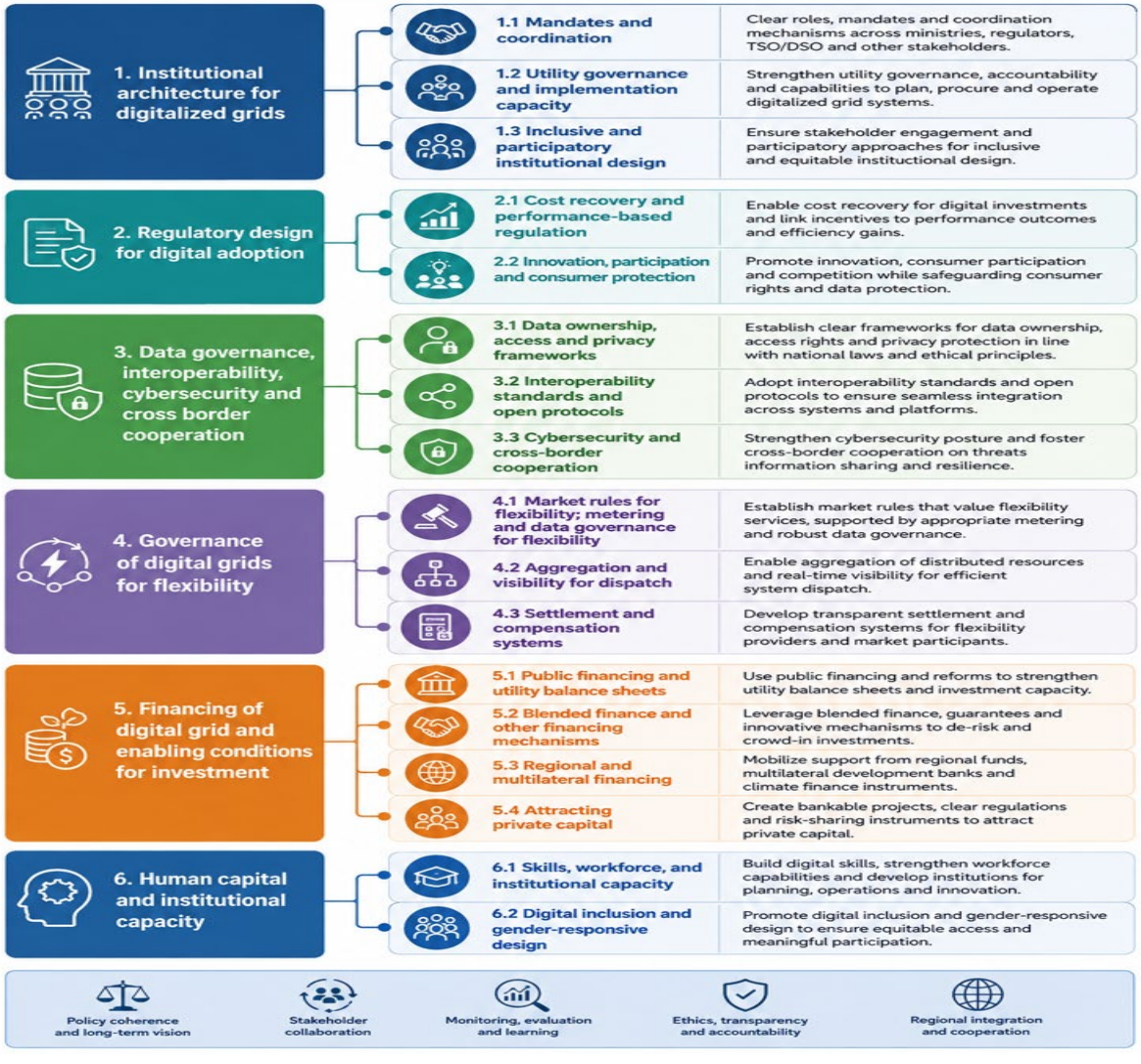
Securing digitalized grids requires an institutional response that extends across agencies and national boundaries. Domestically, national cybersecurity strategies for critical infrastructure, sector-specific computer emergency response teams and information-sharing arrangements among utilities, regulators and cybersecurity agencies form the backbone needed to detect, respond to and recover from grid incidents. Several Arab countries have established cybersecurity agencies with cross-sectoral mandates; their dedicated engagement with energy-sector technology, as distinct from broader information technology systems, varies considerably.

The National Cybersecurity Authority of Saudi Arabia, established in 2017, provides a notable model for protecting critical energy infrastructure through mandatory cybersecurity controls, centralized threat monitoring and dedicated incident response mechanisms. This centralized yet sector-specific approach is increasingly relevant for other Arab countries. Similarly, the Cybersecurity Authority of the Sudan provides an institutional foundation to support cybersecurity in the electricity sector as grid digitalization advances.[71] In July 2026, the Ministry of Energy of the Syrian Arab Republic signed a memorandum of understanding with the Saudi cybersecurity firm Cypher to establish an integrated protection system and regulatory framework for critical energy-sector infrastructure. Part of the post-conflict digital transformation of the country, the agreement marks a deliberate effort to embed cybersecurity safeguards into the electricity sector.[72]

Regional electricity trade, shared control-room coordination and cross-border demand-response services depend on exchanging operational data under agreed terms. Because an incident in one interconnected system carries direct implications for its neighbours, the case for regional information-sharing, joint incident-response protocols and harmonized cross-border standards is strengthening. The wider regional cooperation agenda requires sustained political commitment alongside technical alignment.

GCCIA has a strong information security management system and is ISO/IEC 27001 certified, which ensures protection of sensitive data across borders.[73] This illustrates how other cross-border interconnection initiatives, including those linking the Mashreq and North Africa, could embed cybersecurity governance structures as electricity trade expands.

Figure 14. Governance framework for digitalized, flexible and inclusive grids



Source: Compiled by ESCWA.
Note: TSO/DSO = transmission and distribution system operators.

E. Governance of digital grids for flexibility

Renewable integration and demand-side flexibility depend on whether the underlying digital infrastructure, such as metering, visibility and settlement, is governed in a way that lets flexibility be measured, dispatched and paid for.

1. Metering and data governance for flexibility

Activating flexibility first requires granular, interval-level consumption and generation data, since utilities and aggregators cannot compensate a resource for a response they cannot measure. Rules on who can access these data, on what terms and within what latency determine whether third-party aggregators, demand-response providers and system operators can build products around them. The key question is therefore not whether data can be collected, but under what rules they can be shared beyond the utility, which will shape how flexibility markets develop in the region.

Box 8. Flexibility market

Flexibility markets are mechanisms through which electricity generation or consumption can be adjusted at specific times and locations to maintain system balance and support efficient grid operation. Resources can include generators, energy storage systems, demand response, electric vehicles, and aggregated distributed energy resources. Flexibility services may be procured through markets, contracts or other arrangements that reward participants for increasing, reducing or shifting electricity generation or consumption in response to system needs. Effective participation typically relies on timely and reliable metering and data systems that can measure and verify the provision of flexibility services.

Source: IEA, 2023.

2. Aggregation and visibility for dispatch

Metering data become useful for flexibility once distributed and demand-side resources are visible to, and dispatchable by, the system operator. This requires rules that let individual assets be aggregated into a single resource for operational purposes, and communications standards that let aggregator platforms exchange data with control-room systems on compatible protocols. Where registration of distributed assets or interoperable systems is absent, distributed and off-grid capacity remains invisible to central dispatch regardless of its installed capacity.

The Shams Dubai initiative, launched by DEWA, requires eligible rooftop solar installations to be connected under DEWA's net-metering framework and equipped with bidirectional smart meters. The programme establishes technical and capacity limits for grid connection and enables DEWA to monitor and record electricity exported to and imported from the grid, providing visibility over distributed renewable energy generation connected to the network.[74] Law No. 82–21 of Morocco on electricity self-generation similarly links new connections to published, rolling hosting-capacity assessments, so that distributed additions are registered against a system-wide view of available capacity.[75] Both examples show how governance choices enable DER visibility.

3. Settlement and compensation systems

Flexibility is activated only if a settlement system exists to compensate it and to translate metering and aggregated asset capacity into a defined payment, credit or tariff adjustment. Where settlement

rules do not extend to behind-the-meter resources, or cannot attribute value to energy storage services, flexibility resources have limited incentive to participate even when technically available.

Settlement design need not stop at compensating individual assets; it can instead be structured around contracted outcomes. The Solar Energy Corporation of India illustrates this approach. Rather than defining ownership, classification or dispatch rules for storage, it tendered a firm, round-the-clock renewable-plus-storage product, with the winning bid (approximately $0.055 per kWh) undercutting new coal, generating multipliers for climate mitigation efforts. For Arab regulators, this offers an alternative to the direct utility-ownership model, based on settling and paying for a delivered outcome rather than for a storage asset.[76]

F. Financing of digital grid and enabling conditions for investment

A digital grid requires investment, and the conditions for mobilizing, deploying and sustaining this capital need to be created deliberately and linked to implementation capacity. Digital grid investments require not only capital expenditure for initial deployment but also continued financing for maintenance, software licensing, cybersecurity, data management, and workforce development.

This section examines public financing, blended finance and public-private partnership models, regional and multilateral financing instruments, and the conditions required to attract private capital at scale.

1. Public financing and utility balance sheets

The financial capacity of publicly owned utilities to fund digital investment is shaped by fiscal space, the treatment of consumer subsidies, and the extent to which sovereign guarantees are available to support borrowing. In several Arab countries, below-cost tariffs and chronic consumer subsidies constrain utility revenues and, by extension, their capacity to internally finance or service debt for digital modernization. Strengthening public financing capacity is therefore a structural precondition for sustained digital investment financed through conventional channels.

2. Blended finance and other financing mechanisms

Where public financing alone is insufficient, blended finance structures that combine concessional public or donor capital with private investment can improve the risk-return profile of digital grid projects sufficiently to attract private participation. Climate funds and multilateral development banks are advocating this approach as a way of assisting countries in meeting the commitments set out in their nationally determined contributions under the Paris Agreement.

Results-based financing, which ties disbursement to measurable digitalization outcomes such as AMI rollout milestones or verified loss-reduction targets, aligns private-sector incentives and

provides lenders with clear performance benchmarks. For example, the €300 million sustainability-linked loan signed in 2025 between the European Bank for Reconstruction and Development and ONEE is explicitly tied to ONEE preparing a digital roadmap strategy and implementing digital use cases, alongside decarbonization and dispatch-optimization goals.[77]

Concessional finance can play a corresponding role in countries with more limited fiscal and institutional capacity. In the Comoros, the World Bank supported a solar energy access project that combines investments in solar generation and battery storage with grid upgrades, automation and the commercial and operational recovery of the national electricity corporation SONELEC. The project includes Standard Transfer Specification smart meters, improvements to the utility's management information and customer-management systems, and AMI across customer groups. It illustrates how development finance can combine renewable energy integration with digitalization and utility reform, rather than treating digital-grid investments as stand-alone technology projects.[78]

Djibouti provides an earlier example of concessional financing for initial digital-grid investment. Additional financing from the International Development Association for the Power Access and Diversification Project included a $2 million smart-metering component within a broader programme to expand electricity access and improve the efficiency of *Électricité de Djibouti* by reducing system losses. The intended loss-reduction outcome was not achieved, however, illustrating that concessional finance can enable initial digital investment but must be accompanied by adequate procurement, implementation and utility operational capacity.[79, 80, 81]

In Jordan, the World Bank approved $250 million in additional financing in 2023 for the Electricity Sector Efficiency and Supply Reliability Program for Results. This outcome-tied programme to strengthen the finances of the National Electric Power Company addresses broader sector efficiency and governance reforms that create the preconditions for digitalization. It also functions as a blended-finance-adjacent mechanism (multilateral results-based lending paired with private investment in generation driven by public-private partnerships).[82]

3. Regional and multilateral financing

Regional and multilateral development institutions, together with dedicated green climate finance mechanisms, provide financing instruments that many Arab utilities cannot access through domestic capital markets alone. Effective use of financing instruments requires utilities and Governments to develop bankable project pipelines that meet the required due diligence and high reporting standards, a capacity constraint that underscores the connection between financing access and institutional readiness.

For example, in 2024, the Arab Fund for Economic and Social Development joined the Master Cooperation Agreement of the International Finance Corporation, which commits partners to mobilize $500 million in co-financing alongside more than 35 other multilateral and bilateral development banks to support private-sector-oriented projects across its member States.[83] Through the $200 million Electricity Services Reconstruction and Enhancement Project of the World Bank

(2020–2026), multilateral financing supported the electricity sector of Iraq by introducing AMI, smart meters and metering control centres alongside network rehabilitation, laying the digital foundations for improved efficiency, reduced losses and future grid modernization.[84]

4. Attracting private capital

The broader conditions that determine whether private capital is attracted to digital grid investment include regulatory predictability, transparency in procurement and clear allocation of risk between public and private partners. International good practice, including competitively tendered AMI contracts and standardized public-private partnership contracts that allocate demand, currency and regulatory risk predictably, can reduce the risk premium private investors attach to Arab power-sector digital projects.

The build-own-operate-transfer model, under which a private operator installs and manages metering infrastructure under a defined service contract before eventual transfer to the utility, offers utilities a mechanism to access private capital without assuming full upfront capital risk. Similarly, as-a-service models, including metering-as-a-service and software-as-a-service arrangements for grid analytics, allow utilities to convert capital expenditure into predictable operating expenditure. For example, the Saudi Electricity Company installed more than 10 million smart meters at a cost of SAR 9.5 billion ($2.5 billion), with about 40 per cent of the meters manufactured locally, demonstrating that bundling local-content requirements with large-scale AMI tenders builds domestic industry while attracting private capital.[85]

G. Human capital and institutional capacity

The benefits of digitalization cannot be realized without a workforce capable of planning, operating and continuously improving these systems. Skills needs extend beyond utility technical staff to regulators, ministries and the broader institutional ecosystem.

1. Skills, workforce and institutional capacity

Building the human capital and institutional capacity required for digitalization involves action at four connected levels: national skills pipelines, utility workforce transformation, institutional capacity, and regional knowledge exchange. At the national level, sustained digital transformation depends on skills pipelines that extend beyond individual utility training programmes to encompass science, technology, engineering, and mathematics education linked to energy-sector needs, occupational standards for digital-energy roles, technical and vocational education and training, and certification programmes aligned with international standards.

Table 4. Top 20 demanded technical skills in the region

1	Engineering	11	Digital technologies
2	Operations and maintenance	12	Electrical wiring
3	Oil and gas	13	Marketing
4	Project management	14	Electrical equipment
5	Construction and installation	15	Procurement
6	Electrical systems	16	Research
7	Finance and investment	17	Blueprinting
8	Environment health and safety	18	AutoCAD
9	Petrochemical	19	Project implementation
10	Commissioning	20	International standards

Source: ESCWA, 2025.

ESCWA Skills Monitor data show that workforce demand spans both established power-sector competencies and newer digital capabilities. Engineering and operations and maintenance rank first and second, while digital technologies also feature among the region's 20 most demanded technical skills. This highlights the need for a blended workforce combining electrical and operational expertise with digital, managerial and implementation skills.

The Digital Egypt Builders Initiative provides advanced training in AI, data science, cloud computing, cybersecurity, and software development through partnerships between Egyptian and international universities and technology companies, helping to build a pipeline of highly skilled digital professionals aligned with national digital transformation objectives. The National Vision for the Modern Yemeni State (2019) advances digital transformation chiefly through a knowledge economy. Efforts include digital libraries and knowledge development, and this broader digital development framework could serve as an entry point for future smart-grid and energy-digitalization initiatives.[86] Other Arab countries can build on such national programmes by developing dedicated digital-energy skills roadmaps aligned with national education, labour market and energy sector priorities.

Digitalization in utilities requires effective change management, workforce reskilling, internal mobility, and gender-balanced hiring to build new capabilities while retaining institutional knowledge. Regulators similarly need expertise in areas such as performance-based regulation, data governance, digital tariffs, and cybersecurity. Capacity can be strengthened through dedicated cybersecurity units, standardized procurement frameworks and closer coordination among energy, digital and cybersecurity institutions. Given uneven expertise across the region, joint training, peer learning, harmonized certification, and the sharing of good practices can accelerate capacity development, particularly in least developed and conflict-affected countries, and help all countries participate effectively in more connected regional electricity systems.

2. Digital inclusion and gender-responsive design

Digital transformation is inclusive only if consumers can use digitalized services and the institutions designing them reflect the people they serve. On the consumer side, user-friendly multilingual interfaces, digital literacy programmes for underserved and rural populations, and accessible design, such as screen readers and alternative formats for persons with disabilities, prevent efficiency gains from bypassing those who lack digital fluency. Mobile applications and digital payment options, including app-based billing and mobile-based payments, can further improve accessibility by reducing the need to travel to utility offices, benefiting women, older persons and persons with disabilities who face mobility constraints.[87] Community outreach and awareness campaigns on smart metering and digital tools, together with simplified consumer communication on tariffs and billing, extend these gains further.

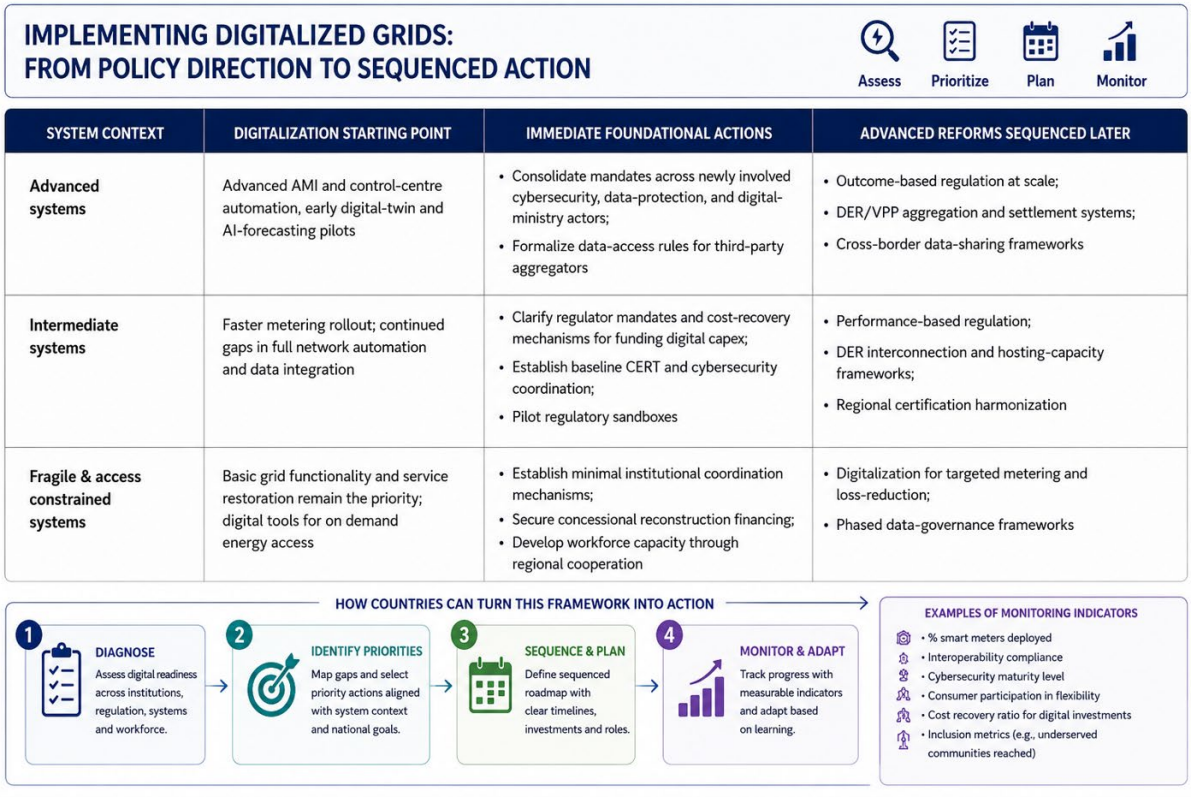
Representation of women in energy sector institutions, from ministries to utility boards and regulatory commissions, remains limited across much of the region, narrowing the perspectives that shape digital grid policy. Gender-disaggregated data, gender-responsive procurement and decision-making that reflects diverse consumer groups are practical starting points, particularly in rural and decentralized contexts, where women often manage household energy and where mini-grid and off-grid programmes offer a direct opportunity to embed inclusive design into local governance from the outset.

H. An implementation framework for differentiated pathways

Robust governance is closely associated with realizing the benefits of digitalization, and governance reforms need to recognize that Arab power systems are at different stages of the digitalization journey. The six pillars discussed above can be organized into two tiers of action: foundational measures that establish the minimum enabling conditions for digital transformation, and more advanced reforms that become feasible once these foundations are in place. The differentiated priorities and actions associated with varying levels of readiness are presented in figure 15.

Putting this framework into practice requires moving from policy direction to sequenced action. National digital-readiness diagnostics, assessing institutional capacity, regulatory maturity and workforce readiness against this framework, can provide the evidence base for each country to identify its own priority actions, timelines and monitoring indicators, grounding digital ambition in the governance capacity and institutional foundations required to deliver it equitably.

Figure 15. Differentiated priorities and sequenced actions



Source: Compiled by ESCWA.
Note: CERT = computer emergency response team; DER = distributed energy resources; VPP = virtual power plant; capex = capital expenditure.

I. Diagnosing the enabling environment for digital power transformation

To assess the enabling conditions discussed in this chapter, the present study proposes the **Arab Digital Power Enabling Environment Scorecard (ADPEES),** which complements the digital maturity assessment by evaluating the policy, institutional, regulatory, financial, and human-capacity foundations required to support and sustain digitalized power systems across the Arab region.

1. Concept and methodology

ADPEES recognizes that technology deployment and the enabling environment do not always advance at the same pace. Extensive deployment of smart meters, grid automation and other digital technologies does not necessarily imply robust regulatory, institutional, cybersecurity, or data-governance arrangements. Conversely, countries may have established strong enabling frameworks even where digital deployment remains limited.

Designed as a diagnostic rather than a ranking tool, ADPEES helps identify strengths, gaps and priority areas for action across the following five dimensions of the enabling environment for digitalized power grids:

- Strategic and institutional governance: National strategies, institutional mandates and coordination mechanisms for digital transformation.
- Data governance, interoperability and cybersecurity: Frameworks for data management, system interoperability, privacy, and cybersecurity.
- Regulatory, technical and market readiness: Enabling conditions for flexibility and renewable energy integration.
- Investment and implementation ecosystem: Financing mechanisms, partnerships and institutional arrangements supporting digital investment.
- Human capacity and inclusive digitalization: Workforce skills, institutional capacity and equitable access to digital energy services.

Ratings reflect the strength of evidence identified in the country profiles and supporting documentation, rather than technology deployment alone. The detailed methodology and country-level results are provided in annex 2, while table 5 presents a summary of the assessment across the five dimensions.

Table 5. Arab Digital Power Enabling Environment Scorecard

Country	1. Strategic and institutional governance	2. Data governance, interoperability and cybersecurity	3. Regulatory, technical and market readiness for flexibility and renewable energy integration	4. Investment and implementation ecosystem	5. Human capacity and inclusive digitalization
Algeria	S	L	M	S	S
Bahrain	S	M	M	S	M
Comoros	L	N	L	S	L
Djibouti	L	N	L	S	L
Egypt	M	M	M	S	M
Iraq	M	L	M	M	N
Jordan	S	M	S	M	S
Kuwait	M	M	M	S	M
Lebanon	L	L	L	L	M
Libya	L	N	L	N	N
Mauritania	L	N	M	S	M
Morocco	S	M	S	S	M
Oman	S	M	S	S	M
State of Palestine	M	M	M	M	M

Country	1. Strategic and institutional governance	2. Data governance, interoperability and cybersecurity	3. Regulatory, technical and market readiness for flexibility and renewable energy integration	4. Investment and implementation ecosystem	5. Human capacity and inclusive digitalization
Qatar	S	M	S	S	M
Saudi Arabia	S	S	S	S	M
Somalia	L	N	L	L	L
Sudan	N	L	N	N	N
Syrian Arab Republic	M	L	M	L	N
Tunisia	M	L	S	S	L
United Arab Emirates	S	S	S	S	M
Yemen	N	N	N	N	N

Source: Compiled by ESCWA.
Note: The ratings are ordinal categories and should not be interpreted as precise quantitative measurements. They are intended to support comparison across policy areas, identify evidence gaps and inform further country-level assessment. S = Strong; M = Moderate; L = Limited; N = No evidence identified.

Table 6. Assessment rating scale

Rating	Definition
Strong (S)	Clear and relatively comprehensive evidence of established policies, institutions, systems, or implementation relevant to the subcategory.
Moderate (M)	Evidence of progress and foundational elements, but important policy, institutional or implementation gaps remain.
Limited (L)	Limited or fragmented evidence of development or implementation, with significant strengthening required.
No evidence identified (N)	Relevant evidence was not identified in the documentation reviewed. This does not necessarily mean that no relevant policy or initiative exists; it may not be publicly available.

Source: Compiled by ESCWA.

2. Key findings

ADPEES indicates that the Arab region has moved beyond isolated digitalization projects and is increasingly establishing the foundations of digitally enabled power systems. Progress in infrastructure modernization, financing and implementation has been substantial. The next phase of digital-power transformation will depend on strengthening cybersecurity, data governance, workforce development, institutional capacity, digital inclusion, and the scaling of successful initiatives into system-wide implementation.

The assessment also reveals the following:

- **Infrastructure and implementation ecosystems are the region's strongest dimensions.** Most Arab countries have made significant progress in grid modernization, renewable energy integration, smart-grid deployment, and utility digitalization.
- **Governance frameworks are advancing; institutional capacity remains uneven.** Many countries are still working to translate strategic ambitions into effective institutional arrangements, implementation mechanisms and long-term digital-energy roadmaps, particularly in conflict-affected countries and LDCs.
- **Data governance and cybersecurity are the areas most in need of strengthening.** This is the least developed enabling-environment dimension across the region: most countries show moderate, limited or no evidence of comprehensive cybersecurity and interoperability frameworks, a critical priority as electricity systems are becoming increasingly digital and interconnected.
- **Human capacity and digital inclusion show uneven progress.** Workforce development, utility readiness, regulatory capacity, and digital inclusion are important areas for strengthening across much of the region.

6. Policy recommendations

Digitalization can strengthen regional cross-border cooperation through enhanced data exchange and system coordination, promote alignment through interoperable standards and harmonized frameworks, and build the skills needed to plan, operate and regulate increasingly digitalized power systems. Its success depends on supportive governance, regulation, financing, data governance, cybersecurity, and human capacity, and on implementation pathways that reflect different national starting points while helping to reduce existing energy and digital divides. To advance, member States should undertake the following:

- **Focus on power-system outcomes.** Digitalization should advance reliability, affordability, resilience, renewable energy integration, efficiency, and inclusion, rather than technology deployment for its own sake.
- **Follow differentiated and sequenced pathways.** National priorities should reflect system needs and readiness, with foundational governance and operational capabilities preceding more advanced technologies and market arrangements.
- **Embed inclusion, security and interoperability by design.** Digitalization should protect vulnerable consumers, address gender and geographic inequalities, manage cybersecurity and data risks, and preserve opportunities for future regional cooperation.

A. National-level recommendations

More specifically, country-level interventions should aim to achieve the following:

- **Develop integrated grid-modernization roadmaps and strengthen coordination.** Establish country-specific priorities, responsibilities, financing, and timelines based on sector assessments, while aligning digitalization with renewable integration, resilience, affordability, and inclusion. Clarify institutional mandates and formalize interagency coordination. Lead actors: Energy ministries, regulators, utilities, and ministries of finance.
- **Establish data governance, interoperability and cybersecurity frameworks.** Define rules for data access, sharing, privacy, and security; require interoperable and upgradeable systems; and strengthen cybersecurity and incident-response capabilities across electricity infrastructure. Lead actors: Regulators, data protection authorities, cybersecurity agencies, utilities, system operators, and *private digital-technology firms*.
- **Sequence, test and monitor implementation.** Put enabling frameworks in place alongside technology deployment. Prioritize high-impact applications, pilot and evaluate solutions, scale proven approaches, and track progress regularly to update roadmaps and investment priorities. Lead actors: Energy ministries, regulators and utilities.

- **Prioritize service quality, resilience and foundational utility capabilities.** Monitor reliability, affordability, service quality, and recovery alongside access, using disaggregated data to target underserved populations. Deploy least-cost solutions, including grid expansion, distributed renewables, mini-grids, and storage where appropriate. Strengthen core utility capabilities such as metering, loss reduction, SCADA, outage management, forecasting, and preventive maintenance, and ensure procurement supports interoperability, cybersecurity, data portability, and workforce development. Lead actors: Utilities, system operators, regulators, and local authorities.
- **Modernize regulation while protecting consumers.** Update grid codes, tariffs and market rules to enable distributed energy resources, storage, demand response, and ancillary services. Establish clear rules for interconnection, compensation, data access, and system visibility, while supporting cost recovery and performance-based incentives. Ensure transparent billing, privacy safeguards, consumer engagement, and accessible service channels. Lead actors: Regulators, utilities, and transmission and distribution system operators.
- **Strengthen financial sustainability and mobilize investment.** Improve utility viability through transparent tariff and subsidy reforms linked to better service and accountability, with targeted consumer support where feasible. Develop bankable projects and mobilize public, concessional and blended finance for both capital and recurring digitalization costs, and incorporate these investments into nationally determined contributions in line with national climate commitments. Lead actors: Ministries of finance, energy and environment, regulators, utilities, and development finance institutions.
- **Build human and institutional capacity.** Align education, training and certification systems with digital energy needs, while strengthening utility and regulatory expertise in cybersecurity, data governance and digital regulation. Promote the participation of women and underrepresented groups, improve consumer digital literacy, and ensure accessible services for those unable to use digital platforms. Lead actors: Ministries of education and labour, utilities, regulators, universities, and training institutions.

B. Regional and subregional recommendations

To strengthen the resilience of interconnections and energy cooperation across countries, the following regional recommendations are proposed:

- **Advance electricity trade and interconnection governance.** Progressively align transmission access, wheeling charges, congestion management, reserve sharing, scheduling, and settlement. Establish arrangements for secure data exchange, coordinated restoration and mutual emergency support. Lead actors: Governments, regulators, system operators, and interconnection authorities.
- **Harmonize regional data governance, technical standards and cybersecurity frameworks.** Align grid codes, operating procedures, data models, communication and metering protocols, and minimum cybersecurity requirements. Enable secure real-time data exchange, joint forecasting, reserve sharing, and coordinated incident response. Lead actors:

Regional and intergovernmental organizations, data protection authorities, interconnection authorities, system operators, regulators, and cybersecurity agencies.

- **Coordinate regional planning and investment.** Conduct joint assessments of priority interconnections, grid reinforcements, renewable energy zones, flexibility resources, and shared digital platforms. Mobilize regional and multilateral finance and aggregate projects or procurement to reduce costs, improve interoperability, promote regulatory and technical alignment, and strengthen investment readiness. Lead actors: Regional and intergovernmental organizations, Governments, development banks, funds, and private-sector investors and financiers.
- **Strengthen regional institutions, skills and peer learning.** Expand cooperation mechanisms in underdeveloped subregions and promote regulatory dialogue, technical assistance, knowledge exchange, and monitoring. Develop regional certification and peer-learning programmes for utilities and regulators while strengthening the technical, institutional and regulatory skills needed to plan, operate and oversee increasingly digitalized and interconnected power systems. Lead actors: Regional and subregional organizations, utilities, regulators, and training institutions.

C. Concluding message

Realizing inclusive, sustainable and digitalized power systems in the Arab region will depend on effective governance, financing, regulatory reform, institutional capacity, and regional cooperation. Governments, regulators and utilities should translate these recommendations into sequenced, evidence-based implementation plans supported by continuous monitoring, adaptive learning and cross-border collaboration, with the support of regional and intergovernmental institutions.

Annex 1. Definitions

Digitalization: The systematic use of digital technologies and data across the electricity value chain to improve system visibility, control, coordination, and adaptability.

Smart grid: Electricity networks that use digital communication, sensing and control technologies and are characterized by the bidirectional flows of both electricity and information.

Digital grid: A broader concept than a smart grid, understood as a power network in which sensing, communication, computation, and automated control are embedded across the entire electricity value chain.

Power system resilience: The ability to limit the extent, severity and duration of system degradation following an extreme event.[88] The concept spans physical, cyber- and organizational dimensions and is central to the design of critical infrastructure such as power systems. A resilient system acknowledges that failures and disruptions will occur and designs for graceful degradation, rapid recovery and ongoing adaptation.[89]

Grid modernization: The systematic transformation of electricity transmission and distribution infrastructure through advanced physical, digital, communication, and control technologies to improve resilience, reliability, security, affordability, flexibility, and sustainability.[90] The World Bank approaches grid modernization as a combination of technological improvements, investment planning, and improvements in operations and governance.[91]

Data governance: Data governance for digitalized grids encompasses the control of the power-grid data lifecycle, from planning and generation or collection through processing, application and monitoring, to final disposal. It ensures defined data requirements, standards, resource allocation, quality and performance controls, auditability, and appropriate deletion, transfer or reuse of data.[92]

Advanced metering infrastructure (AMI): An integrated system of smart meters, communications networks and data management systems that enables two-way communication between utilities and customers.[93]

Supervisory control and data acquisition (SCADA): A computerized system that is capable of gathering and processing data and applying operational controls over long distances with applications in power transmission and distribution and pipeline systems. It lets control centres monitor and operate dispersed grid assets.[94]

Distributed energy resources (DERs): Small-scale energy resources, such as rooftop solar panels and battery storage, that are located close to where electricity is used and connected to the distribution grid, and that are transforming the way electricity is generated, traded, delivered, and consumed.[95]

Power system flexibility: The ability of a power system to reliably and cost-effectively manage the variability and uncertainty of electricity demand and supply across all relevant timescales.[96]

Interconnector: A transmission line that crosses or spans a national border and connects the transmission systems of two or more countries, enabling cross-border electricity exchange and trade.[97]

Annex 2. Methodology of the Arab Digital Power Enabling Environment Scorecard

A. Purpose and scope

The Arab Digital Power Enabling Environment Scorecard (ADPEES) is proposed by ESCWA to provide a comparative assessment of the conditions supporting electricity-sector digitalization across Arab countries.

ADPEES is intended as a regional diagnostic rather than a ranking of countries. It identifies areas of relative strength and areas requiring further development, while recognizing that countries have different power-system structures, institutional arrangements, development priorities, and starting points.

B. Assessment framework

The diagnostic tool is organized around five dimensions and ten subcategories.

Dimension	Subcategories	Scope of assessment
1. Strategic and institutional governance	1.1 National strategy	• National digital energy strategies, policies, road maps, and grid-modernization plans • Monitoring and accountability mechanisms
	1.2 Institutional mandate	• Institutional mandates • Inter-agency coordination • Implementation responsibilities • Dedicated budgets
2. Data governance, interoperability and cybersecurity	2.1 Data governance and interoperability	• Energy-data standards • Access and sharing rules • System interoperability • Data privacy and consumer protection • Responsible use of AI
	2.2 Cybersecurity	• Cybersecurity requirements • Incident-response arrangements • Cooperation on cross-border data exchange and cyberincidents • Critical-infrastructure protection

Dimension	Subcategories	Scope of assessment
3. Regulatory, technical and market readiness for flexibility and renewable energy integration	3.1 Regulation and market readiness	• Regulatory frameworks for distributed generation, storage, demand response, aggregators, and electric vehicles • Grid-access and tariff rules • Regulatory pilots and sandboxes • Settlement
	3.2 Infrastructure for flexibility	• Smart metering • System visibility • Aggregation • Dispatch and renewable energy integration
4. Investment and implementation ecosystem	4.1 Public, domestic, blended, and multilateral finance	• Public and utility financing for digital investment • Multilateral and blended-finance mechanisms • Regulatory predictability • Risk allocation • Technology partnerships • Technology transfer and local-content considerations
	4.2 Public-private partnerships and bankable project pipelines	• Procurement frameworks • Public-private partnerships • Bankable project pipelines
5. Human capacity and inclusive digitalization	5.1 Skills and workforce	• Digital skills and workforce strategies • Capacity of utilities, regulators and system operators • Professional training and certification • Participation of women in the workforce and decision-making
	5.2 Digital inclusion	• Affordability • Accessibility • Digital literacy • Consumer participation • Protection of vulnerable and underserved consumers

Source: Compiled by ESCWA.

C. Evidence and assessment approach

The assessment was developed through a country-by-country review of evidence available up to August 2026. Sources included national energy and digital-transformation strategies, laws and regulations, utility modernization plans, smart-grid and smart-meter programmes, institutional and cybersecurity frameworks, official digital platforms, financing agreements, multilateral development projects, workforce-development programmes, and relevant academic and technical literature.

Ratings reflect the strength, comprehensiveness and maturity of the evidence identified for each subcategory. The assessment does not count the number of policies, programmes or projects.

Instead, it considers whether the relevant enabling conditions are established, sufficiently comprehensive and supported by evidence of implementation.

The ten-subcategory assessment is the principal diagnostic tool. The five-dimension assessment presented in table 5 provides a higher-level synthesis of the two subcategories under each dimension. Dimension-level ratings are based on a qualitative synthesis of the underlying evidence rather than the calculation of a regional league table or composite country score. No overall country score or ranking is produced.

Where evidence was incomplete, inconsistent or unavailable, the assessment applied a cautious rating. Differences in data availability and public reporting should therefore be considered when comparing countries.

D. Interpretation of results

The heat maps should be read horizontally and vertically. Reading across a country's row provides an overview of the relative balance of its enabling environment. Reading down a subcategory highlights areas in which evidence is relatively strong or weak across the region.

Differences between the five-dimension and ten-subcategory assessments are expected. Aggregation can mask important differences within a dimension. For example, a country may have partly developed general data-governance arrangements but limited energy-sector cybersecurity requirements, or extensive digital infrastructure but weaker regulatory arrangements for using that infrastructure to enable flexibility.

The results should therefore be interpreted alongside the country examples and thematic analysis presented in chapters 3 to 5. They should not be used independently to evaluate overall power-sector performance, electricity access, service reliability, or progress towards Sustainable Development Goal 7.

E. Detailed 10-subcategory assessment

ADPEES: Detailed assessment by country and subcategory

Country	1. Strategic and institutional governance		2. Data governance, interoperability and cybersecurity		3. Regulatory and technical and market readiness for flexibility and renewable energy integration		4. Investment and implementation ecosystem		5. Human capacity and inclusive digitalization	
	1.1. National strategy	1.2. Institutional mandate	2.1. Data	2.2. Cybersecurity	3.1. Regulation and market readiness	3.2. Infrastructure for flexibility	4.1. Finance	4.2. Public-private partnerships and bankable project pipelines	5.1. Skills	5.2. Inclusion
Algeria	S	S	M	N	M	S	M	S	S	S
Bahrain	M	S	S	N	M	S	M	S	M	M
Comoros	L	N	N	N	N	M	S	M	N	M
Djibouti	L	N	N	N	N	M	S	M	N	M
Egypt	M	M	S	N	M	S	S	S	S	M
Iraq	M	M	M	N	M	S	M	M	N	N
Jordan	S	S	S	L	S	S	S	S	S	M
Kuwait	M	M	M	L	M	M	M	M	L	M
Lebanon	L	L	L	N	L	L	L	L	M	M
Libya	L	N	N	N	N	M	N	L	N	N
Mauritania	L	L	N	N	M	S	S	M	N	S
Morocco	M	S	S	N	S	S	S	S	M	M
Oman	S	S	S	M	M	S	S	S	S	M
State of Palestine	M	M	S	N	M	M	M	M	N	S
Qatar	S	S	M	M	M	S	S	S	L	M
Saudi Arabia	S	S	S	S	S	S	S	S	M	M
Somalia	L	N	N	N	N	M	M	M	N	S
Sudan	N	N	N	M	N	N	N	N	N	N
Syrian Arab Republic	M	M	N	M	M	M	L	M	N	N
Tunisia	M	M	M	N	M	S	S	S	N	M
United Arab Emirates	S	S	S	S	S	S	S	S	S	M
Yemen	N	N	N	N	N	N	N	N	N	N

Source: ESCWA assessment based on country profiles and supporting documentation reviewed up to August 2026.
Note: S = Strong; M = Moderate; L = Limited; N = No evidence identified. Ratings reflect evidence identified through the desk review and do not constitute a ranking of countries. “No evidence identified” should not be interpreted as confirmation that no relevant policy, programme or institutional arrangement exists.

F. Methodological limitations

The assessment is subject to several limitations, including the following:

- Availability and detail of publicly accessible information vary substantially across countries and assessment areas. Countries with more extensive public reporting may receive stronger ratings than countries where relevant initiatives exist but are not documented or readily accessible. Where one of the two subcomponents represents a critical enabling condition and evidence is absent, the overall pillar rating may be capped at “Limited” or determined through expert judgement rather than mathematical averaging.
- National strategies and general digital-governance frameworks do not always provide sufficient information to determine how effectively they are applied in the electricity sector. Where possible, the assessment considered implementation evidence, but this was not consistently available across all countries and subcategories.
- The assessment captures conditions at a particular point in time. Digital-energy policies, regulations, technologies, and institutional arrangements are evolving rapidly, and individual ratings may change as new information becomes available or initiatives progress from planning to implementation.
- The assessment evaluates enabling conditions rather than the effectiveness or outcomes of individual digital investments. A strong enabling framework does not guarantee successful implementation, while a country with limited formal frameworks may nevertheless achieve results through individual utility initiatives or externally supported projects.

ADPEES should therefore be treated as an initial baseline. The framework and country assessments can be refined through consultation with national authorities, regulators, utilities, and other stakeholders, as well as through the incorporation of additional evidence and measurable implementation indicators in future iterations.

Bibliography

Abu Dhabi Department of Energy (2024). The Future of Renewable Energy Optimization Through Smart Grids and Artificial Intelligence.

Allianz (2026). Allianz Risk Barometer Annual report.

Al-Salaymeh, Ahmed, and others (2022). Smart Meters Rollout in Jordan: Opportunities, Business Models, Challenges, and Recommendations. International Journal of Energy Economics and Policy, vol. 12, No. 4.

Arab Fund for Economic and Social Development (n.d.). Electrical Interconnection Between the Arab Republic of Egypt and the Kingdom of Saudi Arabia.

Arab News (2021). SEC deploys 10m smart meters in move toward digital.

Atos (2021). Atos and Siemens to support Morocco in the smart management of its power grid.

Bahrain Electricity and Water Authority (2026). Vice President of Electricity Affairs: Control Centre's Innovation Award Reflects Strategic Investment in Advanced Technologies.

CEN-CENELEC-ETSI Smart Grid Coordination Group (2014). Applying, testing & refining the Smart Grid Architecture Model.

Chatham House (2023). Scaling up sustainable energy in Jordan's public buildings.

Cigre (2019). Defining power system resilience.

Clifford Chance (2023). Renewable Energy Sector Reform in Morocco – How Will it Impact the Market?

Dhofar Integrated Services Company (2023). Report and Financial Statements.

Dubai Electricity and Water Authority (DEWA) (n.d.a). Shams Dubai.

_____ (n.d.b). Smart Grid.

_____ (2022a). DEWA completes 100% of the short-term goals of its D 7 billion Smart Grid Strategy.

_____ (2022b). DEWA launches Automatic Smart Grid Restoration System to enhance its innovative power grid management.

_____ (2025). Consolidated Financial Statements.

Ecofin Agency (2025). Algeria Plans 2026 Overhaul of National Electricity Control System.

Economic and Social Commission for Western Asia (ESCWA) (n.d.a). Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR).

_____ (n.d.b). Supporting increased energy security and resilience through energy transition.

_____ (2017). Arab Climate Change Assessment Report: Main Report.

_____ (2022). Future climate projections for the Mashreq region: summary outcomes.

_____ (2024). Small-Scale Renewable Energy Technological Solutions in the Arab Region: Operational Toolkit.

_____ (2025). Investing in the Future: The Role of Human Capital in Enabling Just Energy Transitions in the Arab Region.

_____ (2026a). Policy Brief on SDG 7 in the Arab region: progress, gaps and priorities.

_____ (2026b). Conflict and its shockwaves: escalating impacts and risks for energy, water and food systems in the Arab region.

_____ (2026c). Improved mapping and monitoring of solar energy access for enhanced climate policy action and socioeconomic resilience: Policy and technical capacity assessment report.

Egypt Oil & Gas (2019). Egypt to Turn 27 MM Electricity Meters into Prepaid Ones.

Egyptian Electricity Holding Company (2024). Annual Report 2023/2024.

Energy Institute (2026). Statistical Review of World Energy.

European Bank for Reconstruction and Development (2025). EBRD provides €300 million first sustainability-linked loan to ONEE in Morocco.

European Union (2019). Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast), Article 2(1). Official Journal of the European Union, L 158, 14 June 2019.

European Union Institute for Security Studies (2025). Energising Syria's future.

EY (2025). Future of Energy.

Global Centre for Risk and Innovation (n.d.). Quantum Nexus.

Global System for Mobile Communications Association (GSMA) (2024). The Mobile Gender Gap Report 2024.

Gulf Cooperation Council Interconnection Authority (GCCIA) (n.d.). Corporate Governance.

_____ (2021). GCC Grid, Issue 05.

_____ (2022). GCC Grid, Issue 06.

_____ (2024). GCC Grid, Issue 07.

Institute of Electrical and Electronics Engineers (n.d.a). What Are Smart Grids?

_____ (n.d.b). What is System Resiliency?

_____ (2021). Jordan International Joint Conference on Electrical Engineering and Information Technology, JEEIT 2021 – Proceedings.

International Energy Agency (IEA) (n.d.). Energy system of Middle East database. Accessed on 24 July 2026.

_____ (2011). Technology Roadmap: Smart Grids.

_____ (2022). Unlocking the Potential of Distributed Energy Resources.

_____ (2023). Electricity Grids and Secure Energy Transitions.

_____ (2025). The Future of Electricity in the Middle East and North Africa.

International Finance Corporation (2024). Arab Fund for Economic and Social Development and IFC Enhance Collaboration Through Co-Lending Platform.

International Monetary Fund (2025). Reforming Energy Subsidies in the Arab Region.

International Renewable Energy Agency (IRENA) (n.d.). IRENASTAT Online Data Query Tool. Accessed on 24 July 2026.

_____ (2018). Power System Flexibility for the Energy Transition, Part 1. Abu Dhabi.

_____ (2025). Digitalisation and AI for power system transformation: Perspectives for the G7.

_____ (2026). Renewable capacity statistics 2026.

National Renewable Energy Laboritory (2019).

International Telecommunication Union (2022). Requirements for distributed ledger technology-based power grid data management.

Itron (2017). Silver Spring Networks Completes IoT Network Canopy Rollout for DEWA.

Kuwait Telecommunications Company (2024). STC signs strategic agreement with the Ministry of Electricity, Water and Renewable Energy to supply Smart Electricity Meters.

Libya Herald (2024). 378,000 installed prepaid electricity metres saved 210 MW of consumption – 2 million metres to be installed.

Middle East Energy Dubai (2023). How Middle East Energy Transition Will Stimulate Grid Modernization & Digitalization.

Middle East Solar Industry Association (MESIA) (2025). MESIA Mid-Year Solar Report 2025.

MITSloan ME Editorial (2026). Oman Advances Smart Grid Ambitions with Digital Twin AI Initiative.

Nama Electricity Distribution Company (2025). Annual report.

National Electric Power Company (2024). Annual report.

National Institute of Standards and Technology (NIST) (n.d.). SCADA. CSRC Glossary.

National Renewable Energy Laboratory (2019). Resilience Roadmap: A Collaborative Approach to Multi-Jurisdictional Resilience Planning.

Nebras Energy (2025). Consolidated Financial Statements.

Office of Gas and Electricity Markets (Ofgem) (n.d.). Energy network price controls.

_____ (2023). Proposal to introduce the Future Regulation Sandbox.

Oman Electricity Transmission Company (2026). Oman Grid Half-yearly bulletin.

Oman News Agency (2025). Nama Group Electricity Companies Showcase Key Energy Sector Strategies and Initiatives.

O'Sullivan, Kimberley, Helen Viggers and Philippa Howden-Chapman (2014). The influence of electricity prepayment meter use on household energy behaviour. Sustainable Cities and Society, vol. 13.

Palestine Electric Company (2022). Annual report.

PAREMA (2026). Self-Generation of Electricity – New Implementing Decree.

Petitet, Marie, and others (2025). Cross-border electricity trading in the GCC countries, Egypt, Jordan and Iraq: Hourly market coupling or bilateral agreements? Energy, vol. 327.

Pittalis, Marco, and others (2023). Quantifying impacts and benefits of advanced remote monitoring solutions for the operation of mini grids in sub-Saharan Africa. Energy for Sustainable Development.

Power Africa (2022). Strengthening Power Grids in Somalia with Digital Technology.

PR Newswire (2024). SparkMeter Signs Two New Contracts in Somalia to Modernize African Utilities.

PV Magazine (2026). SECI's 1 GW FDRE-RTC power tender discovers INR 5.25/kWh tariff.

Qatar General Electricity and Water Corporation (2026). KAHRAMAA Launches the 3rd Phase (2026-2030) of its Long-Term Strategy "The Leading Practices Phase" Continuing the Journy of Corporate Development and Reinforcing Its Position as a Leading Utility by 2030.

Qatar Ministry of Communications and Information Technology (2025). MCIT and KAHRAMAA Announce the Launch of the Second Release of the Tarsheed Smart Electric Vehicle Charging Platform.

Saudi Arabia Energy (2024). Saudi Arabia's Transition to Smart Energy Grids.

Saudi Compliance Institute (2026). Winning Government Tenders: Navigating the New 30% LCGPA Local Content Requirement in KSA.

Saudi Energy (2025). Financial annual report.

Saudi Press Agency (2025). NEOM, DataVolt Launch Sustainable AI Project in Oxagon with $5 billion Investment.

Shamal Az-Zour Al-Oula Power and Water Company (2025). Independent auditor's report and financial statements for the year ended 31 December 2025.

Siemens (2026). Siemens Opens New Electrification and Automation Factory in Egypt, Investing in Localized Production and Supporting the Nation's Renewable Energy Ambitions.

Siemens Advanta (n.d.). Revolutionizing Tunisia's Energy Infrastructure for 5.5 million customers.

Société Mauritanienne d'Électricité (SOMELEC) (2021). Compteurs intelligents Mousef, un changement qualitatif.

_____ (2023a). Fourniture du Materiel et L'execution des Travaux Complementaires dela Phase Pilote du Marche N° 14/CAE/2022 pour la Realisation d'une Plateforme Pilote de Supervision de Compteurs Intelligents et Acquisition de 350.000 Compteurs intelligents.

_____ (2023b). Campagne de pose des compteurs intelligents.

_____ (2026a). Avis d'infructuosité, DCCO no 16/CAE/2026.

_____ (2026b). Demande de cotation à compétition ouverte no 16/CAE/2026 pour l'acquisition et l'installation d'une infrastructure serveur pour la gestion des compteurs intelligents.

Société Tunisienne de l'Électricité et du Gaz (STEG) (n.d.). Programme Smart Grid.

_____ (2023). Financial Statement.

Sonelgaz (n.d.). Transport Electricity and System Operator (STOS) Training Programme.

_____ (2024). Rapport d'activites.

Sophos (2024). The State of Ransomware in Critical Infrastructure 2024.

Stouffer, Keith, and others (2023). Guide to Operational Technology (OT) Security.

Sudanese Cybersecurity Authority (n.d.). Available at https://sca.gov.sd/en.

Syrian Future Movement (2026). Syrian-Saudi partnership to enhance cybersecurity in the energy sector.

TAQA (2025). Integrated Report 2025.

Taqinor (2026). Law 82-21 – Decree 2-25-100, Three regimes, only one is yours.

Trustwave (2025). Risk Radar Report: Energy & Utilities Sector.

United Arab Emirates Government Platform (n.d.). Data protection laws.

United for Efficiency (U4E) (2026). Djibouti Savings Policy Assessment.

United Nations Office for the Coordination of Humanitarian Affairs (OCHA) (n.d.). Electricity in the Gaza Strip.

United States Department of Energy (n.d.). About the Grid Modernization Initiative.

_____ (2016). Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program.

Utilities Middle East (2023). GCCIA SuperGrid: Paving the way for billion-dollar power trading boom in the Gulf.

World Bank (2010). Financing Agreement: Additional Financing for the Power Access and Diversification Project.

_____ (2012). Project Paper on a Proposed Additional Grant for the Power Access and Diversification Project, Report No. 68192-DJ.

_____ (2015). Practical Guidance for Defining a Smart Grid Modernization Strategy.

_____ (2016). Performance and Learning Review of the Country Partnership Strategy for the Republic of Djibouti, Report No. 104985-DJ.

_____ (2019). Iraq Electricity Services Reconstruction and Enhancement Project: Project Appraisal Document. Report No. PAD2601.

_____ (2022). Comoros Solar Energy Access Project (P177646): Project Information Document.

_____ (2023a). Electricity Sector Efficiency and Supply Reliability Program-for-Results (P171296).

_____ (2023b). Two New Projects to Foster Climate Responsive Investments for Growth and Job Creation and to Support Jordan's Electricity Sector Efficiency.

_____ (2025a). Project Information Document.

_____ (2025b). Gender and Inclusion in Digital.

_____ (2026a). Economic Update on the West Bank and Gaza.

_____ (2026b). Initial Project Information Document.

_____ (2026c). Electric power transmission and distribution losses (% of output) database.

Yemen Supreme Political Council (2019). National Vision.

Endnotes

1. The methodology for developing the ADPEES is explained in annex 2.
2. Electricity access in conflict-affected countries rose from 72.4 per cent in 2014 to 81.6 per cent in 2024. It nevertheless remained significantly below the regional average.
3. ESCWA, 2026a.
4. Ibid.
5. ESCWA, 2026a.
6. IRENA, 2026.
7. The survey was conducted in May 2024 over a four-week period and collected 420 responses from individuals across 21 Arab countries, capturing both country of origin and country of residence. See ESCWA, 2025.
8. ESCWA, 2025.
9. Data compiled by ESCWA based on IEA, n.d. No data are available for the Comoros, Djibouti, Mauritania, the State of Palestine, and Somalia.
10. IEA, 2025.
11. IMF, 2025.
12. ESCWA, 2025.
13. Shamal Az-Zour Al-Oula Power and Water Company, 2025; Dhofar Integrated Services Company, 2023; Nama Electricity Distribution Company, 2025; Nebras Energy, 2025; Saudi Energy, 2025; TAQA, 2025; DEWA, 2025; Palestine Electric Company, 2022; Sonelgaz, 2024; National Electric Power Company, 2024; STEG, 2023; Egyptian Electricity Holding Company, 2024.
14. DEWA, n.d.a.
15. ESCWA, 2026a.
16. IEA, 2025.
17. National Renewable Energy Laboratory, 2019.
18. ESCWA, 2026b.
19. Ibid.
20. European Union Institute for Security Studies, 2025.
21. World Bank, 2026b.
22. World Bank, 2026c.
23. Chatham House, 2023.
24. Institute of Electrical and Electronics Engineers, n.d.a.
25. IEA, 2011.
26. DEWA, n.d.b.
27. Qatar General Electricity and Water Corporation, 2026.
28. Nama Electricity Distribution Company, 2025.
29. Oman News Agency, 2025.
30. Kuwait Telecommunications Company, 2024.
31. Ecofin Agency, 2025.
32. Atos, 2021.
33. STEG, n.d.; Siemens Advanta, n.d.
34. Siemens, 2026.
35. SOMELEC, 2021.

36. SOMELEC, 2023a.
37. SOMELEC, 2023b.
38. SOMELEC, 2026a.
39. SOMELEC, 2026b.
40. IRENA, 2025.
41. Ibid.
42. Ibid.
43. Libya Herald, 2024.
44. Qatar Ministry of Communications and Information Technology, 2025.
45. Al-Salaymeh and others, 2022.
46. Taqinor, 2026.
47. Power Africa, 2022.
48. PR Newswire, 2024.
49. Saudi Compliance Institute, 2026.
50. Pittalis and others, 2023.
51. ESCWA, 2024.
52. O'Sullivan and others, 2014.
53. Egypt Oil & Gas, 2019.
54. GSMA, 2024.
55. IEA, 2025.
56. Ibid.
57. GCCIA, 2021.
58. Utilities Middle East, 2023.
59. IEA, 2025.
60. MESIA, 2025.
61. GCCIA, 2022.
62. Ibid.
63. Ibid.
64. GCCIA, 2024.
65. Clifford Chance, 2023.
66. Bahrain Electricity and Water Authority, 2026.
67. World Bank, 2023a.
68. Ofgem, n.d.
69. Ofgem, 2023.
70. United Arab Emirates Government Platform, n.d.
71. Sudanese Cybersecurity Authority, n.d.
72. Syrian Future Movement, 2026.
73. GCCIA, n.d.
74. DEWA, n.d.a.
75. PAREMA, 2026.
76. PV Magazine, 2026.
77. European Bank for Reconstruction and Development, 2025.
78. World Bank, 2022.
79. World Bank, 2010.
80. World Bank, 2012.
81. World Bank, 2016.

82. World Bank, 2023b.
83. International Finance Corporation, 2024.
84. World Bank, 2019.
85. Arab News, 2021.
86. Yemen Supreme Political Council, 2019.
87. World Bank, 2025b.
88. Cigre, 2019.
89. Institute of Electrical and Electronics Engineers, n.d.b.
90. United States Department of Energy, n.d.
91. World Bank, 2015.
92. ITU, 2022.
93. United States Department of Energy, 2016.
94. NIST, n.d.; Stouffer and others, 2023.
95. IEA, 2022.
96. IRENA, 2018.
97. European Union, 2019.

The present publication examines how Arab countries can modernize and digitalize their power grids to build more reliable, resilient, sustainable and inclusive electricity systems. It assesses regional progress and persistent challenges, including ageing infrastructure, electricity losses, financial constraints, climate and conflict-related risks, uneven institutional capacity and disparities in access and service quality.

The publication explores how technologies such as smart meters, advanced monitoring, automation, forecasting and artificial intelligence can improve system efficiency, resilience and renewable energy integration. It also examines the role of cross-border electricity cooperation in strengthening regional energy connectivity, and enhancing technical and institutional capabilities through interoperable systems, harmonized standards and coordinated planning. Drawing on regional and international experience, it analyses governance, regulation, financing, cybersecurity, data governance and capacity-building needs, assesses countries' readiness for digital power transformation, and provides policy recommendations to support countries in advancing resilient, inclusive and interconnected power systems.

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