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(Vector 3). E-mobility as a catalyst and enabler in modernizing regional electrification and the transition to renewable energy

The GCC countries

(save Qatar) plus **Jordan**, **Morocco** and **Tunisia** rank above the world median of

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but only three of them
are above

75 per cent



reliability. The rest of the region is at or below the median, and the least developed and conflict countries are assessed at **0 per cent**

A potential outcome along this vector, circa 2040: Decision makers in the Arab region have recognized and facilitated a “virtuous circle” in which large-scale adoption of e-mobility benefits from grid modernization and the transition to renewable energy sources and in turn helps make those innovations scale. Electric grids throughout the region have expanded and modernized with smart technology investments. Alongside ongoing investments in power generation projects, these grid improvements have enabled countries to make strong progress on goals to increase the share of renewables in their energy mix. Charging infrastructure investments have favoured “smart charging” and particularly bidirectional vehicle-to-everything (V2X) charging, with parts of the region becoming proving grounds for this technology. Electric utilities have adapted their operating models, with new regulatory frameworks and structures allowing for multiple electricity buyers, private participation in markets and unbundling distribution from generation. Time-of-use tariffs incentivize EV-owning individuals, fleet owners and transit systems to sell energy back into the grids, acting as mobile storage at scale for solar and wind energy. Electric rail and e-bus fleet acquisition projects have favoured these renewable energy sources to move public transit e-mobility more toward truly clean solutions. These investments in V2X and renewables-powered public transit have been made in a coordinated manner between energy, transport, environment, public works and other ministerial authorities within individual countries in the region and in some cases across borders. Access to reliable electricity is measurably more widespread and equitable at the same time that residents are more able to enjoy the economic, social and health benefits of increased mobility options.



Natural gas is the dominant **source of power generation** in **Arab countries** (between 90 and 100 per cent in Algeria, Bahrain, Jordan, Oman, Qatar, Tunisia and the United Arab Emirates), and many still rely on **heavy fuel oil, diesel** and **coal** as power sources. For Arab region grids, adding **renewable energy capacity** without adding to or improving system flexibility risks **brownouts** or **blackouts**.

A. Advancement of e-mobility in the Arab region faces a causality conundrum

The advancement of e-mobility, the transition to renewable energy and electric grid modernization in the Arab region are inextricably linked from a practical standpoint, but not yet in policy or implementation. Scaling the number of EVs of all types in the region will require significant increases in electricity generation capacity and improvements in the reliable, dynamic distribution of electric power. The desired impact of a large-scale shift to e-mobility on carbon emissions, other climate change impacts and public health will not be achievable unless the majority (and over time the entirety) of the electricity powering EVs is from clean renewable sources. On one hand, countries of the region have ambitious renewable energy transition targets, and investments are underway to enable meeting them. By one estimate, projects valued at more than \$100 billion are planned, with more than \$20 billion at contract tendering stages and nearly \$3 billion worth awarded in the first half of 2021 alone.¹⁴³ But these are overwhelmingly on the generation side of the equation. Projects to expand and improve grid capacity to handle these large increases in variable energy lag behind and face much more difficulty gaining financing. Substantial leaps in e-mobility, renewable energy and grids in the region are increasingly interdependent.

1. Grid challenges pose challenges to e-mobility

The enabler of any low-carbon technology implementation is infrastructure, and at the core of e-mobility deployment, and the renewable energy transition it relies on, is the power grid. At different levels, Arab countries' power grids are characterized by a set of challenges including

unreliability, limited capacity, inefficiency, low flexibility and underinvestment.

Resultant problems such as shortages, blackouts/brownouts and uneven access are present even in higher-income countries and are acute in the least-developed countries and countries in conflict. According to the World Bank's index (2019 data), the reliability of electricity in the Arab region overall is concerning. The GCC countries (save Qatar) plus Jordan, Morocco and Tunisia rank above the world median of 62 per cent, but only three of them are above 75 per cent reliability. The rest of the region is at or below the median, and the least developed and conflict countries are assessed at 0 per cent.¹⁴⁴ Electricity losses (energy dissipated between the generation source and the end user due to technical and operational practice reasons) average 18 per cent in Arab countries, with Gulf states having the lowest values averaging at 8 per cent. Iraq, Lebanon and countries in conflict have the highest levels of technical and non-technical losses in the region, ranging from 35 to 50 per cent, meaning approximately half of the generated power is lost within the network.¹⁴⁵

Arab countries' grids also are characterized by low flexibility, and overall system flexibility dictates the level of renewable energy integration that is possible. The type of electricity generation units and the sources of generation directly impact the level of flexibility. Natural gas is the dominant source of power generation in Arab countries (between 90 and 100 per cent in Algeria, Bahrain, Jordan, Oman, Qatar, Tunisia and the United Arab Emirates), and many still rely on heavy fuel oil, diesel and coal as power sources. For Arab region grids, adding renewable energy capacity without adding to or improving system flexibility risks brownouts or blackouts. Countries in conflict (Iraq, Libya, the State of

Palestine, Somalia, the Syrian Arab Republic, Yemen) have the highest grid reliability and flexibility challenges in addition to their very high losses.¹⁴⁶

The state of the electrical grids throughout the Arab region is at the core of the e-mobility challenge as well as the renewable energy transition challenge. As described by the global research consultancy Wood Mackenzie, “fragile grids are a major bottleneck to the decarbonization of power, make power sector reforms difficult, are poorly positioned to provide resilience in the face of rising temperatures, and perpetuate civil unrest”.¹⁴⁷ It will be essential to the future of e-mobility in the Arab region to address this, as EVs introduce new, transient and unpredictable point loads on grids whose resiliency is already challenged. Weather conditions of intense heat (especially but not only in summer), old and inadequate infrastructure, damage from wars and conflict and other factors also make grids a point of vulnerability for e-mobility objectives. Increased peak demands can be partially mitigated by using smart meters, distributed energy resources (DER) like solar and battery storage and advanced communication systems. But all of these require investment, as well as basic expansion, i.e. additional new substations and transmission lines.

Some of this investment is underway and planned, with one analysis noting upwards of \$17 billion on smart-grid improvements across the Middle East and North Africa between now and 2027 alone. Doug Waters, Global Director at Uniper Energy Services, noted at the Middle East Energy conference in Dubai in March 2020 that “MENA grid transformation is integral to optimizing renewable utilization, including for new technologies and demands like electrical vehicles”. There are also longstanding and newly emerging efforts to integrate the grids of different Arab countries as an element of the needed modernization and strengthening needed for e-mobility and other objectives. One is between Iraq and Jordan, projected to enable Jordan to deliver up to 1TWh/year to Iraq in the project’s first phase alone. There are also plans to develop a common Iraq-GCC power grid. A \$1.6 billion project between Egypt and Saudi Arabia, in addition to an ambitious vision to connect the Morocco and United Kingdom grids with undersea cables. At the same time, projections are for progress to be difficult and slow, in part because financing models for grid modernization are few compared to those that are established and available for projects to increase power generation capacity. The absence of appropriate legal and regulatory frameworks and grid codes poses additional complications to cross-border grid integration in the region.¹⁴⁸

2. Meeting rising electricity demand with grid modernization and renewable energy is key to e-mobility

The significant projected growth in electricity demand in the Arab region will further exacerbate the grid situation, and further indicates that grid challenges pose risks to e-mobility and the renewable energy transition. Total electricity demand is projected to triple by 2050. Transport will be one of three sectors along with manufacturing and buildings driving growth in the region’s overall energy consumption.¹⁴⁹ This is not a new phenomenon, but a further acceleration of one seen over the past 20 years. For example, the energy consumption increase in the GCC over that period was the world’s largest other than in China.¹⁵⁰ It is widely understood that grid modernization is an imperative to satisfy transmission and distribution even for the region’s current electricity needs, let alone those of the future. Those needs will be driven in part by e-mobility.

Globally the transport sector is responsible for more than 30 per cent of energy consumption and 25 per cent of energy-related CO₂ emissions, and the sector’s energy demand has risen more than 20 per cent since 2010. In the near term, the increase in electricity demand in the Arab region for e-mobility will be modest. But this will rise over time (beyond 2030) to a need for an additional 10-15 per cent new electricity generation capacity, according to one World Bank estimate. In the United Arab Emirates, second to Jordan in EV penetration in the region, a 5 per cent EV share of the country’s total automobile market by 2030 would increase electricity demand by only 0.08 per cent, and by only 0.49 per cent even with a 30 per cent share. But for e-mobility region-wide in all its forms (considering personal EV ownership, e-bus fleet deployments, electric rail systems, electric two- and three-wheelers, etc.), substantial growth in electricity generation capacity will be needed beyond 2030. And while Bloomberg’s more conservative scenario projects EV adoption displacing more than 20 million barrels per day of oil by 2050 from the replacement of ICE vehicles, it remains unclear how much of the very large electricity demand for these EVs will be generated from fossil fuels versus renewable energy.¹⁵¹

In addition to e-mobility needing to be powered by renewable energy for its impact on climate and health to be realized, a variety of forces are driving the transition in the Arab region. These include COP and other diplomatic commitments, energy security concerns and economic opportunities and threats. In the context of COP, Bahrain and Saudi Arabia have pledged to be net-zero by 2060, and the United Arab Emirates by 2050, with each projecting upwards of \$150 billion in green economy investments.¹⁵² Every country in the Arab region is planning for a significant percentage of its energy generation capacity



to be from renewable sources by between 2030 and 2035. Pledges range from Morocco and the Sudan at 50 per cent, Egypt and the United Arab Emirates at more than 40 per cent and even some of the less-developed countries and countries in conflict at between 15 and 30 per cent.¹⁵³ By 2050, solar is projected to be the main source of energy in the Middle East and North Africa, generating 39 per cent of total supply, with onshore wind second at 28 per cent.¹⁵⁴

The tie between e-mobility and the transition to renewables is significant in specific ways in the Arab region. The International Council on Clean Transportation projects that transportation CO₂ emissions in the Arab region will more than double between 2020 and 2050 in the absence of a shift to renewable energy sources powering clean means of mobility (electric or other). At the same time, the global growth of the EV market and shared mobility, along with fuel efficiency mandates driving R&D for improvements to whatever ICE engines still are being manufactured in the future, are projected to affect the economies of Arab region oil-exporting countries significantly. Oil demand for road transport is projected to peak in 2027 followed by an accelerating decline.¹⁵⁵

Energy security and responding both to economic opportunities and economic vulnerabilities also are key drivers of the Arab region's energy transition. High-income countries are either freeing oil for export and building their capacity to handle fossil fuel market volatility, as in Saudi Arabia, or reducing their need for gas imports, as in the United Arab Emirates. Most middle-income countries are targeting renewable energy to reduce their heavy reliance on fuel imports, with the exception of Algeria and Egypt which are aiming to displace fuel from power generation for exports. In the least developed countries and countries in conflict (with the exception of Libya), and

in Lebanon, renewable energy is being embraced as much as resources allow, chiefly as a means to mitigate severe black-outs and other power problems.¹⁵⁶

As yet, implementation of renewable energy currently lags well behind targets, with most countries in the region at less than 1 per cent of installed capacity and/or generation, with a few exceptions. The United Arab Emirates and Lebanon stand at 6 and 7 per cent of installed capacity respectively, and Egypt stands at 9 per cent of generation and 11 per cent of installed capacity. Jordan with 20 per cent of its generation and Morocco with 40 per cent of its installed capacity are leading renewable energy deployment among Arab countries.¹⁵⁷ The most obvious consequence of the increasing electricity demand is further increasing the region's already high natural gas dependence to the point of a risk of shortage. The gas demand in high-income countries has more than doubled in the past two decades, with two-thirds of the growth attributed to electricity generation. This is increasing the need for imports for most countries, tightening the export potential of some others, and increasing countries' susceptibilities to political risks.

The economic potential of renewable energy for the region is high, important for oil-exporting countries as the global demand for oil declines over the next two decades driven by e-mobility and other climate change adaptation strategies. Already Saudi Arabia and the United Arab Emirates are seeing their role in the renewable energy sector growing in the region (and beyond). The Saudi Public Investment Fund (PIF) holds a 50 per cent stake in ACWA Power, while Abu Dhabi's National Energy Company (TAQA) acquired a 43 per cent stake in Masdar and Abu Dhabi's National Oil Company (ADNOC) acquired a 24 per cent stake, and 33 per cent in Mubadala. These two companies are developing renewable energy

projects in many countries in the region including Egypt, Iraq, Jordan, Morocco, the Sudan and the United Arab Emirates driven by their access to finance.¹⁵⁸

A growing number of analyses point to the prospects of the region's vast potential to generate renewable energy. One has generated models for "how the sunshine that so reliably bathes the region could provide a significant portion of the estimated 40,000 terawatt hours of electrical energy the world will need by 2050". The means would be a "potential high voltage electricity transmission grid that would tap into solar energy

generated in Algeria, Egypt, Iran, Iraq, Kuwait, Libya, Morocco, Oman, Saudi Arabia, Tunisia, Türkiye and the United Arab Emirates". The consulting firm Ankura cites a study dating back to 2008 by the Centre for Global Development indicating "solar power in the Middle East and North Africa has the potential of meeting 50-70 per cent of global electricity demand".¹⁵⁹ Job creation is also a driver of the renewable energy transition across all countries in the region, as the renewable energy industry is cross-sectoral and creates opportunities across industry, agriculture, water treatment and other sectors and opens the door for increased innovation and entrepreneurship.

B. E-mobility has potential to help shift the causality conundrum toward a virtuous circle

Mass electrification of mobility could become an important element of the solution for improving flexibility and reliability in the electricity grids of Arab countries that today unreliably power not only EVs, but also the residential, industrial and other sectors of the region's societies. In doing so, it could also help make possible the integration of high levels of renewable energy into the energy mix in the region, unlocking the immense potential of solar power in particular to transform Arab economies and mitigate climate change.

1. Electric vehicle batteries as storage for variable renewable energy

The variability of solar and wind power – uncertain output, intermittent availability and asynchronous interconnection to the grid – is what complicates the growth of renewables in any country. Matching the volume and timing of supply and demand in the face of those factors requires variation management solutions. Expansion and modernization of grid infrastructure and improved interconnection between different grids, both discussed above, are two of these solutions, and both must be pursued. Storage of variable renewable energy for dispatch when and where it is needed is an important solution as well. It is garnering increasing attention and implementation as advances in battery technology improve the economics and feasibility of grid-scale storage. For example, a recently completed three-year study by the MIT Energy Initiative details how "storage technologies will have the ability to substitute for or complement essentially all other elements of a power system, including generation, transmission, and demand response". It will "make deep decarbonization of reliable electric power systems affordable" including in emerging market and developing economy countries including Arab countries.¹⁶⁰

The batteries of EVs driving on the streets and highways of Arab countries is how e-mobility can be a factor in solving for grid modernization and renewable energy in the region.

At the global level, EVs by 2030 will offer an aggregated storage capacity of 7 TWh of electricity, based on an estimate of 140 million total EVs. The same source projects a total of 30 TWh of storage capacity in EVs in 2040.¹⁶¹ To illustrate in an Arab region context, the European engineering and design consultancy AFRY estimates that if Dubai achieves its stated 2030 target of only 10 per cent EV penetration, this would create 3 GW of battery storage in the city's vehicle fleet – enough energy to power 750,000 homes or their equivalent.¹⁶² As the number of EVs as a percentage of the car parc in all countries in the Arab region grows (total of all cars as well as buses and two- and three-wheelers), the potential for e-mobility as a variable renewable energy storage option in support of grids will be significant.

The prospect of e-mobility as "variable renewable energy storage on wheels" can reduce the need for investment by Arab region utilities in stationary energy storage. There is a projected global demand of more than 2.5 TWh per year of stationary storage by 2030, accounting for 29 per cent of the total battery market.¹⁶³ The same analysis by AFRY estimates that the Dubai government would be able to offset more than \$100 million in spending annually on thermal and stationary battery capacity. Storage potential in EVs offers utilities and other power sector entities other financial benefits as well. In a paper published in Applied Energy, researchers from MIT and Princeton assess that "battery storage helps make better use of electricity system assets including wind and solar farms, natural gas power plants, and transmission lines, which can defer or eliminate unnecessary investment in these capital-intensive assets ... substitution of batteries for generation or transmission capacity is a primary source of storage value".¹⁶⁴ While this judgment

considers all forms of battery storage collectively, storage in EV batteries can play a growing role in this equation as e-mobility scales. Batteries and other energy storage systems can enable utilities to defer upgrades of their transmission and distribution networks, reducing the pressure to spend as much as fast on the grid modernizations described above.¹⁶⁵

2. Smart charging, and especially vehicle-to-grid (V2G), is the key to e-mobility facilitating the energy transition

There are several prerequisites for e-mobility to be able to play this role in Arab countries' renewable energy transition and the reliability of their electricity supply. The most directly impactful of these is deployment of bidirectional charging infrastructure widely described as "vehicle-to-grid" (V2G) technology, a type of smart EV charging.

Smart charging strategies (called V1G) will be essential in the Arab region, and globally, given the influx of EVs and the ultra-fast chargers (>150kw) coming online. Smart charging reduces costs associated with the fast and ultra-fast charging that are priorities for the mobility sector. Yet, slow charging is best suited for the smart approach because it boosts system flexibility. Unlike uncontrolled charging, it decreases simultaneity and lowers peaks in demand. Battery swapping, charging stations with buffer storage and night-time charging for EV fleets can also help avoid peak-demand stress from fast and ultra-fast charging.

Smart charging could provide flexibility at both the system and local levels. At the system level, smart charging could facilitate balancing in the wholesale market. With V1G, EV charging patterns could be controlled to flatten peak demand, fill load valleys and support real-time balancing of the grid by adjusting the vehicles' charging levels. With V2G, by injecting electricity back to the grid, EVs also could provide ancillary services to transmission system operators. Smart charging could help distribution system operators manage congestion, and could help customers manage their energy consumption and increase their rates of renewable power self-consumption.¹⁶⁶

V2G is the form of smart charging technology that allows vehicle batteries (cars, buses and other EVs) to send electricity back to the power grid at times when it is needed to meet demand peaks. It is an element within a broader concept of vehicle-grid-integration (VGI) that envisions a suite of services provided through EV charging that individually and collectively contribute to reliable dynamic management

of the grid. Batteries become not only the source of power for the EVs, but also backup storage cells for the grid, able to power houses, buildings and anything else connected to the power grid. Expanding the bidirectional charging to these other elements of the built environment is sometimes referred to as vehicle-to-everything or V2X. Bidirectional charging stations are equipped with software that communicates with the central grid to assess overall system demand at any given time, encourages consumption at off-peak hours and pulls in additional energy from connected vehicles when needed.¹⁶⁷

For utilities, the economics of V2G are substantial incentives from the standpoint of reducing or even potentially obviating the need for some infrastructure expenditures. One recent study assessed that upgrading the grid in the city of Hamburg to manage the electricity distribution congestion projected in a future high EV adoption scenario would cost more than ten times the cost of the city implementing V2G charging infrastructure. In a study by Lawrence Berkeley Laboratory, a car parc of 500,000 battery EVs and one million plug-in hybrid EVs charging in a V2G infrastructure would eliminate the need for building an estimated \$12-15 billion stationary storage capacity of 5GW.¹⁶⁸ In comparative terms, V2G potentially could be of significant benefit in offsetting the scale of investments that will be needed to modernize grids throughout the Arab region and expand the region's electricity generation, transmission and distribution infrastructure.

A recent study on e-mobility opportunities and challenges in Egypt by the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) noted the benefits of V2G for the grid in that country. They assessed that it has potential to help mitigate a number of the vulnerabilities that grids throughout the Arab region face. Specifically, V2G can contribute to preventing grid overloading, minimizing technical losses of power between the generation source and end users, recovering from failures, maximizing the proportion of renewables in the energy generation mix, reducing operational costs and maximizing profit.¹⁶⁹

The benefits of V2G for EV owners and other citizens in Arab countries is another important dimension in considering the interrelationships of e-mobility, grid modernization and renewable energy transition in the region. The ability to send electricity back to the grid means individuals can sell that electricity back to the provider, representing opportunities for savings on household energy bills. One analysis (global, not Arab-specific) estimates savings of up to 15 per cent. A two-year-long V2G trial in the United Kingdom (Project Sciurus) saw its participants average £420 per year in financial reward from selling their surplus energy back to the grid. Such savings can partially compensate for the currently higher purchase cost

of EVs and thereby potentially boost the adoption rate, for individuals and fleet owners.¹⁷⁰

In Arab countries, the prospects for V2X may be of particular interest. In a region where the reliability of electricity is a critical vulnerability, enabling individual and fleet EV owners to help power homes and businesses could have significant benefits once V2G is able to scale. According to the Tokyo Electric Power Company (TEPCO), the inventor of bidirectional charging technology, one electric car can provide between three and four days electricity for an average family home. The smart battery software company Moixa estimates that 10 Nissan Leafs (currently one of the few V2G-capable electric cars) can power 1,000 homes for an hour. In an early and notable demonstration of the value of V2G for reliability, more than 60 Leafs were donated by Nissan to the emergency response and recovery effort after the 2011 Fukushima earthquake and tsunami. The EVs provided power during days of rolling blackouts that enabled area residents to heat their homes and charge computers and mobile phones. More recently, Ford F-150 trucks with special edition V2H (vehicle-to-home) adapters were employed during power failures during a winter storm in Texas.¹⁷¹

3. Public transportation could play a distinctive role in the virtuous circle with V2G

As described in Section 3 of this report, the public transport sector in the Arab region is already making strides in the adoption of e-buses and electric rail and metro systems. Egypt has a project with the World Bank to procure 100 electric buses for use initially in Cairo and later throughout the country. It is also at work on its first all-electric high-speed rail line running 1,000 km from the Red Sea to the Mediterranean. In the United Arab Emirates, e-bus pilots are underway in Dubai, Abu Dhabi and Sharjah, while Qatar is pursuing a 25 per cent electric public transit bus target. Tunisia has completed an e-bus pilot, and Jordan is working on plans to electrify its entire public vehicle fleet. Morocco has launched an electric BRT (bus rapid transit) programme in Marrakesh that will expand to three additional lines and 48 additional buses by 2030.¹⁷²

If it is equipped with future V2G charging models, electric public transportation in the region would have the potential to accelerate the use of renewable energy, not only to power its own vehicles, but also other sectors of the economies. As the International Association of Public Transport (UITP) describes, “the transport sector is typically a major land and building owner, so it can use its infrastructure and purchasing

power to drive the demand for renewables in a city”. They go on to say that “given the significant size of new public transport infrastructure projects, they can lay a foundation” for renewable energy to become a larger component of a country’s overall energy mix, including Arab countries.¹⁷³

Models exist that Arab transit systems could emulate and adapt to become more renewables-based in their operations. For example, the system in Fujian Province in China is equipped with integrated solar-storage charging stations for electric buses, saving up to 100,000 kWh of electricity each year. Madrid has solar PV on the roofs of its electric buses, providing up to 1 MW of renewable energy. Delhi’s Metro Rail Corporation has installed solar rooftops on all station buildings and depots with the capital cost invested by the solar developer. In one Arab region example that is already deployed, the Dubai Roads and Transport Authority has installed solar cells in RTA buildings and facilities including at its headquarters building, a metro terminal and nearly 900 bus shelters. The rail sector is the most highly electrified transport sector globally including in the Arab region, and operators in these systems also have an ability to directly link and power projects in their systems from renewable energy sources.¹⁷⁴

As they grow, the e-bus fleets and railways of Arab region transit systems can become a significant factor in grid stabilization and management and renewable energy scale-up in their countries. If they are designed in the future to leverage a V2G/V2X model, they could help enable local grids to accommodate more variable renewable energy and help power local businesses and homes. Fleet vehicles are uniquely suited for V2G, given their regular and predictable usage patterns and the fact that they generally return to depots and terminals at the end of the day. They can charge sitting idle overnight at low-demand times to have full power to send back into their local grids during operations at more peak times. School bus fleet trials have been seen in the United States and the United Kingdom, providing proofs of concept that can be applied in other kinds of public bus fleets globally, including in the Arab region.¹⁷⁵

Another way electric buses could contribute to the storage solution for renewable energy and grid management is by repurposing their batteries for stationary storage at the end of their expected life (length of time they are capable of powering and operating a vehicle, around seven years). Given the residual capacity remaining at that point, there is opportunity for second-use variable renewable energy storage by utilities or other enterprises in stationary applications. Increasing the residual value of electric buses in this way can also boost e-bus adoption by offsetting the investment risk for purchasers.¹⁷⁶

4. Arab region power markets must adapt to enable V2G and a renewable energy transition

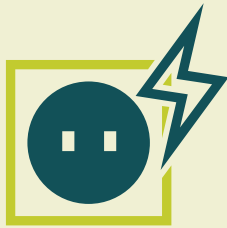
For all Arab countries, the power market structure slows progress on the transition to renewable energy, and will also slow the advancement of e-mobility in the region. A path toward an e-mobility future that incorporates V2G when the technology is available at scale is even more challenging under current power market structures.

The single-buyer model (SBM) characterizes the Arab region power sector, and the dominant variant of the model in most Arab countries is vertical integration of power generation, transmission, distribution and supply all under the control of the utility. Utilities are mostly State-owned enterprises (SOEs), with private sector engagement typically limited to the power generation sector, meaning the Government is ultimately the single electricity buyer. The third and related salient attribute of the power sector model is the tariff structure. A report by the International Monetary Fund in 2019 noted that energy subsidies in the Middle East and North Africa (as they define the region) constituted approximately 13 per cent of GDP. Chatham House notes that electricity subsidies “play an increasingly important role, either via tariffs that lie below the cost of production, or through the use of low-priced fossil fuel inputs for power generation”. In 2020, electricity subsidies among Arab countries were greatest in Saudi Arabia (\$4.6 billion), Egypt (\$2.6 billion), Kuwait (\$1.9 billion) and Algeria (\$1.4 billion).¹⁷⁷

Multiple forces today are driving Arab countries toward power market restructuring. These include the heavy burden on public finances from subsidizing energy, soaring electricity consumption, projected declines in oil export revenue and the need to recover the high capital costs of renewable energy plans. New, more liberalized market models will over time enable the region’s utilities to operate the type of grids necessary for large-scale variable renewable energy generation, transmission and distribution as well as for a V2X e-mobility future. Only when these power sector reforms are implemented will Arab countries be able to operate the grids that they and other countries need for such a future. They have been described as “adaptive grids – the coming dual network of energy and information flow that unleashes pricing and market forces to optimally and dynamically facilitate the matching of energy supply and demand”. They are “grids in which electricity is transported bidirectionally, traded at (relatively) dynamic prices, and generated and consumed under human-tailored agential control”.¹⁷⁸

While bidirectional V2G/V2X infrastructure and utilization still are very limited, globally, even unidirectional V1G smart charging “needs the existence of an attractive energy trading policy between the EV owners and the power utility”. V1G is already implemented in many countries around the world. It relies, as V2G does, on a power market structure that financially incentivizes owners through revenue in the form of savings or rebates on their energy bill to charge EVs during non-peak hours. Bidirectional V2G provides an even greater range of ancillary services to the grid, but V1G also benefits the utility through power grid regulation (preventing grid overloading) and providing spinning reserve (unused capacity to compensate for power shortages). In exchange, the utility must be able to provide EV owners revenue based on the amount of time each makes those services available.¹⁷⁹ In an accommodating power market structure, the utilities of Arab countries could control the timing of charging of EVs remotely according to the needs of the grid, enabling financial benefit to themselves and EV owners. One study estimated that this kind of V1G-enabled load shifting, if implemented in California, would equate to \$1 billion in value over a decade

In 2020,
**electricity
subsidies**



among **Arab countries** were
greatest in **Saudi Arabia (\$4.6
billion)**, **Egypt (\$2.6 billion)**,
Kuwait (\$1.9 billion) and
Algeria (\$1.4 billion)

to 2030.¹⁸⁰ In more fully liberalized Arab power markets in the future, V1G could pave the way for eventual bidirectional V2X innovations to enable the “virtuous circle”.

5. An opportunity for the Arab region to take steps toward a pioneering e-mobility model

If approached as a deliberate, integrated and mutually supportive objective of the transport and energy sectors and ministries of Arab countries, the advancement and scaling of e-mobility can help facilitate the transition to renewable energy, and vice versa. Grid modernization is essential to both aims, and e-mobility can be not only a beneficiary of that, but

also a spur to expansion and modernization of grid capacity.

Increased numbers of electric cars, buses and other forms of mobility will be one source of the increased stress on the grids in the region. But with appropriate grid modernization and power market restructuring, V2G could make those vehicles pivotal to a dynamic management of supply and demand that will help grids integrate much more variable renewable energy into their energy mix. That on-demand clean energy could be used to power houses, buildings, industrial operations and more. EVs capable of V2X could improve reliable electricity for parts of the populations that lack it in the countries of the region. They can also be a source of economic benefit for private owners and fleet operators. It would be a leading-edge innovative e-mobility future for Arab countries and their peoples.

C. Key challenges in pursuing this e-mobility pathway

Progression on this pathway to an Arab region e-mobility future faces some key challenges that are foreshadowed in the preceding narrative.

1. Barriers to power market restructuring and tariff reform

In the Arab region, power sector reforms are slow and typically happen more in response to crisis than proactively. The reasons for maintaining single-buyer models and electricity subsidies are socio-political as well as economic. Across Arab countries, States are supported by fossil fuel rents and subsidies, which in some cases are seen as critical to the stability of social and governance structures. Even in countries that are not petroleum rich and rely heavily on fuel imports, the inability to provide affordable energy has prompted Governments to support subsidies. And as subsidies fall within the social contract, their elimination poses risks of social unrest. Fiscal pressures on budgets are a major incentive for Arab region Governments to embark on structural changes to their power sectors, including changing subsidy/tariff phase-outs, but doing so comes with risks. These risks and barriers notwithstanding, renewable energy transition commitments and the global shift away from fossil fuels demand structural reforms to power markets. This e-mobility pathway and other e-mobility pathways in the region do as well.

2. V2G is in its infancy

The benefits of bidirectional energy exchange between power grids and e-vehicles of all types are clear, but as yet the ability

to obtain these benefits is far from realized anywhere in the world. The obstacle is not in terms of V2G technology, which requires further maturation but at an essential level is proven. It is more in terms of the implementation. Today, V2G is not operationally implemented at scale anywhere, but rather is in trials in approximately 50 projects globally (25 in Europe, 18 in North America, 7 in Asia). Only a few EV makes and models are currently V2G capable, but multiple global automakers have announced plans for some or all of their future models. The Arab region cannot control the pace and scale of V2G by automotive or infrastructure technology developers. But decision makers in the region can and should take steps in the nearer term to be ready to implement V2G when the implementation is available in the longer-term future.¹⁸¹

3. High cost of grid modernization and charging infrastructure buildout

The charging infrastructure necessary for e-mobility at scale will be a vast cost for the Arab region, if we consider it as a proportion of total Bloomberg projections of \$600-900 billion by 2040.¹⁸² Investment requirements for grid modernization to enable the renewable energy transition and e-mobility at scale may be comparable. Where this capital will come from is a critical question for Arab region Governments, especially as oil export revenues decline. At the same time, these investments also will be critical to enable the green economies that all countries of the region aspire to. Those new economies will generate significant public revenues over time if they are enabled with the infrastructure they require.

4. Social barriers to V2G take-up

There are considerable social and personal emotional barriers to EV adoption in any future e-mobility pathway, including this one. Many have to do with “range anxiety”, meaning concerns that vehicles will not have power when needed, due to the vehicles’ perceived technical inadequacies and/or the unavailability of sufficient charging infrastructure. In this

pathway to an e-mobility future, other concerns are added to this baseline which must be addressed. Prospective EV owners may fear the utilities’ control over charging timings and patterns or may perceive the V2G process as burdensome. Revenue to EV owners for the services they provide to the grid will mitigate this risk. But communications campaigns will also be necessary to overcome these and other social barriers, to EV use in general and especially to EVs in a V2G future.

Recommendations for making e-mobility a catalyst in electricity system modernization and the transition to renewable energy (Vector 3)

Based on our research and analysis, the following recommendations individually and collectively have potential to advance and accelerate the movement of the Arab region on this pathway for an e-mobility future. In some cases they are adapted and customized for the Arab region from recommendations drawn from other analyses that focus on vehicle-to-grid (V2G) charging technology and models, power market reform, grid modernization and the transition to renewable energy.



Work with multilateral development banks and other international development and climate finance institutions to secure concessional and blended finance for grid expansion and modernization projects

Meeting the region’s renewable energy, climate change adaptation and e-mobility goals will require immense investments in the grid infrastructure and new financing models for grid expansion and modernization. As the power network in Arab countries is publicly owned, grid investments have predominantly depended on public spending. Yet, pressure on public budgets and financial constraints in most countries have led to grid under-investment, creating major bottlenecks for the energy transition. Financial assistance is a priority need and must be sought, in the form of concessional loans, blended finance and climate funds to drive capital for the necessary grid infrastructure. The eligibility criteria and key performance indicators for such projects should be tailored for the current grid and power generation status in countries. Special vehicles should also be put in place for low-income and conflict countries, considering their lower ability to tap into private financing.



Revise legal, policy and regulatory frameworks to restructure power markets, increase private participation and develop multi-producer and multi-buyer models

The e-mobility and renewable energy transition goals of Arab countries will be difficult to achieve under currently

dominant power market structures characterized by vertical integration and a single-buyer model. These structures hinder the advancement of an electric mobility paradigm in which vehicles export electricity back to the power grid and to other powered devices and infrastructure. Arab countries should move towards a multi-buyer model. This reduces the risk of the single buyer not having the necessary credit rating to sign off-take agreements or facing delays in auctioning renewable energy projects and power purchases. Depending on the country, unbundling to allocate responsibilities for electricity generation, transmission and distribution to distinct entities operating independently, and a move towards market-based structures, will require defined legislation. Such legislation would provide a legal mandate for restructuring and allow participation of multiple entities in the sector, establishing or restructuring grid operators and electricity regulatory bodies. Additionally, increased private sector participation and appropriate legal, regulatory and policy frameworks and grid codes are all prerequisites for a more competitive market. Given their size and purchasing power, one priority could be to facilitate public transport authorities in negotiating and implementing renewable power purchase agreements (PPAs) with terms allowing for the sale of excess energy back to the grid.



Eliminate subsidies and implement time-of-use tariffs for electricity

Electricity and fossil fuel subsidies have not only led to wasteful energy consumption and strained utilities

and government budgets. They have also hindered the deployment of low-carbon technologies, including renewables and EVs. As part of electricity tariff restructuring, demand response pricing would be one key to making e-mobility actually an enabler of increased grid resilience and the region's overall renewable energy transition. It would also help manage the impact of increased EV adoption on electricity demand. Incentivizing customers to consume energy when the production cost is low (off-peak) and disincentivizing when the cost of generating electricity is high (on-peak) has the potential to become two of the most cost-effective demand flexibility measures. They will also help enable the integration of a high share of variable renewable energy. This will require shifting from dominant flat electricity tariff schemes, which provide no incentives for end users to reduce consumption during peak hours, to a time-of-use (TOU) tariff scheme instead. In some Arab countries, the time-of-use model is applied for some industrial consumers. Utilities and/or regulators should adopt TOU pricing for other consumer categories as well.



Ensure that grid modernization and expansion efforts incorporate technologies and operational and other steps necessary to enable bidirectional charging of EVs

Investing in vehicle-to-grid charging can be a major way for utilities to reduce their carbon footprints, balance supply and peak demand, defer investments, avoid grid congestion, improve grid stability and gain other important operational and financial positives. As described throughout this report, building a sufficient number of charging stations is one of the most urgent priorities, globally, to make possible the projected and desired increases in EVs of all types. The buildout of this infrastructure in Arab countries is at an extremely early stage, but plans and investments are underway. Examples include Dubai's "EV Green Charger" initiative, an Egyptian public-private joint venture to locally manufacture charging stations and others. Governments in the region should examine the current low levels of charging infrastructure for the degree of opportunity it might present to prioritize bidirectional-capable stations before significant sunk costs have been incurred for



unidirectional technology. This “leapfrogging” strategy could be reflected in plans for procuring and installing public charging stations; financial incentives for consumers and businesses to purchase and install the currently more expensive bidirectional chargers at homes and commercial properties; standardizing codes and requirements for charging infrastructure and processes; simplifying permitting for charger sites and ensuring that permitting regulations do not hinder future deployment of bidirectional chargers; adopting innovative financing models such as carbon credits to support the buildout of the more costly bidirectional-capable infrastructure; and more. As EV charging infrastructure is eventually built out in the least developed and conflict-stricken Arab countries, making it bidirectional capable can be of particular value given the ability of batteries and other energy storage systems to enable utilities to defer upgrades of their transmission and distribution networks and reduce the scale of investment needed for grid modernization.



In each Arab country, form an e-mobility working group with a designated “national champion” to coordinate and integrate transport-related, environment, energy, telecommunications and infrastructure policies for mutual benefit and promotion of mutually supportive renewable energy transition and e-mobility objectives

Aligning policy objectives and action plans across the transport, climate and environment, energy and public works sectors will help meet symbiotic targets for e-mobility, the energy transition and grid modernization. Mitigating often-conflicting agendas is essential, as policies across each sector are often segregated and coordination across corresponding institutions is often absent. Identifying areas of mutual benefit and potential divergent points is a first step to ensuring closer alignment in policymaking. Subsequent steps should craft policy options that are cross-sectoral, such as e-mobility action plans that optimize the impact on power demand with grid, storage and system flexibility benefits; packaging investment plans to maximize private sector participation in grid modernization, charging infrastructure buildout and EV fleet procurement; and other synergies. Coordination is especially needed in low-income countries and countries in conflict, and in rural areas, where balancing power supply and demand is already a challenge even prior to EV integration. Inter-

ministerial committees should be established within each country to facilitate such high-level policymaking discussions. Stakeholder coordination committees should then be formed across corresponding departments and institutions to identify the actions plans and follow-up. These coordination committees should also include grid operators and technical planning experts to adopt grid codes and standards for vehicle-to-grid integration. The outcomes should be made available for consultation with and from institutions in the private sector, the research and development sector and academia to ensure their early engagement in the process and their buy-in of the proposed projects.



Provide financial support or policy incentives to encourage transport service providers including mobility-as-a-service providers to adopt V2G-capable EV fleets and charge on certain schedules

Steps should be taken to turn the cyclical electricity demand of EV-equipped transport service providers (public transit systems, cargo shippers, MaaS providers) into a public benefit. Some of these fleets tend to have lower plugins during the day when intermittent solar is abundant and grid congestion is higher. It will be important for supply/demand management to ensure that a certain number of them are connected and charging during these “peak supply” times rather than peak demand hours. This can happen through the proposed tariff restructure and established partnerships with large EV fleet owners to incentivize them to adopt V2G-capable vehicles and connect a share of their fleets to the grid at specific times. This will also create opportunities for innovation and entrepreneurship, such as developing aggregators and third parties to manage the connected loads per grid operators and utilities’ needs.



Develop and deploy communications campaigns that incorporate Arab region success stories and other means to overcome social and other barriers to EV adoption and V2G charging models and inform strategies for overcoming these barriers

Consumers will need to be persuaded and incentivized to adopt EVs, in general and also to participate in V2G. Range anxiety concerns are mostly technology-risk related and stem from a lack of awareness of several factors. These include awareness of the technologies

involved, the financial and other benefits they can provide to consumers and the mechanisms that can protect against perceived risks to consumer needs and convenience. Consumers will be wary of their EVs being unable to get them where they want to go, fearful of losing capacity or power or concerned about how long it will take to recharge their battery. They also may have concern about potential wear and tear of their EV's battery with its energy going back and forth to the grid,

especially in the high temperatures that characterize Arab countries. In V2G, consumers will expect to be compensated for not only the energy itself, but also the value of the flexibility they provide, and may fear the whole model is too complex or risky. Addressing all these concerns and expectations will need early consumer engagement, with structured and extensive public awareness and public relations campaigns that include pilot projects to overcome such barriers.