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Arab Petroleum Investments Corporation

LEVERAGING ENERGY STORAGE SYSTEMS IN MENA

Opportunities, Challenges and Policy Recommendations

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About APICORP

The Arab Petroleum Investments Corporation (APICORP) is a multilateral development financial institution established in 1975 by an international treaty between the ten Arab oil exporting countries. It aims to support and foster the development of the Arab world's energy sector and petroleum industries. APICORP makes equity investments and provides project finance, trade finance, advisory and research, and its headquarters is in Dammam, Kingdom of Saudi Arabia. APICORP is rated 'Aa2' with a stable outlook by Moody's and 'AA' with a stable outlook by Fitch.

Contents

Acronyms

ADWEA	Abu Dhabi Electricity and Water Authority
BTM	Behind-the-Meter
CAES	Compressed Air Energy Storage
C/I	Commercial/Industrial
DEWA	Dubai Electricity and Water Authority
EPC	Engineering, Procurement and Contracting
ESS	Energy Storage Systems
FTM	Front-of-the-Meter
GCC	Gulf Cooperation Council
IPP	Independent Power Producers
KPI	Key Performance Indicator
LCOE	Levelized Cost of Electricity
LCOS	Levelized Cost of Storage
LDES	Long-Duration Energy Storage
Li-Ion	Lithium-Ion
MDB	Multilateral Development Bank
MENA	Middle East and North Africa
NaS	Sodium Sulfur
PHS	Pumped Hydro Storage
PPA	Power Purchase Agreement
REPDO	Renewable Energy Project Development Office
SBM	Single Buyer Model
SOE	State-Owned Entity
TSO	Transmission System Operator
VRE	Variable Renewable Energy

I. Executive Summary

Renewable energy systems have been gaining momentum across MENA countries, driven by ambitious national energy targets, technology cost declines, and increasing investments in low-cost and low-carbon technologies. The national renewable energy targets set for 2030, ranging between 15-50% of electricity generation, depict governments' will to double down efforts and increase the share of renewables in the energy mix.

Meeting the national renewable energy targets requires scaling up and systematic integration of variable renewable energy (VRE) systems into the power grid, which in turn necessitates deployment of energy storage solutions (ESS) for firming the power capacity, building flexibility, and ensuring power systems stability. ESS also plays a critical role in managing intermittencies of VREs and mitigating potential power supply disruptions while providing ancillary services.

The pace of integration of energy storage systems in MENA is driven by three main factors: 1) the technical need associated with the accelerated deployment of renewables, 2) the technological advancements driving ESS cost competitiveness, and 3) the policy support and power markets evolution that incentivizes investments.

Within the spectrum of energy storage technologies, the ranges of applications and captured revenue streams differ depending on the selected site, power system requirements, market structure, regulatory frameworks, and cost-effectiveness of the selected solution. Electrochemical storage (batteries) will be the leading energy storage solution in MENA in the short to medium terms, led by sodium-sulfur (NaS) and lithium-ion (Li-Ion) batteries.

Several MENA countries - especially in the GCC - are equipped with competitive advantages in renewable plus storage procurement, due to the availability of vast lands and low-cost solar and wind generation capacities. In the GCC, it is expected that the bulk of the ESS deployment will be front-of-the-meter (FTM)[1] applications driven by VRE integration and firming. Although the current application of on-grid ESS in MENA remains relatively low - estimated at an operational capacity of 1.46 GW as compared to the global 10 GW - FTM applications still contribute 89% of the installed capacity in MENA, with the remaining share dedicated to behind-the-meter (BTM)[2] applications.

Although the energy storage market in MENA is bound to grow, several barriers exist that hinder the integration of ESS and the ramping up of investments. Financial, regulatory, and market barriers need to be addressed via policy tools that lay the foundations for an evolved power market to integrate the deployed ESS.

Among the structural market barriers that exist is the single-buyer model, which poses additional challenges portrayed in the national utilities business models. The focus of investments in generation and the take-or-pay agreements soliciting generated electricity - which may not be available all the time - do not provide adequate incentives for investing in energy storage. This is also the case for renewable energy auctions award criteria that focus on the lowest price and most technically compliant offer without considering the stacked revenues of ESS.

[1] Front-of-meter refers to grid scale energy storage connected to the generation sources or the transmission and distribution networks.

[2] Behind-the-meter storage refers to the electricity stored on-premises behind the consumer's meter.

Ten key policy support actions are recommended to achieve the objective of successfully integrating energy storage systems in the power markets in MENA:

1. **Define energy storage as a distinct asset category** separate from generation, transmission, and distribution value chains. This is essential in the implementation of any future regulation governing ESS.

2. **Adopt a comprehensive regulatory framework with specific energy storage targets in national energy policies** by setting achievable targets and timelines to drive energy storage deployment.

3. **Amend the net-metering scheme** when the share of renewables in the power mix becomes significant to ensure the scheme does not create barriers to ESS while maintaining incentives for distributed renewable energy.

4. **Define the ownership mandates of utilities, developers, operators, and regulators for ESS** due to the cross-functional nature of energy storage and value created across different segments of the power value chain.

5. **Establish a MENA Energy Storage Alliance** supported by governments and the private sector to foster the development of ESS in the region by enhancing public-private partnerships.

6. **Create incentives to attract private sector investments** through tax credits, tax exemptions, accelerated depreciation, and government equity ownership.

7. **Adopt a time-of-use tariff** to ensure the economic viability of energy storage systems and incentivize reduced consumption at peak demand.

8. **Endorse eligibility of ESS in green financing facilities** and promote them as technologies eligible for funding within green financing frameworks.

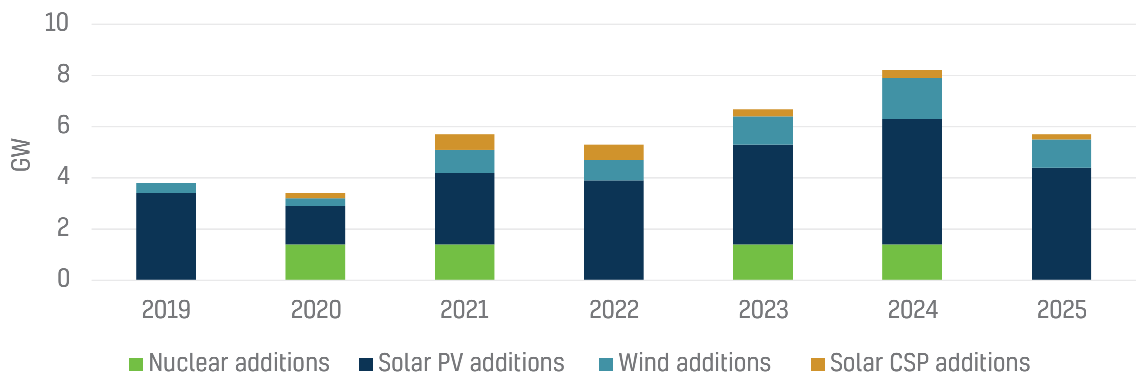
9. **Auction portfolios of renewables-plus-storage assets** to optimize renewable energy integration and enable off-takers to purchase fully dispatchable and stable electricity.

10. **Emphasize FTM applications** for utility-scale solutions to assist in scaling up the deployment of VREs.

II. MENA's renewable energy sector has been gaining momentum

Renewable energy systems have been gaining momentum across MENA, driven by ambitious national targets, technology cost declines, and increasing investments in low-cost and low-carbon technologies. The national renewable energy targets set for 2030, ranging between 15-50% of electricity generation, portray governments' will to double down efforts and increase the share of renewables in the energy mix. As of 2020, the total installed capacity of renewable energy in MENA surpassed 10.6 GW, almost double the 2010 capacity of 5.4GW[3]. The increase in renewables is mainly driven by wind power, solar PV, and hydropower. The MENA region added an estimated 1.5 GW of solar power in 2020, with a further 3 GW in 2021 and almost 20 GW expected to be added over the next five years[4].

Additions of low-carbon energy carriers for electricity by installed capacity in MENA (2019-2025)



Source: APICORP

Although the pace of integrating VREs into the generation mix differs between MENA countries, governments share a common goal of reducing domestic dependence on fossil fuels for power generation. The objective is either to reduce hydrocarbon imports and enhance energy security, as in the case of net-importing countries, or free up hydrocarbons for additional export volumes, as in the case of net-exporting countries.

[3] Data compiled from IRENA (2020), Renewable energy statistics.

[4] APICORP (2021), MENA Energy Investment Outlook 2021-2025.

To diversify the power mix with low-cost and low-carbon energy sources while enhancing energy security, MENA countries have been focusing on the generation side of the value chain by setting ambitious renewable energy targets for the medium and long terms, as shown below:

Renewable energy targets in selected MENA countries

Country	RE policy targets	Target Year	Progress '21
Saudi Arabia	10% of electricity generation from renewable energy by 2025, 50% by 2030	2025 & 2030	< 1% of installed capacity
UAE	Dubai: 7% alternative energy generation by 2020, 25% by 2030, and 75% by 2050, including nuclear energy Abu Dhabi: 7% of installed capacity by 2020 Federal: 44% of generation mix by 2050	2020, 2030 & 2050	3% of generation, 6% of installed capacity
Oman	10% of electricity generation by 2025, 30% by 2030	2025, 2030& 2040	< 1% of generation < 1.5% of installed capacity
Qatar	20% of electricity generation by 2030	2030	< 1% of installed capacity
Kuwait	15% of electricity generation by 2030	2030	< 1% of installed capacity
Jordan	21% of generation mix by 2020, 31% by 2030	2020 & 2030	20% of generation
Iraq	5% of electricity generation by 2025, 20% by 2030	2025 & 2030	< 1% of installed capacity
Lebanon	12% of generation mix by 2020, 30% by 2030	2020 & 2030	7% of installed capacity
Egypt	20% of electricity generation by 2022, 42% by 2035	2022 & 2035	9% of generation, 11% of installed capacity
Tunisia	30% of generation mix by 2030	2030	
Morocco	42% of installed capacity by 2020, 52% by 2030	2020 & 2030	37% of installed capacity
Algeria	37% of installed capacity by 2030	2030	< 1% of installed capacity

Morocco and Jordan are currently at the forefront of renewable energy deployment in MENA, nearing their 2020 targets. Morocco has reached 37% of its installed capacity from renewable energy in 2020, compared to its target of 42%. Meanwhile, Jordan has achieved nearly 20% of generation capacity out of its target of 21%. Other countries such as the United Arab Emirates, Egypt, Saudi Arabia, and Oman have relatively low renewable energy generation, but the share is expected to witness a significant hike with large capacities planned and committed in the project pipeline.

Beyond the focus on increasing renewable energy on the generation side, meeting national renewable energy targets requires thorough integration of variable renewable energy (VRE) systems into the power grids. This necessitates reinforcing the power network, firming capacities, and enhancing the grids' stability and flexibility. Increasing the deployment of intermittent energy sources without integrating energy storage systems may jeopardize the power system stability and security of supply.

III. Energy Storage System deployment in MENA

Energy Storage Systems (ESS) play a critical role in the integration of VRE into the power grid, as these systems manage the intermittencies of renewable energy resources and mitigate potential power supply disruptions. While the Levelized Cost of Electricity (LCOE) of renewables has become lower than that of fossil fuel, the curtailment factor and grid upgrades need to be factored into system planning as electricity generated from renewable resources may not necessarily be dispatchable at times of peak demand.

With the increasing share of VRE in the power generation mix – as in the case of solar PV in MENA - the market volatility resulting from the supply-demand mismatch presents challenges to the grid operator. This will force electric utilities to manage the oversupply through curtailment and rapid ramp-up of other baseload sources when solar generation falls.

To flatten the duck curve[5], several measures need to be taken to avoid curtailment, including adding flexibility to the system, managing the demand side, and storing electricity for different times of usage. ESS can play a central role in reducing curtailment by ensuring that the generated electricity is stored for when it is needed, while providing flexible ramp-up. ESS can also provide capacity firming, energy arbitrage, frequency regulation, among other ancillary services[6]. Additionally, energy storage can assist in deferring the upgrades needed for the transmission and distribution networks, reducing the need for additional grid investments.

While in the past the power systems' focus has been on matching the load demand through increasing generation capacities, there is now a growing focus on reducing the peak load; a service ESS can also fulfill. This service is much needed in MENA as power demand is expected to sustain its growth in the medium term.

The application of on-grid ESS in MENA remains relatively low, estimated at an operational capacity of 1.46 GW compared to 10 GW globally, almost equivalent to the UK's operational capacity of 1.1 GW. The market share of FTM applications in MENA is around 89% of installed capacity - equivalent to 1.3GW – as compared to a 50% FTM market share in Europe. BTM applications in MENA are estimated at only 11%. This wide gap between the market shares of the two applications in MENA is most likely to persist given the power market structure, utility business models, and tariff subsidies.

[5] The duck curve is a graph of power production over the course of a day that shows the timing imbalance between peak demand and renewable energy production.

[6] Refer to Annex I for the definitions of services.

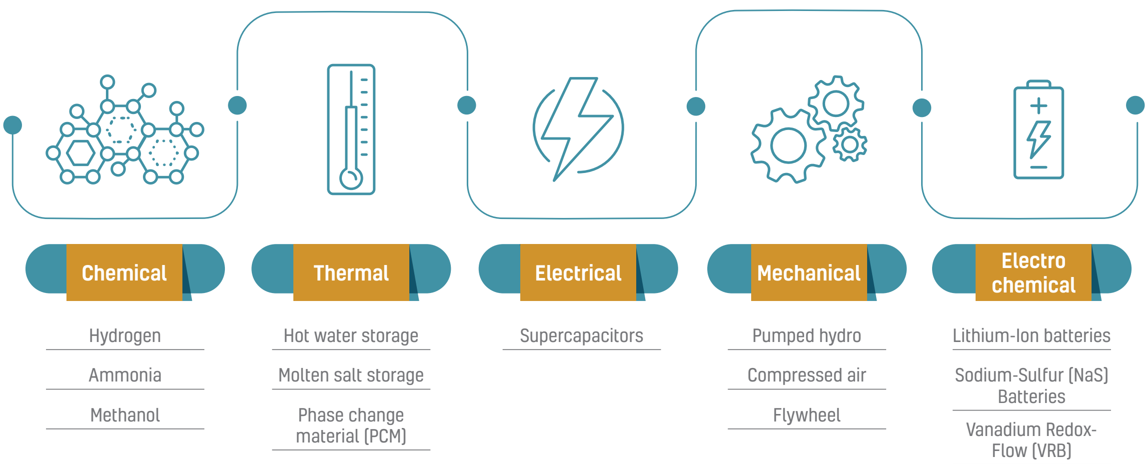
A spectrum of technologies

Pumped hydro storage (PHS) has the largest share of installed capacity in MENA at 55%, as compared to a global share of 90%. Pumped hydro storage is one of the oldest energy storage technologies, which explains its dominance in the global ESS market. In MENA, Morocco's National Office of Electricity implemented two PHS projects in Agadir and Afourer in 2013, with capacities of 350 MW/2,800 MWh and 465 MW/3,720 MWh, respectively. An additional 250 MW PHS project is under construction in Hatta, UAE, to be operated by the Dubai Electricity and Water Authority (DEWA). Although PHS dominates the ESS landscape in MENA, the technology is non-modular, capital intensive, and has a lower efficiency as compared to other ESS technologies.

Electrochemical energy storage, or batteries, are gaining traction in MENA, where out of the total on-grid ESS projects, 80% are of the battery type. However, this share constitutes only 7% of the operational ESS energy, equivalent to 677 MWh, the bulk of which is installed in the UAE. Currently, NaS battery technology dominates the battery storage capacity in operation in MENA, particularly in the UAE, with a total of 108 MW/648 MWh projects developed by the Abu Dhabi Water and Electricity Authority (ADWEA).

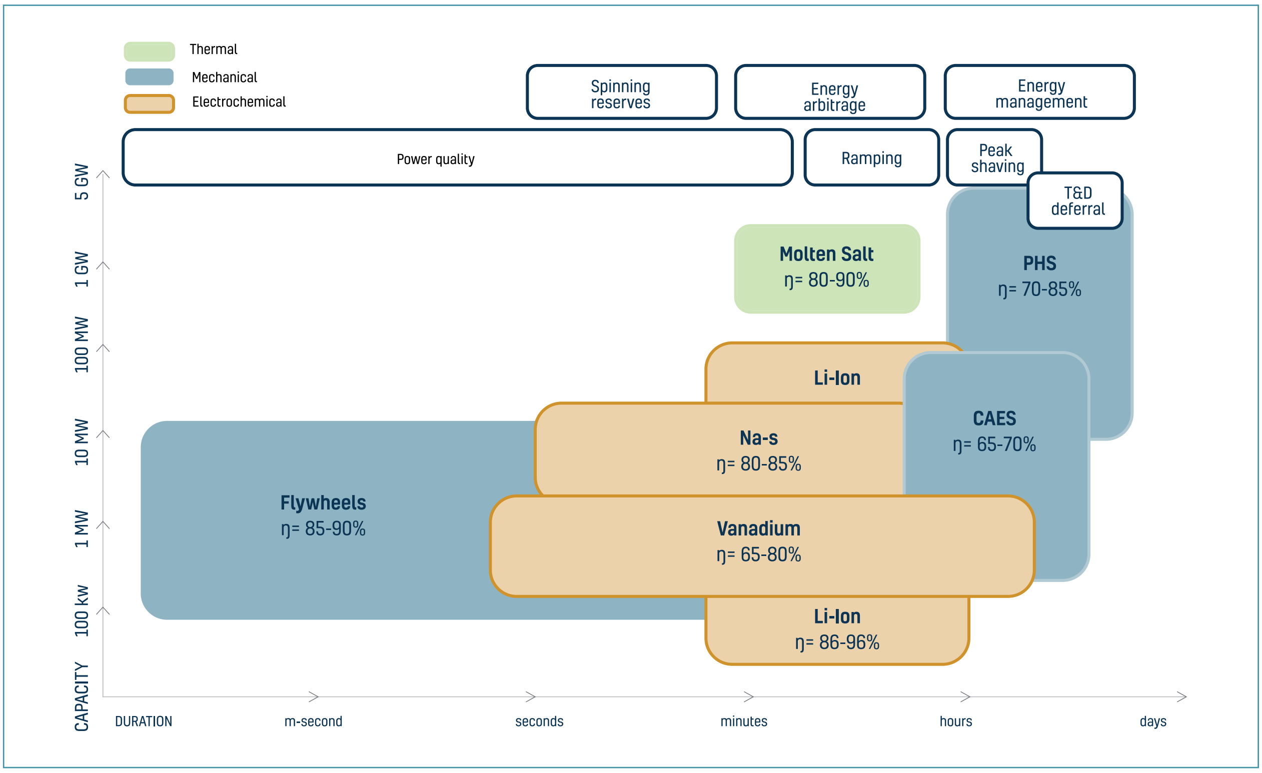
Li-Ion batteries record the fastest growing market share among electrochemical technologies due to their wide applications, from electronic appliances to power systems, as well as in transport. In MENA, Li-Ion batteries have a significant share of the battery grid-scale applications coupled with solar energy systems. The operational capacities range from 0.1 MW in Morocco's Demostene Green Energy Park to 23 MW in Al Badiya Solar-Plus-Storage at Al-Mafraq in Jordan. Although Li-Ion is currently among the low-cost types of ESS, it stands at a disadvantage in elevated climate temperatures where it experiences a drop in its efficiency.

Energy storage landscape based on existing technologies



Source: APICORP

Characteristics and applications of various energy storage systems



Other battery technologies are currently making an entry into the MENA market. A pilot Vanadium Flow battery of 0.13 MW/0.50 MWh has been implemented at the Nour plant, in Ouarzazate, Morocco. Flow batteries have significantly lower efficiencies than Li-Ion batteries but provide longer storage durations, lower degradation, and lower safety concerns.

The type of energy storage applications in MENA differ depending on the selected site, power system requirements, power market structure, regulatory frameworks, and cost-effectiveness. The technology costs, coupled with system needs in MENA, demonstrate that batteries will be the leading energy storage system for short and medium-term applications. This includes NaS, Li-Ion, and flow batteries.

Almost all the ESS projects operational in MENA are within the 10-hour duration segment, similar to the global trend where this time segment represents 90% of the total installed energy storage capacity[7]. MENA storage duration ranges between 32 minutes and 2 hours in the case of Li-Ion batteries, 6 hours for NaS, and 10 hours in the case of thermal storage[8].

[7] According to the Department of Energy Global Energy Storage Database.

[8] Details of MENA ESS projects are listed in Annex II.

A nexus of applications

ESS is used in the MENA region for different primary and secondary functions, including energy arbitrage (for 64% of applications), capacity firming (19%), frequency regulation (6%), and other ancillary services[9]. 30 projects are planned in MENA between 2021-2025, with a total capacity/energy of 653 MW/3,382 MWh. 24 of these projects are dedicated to VRE integration, with a primary function of renewable energy integration and grid firming. The share of batteries out of the operational ESS energy is expected to rise from the current 7% to 45% by 2025 in MENA.

Additionally, FTM applications are expected to remain dominant compared to BTM applications, as FTM constitutes 96% of the planned on-grid energy storage capacities.

Opportunities for deploying ESS in MENA

The pace of integration of ESS in MENA is driven by three main factors: 1) the technical need associated with the accelerated deployment of renewables, 2) the technological advancements driving ESS cost competitiveness, and 3) the policy support and power markets evolution that incentivizes investments.

The technical need for ESS in MENA is mainly driven by ambitious renewable energy targets and mounting peak electricity demand. The need for power system flexibility and capacity firming, especially in Saudi Arabia, the United Arab Emirates, Oman, Egypt, and Morocco is emerging.

GCC countries are equipped with competitive advantages in renewable plus storage procurement, due to the availability of vast lands and low-cost solar and wind generation capacities. In the GCC, it is expected that the bulk of ESS deployment will be FTM applications driven by VRE integration and firming. The six GCC states have significant capacity reserves margins reaching 35% in Saudi Arabia as a result of the 400 kVA GCCIA interconnection grid linking the GCC countries since 2011. Currently, the interconnection grid is under-utilized, with the electricity traded reaching only 5% of the designed capacity[10]. The increased integration of renewable energy in the GCC provides opportunities for additional electricity trading driven by FTM energy storage applications.

Several MENA countries, especially in North Africa and the GCC, have built large power generation capacities with excess power supply utilized during peak load, only to remain in standby mode throughout most of the year. Additionally, grid operators have been relying on spinning reserves or rotating mass for grid stability, powered by natural gas to quickly ramp up or down supply to meet demand variations. Some grid operators are switching to synthetic inertia and ESS, especially with rising VRE integration, whereas other grid operators are considering ESS for black start[11] to restore power in the case of a grid outage.

In a number of Levant countries, such as Lebanon and Iraq, power rationing creates a different need for ESS. The value of lost load associated with the duration, season, and timing of the outages is high and generates tremendous financial losses. This situation should drive policymakers towards adopting renewables plus storage micro-grids to stabilize the power system. This is especially critical during the peak season, when temperature increases trigger higher power rationing. These countries also rely on expensive private diesel generators reducing

[9] Refer to Annex I for the definitions of services.

[10] KAPSARC (2020), Energy Exchanges on the GCCIA Interconnector.

[11] Refer to Annex I for the definition of black start.

the competitiveness of Commercial/Industrial (C/I) consumers. The bulk of ESS in these countries may be BTM applications driven by the need to secure reliable and continuous power.

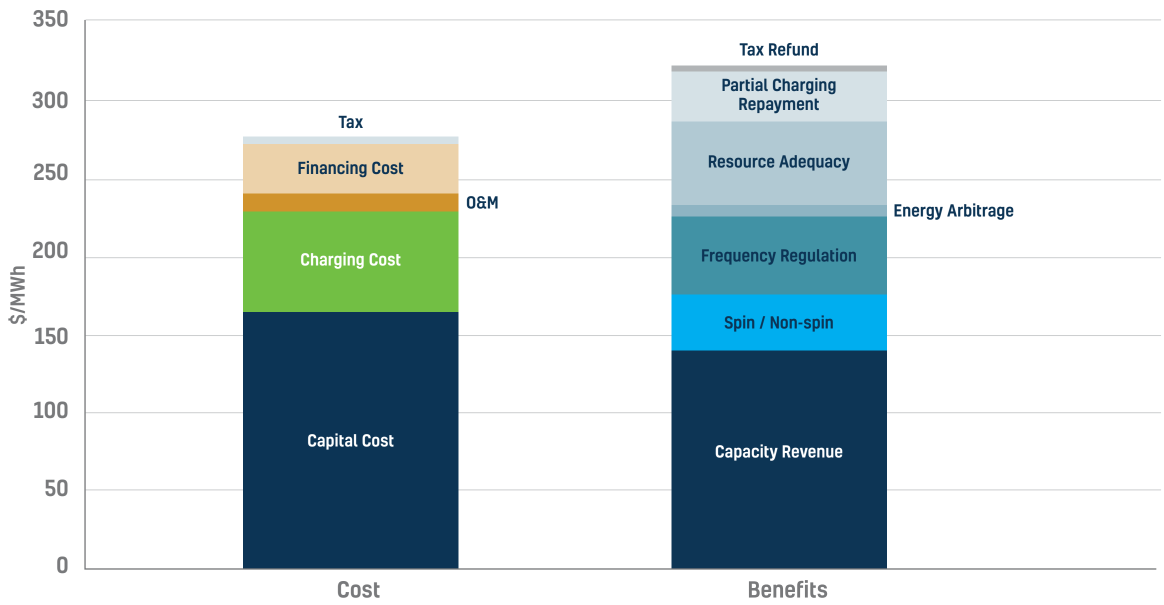
ESS offers a myriad of primary and ancillary services that provide opportunities for creating and capturing value during the procurement and deployment processes. In early deployment, the key objective of ESS is to minimize cost by optimizing the selected energy storage system and maximize value by stacking as much revenues as possible. However, identifying and modeling the created value offered by ESS poses a major challenge in existing business models, limiting the monetization of ESS services. A synergy is essential between national power utilities, regulators, and energy storage developers to enable stacking revenues and making a business case for ESS.

Assessing the costs and benefits of ESS in MENA

For the system to be economically viable, the ratio of system benefits to system costs should exceed one. Yet not all ESS services can be easily monetized, as this is highly dependent on the electricity market and regulations, where some services are valued and directly compensated while others are easily missed.

The revenues of the different applications depend on the power market, dispatch price, and percentage of deployment time. In addition to capacity payments, some of the most commonly valued services in markets that have been at the forefront of ESS are frequency regulation, transmission and distribution deferral, energy arbitrage, and spinning reserves. It is worth noting, however, that the value of services may decrease over time as the deployment of ESS increases, but developers can benefit from the first-mover advantage and secure market shares early on.

Costs vs benefits ($/MWh) – Battery Storage Solution (100 MW/200 MWh)[12]



Source: APICORP

[12] The modeling assumptions are listed in Annex III.

As shown in the results of the economic modeling of a standard FTM battery solution, the revenue streams include capacity payment and stacked revenues from various services. Service revenues are calculated based on international fees and amended for percentage of deployment to cater for applications in MENA. Operation and maintenance costs account for augmentation costs as of year 3. The system also accounts for one replacement over the project lifetime of 20 years.

Initial capital costs constitute 59% of the total system cost, charging costs 24%, financing costs 11%, operation and maintenance costs 4%, while taxes account for less than 2%. These costs and revenues are theoretical and actual costs will vary by country depending on the selected technology, pertinent risks and cost of financing.

The total unit cost is estimated at around USD 276/MWh as compared to a stacked revenue stream of USD 322/MWh with tax credits and partial charging repayments. This demonstrates that a direct policy intervention in the mode of fiscal incentives is needed to make a business case for ESS deployment in MENA. In addition to revenue stacking, early adoption of ESS will require financial incentives, such as tax refunds and exemptions, charging repayments, waivers, government subsidies, government equity provision, and accelerated depreciation measures.

IV. Barriers for ESS deployment in MENA

1. Financial and regulatory barriers

Investment shortcomings in T&D applications

Although power sector investments over 2021-2025 are the highest across the various energy sectors, accounting for USD 250 bn[13] of USD 805 bn, around 40% of these investments are allocated to renewables, with a large share earmarked for generation. Only 8-12% of power investments are dedicated to T&D compared to a global average of 20%. If ESS is to be considered part of the T&D value chain under any regulatory framework, more investments need to be diverted to grid reinforcements in light of increased integration of VREs.

On the other hand, private sector investments are constrained in bundled power markets. In such markets, subsidies have reduced the ability to attract investments in the power sector as investors' risk-aversion grows in light of their inability to recover investment costs. The sector has therefore been largely dependent on government spending through its fiscally-tight national utilities.

ESS necessitates significant project financing and long-term planning. The lack of capital investments and financial incentives hinders the deployment of grid-scale ESS. The early adoption of renewable energy was subject to the same challenges, which required innovative financing mechanisms, subsidies, and auctions. The multi-functional nature of ESS compared to renewable energy, and the variable cash flow driven by variable stacked revenues, indicate that the business models and financing mechanisms that have worked for renewables may not necessarily work for ESS.

Limited borrowing ability and high cost of financing

Power projects in MENA have historically secured loans with a gearing ratio ranging between 65:35 and 85:15. Depending on the financial status of the off-taker, some form of government guarantee or other types of credit enhancements, including political and commercial risk coverage, may be necessary to tap into higher shares of loans at lower costs of financing, especially for emerging technologies such as ESS.

While ESS creates an opportunity to stabilize the grid and displace some of the reliance on diesel generators in countries suffering from power crunches, the latter's typical high political and economic risks drive up the risk premiums and cost of financing. With the lack of a long-duration grid-scale ESS to date, ESS is still viewed as an emerging technology in MENA and associated with high technology and financing risks by the private sector. Accordingly, ESS projects might require more equity spending as compared to conventional power and renewables projects for the short to medium term.

[13] APICORP (2021), MENA Energy Investment Outlook 2021-2025.

Existing subsidy and tariff structures

As a direct result of subsidies, the discrepancies between cost recovery and tariff in MENA cost state budgets more than USD 40 bn annually. Since the electricity tariff is not cost-reflective across most MENA utilities, determining the actual value and accounting for the costs of energy storage is a challenge.

The tariff structure, driven by the cost of production at the time it was set decades ago, has resulted in significant underpricing and an inability to model and compare the costs of various emerging technologies. In addition to its negative financial impact on state budgets and ability to attract investments, the underpricing of electricity tariffs in MENA has led to increased electricity consumption and contributed to the annual growth in peak demand, averaging 4% annually in the GCC and 3.3% in non-Gulf countries from 2010-2017.

DEWA has managed to restructure electricity tariffs to better reflect the cost recovery through enhanced digitalization platforms and thorough communication campaigns to shape consumer behavior. Although the pace of tariff reform is slower in Saudi Arabia, the government has started gradually lifting energy subsidies, including electricity, gasoline, and other fuels sold domestically. Oman introduced a cost-reflective tariff in 2017 for large industrial, commercial, and public facilities.

A major challenge to address in the pricing policy is restructuring the electricity tariff without affecting businesses and consumers. As the tariff does not reflect the true cost of recovery, the cost of storage deployment or any other grid stability mechanism will be initially borne by national utilities. Lifting subsidies will result in organic growth of distributed renewable energy in several countries, as consumers seek alternatives, driving BTM storage applications.

Existing regulatory frameworks

Energy policies in MENA countries do not include clear definitions or regulations governing ESS. The lack of a comprehensive regulation hinders ESS deployment and increases investors' risk-aversion, with gaps in the governing framework. Although some auctions are focused on ESS or solar plus storage, deployment targets emphasize only renewable energy generation and do not account for energy storage systems.

Moreover, some regulations may be unfavorable to the deployment of ESS, such as the net-metering scheme on a flat tariff. Net-metering enables the end-user to offset the electricity consumed from the utility side by injecting excess electricity generated on-site into the grid, during a defined period. This scheme has provided an incentive for consumers to invest in distributed renewable energy such as rooftop solar systems, but provides no incentive for BTM energy storage, within a flat tariff pricing structure. Regulations should cater to creating the necessary price signals to incentivize investments in ESS. The net-metering scheme has been adopted by various MENA countries including Saudi Arabia, the UAE, Jordan, and Lebanon. Oman developed the Sahim scheme, offering financial compensation for the electricity injected into the grid through a feed-in tariff.

Given the residential sector leads in anchor load in the region, at an estimated 41% of total power consumption, followed by the commercial sector, opportunities for distributed renewable energy and BTM storage solutions are substantial. That said, further policy support and net-metering scheme reforms are needed to shape consumer behavior towards increased investments in BTM energy storage.

2. Market barriers

The limitations of the Single-Buyer Model

The single-buyer model (SBM) characterizes MENA's power market structures, with approximately 60% of countries having only one vertically integrated electricity utility[14] - the majority of which are State-Owned Entities (SOE). Although the private sector is becoming increasingly engaged within the SBM, mostly through Independent Power Producers (IPPs) models, state shares remain dominant. Governments' influence over the power sector has limited the prospects for subsidy reforms and private sector engagement.

The SBM has created liabilities for MENA governments in terms of providing guarantees and covering utilities' fiscal dues. Some governments have been locked in costly take-or-pay agreements, which had to be paid even when supply was curtailed or demand reduced.

To rectify the inefficiencies of the SBM, many MENA utilities have considered privatization or public-private participation through unbundling electricity utilities into distinct generation and distribution companies, while maintaining the transmission network as a separate utility managed by a Transmission System Operator (TSO). Several utilities have plans for privatization or market liberalization but have been facing lengthy implementation delays and retain the unbundled model.

Moving from a single buyer into the wholesale market is challenging, especially when the pricing structure does not reflect the actual cost of electricity. The current utility business model limits the prospects of energy storage expansion opportunities, unless driven by direct governmental support.

Renewable energy auction design

Auctions in MENA have been a major driver for renewable energy deployment, most notably for solar and wind, but only a few have included energy storage. These auctions have driven competition and attracted local and foreign investor interest, resulting in competitive prices. Every round of renewable energy auctions yields lower prices, as experience grows and the perception of risk decreases with higher deployment rates.

Saudi Arabia and the UAE have been setting record low tariffs for solar energy projects. In Saudi Arabia, each of the two awarded rounds of the Renewable Energy Project Development Office (REPDO) auctions, totaling 2.17 GW, in addition to the PIF-led projects, has received record-low prices. The 300 MW Sakkaka solar PV project, the first project under REPDO, set a record tariff of 1.34 USD cents/kWh in February 2018. In April 2020, seven solar PV projects, with a total capacity of 1.47 GW, were awarded, with one of the projects having a new record tariff of 1.04 cents/kWh. The 1.5 GW PIF-led Sudair solar PV set the second-lowest tariff at 1.24 cents/kWh[15]. In the UAE, the world's largest single-site solar PV farm, Abu Dhabi's 2 GW Al Dhafra plant, was awarded at a tariff of 1.35 cents/kWh.

[14] Details of MENA electricity utilities business models are listed in Annex IV.

[15] APICORP (2021), MENA Energy Investment Outlook 2021-2025.

While auctions have driven the deployment of renewables, the award criteria have focused only on selecting the lowest price and technically-compliant offer. For energy storage, in addition to the stored electricity, the values accrued from stacked services such as spinning reserves, frequency regulation, and energy arbitrage are major criteria in the selection of technology and its applications.

The renewable energy auctions led to the signing of power purchase agreements (PPAs) spanning over periods of 20 to 25 years, with take-or-pay or pay-as-generated clauses. The counterparty and grid risk are borne by off-takers, mostly the single-buyer utility. The latter has therefore been compensating developers for generated electricity, even in the case of curtailment and when electricity is not consumed. ESS may rectify this through the provision of dispatched electricity when needed, reducing the risk of the off-taker purchasing non-dispatchable electricity. Accounting solely for the lowest technically-compliant offer may not reap the full benefits of the offered ESS application; additional award criteria are required when designing future auctions.

V. Emerging business models for integrating ESS into power grids

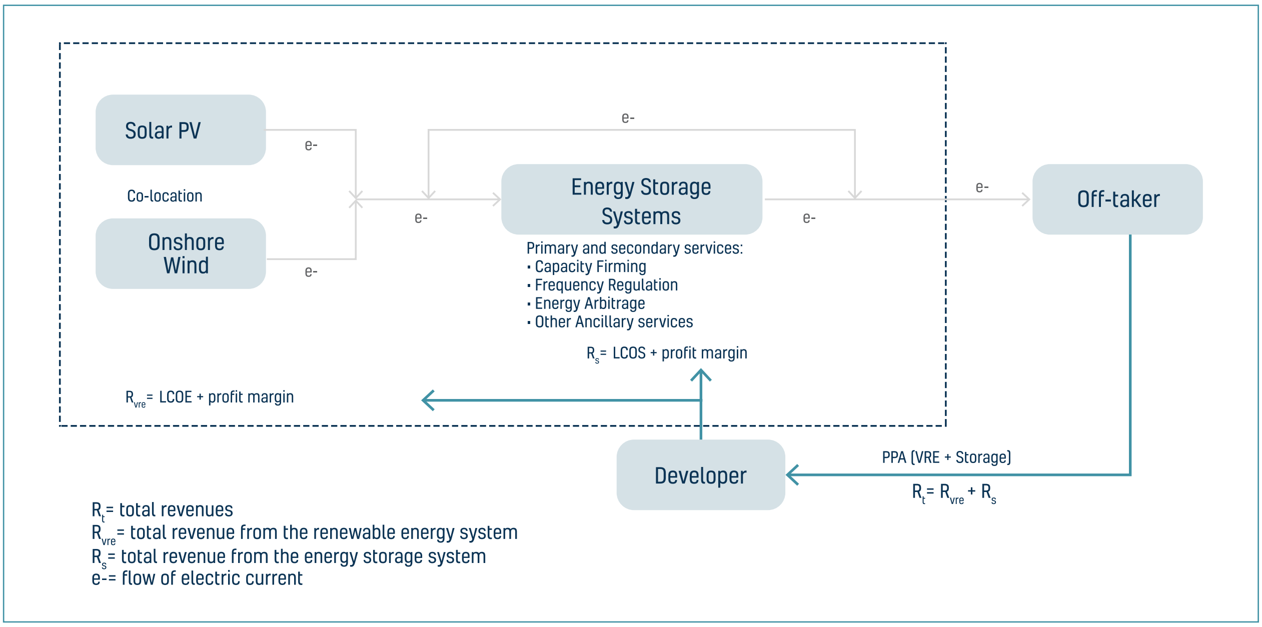
Primary, secondary, and other ancillary services should be prioritized and their value monetized and stacked to make a business case for energy storage. This will give rise to developers signing PPAs with off-takers that combine both the fixed and variable costs of renewable energy and energy storage systems.

The required services, especially primary services, should be decided upon by regulators, operators, and/or utilities, to identify the most suitable ESS technology application and corresponding capacity. This will further enable the elaboration of the most cost-effective ESS solution to be solicited as part of a renewable energy plus storage auction. In countries with empowered electricity regulators, the auction may be technology blind, and the regulator can only specify the required dispatchable electricity and services.

To optimize ESS usage, co-location of renewable energy plants, depending on the sites' available resources and load profiles, is key. As it remains difficult to monetize all services provided by ESS, developers' revenue streams should include revenues from renewable energy systems and ESS. The required ESS service provisions and costs shall be negotiated between the regulator, utility, and developer to ensure fair monetization of the value created by ESS. This is essential, as ESS leads to indirect benefits such as generation deferral and T&D investments.

As illustrated in the schematic below, the off-taker signs with the developer a PPA covering the renewable energy systems and capacity agreement for energy storage systems. These off-take agreements can include different fixed and variable costs.

Depending on the ESS size and capacity, energy storage and renewable energy developers may enter into joint ventures or consortiums to develop renewable energy plus storage systems. Where the energy storage sizing is low, the renewable energy developer could bring in energy storage developers through Engineering, Procurement and Construction (EPC) contracts.



VI. Ten policy action steps to promote further ESS deployment

The suggested ten policy action steps help reduce the barriers that limit the deployment of ESS solutions and enhance further integration of VRE into the grid. The financial, regulatory, and market barriers in MENA require strong policy support to create the necessary ecosystem for the scaling up and activation of energy storage markets. These action steps may serve as a roadmap for policymakers, regulators, developers and utilities, and other stakeholders within the ESS market ecosystem.

1. **Define energy storage as a distinct asset category detached from generation, transmission, and distribution value chains.** This is essential in the implementation of any future regulation governing ESS, especially as energy storage creates value across all three segments with the increased unbundling of national utilities in MENA. Developers focused on generation can build, own, and operate ESS for VRE and ancillary services, whereas distribution companies can enhance demand-side response through BTM applications. Classifying energy storage solely as part of generation may render it illegal for implementation by TSOs and distribution companies, which would then need to acquire a generation license. Conversely, classifying it as part of the distribution sector only may present challenges to generation companies, especially if utilities are no longer vertically integrated.

2. **Adopt a comprehensive regulatory framework with specific energy storage targets in national energy policies by setting achievable targets and timelines to drive energy storage deployment.** Energy and electricity laws and regulations should account for the deployment of energy storage and be amended accordingly. In addition to renewable energy targets, MENA countries should enact legislation setting deployment goals for energy storage systems. These goals should include capacity (MW) or energy (MWh) targets within a defined period, such as 2030 with interim targets for 2025, and metrics and indicators to track and measure progress.

3. **Amend the net-metering scheme when the share of renewables in the power mix becomes significant, to ensure the scheme does not create barriers to ESS deployment.** Provisions should be made to safeguard the incentive for consumers to invest in distributed renewable energy. A potential amended scheme may be to approve net-metering for 60-70% of the generated power from a renewable energy system, which would maintain the incentive for distributed renewable energy and increased deployment of BTM storage.

4. **Define the ESS ownership mandates of utilities, developers, operators, and regulators.** Since ESS solutions create value across different segments of the power value chain, ESS asset ownership should be well-defined and all related applications integrated for successful deployment. For instance, as frequency regulation is typically mandated to the TSO, updating the grid code to enable frequency regulation and other services through

other technologies such as ESS may be needed. The mandates for the establishment and management of the interconnection application terms should be also defined between regulators and utilities.

5. **Create an Energy Storage Alliance in MENA supported by governments and the private sector to foster the development of ESS in the region, by enhancing public-private partnerships.** A key objective of this alliance is to foster the development of ESS in the region through experience sharing and standardization. A task force may consist of representatives of energy storage project developers and manufacturers, subject matter experts, grid operators, regulators, and financial institutions to share experiences and mind the knowledge gap around the different ESS technologies and applications. This will enable better technology selection and applications from the regulator and utility side, and a better understanding of the needed structure for project financing. The task force may also issue common codes and standards to match the market structure and regulations to build performance indicators around the different technologies and applications. The alliance's outputs would therefore mitigate some of the project risks, lower project implementation costs, and reduce delays in project financing.

6. **Create incentives to attract private sector investments through tax credits, tax exemptions, accelerated depreciation, and government equity ownership.** Government financing is important for project piloting and creating sources of finance for the early adoption of grid-scale energy storage. Initial government equity ownership, where the government commits to owning a share of the project at the development stage to sell off to private investors at a later stage, should be made available to reduce financial risks and encourage private investments. The early adoption of ESS will also require fiscal incentives and tax exemptions. These could be in the form of customs duty and tax exemptions, such as from value-added tax. High energy consumers, including C/I consumers, may be provided with an ESS tax credit for defined technologies with a minimum/ maximum (MWh) energy range to incentivize consumers to store energy. Other incentives include accelerated depreciation, which is a capital incentive that lowers the net present value of taxes paid over a project's lifetime.

7. **Adopt a time-of-use tariff to ensure the economic viability of energy storage systems and incentivize reduced consumption at peak demand.** Several factors should be accounted for in this restructuring, mainly: 1) reducing wasteful consumption and promoting energy efficiency measures, 2) stimulating investments at the utility and end-user sides, 3) ensuring cost competitiveness in the industrial, commercial, and agricultural sectors, and 4) limiting variable loads. The time-of-use tariff restructuring would also increase the deployment of BTM storage applications to store electricity at peak consumption, especially among C/I consumers.

8. **Endorse ESS eligibility in green financing facilities and promote them as technologies eligible for funding within green bond frameworks.** With the rising momentum in energy transition and issuance of green bonds globally and in the MENA region, it is essential to classify energy storage systems as assets that qualify under the green bond frameworks. The proceedings of these bonds may be allocated for renewable energy plus storage grid-scale systems or micro-grids applications for municipalities, and residential or C/I consumers. According to the Green Bond Principles, energy storage is eligible for BTM applications under the energy efficiency category. The eligibility of ESS shall stretch to FTM applications whether within the generation, transmission, or distribution value chains.

9. **Auction portfolios of renewables-plus-storage assets to optimize renewable energy integration and enable off-takers to purchase fully dispatchable and stable electricity.** This approach reduces the risk of curtailment and exposure to the take-or-pay agreements. Soliciting the purchase of firm capacity builds the case for energy storage, as this requires developers to commit to an amount of electricity available to dispatch at all times. With increasing commitments to greenhouse gas emission reduction and renewable energy integration, it is essential to consider the renewable energy industry as an enabler and plan for the co-location of renewable energy systems. This also enables the co-location of various renewable resources at one connection point, interconnected to a utility-scale energy storage system, which may be considered as part of the generation assets. Such models also allow for optimal planning of FTM storage capacity and guarantee supply of electricity at various times. The procurement and award selection criteria of the auctions should include revenue streams stacking of ESS with various primary, secondary and ancillary services, in addition to being the lowest-cost and technically compliant offer.

10. **Emphasize FTM applications for utility-scale solutions to assist in scaling up the deployment of VREs.** As several MENA countries are scaling up their renewables projects to achieve their renewable energy policy targets, power grids will reach a tipping point where renewables can no longer be ramped up without a utility-scale energy storage solution. Deploying and integrating FTM energy storage solutions will create a positive feedback loop that will incentivize additional scaling up of renewable energy projects. This will be a key driver for cost-competitive ESS projects in FTM applications.

VII. Conclusion

Variable renewable energy systems are gaining momentum across MENA, driven by ambitious national energy targets, technology cost declines, and increasing investments towards low-cost and low-carbon technologies. Meeting national renewable energy targets requires scaling up and systematic integration of variable renewable energy (VRE) systems into the power grid which in turn necessitates deployment of energy storage solutions for firming the power capacity, building flexibility, and ensuring power systems stability. ESS plays a critical role in managing intermittencies of VREs and mitigating potential power supply disruptions while providing ancillary services.

The range of applications and captured revenue streams from different ESS technologies differs depending on the selected site, power system requirements, market structure, regulatory frameworks, and cost-effectiveness of the selected solution. Electrochemical storage (batteries) will be the leading energy storage solution in MENA for in the short and medium terms, led by NaS and Li-Ion batteries.

Several MENA countries, especially in the GCC, are equipped with competitive advantages in renewable plus storage procurement, due to the availability of vast lands and low-cost solar and wind generation capacities. In the GCC, it is expected that the bulk of the ESS deployment will be FTM applications, driven by VRE integration and firming.

Although the energy storage market in MENA is bound to grow, several barriers exist that hinder the integration of ESS and ramping up of investments. Ten key regulatory, financial, and market policy action steps are suggested to achieve the objective of successfully integrating energy storage systems in the power markets in MENA and to serve as a roadmap for various stakeholders in the energy storage ecosystem.

VI. ANNEX

Annex I: Definitions of key services provided by ESS

Avoided Curtailment	Energy storage is used to absorb renewable generation that would otherwise be curtailed.
Back-up Power	Energy storage is used to provide electricity when the grid connection is unable to meet demand or suffers an outage.
Black Start	An ancillary service, whereby an energy storage system is used to restore part of a grid or power station.
Capacity Firming	Energy storage is used to smooth out any variability in generation from intermittent renewable generation.
Capacity Value	Most markets require "operational" (in place all of the time to provide ancillary services) and "peaking" (only required at peak times of day/year) capacity.
Congestion Management	Energy storage is used to support network infrastructure to avoid overloading lines and transformers.
Distribution Load Management	The process by which supply is managed by adjusting the load rather than increasing generation outputs.
Distribution Upgrade Deferral	Energy storage is used instead of expanding capacity or improving network points on the distribution network.
Frequency Regulation	The ESS provides frequency regulation / response or control reserve /containment services. Frequency regulation is an ancillary service provided by generators that respond quickly (from sub seconds to minutes) to signals to help correct fluctuations in frequency.
Managing Imbalance Charges	TSOs are responsible for maintaining balance in the system. Anyone deemed to be causing an imbalance is subject to a charge where they are forced to purchase/sell power to equalize demand and supply (net 0).
Operating Reserves	An energy storage system is discharged to provide the immediate shortfall in supply.
Operational Improvements	Energy storage is used for optimizing operation of plants to reduce maintenance costs or the number of generators installed.
Optimizing Self-Consumption	An energy storage system is used to capture surplus renewable generation to be used on site.
Other Ancillary Services	Anything that has not already been covered by major functions, including but not limited to digital inertia and reactive power.
Peak Shaving	The ESS is used to intelligently manage a customer's load profile and reduce peaks to reduce the electricity bill by avoiding demand charges or coincident peak charges.
Ramp Rate Control	Energy storage systems are used to smooth short-term generation spikes and drops from renewable energy plants.
Resource Adequacy	Energy storage is used to ensure supply for all hours during a defined period.

Test Case	Energy storage is primarily used to test a range of other functions to assess its capabilities.
Time of Use Optimization	An energy storage system is charged from the grid or by on-site generation to be used at a later time to take advantage of price differentials.
Transmission Upgrade Deferral	Energy storage is used instead of upgrading the transmission network infrastructure.
Voltage Support	The storage system provides the grid with the necessary output to ensure the voltage level on the network remains steady.
Wholesale Price Arbitrage	Optimizing energy storage systems against wholesale prices—discharging at high prices and charging at low prices.
Spinning/ non-spinning reserves	The additional available generation capacity that can be operated when there is a shortfall in supply.

Annex II: Operational and Planned ESS Projects in MENA

No.	Project Name	Status-Major	Country/ Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
1	SILA NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	20.00	120.00	0 - 06:00	2013	2018
2	GICG NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	40.00	240.00	0 - 06:00	2013	2018
3	E25 NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	8.00	48.00	0 - 06:00		2010
4	MOSG NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2014
5	Qatar Science and Technology Park	Operational	Qatar	BTM	Optimising Self-Consumption	Li_ion	0.25	0.50	0 - 02:00	2012	2012
6	Ingeteam stand alone system	Operational	Tunisia	Off grid	Back-up Power	Lead	0.01	0.15	0 - 15:00		2006
7	Demostene - Green Energy Park	Operational	Morocco	BTM	Optimising Self-Consumption		0.10	0.10	0 - 01:00		2017
8	Duserve FM Trial	Operational	United Arab Emirates	BTM	Optimising Self-Consumption	Li_ion	0.18	0.38	0 - 02:05	2017	2019
9	Al Badiya Solar-plus-storage at Al-Mafraq	Operational	Jordan	FTM	Capacity Firming	Li_ion	23.00	12.60	0 - 00:32	2017	2019
10	Siah Bishe Pumped Storage Power Plant	Operational	Iran	FTM	Wholesale Price Arbitrage	Pumped hydro	1040.00	7280.00	0 - 07:00	1985	2013
11	Noor 3 project	Operational	Morocco	BTM	Peak Shaving	Molten Salt	150.00	1050.00	0 - 07:00	2017	2018

No.	Project Name	Status-Major	Country/ Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
12	Mam Rashan Refugee Camp	Operational	Iraq	BTM	Optimising Self-Consumption		0.13	0.13	0 - 01:00		2018
13	Solveo Demonstrator (IRESEN)	Operational	Morocco	FTM	Capacity Firming	Li_ion	0.13	0.10	0 - 00:45		2018
14	Mohammed bin Rashid Al Maktoum Solar Park	Operational	United Arab Emirates	FTM	Capacity Firming	Sodium	1.20	7.20	0 - 06:00	2018	2018
15	Ait Baha Plant Thermal Storage - Airlight Energy	Operational	Morocco	FTM	Capacity Firming	Other Thermal	0.65	5.85	0 - 09:00	2012	2014
16	NOOR I (Ouarzazate) CSP Solar Plant	Operational	Morocco	FTM	Capacity Firming	Molten Salt	160.00	480.00	0 - 03:00	2013	2016
17	NOOR II (Ouarzazate) CSP Solar Plant - ACWA	Operational	Morocco	FTM	Capacity Firming	Molten Salt	200.00	1400.00	0 - 07:00	2015	2015
18	Abu Dhabi TES Pilot - EnergyNest AS	Operational	United Arab Emirates	FTM	Wholesale Price Arbitrage	Other Thermal	0.10	1.00	0 - 10:00	2015	2015
19	Abdelmoumen Pumped Storage Power Station	Operational	Morocco	FTM	Wholesale Price Arbitrage	Pumped hydro	350.00	2800.00	0 - 08:00	2013	2013
20	Afourer Pumped Storage Scheme	Operational	Morocco	FTM	Wholesale Price Arbitrage	Pumped hydro	465.00	3720.00	0 - 08:00	2013	2013
21	E14 NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2014
22	GIC-B NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2014

No.	Project Name	Status-Major	Country/Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
23	GIC PRY5 NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2014
24	W59 BSS02 NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2015
25	GIC A NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2015
26	W59 BSS01 NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	4.00	24.00	0 - 06:00	2013	2015
27	Al-Wathba NaS Project	Operational	United Arab Emirates	FTM	Frequency Regulation	Sodium	12.00	72.00	0 - 06:00	2013	2016
28	Off-grid workers accomodation in MENA	Operational	United Arab Emirates	Off grid	Optimising Self-Consumption	Li_ion	0.01	0.03	0 - 04:25	2018	2018
29	Luxor Solar	Operational	Egypt	BTM	Optimising Self-Consumption	Li_ion			-	2015	2016
30	Adam oil concession	Operational	Tunisia	Off grid	Capacity Firming	Li_ion	2.20	1.50	0 - 00:40	2018	2019
31	Al Ruwayyah smart grid station	Operational	United Arab Emirates	FTM	Capacity Firming	Li_ion		0.50	-		2019
32	Engie - saldabilità UAE	Operational	United Arab Emirates	BTM	Frequency Regulation				-	2018	2019
33	Engie - saldabilità Algeria	Operational	Algeria	BTM	Frequency Regulation				-	2018	2019

No.	Project Name	Status-Major	Country/ Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
34	South Amman Solar Power Plant	Operational	Jordan	FTM	Capacity Firming	Li_ion	3.60	2.60	0 - 00:43	2020	2020
35	UNIDO Morocco Project	Operational	Morocco	FTM	Ramp Rate Control	Flow	0.13	0.50	0 - 04:00	2019	2019
36	Nuaija Station T&D	Operational	Qatar	FTM	Network peak shaving	Li_ion	1.00	4.00	0 - 04:00	2020	2020
37	NREA Hurghada 20MW solar plant - Li-ion	Planned	Egypt	FTM	Capacity Firming	Li_ion	15.00	15.00	0 - 01:00		2021
38	Gravity storage demonstrator at Al-Ayuni granite quarry	Planned	Saudi Arabia	FTM		Gravity storage		0.30	-	2017	2021
39	NREA Hurghada 20MW solar plant - Sodium-Sulfur	Planned	Egypt	FTM	Capacity Firming	Sodium	2.50	15.00	0 - 06:00		2021
40	Hybrid CSP and PV system	Planned	United Arab Emirates	FTM	Capacity Firming	Molten Salt	100.00	1500.00	0 - 15:00	2016	2021
41	Solar plus storage tender project 4/6	Planned	Lebanon	FTM	Capacity Firming		35.00	35.00	0 - 01:00	2019	2023
42	Solar plus storage tender project 5/6	Planned	Lebanon	FTM	Capacity Firming		35.00	35.00	0 - 01:00	2019	2023
43	Solar plus storage tender project 6/6	Planned	Lebanon	FTM	Capacity Firming		35.00	35.00	0 - 01:00	2019	2023
44	Noor Ouarzazate Solar plant Storage part 4	Planned	Morocco	FTM	Operational Reserves	Other Thermal	100.00		-	2019	2021

No.	Project Name	Status-Major	Country/ Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
45	Adam Oil plant	Planned	Tunisia	BTM	Ramp Rate Control	Li_ion	1.50	2.20	0 - 01:28	2020	2021
46	Noor Midelt EDF triple solar hybrid	Planned	Morocco	FTM	Capacity Firming				-	2019	2022
47	Azelio test case phase 1	Planned	Jordan	BTM	Test Case	Other Thermal	0.05	0.65	0 - 13:00	2020	2021
48	Azelio test case phase 2	Planned	Jordan	BTM	Peak Shaving	Other Thermal	3.00	39.00	0 - 13:00	2021	2021
49	Azelio test case phase 3	Planned	Jordan	BTM	Peak Shaving	Other Thermal	7.00	91.00	0 - 13:00	2022	2022
50	Azelio test case phase 4	Planned	Jordan	BTM	Peak Shaving	Other Thermal	15.00	195.00	0 - 13:00	2023	2023
51	Juba - Elsewedy Electric	Planned	Sudan	FTM	Capacity Firming	Li_ion		35.00		2019	2021
52	Tanweer hybrid energy plant	Planned	Oman	FTM	Capacity Firming	Li_ion	28.00	14.00	0 - 00:30	2020	2023
53	Themar Al Emarat microgrid	Planned	United Arab Emirates	BTM	Optimising Self-Consumption	Li_ion	0.25	0.29	0 - 01:08	2019	2021
54	Mohammed bin Rashid Al Maktoum Solar Park - Li-ion	Planned	United Arab Emirates	FTM	Capacity Firming	Li_ion	1.20	8.20	0 - 06:50	2018	2021
55	ADWEA Al Dhafra	Planned	United Arab Emirates	FTM	Capacity Firming	Li_ion	250.00	300.00	0 - 01:12	2020	2022

No.	Project Name	Status-Major	Country/ Territory	Siting - Major	Primary Function	Sub Technology	Total System Power (MW)	Total System Energy (MWh-nameplate)	Duration (days - Hrs:mins)	Start Year	Operational Year
56	Mohammed VI Museum of Modern and Contemporary Art	Planned	Morocco	BTM	Optimizing Self-Consumption	Li_ion	0.10	0.05	0 - 00:30	2020	2021
57	Red sea development zone	Planned	Saudi Arabia	Off grid	Capacity Firming	Li_ion	170	1000.00	-	2020	2022
58	Mohammed bin Rashid Al Maktoum Solar Park - Thermal	Planned	United Arab Emirates	FTM	Capacity Firming	Other Thermal			-		2023
59	Azelio Jet Energy TES:POD - Project 1	Planned	Morocco	FTM	Frequency Regulation			0.05	-		2021
60	Azelio Jet Energy TES:POD - Project 2	Planned	Morocco	FTM	Frequency Regulation			5.00	-		2022
61	Azelio Jet Energy TES:POD - Project 3	Planned	Morocco	FTM	Frequency Regulation			10.00	-		2023
62	Azelio Jet Energy TES:POD - Project 4	Planned	Morocco	FTM	Frequency Regulation			15.00	-		2024
63	Azelio Jet Energy TES:POD - Project 5	Planned	Morocco	FTM	Frequency Regulation			15.00	-		2025
64	Sukari gold mine	Planned	Egypt	Off grid	Optimising Self-Consumption	Li_ion	7.50		-	2021	2022

Annex III: Modeling Assumptions

Charging cost	$31/MWh
O&M cost	$10/MWh
Financing cost	WACC = 5% ; D/E: 60/40
Taxes	10%
Initial cost	$164/MWh
Battery efficiency	85%
Battery capacity	100 MW
Battery energy capacity	200 MWh
Warranty cost	1%
Depth of discharge	95%
Cycles per day	1
Operating days per year	350
Spinning/ Non-spinning reserves revenues	$10/MWh deployed 36% of the time
Frequency Regulation	$10.55/MWh deployed 51% of the time
Energy Arbitrage	$10/MWh deployed 5% of the time
Resource adequacy/demand response	$56/MWh deployed 10% of the time

Annex IV: Overview of national electricity utilities in MENA

MENA Country	Model	Off-taker	Electricity Utility Business Model
Saudi Arabia	Single-buyer	SEC	Established as a joint-stock company, SEC is a vertically- integrated entity. The state owns 81.24% of the shares. It divides the kingdom into 4 geographic areas: Western, Eastern, Southern, Central areas. It owns 8 companies operating in transmissions, telecommunication infrastructure, services and support, procurement, and carbon emissions business.
Oman	Single-buyer	OPWP	Unbundled into 12 GU (5 state-owned, the rest are private)/ 2 vertically integrated utilities
Abu Dhabi	Single-buyer	ADWEA	Unbundled into several private IWPPs in generation, 2 distribution companies, and 1 transmission company
Dubai	Single-buyer	DEWA	1 state-owned vertically- integrated utility
Bahrain	Single-buyer	Ministry of Electricity and Water	Ministry of Electricity and Water responsible for the generation, transmission, and distribution of electricity
Qatar	Single-buyer	KAHRAMAA	1 state-owned vertically- integrated utility
Kuwait	Single-buyer	Ministry of Electricity and Water	Ministry of Electricity and Water is responsible for electricity service provision
Egypt	Single-buyer	EEHC	Joint-stock company. Unbundled into generation companies (1 state-owned and IPPs), 1 transmission company, and 9 distribution companies
Jordan	Single-buyer	NEPCO	Unbundled utility. 5 GUs (1 state-owned & 4 private), 3 DUs (private), state-owned transmission utility

Lebanon	Single-buyer	EDL	1 state-owned vertically- integrated utility
Iraq	Single-buyer	Ministry of Electricity	Ministry of Electricity of Iraq is the federal government entity in charge of both the policymaking and the electricity supply. The generation, transmission, and distribution, and distribution are divided into geographically distributed directorates
Tunisia	Single-buyer	STEG	1 state-owned vertically- integrated utility
Morocco	Single-buyer	ONEE	1 state-owned vertically integrated utility, with select private sector concessions to AMENDIS, LYDEC, and REDAL
Algeria	Single-buyer	SONELGAZ/OS	Holding company with 8 subsidiaries

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