

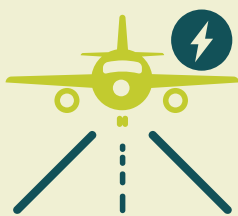
A low-angle, close-up photograph of a large commercial airplane on a runway. The aircraft is positioned diagonally across the frame, with its tail fin pointing towards the top right corner. The sun is setting directly behind the plane, creating a strong backlighting effect that silhouettes the aircraft and casts a long, bright, golden glow across the wet asphalt of the runway in the foreground. The sky is filled with soft, orange and pink clouds. The runway has yellow diagonal stripes visible in the lower right. A large white number '2' is overlaid on a green rectangular background in the upper right quadrant of the image.

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E-mobility in maritime, aviation and cargo transport

Because it is the dimension of e-mobility with the greatest opportunity for transformative impact in the Arab region, this report focuses predominantly on EVs and transport systems that move people and goods on streets, roads, highways and railways. This section provides information about emerging e-mobility developments in maritime transport, the aviation sector and heavy road vehicles.

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A. E-mobility in maritime transport

Electric propulsion of ships is beginning to take hold in the maritime industry, for reasons that mirror the rise of land e-mobility. First and foremost, it is in response to the imperative to reduce carbon emissions. The International Maritime Organization (IMO), an agency of the United Nations, estimated several years ago that maritime transport globally generates one billion tons of CO₂ each year. In April 2018, the 173 IMO member States agreed to a pledge to reduce CO₂ emissions from ships to 50 per cent of 2008 levels by 2050. That is the year by which a European Union study estimated maritime transport will produce nearly 20 per cent of global emissions in the absence of IMO and shipping company action.⁴⁰

To replace heavy diesel oil and the somewhat less harmful marine diesel fuel, the use of cleaner energy sources is under study and increasingly underway, including liquefied natural gas, hydrogen and electric energy. Fully electric-powered propulsion is more feasible for ships on inland waterways, which sail short distances and dock frequently, than for much larger oceangoing container ships, passenger ocean liners, tankers, etc. Electric ferries, tugboats, smaller cargo ships and drill ships (used in exploratory offshore drilling of new oil and gas wells and for scientific drilling) are in operation throughout the world. Considerable advancement in battery technology will be necessary for large oceangoing ships to go electric, which is not expected in the next two decades. Current batteries to power these ships for their long-distance voyages and heavy loads are much too large and heavy to be commercially or operationally feasible.⁴¹

Cost of operations is another driver that will make electric power ships more attractive and widespread over time. The diesel oil or marine diesel fuel that most ships use is typically more than 50 per cent of total operating costs. Maintenance costs also will be lower given the simpler design of electric motors. One ferry fleet operator in the United States currently using a hybrid-electric propulsion system in its new ships reports a fuel cost savings of more than 30 per cent. Fully electric systems will produce even greater savings, as evidenced by a Norwegian ferry operator's 80 per cent reduction in total operating costs.⁴²

A number of major design and manufacturing companies around the world serving the shipping industry are working on electric drive offerings including Kongsberg, ABB, Siemens,

General Dynamics Electric Boat and Wartsila. One start-up, Fleetzero, is working on an approach to electrifying maritime transport that addresses the long-distance challenge as well as other shipping supply chain challenges. Their model uses cargo ships smaller than the mega container ships that have proliferated in international shipping, with custom-designed batteries that fit in a standard shipping container and are rapidly swapped at port stops for charged replacements. Fleetzero's model also enables the use of smaller ports that have seen their role in maritime trade diminish. This could create economic opportunity in those ports, reduce congestion in larger ports and potentially reduce truck cargo shipments and their CO₂ emissions.⁴³

B. E-mobility in the aviation sector

The electrification of commercial aviation is also increasing, and it offers a number of the same benefits and opportunities as electric-powered maritime transport, while facing the same core challenges. Prior to the COVID-19 pandemic, the aviation sector generated nearly the same amount of CO₂ emissions as the shipping industry, approximately one billion tons annually, 3 per cent of global emissions. This is expected to rise by between three- and seven-fold by 2050. An even more significant parallel between the future prospects of e-aviation and e-shipping is the difficulty that larger and longer-distance vessels face in going electric. Battery-electric planes for small numbers of passengers over shorter-haul flight routes are nearing feasibility already today, and are expected to be operating as soon as 2025. United Airlines is the first major carrier projecting such flights, on 100 recently purchased Swedish-made 19-seat aircraft. But for large aircraft to fly long distances, the same kinds of battery advances are needed as for large oceangoing ships. In a recent interview, Carnegie Mellon University's Venkat Viswanathan told reporters "you probably need like three, four times the weight of the airliner [in batteries] to be able to power that, which is why you can't make them".⁴⁴

On the one hand, looking globally, approximately 50 per cent of the flight routes served today by commercial aviation are 500 miles (800km) or less – approximately two billion air tickets are sold each year for these flights. Industry and engineering experts concur that such distances are expected to be feasible with battery-powered electric aircraft by 2025. At the same time, Wright Electric's CEO Jeffrey Engler notes that "on the emissions side, 95 per cent of the carbon footprint of the industry is airplanes larger than 100 passengers" which typically do not serve short-haul routes. Fortunately,

a great deal of effort is going into electric planes, including one carrying nearly 200 passengers under development by Wright's company for the British airline EasyJet, with a projected 2030 operational date. Somewhere between 150 to 200 companies globally are working today on electric plane projects, including air-taxi type vehicles and traditional passenger planes. UBS estimates that 25 per cent or more of the civil aviation industry will be hybrid-electric or fully electric by 2035, and has made projections of a more than \$150 billion hybrid-electric aviation market by 2040. By one estimate, approximately \$250 million was invested in electric aviation start-ups between 2017 and 2019.⁴⁵

The role of government will be pivotal in the expansion and scaling of electric aviation. On the one hand, some innovative policy approaches have already been announced, for example in declarations by Denmark and Sweden to make all domestic flights fossil fuel-free by 2030 (and in Norway by 2040). At the same time, the regulatory difficulties appear considerable in the absence of changes in approach by many Governments. In most countries the rules and regulations governing certification of aircraft for flight safety, control of aircraft operations in shared airspace and other aspects of aviation are stringent and slow to be changed. Some will have to be changed by virtue of the technology – for example, restrictions on lithium-ion batteries on board aircraft, which clearly will complicate the use of such batteries to power the aircraft. Some innovators in the industry are looking at retrofitting already-certified existing aircraft with batteries as a means of reducing the timeline required to electrify aviation.⁴⁶

One approach to the short-haul movement of small numbers of passengers by electric-powered aircraft are the so-called "air

According
to McKinsey and
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Forum (WEF),
road freight produces



**53 per cent
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transport
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a share expected to rise
to **56 per cent by 2050.**

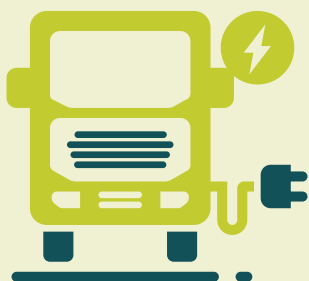
taxis” under development by a number of start-ups around the world. Many of these start-ups have financial backing from major established aviation and aerospace corporations like Boeing, Lockheed Martin and Airbus, and pre-orders from major airlines including Virgin Atlantic, United and Japan Airlines. These electric vertical take-off and landing (e-VTOL) aircraft are expected to be a growing part of urban mobility, though initially at least predominantly for wealthy and corporate flyers. Entrants in this emerging segment of the e-aviation industry include VoloCity which has flown numerous test flights (including in Dubai), Lilium, Kitty Hawk (investors include Boeing and Google co-founder Larry Page) and Joby. In June 2022, Joby was granted a Part 135 Air Carrier Certificate by the Federal Aviation Administration, permitting it to begin commercial operations in the United States which they expect in 2024. Still, regulatory hurdles will be uniquely significant for the next decade for air taxis relative to other types of electric aircraft, given the intention of many manufacturers and operators to make their VTOLs autonomous as well as electric. Unlike small delivery drones, these passenger-carrying e-aircraft will have to be integrated into air-traffic-control systems.⁴⁷

Finally, electric-powered drones for delivery of small packages will be part of the e-mobility future, particularly in urban environments. Amazon’s exploration of e-drones in their logistics operations is widely known but other major companies also working on it include UPS, DHL, Google, FedEx and Walmart. The impact of e-drone delivery on urban congestion and emissions could be significant over time, as current modes for such “last-mile” deliveries typically are ICE-engine trucks and cargo vans making frequent stops in dense areas. In a recent study, researchers from Lawrence Livermore National Laboratory, Carnegie Mellon University, SRI International and the University of Colorado assessed that delivery of small packages by small drones produced emissions that were 23 to 54 per cent lower than by trucks or vans powered by any type of fuel, or even by electric power. Larger drones carrying larger packages achieved lower reductions in emissions due to several factors, including the energy usage of the increased number of warehouses needed for efficient package distribution and servicing of the drones themselves. E-drones are increasingly part of the planning of many mobility-as-a-service (MaaS) providers. Zipline has emerged as one of the pioneers of the use of e-drones in rural and remote settings, focusing primarily on rapid delivery of medicines and other medical supplies in Ghana, Nigeria, Rwanda and recently approved in Japan.⁴⁸

C. E-mobility for heavy cargo transport

The prospects for electric medium- and heavy-duty trucks (MDTs and HDTs) to transport freight on roads and highways around the world are challenging. But the impact on CO₂ emissions could be substantial if breakthroughs are realized. According to McKinsey and the World Economic Forum (WEF), road freight produces 53 per cent of global trade-related transport CO₂ emissions, a share expected to rise to 56 per cent by 2050.⁴⁹

As with electric maritime and air transportation, the core challenge is the size and weight of cargo trucks combined with the long distances they travel. Even with the advancements seen in battery technology over the last decade, the size and weight of batteries sufficiently powerful to operate cargo trucks on their routes today makes them infeasible. According to one analysis, “it would take a 44,000-pound battery to deliver the same energy as a 2,000-pound diesel fuel tank ... an electric truck with a range of



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965 kilometres would require a 31,000-pound battery costing \$300,000⁵⁰. Like electric buses, discussed in Section 3 of this report, the total cost of ownership (TCO) for electric MDTs and HDTs is expected to reach parity with their diesel counterparts over time. But the upfront cost, until substantial further advancements in battery technology, may keep electric trucks cost prohibitive even past TCO parity timelines.

These challenges notwithstanding, electric trucks are demonstrating market growth and the growth is projected to continue. The same McKinsey-WEF analysis estimates 4 per cent of MDT and HDT sales in Europe will be zero-emissions (battery electric or hydrogen fuel cell electric) by 2025, growing to 37 per cent by 2030, approximately 150,000 trucks. Estimates by the International Energy Agency (IEA) showed 31,000 electric HDTs on the road globally in 2020, approximately 90 per cent of which are in China, where electric truck sales rose by 10 per cent in 2020 over the previous year. Europe's new electric HDT registrations rose more than 20 per cent that same year, but to a total of only 450 such vehicles on European roads. IEA projections for electric HDTs and MDTs required as a percentage of sales globally by 2030 to reach a net-zero scenario by 2050 is 30 per cent. An increasing number of entrants to the electric truck market will help advance the growth of the global fleet. Large OEMs such as Volvo, Daimler, BYD (China) and Renault, as well as new players like Nikola and Tesla, have all developed and currently are selling electric MDTs and HDTs.⁵¹

Growth in global electric cargo truck fleet operations is contingent on the buildout of an appropriate charging infrastructure in different ways than for other kinds of EVs. Given the battery power necessary to operate them, rapid and much more powerful chargers (500 kW or more) are necessary for heavier commercial cargo trucks. Charging is projected to be a mix of depot-based, cargo delivery destination based (potentially enabling charging during

loading and unloading), and enroute public charging along roadways for long-haul routes. The total number of chargers needed will be considerable for truck fleets large enough to meet Paris Agreement emission reductions commitments or net-zero scenarios, and will require substantial investment. In their analysis focused on Europe, the McKinsey-WEF estimate is 140,000 public and destination charging points (plus 1,500 hydrogen-fuelling stations) needed by 2030. Another analysis by the European Automobile Manufacturers Association, which projects a total of 200,000 heavy-duty trucks in the continent's fleet, estimates a total of 250,000 charging points required, distributed with 80 per cent in depots, 15 per cent at cargo destinations and 5 per cent public roadside chargers. Looking both longer term and globally, Bloomberg projects a need for 4 million bus and truck chargers in 2040.⁵²

Successful deployment and operation of electric cargo truck fleets will require new levels of coordination between fleet operators and utilities. With power requirements as much as eight times greater than electric cars, electrifying road freight is expected to put a different level of demand on grids throughout the world. A study in 2021 by the United States National Renewable Energy Laboratory was encouraging about the ability for grids analysed to handle charging for short-haul MDTs. More than 80 per cent were able to support fleets of up to 100 trucks charging in depots without need for significant upgrades. But the prospects for long-haul HDTs, which will also rely on high-power public chargers, is less clear. Because the standardized routes typical of much road freight transport will allow fleet operators to do deliberate charging-point location planning, they may need to develop working relationships with utilities.⁵³

There is greater momentum and development work on electric MDTs and HDTs powered by hydrogen fuel cells than there is for hydrogen-powered electric cars. At the same time, assessments and projections are mixed on how fuel cell EV (FCEV) trucks will compare and compete

with battery EV trucks. On the one hand, the high energy density of hydrogen makes FCEV trucks more feasible than battery-powered trucks for long distances and extremely fast refuelling. Some criticisms focus on the fact that most hydrogen commercially produced is from fossil fuels rather than “green hydrogen”, but the share of renewable energy in the electricity generation mix of many countries is still low as well. Fuelling infrastructure for hydrogen FCEV trucks is extremely limited, making the charging

challenge at least comparable to that of battery-powered cargo trucks. As of February 2022, there were fewer than 700 hydrogen fuelling stations operating globally, in 33 countries, but 20 per cent of those were opened in 2021 alone, and another 250 projects to build additional stations are underway. Many truck OEMs are developing FCEV truck models alongside their battery-powered models, including a Daimler-Volvo joint venture, Cummins, Kenworth (Paccar), Toyota and Hyundai.⁵⁴

D. Land e-mobility futures in the Arab region

The next three sections of this report provide descriptions of three future paths that the trend of e-mobility can take in the Arab region over the next twenty years. We consider these paths as “vectors” – each represents a direction that the advancement of e-mobility can take in the region that can gain magnitude and momentum over that time period.

Each of the next three sections describes a logic of how that trend path advances e-mobility adoption in the region and how that path to greater adoption creates social good.

The vector discussed in Section 3, “Intentional complementary development of electrified public transportation, micro-mobility and Mobility-as-a-service (MaaS)”, contributes to the social good in the form of increased economic development and greater social and economic equity.

The vector discussed in Section 4, “A growing presence in the global e-mobility supply chain, as a strategic element of economic diversification”, contributes to the social good in the form of economic diversification (and resultant economic growth).

The vector discussed in Section 5, “E-mobility as a catalyst and enabler in modernizing regional electrification and the transition to renewable energy”, contributes to the social good in the form of improved electricity reliability and distribution and an accelerated shift to renewable energy.

Social good in the form of reduced carbon emissions, and resultant mitigation or reduction of climate change and its impacts in the region, is an outcome of any and every pathway the e-mobility trend could take – the ones we describe, and many others.

Each section also provides an evidence base for how the magnitude and momentum of movement in the direction of the path described can increase over time. Each is rooted in present-day facts and future projections about relevant factors.

The three vectors are not mutually exclusive. We anticipate they can, and likely will, proceed in parallel to varying degrees, and that there will be degrees of overlap and complementarity between them. Similarly, the forms of social good noted above are not exclusively gained in any possible individual path of the e-mobility megatrend. Any and every potential e-mobility path will deliver multiple forms of social good.

Each section provides recommendations that this analysis suggests are valuable for how they support the path that land e-mobility takes in that section. They represent decisions and actions today that decision makers in the region can take, if they choose, to increase the momentum and the magnitude of land e-mobility’s advancement in the direction it is moving in each section of the report.

