

An aerial, high-angle photograph of a complex highway interchange at night. The image is characterized by long-exposure light trails from vehicles, creating vibrant streaks of white, red, and blue against the dark asphalt. The roads curve and intersect in a dynamic pattern. In the upper right, a yellow rectangular box contains the number '1'.

1

Mobility is transforming

A fundamental and irreversible shift in the paradigm of transportation is underway. More accurately, multiple such shifts are playing out in parallel, on a global scale.

Today, more than 250 companies around the world including automakers, tech titans like Tesla, Uber, Google and Apple, services providers and start-ups are engaged in research, development, prototyping, testing and manufacturing of autonomous vehicles. By one estimate, approximately 25 per cent of vehicles in 2035 will be partially or fully autonomous. Another analysis puts autonomous vehicles at 40 per cent of new vehicle sales and 12 per cent of the vehicle installed base in 2040.¹ With the integration of software and digital information and communication technologies (ICT), vehicles have effectively become supercomputers on wheels. Artificial intelligence, sensors, 5G and connection to the Internet of Things (IoT) are creating a “smart mobility” ecosystem generating and leveraging immense amounts of data. Next year in 2023, an estimated 350 million connected cars will be on roads globally – 24 per cent of all cars versus approximately 8 per cent in 2018.² In 2015, Ford, the namesake company of the inventor of automobile mass manufacturing, declared itself a “mobility company” alongside the launch of 25 smart mobility projects around the world.³

COVID-19 has accelerated the transformation of mobility in unexpected ways. It has accelerated a new questioning by Governments and businesses in many regions of the world of how cities, regions and countries will connect and facilitate the movement of goods and people.⁴ The pandemic has forced a grappling with the weaknesses and limitations of traditional transportation infrastructure and supply chains around the world as people and businesses recognized their reliance on methods of mobility that have lagged behind for decades or more.⁵ Many of these challenges have had special significance in parts of the world in which infrastructure is less developed.

In the Arab region, the opportunities presented by the disruption of old mobility paradigms and the emergence of new ones have the potential to be especially

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significant. Policymakers and actors in the private and socioeconomic development sectors will be able to have potentially momentous impacts on multiple dimensions of the societies of the region if they take advantage of these transformations.

A. The roads of the world today are filled with ICE...

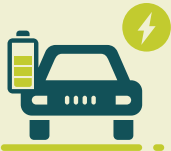
The current paradigm for road, rail and aerial mobility around the world remains predominantly reliant on traditional internal combustion engine (ICE) vehicles. There are well over one billion cars estimated on the road globally today, and the estimated 16 million EVs in operation globally represent less than 2 per cent of that total.⁶ Approximately 60 million ICE vehicles were sold in China, the United States and Europe in 2020.⁷ Around 15 million new ICE vehicles were sold in the United States in 2021, an increase of 3.4 per cent from 2020.⁸ And these ICE vehicles will be part of the paradigm for many years to come. An estimated 23 million used cars, vans, SUVs and pickup trucks were exported between 2015 and 2020, the overwhelming majority of which were ICE. The United Nations Environment Programme assessed that nearly 70 per cent were exported to developing countries including Arab countries, where they can be expected to continue on roads for more than another decade.⁹

B. ...but the next dominant future of mobility is electric

Autonomous and hyperconnected vehicles will be important in the next decades, but the dominant trend in the transformation of mobility is electric mobility (e-mobility) – the accelerating growth of electric cars, vans, buses, scooters, trains and eventually ships and aircraft.

Electric car sales reached 2.3 million in 2020 globally, a 40 per cent increase from 2019 even as overall car sales sagged in the wake of the COVID-19 crisis, and four times the number sold in 2015. More EVs were sold in China in 2021 than in the world at large during 2020, and other markets look poised to further this trend. Passenger electric vehicle sales are on track to rise from 3.1 million in 2020 to at least 14 million in 2025 by one estimate, due to a combination of factors. There were at least 16 million EVs on the road as of 2021, including over one million commercial EVs including delivery vans and trucks, and this trend is only expected to continue, particularly as the availability and cost of these vehicles continue to fall and necessary infrastructure becomes more available.¹⁰

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The increasing embrace of e-mobility is not limited to cars – other kinds of battery electric vehicles (BEV) are also rising in overall use and popularity. Approximately 25 per cent of the two-wheel vehicles on the road today are electric and this number is projected to rise steadily over the next decade. Electric scooters and other e-two-wheelers are most numerous in China, India and Association of Southeast Asian Nations (ASEAN) countries but they are increasing in other regions, including in Arab countries (thus far primarily those of the Gulf Cooperation Council (GCC)). The global fleet of electric two- and three-wheelers today numbers nearly 300 million. In the public transit sector, 2020 saw an impressive increase in the number of new electric buses registered around the world (82,000) up 10 per cent from the two years prior. This increase mainly reflects the Chinese market (98 per cent of the global e-bus stock is in China) but an increasing number of electric fleets are being ordered in Europe, Latin America, South Asia and the Arab region. Today the global fleet of e-buses is nearly 700,000 – and 12 per cent of all e-buses operating today were sold in 2021.

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Plans and prospects for electric two-wheelers and e-buses in the Arab region are discussed further in subsequent sections of this report, particularly Section 3.¹¹

Other indicators also highlight how EVs are gaining momentum in mobility innovation efforts around the world, including in the Middle East. Longer-term forecasting by both public and private stakeholders makes clear that the ascent of e-mobility will continue, driven by both climate change mitigation and consumer preference. Some projections suggest that the shares of EVs in some larger markets in Europe, such as Germany, are likely to reach around 90 per cent by the year 2040.¹² The market growth for EVs beyond passenger vehicles, including buses and cargo transport vehicles, runs on a slower timeline. But projections show that heavy-duty trucks will become more economically appealing to a variety of businesses across the globe as technological advances continue and costs fall. Much of this potential progress is contingent on Governments and private sector decision makers accelerating investment in the necessary infrastructure, including megawatt-scale charging stations and much higher density batteries. These are likely to be seen in the late 2020s as more manufacturers and shipping companies tune into the overall cost-benefit analysis in this arena.¹³

C. Other sustainable vehicle types will supplement but not overtake EVs

Other technologies are advancing that could represent other alternative futures for powering mobility. Biofuels (bioethanol and biodiesel) produced from renewable organic materials have played a growing role in transportation in recent years as an alternative fuel for cars. A number of vehicles have been developed that are biofuel-capable including trucks and vans from Chevrolet, Ford, GMC, Range Rover and even a luxury car by Jaguar.¹⁴ Hydrogen energy is more likely than biofuels to supplement the growing EV phenomenon. Hydrogen fuel cells, which can be used to store power for electric grids as well as potentially to power private and commercial vehicles, have dropped in overall cost of use by at least 60 per cent since 2006. Their overall power and capacity improved at least by four times over that period.¹⁵

There are currently only two hydrogen-powered cars on the consumer market – Toyota’s Mirai model and Hyundai’s Nexo. But alongside their battery electric vehicle (BEV) development, a number of other major automotive OEMs as well as some start-ups are investing in hydrogen fuel-cell electric vehicle (FCEV) innovations, with market entries planned post-2025. These include BMW, Volkswagen, Land Rover and Vauxhall. The primary obstacles to the accelerated adoption of hydrogen-powered vehicles is fuelling infrastructure and cost. As noted in Section 2 of this report, there are fewer than 700 hydrogen refuelling centres in operation globally – more than half are in Asia, with 228 in Europe and 86 in the United States. The Middle East’s first refuelling station for hydrogen fuel cell vehicles opened in Dubai in 2017, and Saudi Aramco opened one in 2021, part of its collaboration with Toyota and Hyundai to research and develop hydrogen fuelled vehicles. As Section 2 also describes, the limitations of battery size and weight will make the prospects of hydrogen fuel cells somewhat more promising over time for electric heavy trucks than for cars. But as sustainable mobility advocacy group Transport and Environment notes, “wherever batteries are a practical solution – cars, vans, urban and regional trucks, ferries – hydrogen will face an uphill struggle because of its lower efficiency and, as a result, much higher fuel costs”.¹⁶

Solar-powered cars are also being developed and starting to emerge in the market. Their design incorporates solar panels into the body of the vehicle (primarily roof and hood), similar to those on residential roofs and other structures. Most are hybrid battery-solar, with the plug-in charging compensating for the thus-far limited capacity of the solar charge to provide meaningful driving range by itself. One example, scheduled to enter production in 2023, is the Lightyear One from the Netherlands-based start-up Lightyear. It is notable for its stated range of 725 kilometres from its fully charged but relatively small battery, enabled by the solar feature which generates electricity for more than 30 km of range per day. The small size of the battery also enables it to be charged more quickly from standard charging points. Peter Harrop, chairman of market research firm IDTechEx, recently noted to an interviewer that “automotive solar panels are a very interesting topic, because the technology can enable EVs to recharge up to 40 per cent faster”. Lightyear’s founder states that that Lightyear One “will consume two to three times less energy than any other electric vehicle on the market today”.¹⁷

There is growing interest in solar-powered vehicles. Start-ups in this currently niche sector raised nearly \$120 million in venture capital in 2021, a modest amount relative to the more established areas of the electric mobility sector but an exceptional rise and rate of growth from less than \$1 million in 2016. One market research assessment estimates that the solar vehicle market could reach \$689 billion by 2027. Established automotive OEMs are developing options with integrated solar panels to add range and while-in-motion recharging capability, including the Mercedes-Benz Vision EQXX and the Hyundai Ioniq. As noted, start-ups in addition to Lightyear are entering the space including Fisker with its Ocean model, Aptera with a two-seat three-wheel

vehicle with a 400-mile range and Squad Mobility with a golf-cart-size two-seater with a 60-mile range, for which the manufacturer anticipates interest from ride-sharing platforms. An aspect of solar cars that could be of particular value in the Arab region is the role the panels can play in vehicle interior climate control. Mark Hanchett, founder of solar EV start-up Atliss, has noted that “even a couple hundred watts from a small solar array may be enough to run fans to provide circulation of air into the cab to avoid the 140 to 160 °F peaks that are possible during the summer”.¹⁸

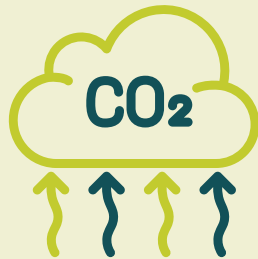
One of these or other energy alternatives could escalate their prominence in the future global mobility paradigm, depending on a variety of factors, including unknown scientific advances or discoveries, as well as improvements to existing technologies. Exploring a variety of alternate energy source futures for mobility should and will continue. But the overwhelming momentum is in e-mobility. Investors outside the automotive sector have invested more than \$330 billion in advanced mobility innovation technology since 2010, more than \$60 billion of which has been in vehicle electrification technologies. Technology, venture capital and private equity firms globally represent more than \$100 billion of that investment. Automotive sector incumbents have allocated more than \$200 billion since 2014 to develop automation, connectivity, electrification and smart mobility technologies in-house, with 80 per cent of that to vehicle electrification.¹⁹ Governments around the world are implementing policies and regulations to boost EV adoption and industry development. These include fuel taxes, zero-emission zones, road pricing, high-occupancy vehicle and transit lane access, as well as policies that subsidize the scaling up of charging infrastructure and transit of EV-enabling materials.²⁰

D. Forces driving the electric transformation of mobility

Although changes to the paradigm of global mobility have been at work for decades, the burgeoning electric transportation paradigm cannot be understood without recognizing how climate change is a driving force. Increasingly dire warnings from international bodies like the Intergovernmental Panel on Climate Change (IPCC) suggest fewer than ten years left before a global shift toward disastrous levels of global warming become irreversible.²¹ Most emissions are driven by a few select human activities and sectors, with electricity and heat generation, industry, buildings and transport making up the vast majority of activities driving global warming and climate instability.²² Transportation and mobility made up

23 per cent of all energy-related carbon dioxide emissions globally in 2019, and 29 per cent of greenhouse gas emissions in the United States.²³

In the Arab region, the threats posed by climate change are as immediate as they are dire. Dangerous effects of rising temperatures have been shown to be substantial contributors to recent and ongoing conflict and economic instability across the region.²⁴ Drastic increases in dry and hot temperatures have already devastated or severely restricted access to potable water and arable land, driving or contributing to forced migration and putting some parts of the region on a path to being “literally uninhabitable”.²⁵



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The advancement of e-mobility is spurred not only by the pressure to reduce greenhouse gas emissions, but also by a variety of other factors, including a variety of health, social and political pressures around the world. Increased numbers of people living in urban areas, and related escalating traffic congestion in major city centres, increase the need for clean private transport and clean public transit. Emissions associated with ICE vehicles present a growing public health challenge, as witnessed in escalating pollution rates in cities in China, India and elsewhere including in the Arab region, particularly Egypt.²⁶ Cairo and Riyadh are among the most

polluted cities in the world according to Eco Experts and the World Health Organization's Global Ambient Air Quality Database.²⁷ Efforts toward social equality, including efforts to make more forms of transit more accessible and safe to a variety of types of people, including women, children and older persons, is another driver of the shifting paradigm for mobility. This is particularly salient in the Middle East, where norms around transportation, safety and public expression of gender increase the importance of reliable clean public transit and the growth of two-wheeled and three-wheeled EVs.²⁸

E. Decision makers are promoting e-mobility to address the transport sector's role in climate change

Governments and the automotive sector are recognizing the urgency of addressing the ways in which ICE-powered mobility around the world has long-lasting and significant impacts on global carbon emissions and climate change.

As noted above, CO₂ emissions from transport represent a significant proportion of overall emissions, depending on the economic status and makeup of the region or country being measured. Passenger cars contributed 60 per cent of total CO₂ emissions from road transport in Europe in 2021, despite the region's relatively abundant public transport options and relatively high EV adoption.²⁹ In response, the European Union has set a goal of reducing emissions from transport by 60 per cent by 2050.³⁰ The European Union has also announced a plan for phasing out ICE vehicles by 2035. More than 20 countries have banned the sale of ICE vehicles and/or set targets for EVs as a share of their car parc (the number of cars and other vehicles in a region or market) between 2025 and 2050. In 2017, China implemented a New Energy Vehicle mandate policy.

These moves are likely to have global ramifications including in the Arab region as other Governments consider how they might follow suit.³¹ One example of policies driving e-mobility in the Arab region is the Dubai Green Mobility Initiative 2030 working in concert with the United Arab Emirates National Smart Mobility Strategy.³²

The automotive sector and other private sector interests are recognizing the urgency, and recognizing the opportunity that the urgency portends. As noted, investments in developing e-mobility vehicles and related technologies (especially batteries) are soaring, projected by one analysis at \$515 billion over the next ten years.³³ Ninety per cent of respondents in a survey conducted by the European Association of Automotive Suppliers reported that they were "reshaping their portfolios to emphasize e-motor technologies and battery innovations".³⁴ At the COP26 Summit in Glasgow, Scotland, a group of automotive OEMs including Volvo, Ford, General Motors, Daimler AG's Mercedes-Benz, BYD in China and a unit of Tata

Motors in India signed a pledge to end fossil fuel car production by 2040.³⁵

A broad question with critical implications for the advancement of e-mobility globally is the buildout of charging infrastructure for EVs. Market analyses make clear that most countries have a significant shortage of charging supplies and infrastructure in place to keep pace even with current EV adoption rates, let alone projected growth if the mandates to phase out ICE vehicles remain consistent. In addition to charging for privately owned EVs, vehicles that travel more than 100 kilometres per day with numerous stops, such as taxis, mini-busses and vans require relatively high-cost fast-charging infrastructure along major travel and shipping routes in many commercial centres. Needs in some parts of the world including the Arab region where charging stations are nearly nil may present particular challenges as the buildout will entail high start-up costs.³⁶ Investment to implement large-scale charging infrastructure will be one of the most significant indicators of commitment by Governments and the private sector to e-mobility globally.

Battery production for e-mobility is another imperative to turn the world away from the impacts of ICE-powered transport on the climate and societies. A significant question will be how manufacturers will be able to produce batteries at the rate needed for e-mobility a scale, and to produce them with more sustainable materials and less environmentally intensive harvesting of materials. Countries around the world, including some in the Arab region, have begun to tackle this challenge through a variety of initiatives. A recent example is the passage in the United States of legislation committing \$3 billion to boost production and R&D in the EV battery value chain.³⁷

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F. The Arab region is poised for e-mobility – What are some future pathways?

Given its diversity, the Arab region has the potential to pursue a variety of paths and approaches to e-mobility. Although to date the region as a whole has lagged behind global adoption rates, there are encouraging indicators of growth and interest in a number of Arab countries. The region's EV market overall was valued at only \$35 million in 2020, but is on track to reach \$84 million by 2026, a compound annual growth rate of 15 per cent over the period. The projected most prominent EV markets in the region in that five-year market assessment are the United Arab Emirates, Saudi Arabia, Egypt and Morocco, in that order.³⁸

As we will describe in subsequent sections of this report, countries throughout the region have made significant leaps and pledges in their commitment to the adoption of EVs and development of e-mobility industrial capability. Jordan, for example, today has at least 20,000 EVs on the road. The Egyptian state-owned company El Nasr Automotive Manufacturing is currently collaborating with Chinese partners to build affordable EVs. A start-up in Lebanon has announced plans to produce up to 10,000 EVs, and other EV start-ups are emerging in other Arab countries.³⁹ In line with many of the 2030, 2040 and even 2050 vision strategies and policies published over the last few years by some Gulf countries and other Arab countries, e-mobility has significant potential to reduce the impact of climate change, provide increased employment and transition the region toward diversified, future-facing economies.

In Sections 3 through 5 of this report, we explore three different potential pathways that e-mobility could take in the Arab region over the next two decades and beyond.

