2023

March

# Charging Up: E-Mobility And The Future of ICE Vehicles

Energy Research Paper

The Al-Attiyah Foundation

The Al-Attiyah Foundation is proudly supported by:

Electric vehicles have gained significant market share in the past year and numerous automakers have committed to predominantly EV futures. EVs have gained range, costs have fallen, and numerous governments have rolled out supportive packages for their manufacturing, purchase and charging. The imperative to tackle climate change, energy security concerns including the war in Ukraine, the desire to build new competitive domestic industries, and the other advantages of e-mobility have all made EVs more important.

What is the future for e-mobility? What does this mean for the outlook for internal combustion engine (ICE) vehicles?

## ENERGY RESEARCH PAPER

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a current energy topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners, and universities, as well as made available on the Foundation's website.


- Electric vehicle[1] (EV) sales will continue growing in 2023 albeit at slower rates (23% year-on-year, compared to 62% in 2022) due to a more negative economic outlook and rising prices on the back of inflation and supply chain constraints.
- Regulatory support for the uptake of EVs will continue shifting from the tax incentive model of previous years to the "polluters pay" model. EVs benefit not only on lower carbon dioxide emissions, but also on lower local air and noise pollution.
- While EVs may have higher up-front costs than internal combustion engine vehicles (ICEVs), their benefits ultimately result in lower lifetime costs when compared to an ICEV, taking into account variables other than the purchase cost, such as maintenance, fuel/charging costs, fuel/charging source, battery size, and type of fuelling/charging infrastructure.
- A common misconception with EVs is that their silence equals lower speed and performance when compared to ICEVs. However, the opposite is true: EVs can accelerate faster than ICEVs and have more than enough speed for typical daily use.
- Rising costs and supply chain constraints are making alternative battery chemistries important. Better safety and stability, and lower cost and stable supply of associated raw materials, alongside improvements in auxiliary technology could cement lithium iron phosphate (LFP) as the mainstay of EV battery chemistries in contrast to ternary (Nickel Cobalt Aluminium (NCA)/Nickel Manganese Cobalt (NMC)) ones .

**1.This paper concentrates on light road vehicles. Electrification of heavy road vehicles (buses and trucks), rail, shipping and air travel are interesting topics in themselves, but present greatly different challenges.**

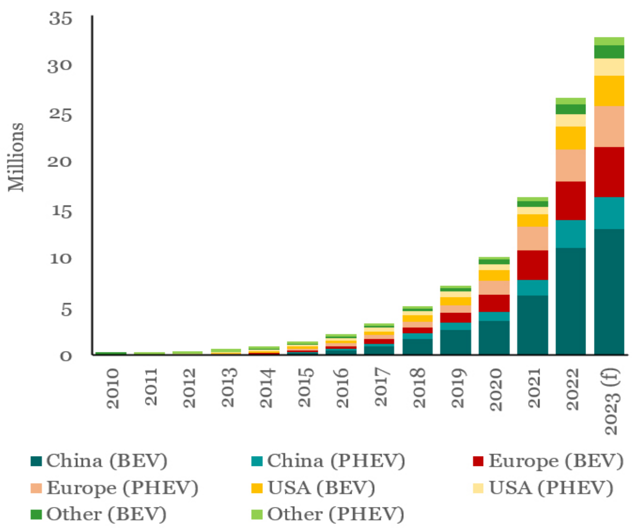
- EVs, e-mobility, and the electrification of transport will lead to a peak in oil transport use by 2030, which itself will drive a decline in oil consumption overall.
- This will also shift the mix of the barrel demanded, away from gasoline (cars), and relatively towards diesel (in geographies where electrification or hydrogen-fuelling options for heavy vehicles such as trucks and buses are either limited or slow-moving), and jet fuel.
- Increased electricity demand from EVs is positive for low-carbon generation, including gas with carbon capture and storage (CCS), renewables and nuclear.
    - It also represents a major opportunity for electricity distribution and storage integration to support EV charging requirements and infrastructure.
- Oil and gas producers can adapt to e-mobility's rapid changes to the transport sector by:
    - Defending demand through improving the acceptability of their hydrocarbons (either through CCS or renewables, which could power fossil fuel infrastructure or operations);
    - Creating demand through investing in new markets (by geography and sector – such as petrochemicals, industry, aviation) and products (such as hydrogen and ammonia, both of which could support green transport);
    - Diversification, by broadening their economies beyond energy.
    - Hedging, by investing in non-hydrocarbon transport options or into EVs themselves, either internationally, or even in domestic manufacturing. This could cover various parts of the value chain – the vehicle, battery, critical materials input, software, charging and electricity retail, or related areas such as autonomous vehicles, presenting a potential "hedge" against losing out to EVs, and;

Global sales of EVs have grown rapidly since 2016, and are projected to almost double in 2023 from 2021 levels (a 99% increase), marking an unprecedented uptick in adoption[i].

China and the EU have led the charge so far thanks to favourable government incentives and subsidy schemes, as well as concerted action (especially in the case of the EU) on meeting aggressive climate goals, of which electrified transport is a key component.

For example, EVs made up 25% of all European, and 21% of all Chinese light vehicle sales in 2022, compared to ~13% globally for the same year (10.5 M new EVs (battery electric vehicles (BEVs) and plug-in hybrids (PHEVs)) out of global light vehicle sales of 81 M new units[ii]).

Figure 1 Global electric car stock by region, 2010-2023 2022[iii]




On an annualised basis, EV sales recorded the most growth in 2021, when they surged by 103% on 2020 levels, and maintained a healthy growth of ~62% in 2022[iv]. Rates of growth in 2023, however, are expected be slower, at around 23%, due to a more negative economic outlook and rising prices on the back of inflation and supply chain constraints.

Still, a global sales growth of an additional 2.5 M units is impressive, and would see EVs make up ~16% of world light vehicle sales, from just 0.8% in 2016[v].

As in past years, BEVs are expected to account for the most of this increase, at around 70%. Clearly the EV market is slated to continue making great strides despite softer economic indicators, and not just in sales.

Original equipment manufacturers (OEMs) are planning to spend nearly US$ 1.2 T through 2030 on EVs and their associated batteries and materials (Table 1), with Tesla, Toyota, Volkswagen, Ford, and Honda contributing the most to dedicated EV investment[vi], while continuing to deliver new electrified models. Currently there are over 500 models of EVs[vii] available on the market, which is more than 5 times than those available in 2015[viii].

A key factor for the surge in spending is the "Tesla Effect", which has made EVs a glamorous investment proposition for both traditional OEMs and new start-ups. Out of the 37 largest global automakers, Tesla is investing the most in EVs (around US$ 100 B) and in batteries (around US$ 400 B) enroute to building 20 million EVs in 2030[ix]. This will continue reinforcing a competitive market differentiated by varying models and features, alternate battery chemistries, R&D, and lifecycle emissions.

EVs have also become a strategic commitment for OEMs. Major automakers now have dedicated production, sales, and electrification targets for their fleets. These are mostly borne out of:

- Fuel economy and emissions targets imposed by national governments as part of national climate action plans (CAPs) or city access restrictions (zero-/low-emissions zones) (such as in Europe and China) on older ICE vehicles, and;
- Increasing global scrutiny on inefficient fossil fuel-based transport, negatively impacting brand image and prestige (particularly for legacy brands, such as US OEMs).

Table 1 Investment into EVs and associated parts through to 2030 by major OEMs[x]

| Brand | Country | Battery Capacity (GWh) | Planned EV Production (Millions) | Battery Investment (US$ B) | EV Investment (US$ B) |
|---|---|---|---|---|---|
| Tesla | US | 3000 | 20 | 400 | 100 |
| Toyota | Japan | 200 | 3.5 | 13.6 | 56.4 |
| VW Group | Germany | 240 | 5 | 57 | 55 |
| Ford | US | 240 | 3 | 7 | 43 |
| Honda | Japan | 96 | 2 | 2.2 | 37.8 |
| GM | US | 140 | 3 | 7.5 | 27.5 |
| BMW | Germany | 120 | 1.5 | 10 | 26.5 |
| SAIC | China | | | 1 | 24 |
| Hyundai / Kia | South Korea | 289 | 3 | | 23.6 |
| Mercedes-Benz | Germany | 200 | | 30 | 17 |
| Dongfeng (DFM) | China | | | | 15.5 |
| GAC | | | | | 15.5 |
| Great Wall | China | | | | 15.5 |
| Nissan | Japan | 130 | 2 | 5 | 12.6 |

| | | | | | |
|---|---|---|---|---|---|
| Jaguar Land Rover | UK | | | | 12 |
| Stellantis | Italy-France-US | 400 | 3 | 24 | 11.5 |
| BYD | China | 489 | | 7.2 | 10 |
| Xiaomi | | | | | 10 |
| Renault | France | 90 | 1 | 2.4 | 9.4 |
| Lucid | US | | 0.5 | | 8 |
| Jidu | | | | | 7.7 |
| Changan | | | 2.7 | 7.5 | 7.5 |
| Chery | China | | | | 7 |
| Rivian | US | 100 | 1 | 2.5 | 5.5 |
| Geely | China | | | 6.2 | 5 |
| VinFast | | 20 | 1 | 2 | 4.5 |
| Volvo | Sweden | 65 | 0.8 | 3.3 | 3.75 |
| BAIC | China | | | | 3.5 |
| FAW | | | | | 3.5 |
| Xpeng | | | | | 3.5 |
| Nio | China | | | 1 | 2.5 |
| Li Auto | | | 2 | | 2 |
| Tata | India | | | | 2 |
| WM Motor | | | | | 1.5 |
| Jianghuai (JAC) | | | | | 1 |
| Mahindra | India | | | | 1 |
| Mazda | Japan | | | | 1 |

Regulatory support for the uptake of EVs continues shifting from the tax incentive model of previous years to the "polluters pay" model (i.e. imposing penalties on the purchase of ICE vehicles in the form of a carbon tax proportional to the vehicle's rate of $CO_2$ emissions per kilometre of travel).

This is most prominent in Europe, where low taxes or purchase grants for zero-emission vehicles (such as BEVs) are being paired with a high tax burden on polluting cars, either in the form of an acquisition tax or an ownership tax.

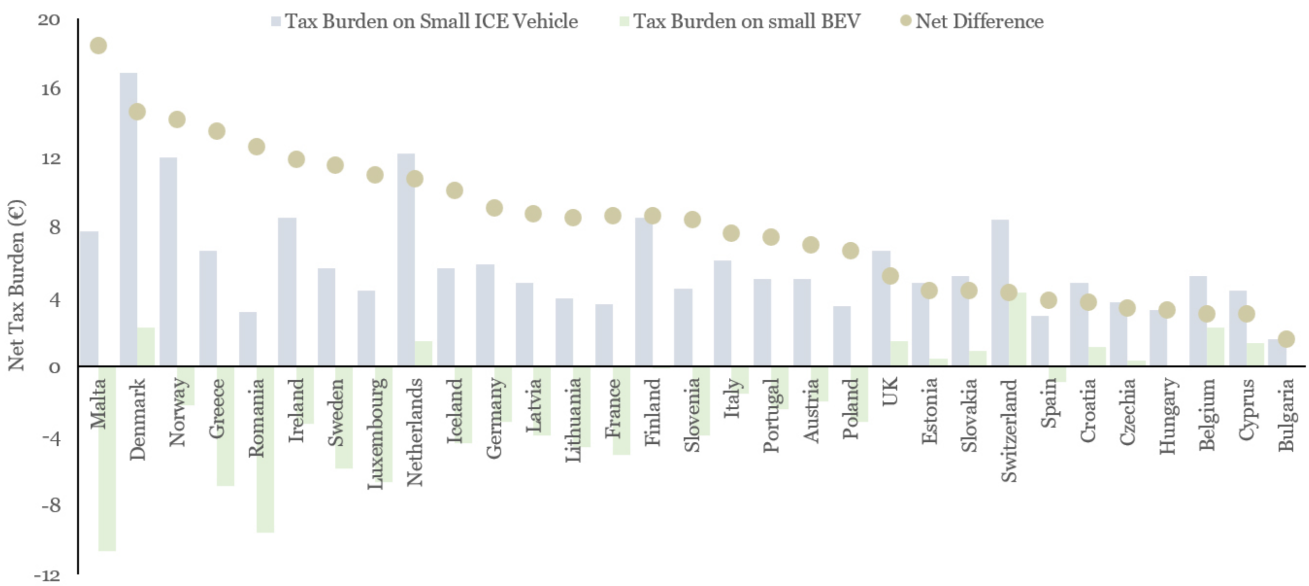
For example, high tax burdens on polluting (i.e. ICE) vehicles in Malta, Greece, Romania, and Sweden are paired with negative tax burdens on BEVs resulting in high tax differentials which can be correlated with the increased uptake of BEVs at the country level.

In some countries, previous tax exemptions on BEVs are now being phased-out as their uptake increases, in line with ambitions to end all sales of ICE vehicles between 2030 and 2035. This is most prominent in Norway, Netherlands, Finland, and the UK. Additional benefits such as free parking, free charging or use of dedicated or high-occupancy lanes will also be withdrawn.

In the UK, Vehicle Excise Duty will be equalised for both zero-emission and ICE vehicles from 2025 onwards as the Expensive Car Supplement Exemption for EVs ends. New BEVs registered from 2025 onwards will be liable to pay the supplement (currently EVs with a list price below £ 40,000 are exempted[xii]). Removing the VED exemption could marginally reduce the incentive to switch to EVs, but a ban on the sale of new ICE vehicles from 2030 onwards will inevitably translate to higher purchases of EVs[xiii]. Impact shall also be minimal given the marginal cost of the VED compared to the overall cost of the vehicle.

In Norway, extremely steep $CO_2$-differentiated purchase taxes on ICE vehicles (between € 3566 for a 1500 kg car with type approval emission rates of 50 $gCO_2$/km and 50 mgNOx/km and € 30,265 for a 2000 kg car with type approval emission rates of 150 $gCO_2$/km and 50 mgNOx/km[xiv]) have done away with the requirement for massive EV subsidisation.

Figure 2 Tax incentivisation of private vehicles in European countries[xi]




Only a negligible share of Norwegian incentives currently is made up by subsidies, with the main driving factor for EV uptake being the high rate of taxation on ICE vehicles.

In Finland, a purchase incentive of € 2000 for new EVs introduced in 2018 ended in March 2023[xv]. A corresponding registration tax exemption meanwhile will also be offset by an increase in the basic tax on electric and hydrogen vehicles as their uptake increases. The basic tax on zero-emission cars is currently €53.29 per year, which will increase by €65 per year, bringing the new tax level to €118.29 per year[xvi].

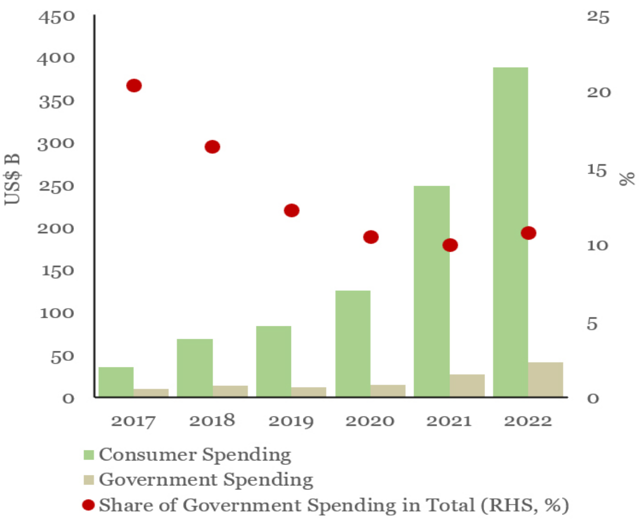
Similarly in other jurisdictions, such as China, national subsidies that at one point handed as much as US$ 8,700 back to EV buyers have now been phased-out, as China retains its status as the world's biggest market for EVs. Still, growth rates have slowed, prompting provinces to offer their own EV "sweeteners" to keep sales elevated in line with Chinese climate action plans[xvii].

For example, Shanghai, which has one of the highest EV penetration rates in China, is offering residents a one-time cash back reward of US$ 1,450 when they buy a new EV to replace an existing ICE vehicle. In Beijing, a similar subsidy reward of between US$ 1,160-1,450 for trading in an ICE vehicle for an EV is stimulating billions of yuan in EV sales[xviii]. Major Chinese cities also increasingly restrict the issuance of new car registrations to EVs only.

Policy and incentives in the US meanwhile are also evolving, with a slew of new credits being reinstated by the Inflation Reduction Act (IRA) of 2022 for EVs purchased from 2023 to 2030.

EV buyers may qualify for up to US$ 7,500 in federal tax credit depending on income tax levels and vehicle specifications, including where it is built.


Figure 3 Consumer and Government Spending on EVs, 2017-2022[xxiii]




For example, if a consumer purchasing a Ford F-150 Lightning owes US$ 3,500 in income tax, then the federal tax credit they'd receive would be US$ 3,500. If they owe US$ 10,000 in income tax, then they'd qualify for the full US$ 7,500 credit[xix].

However, this credit would be split into two equal halves, each half redeemable if the EV has battery components manufactured or assembled in North America, and; has critical minerals that are extracted or processed in the US, or in countries with which the US has a free trade agreement, or uses critical minerals that were recycled in North America[xx].

The IRA effectively changed the qualification rules for the US$ 7,500 tax credit which could previously be availed as a consumer tax break for the first 200,000 vehicles an automaker sold[xxi]. This threshold has now been removed, but the requirements of North American assembly and battery and critical minerals sourcing rules could eliminate some 70% of EV models in the US currently from qualifying for the credit[xxii].

# 11 COSTS AND PERFORMANCE: WHERE DO EVS STAND VIS-À-VIS ICEVS?

Two of the most common prejudices against EVs is their alleged weaker performance compared to ICEVs and their often more expensive upfront costs. These concerns are not without reason:

- On average, EVs' batteries need to be recharged before a similar ICEV would need its fuel tank refilled;
- They take longer to "refuel", and even with the fastest EV charger could take about 15 minutes, which is significantly more than the time it takes to refill an ICEV's tank,;
- Recharging sites are still not as widespread as fuel stations, and may be occupied, out of order, or have incompatible chargers, and;
- The still evolving nature of EV supply chains means that consumers often have to pay more upfront for an EV than an ICEV, which has matured, well-established legacy supply chains.
    - o A related concern is that an EV's battery modules might need to be replaced within its lifetime, depending on frequency of charging and the temperature it is stored at, which could also increase overall costs.
    - o EVs in accidents may have to be written off as it is difficult to assess the integrity of the batteries which are built into the car body.
    - o For these reasons, and because EVs are rapidly evolving and improving, the resale value of EVs may be uncertain and relatively low.

Still, the benefits of an EV ultimately result in lower lifetime costs when compared to an ICEV, taking into account variables other than the purchase cost, such as maintenance, fuel/charging costs, fuel/charging source, battery size, and type of fuelling/charging infrastructure.

An important consideration for EV lifetime costs is also the availability of tax credits or exemptions on ownership or acquisition, or subsidy rewards for trading in an ICEV, which bring down upfront costs significantly. In Table 2, we assume the full US$ 7,500 tax credit as part of the IRA's Clean Vehicle Credit scheme, which puts EV upfront costs at par with ICEVs.

Table 2 Comparison of EV Upfront Costs vs ICEV Upfront Costs, with and without the IRA US$ 7,500 Clean Vehicle Credit[xxiv]

| Vehicle Category | EV Model | EV Upfront Cost (Entry Level Model) | EV Cost (After Tax Credits, US$) | ICEV Model | ICEV Upfront Cost (Entry Level Model) |
|---|---|---|---|---|---|
| Compact Hatchback Sedan | Nissan Leaf | US$ 28,040 | **US$ 20,540** | Toyota Corolla Hatchback | US$ 21,550 |
| Compact Sedan | Tesla Model 3 | US$ 42,990 | **US$ 35,490** | Honda Civic | US$ 25,050 |
| Mid-size SUV | Ford Mustang Mach-E | US$ 46,895 | **US$ 39,395** | Kia Telluride | US$ 35,690 |
| Luxury Crossover SUV | Audi E-Tron | US$ 70,800 | **US$ 63,300** | Porsche Macan | US$ 57,500 |

## What are the variables impacting EV lifetime costs?

**Cost of Fuelling:** A key input that goes into EV costs is the cost of fuelling, i.e. charging, over its lifetime. Cost of charging an EV depends on several factors, including the price of electricity, the location of charging, the generation mix of the location (because generation mixes characterised by cheap renewables have lower LCOEs, instead of those characterised by costlier fuels like petrol/diesel, or fuels subject to a carbon price in certain locations, making electricity prices more expensive), as well as battery size (noting that the energy required to charge the battery is greater than the battery size itself, because some energy is lost during the charging process).

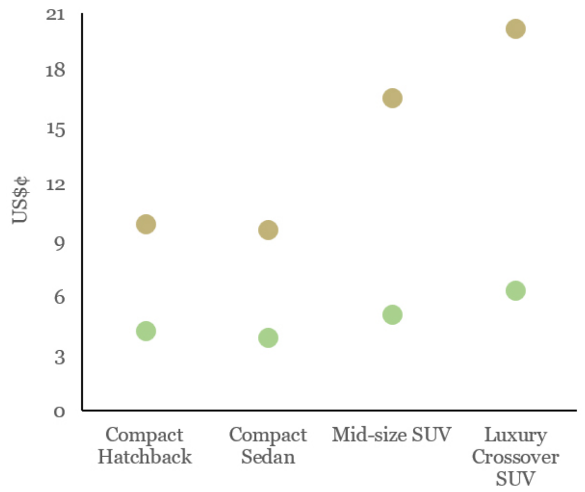
Across all EV manufacturers, the average cost of charging an EV is US$¢ 5.75 per mile, based on the global average cost of electricity of US$¢ 17.2/kWh[xxv]. In the US, where average electricity prices were around US$¢ 14.9/kWh in December 2022[xxvi], the average cost of charging an EV there was US$¢ 5/mile, whereas in Denmark, where electricity costs are much higher, at US$¢ 57.5/kWh, the average cost of charging an EV there is US$¢ 19/mile .Even at the most expensive electricity price, the cost of charging an EV is lower than the cost of fuelling an ICEV[xxvii].

The global average for fuelling a petrol (gasoline)-powered ICEV (compact sedan) was US$¢ 14/mile in 2022, which in Denmark would be as high as US$¢ 35/mile (based on Danish retail gasoline prices), 84% higher than the average cost of charging an EV there[xxviii].

Table 3 Typical Charging Costs of Popular EVs[xxix]

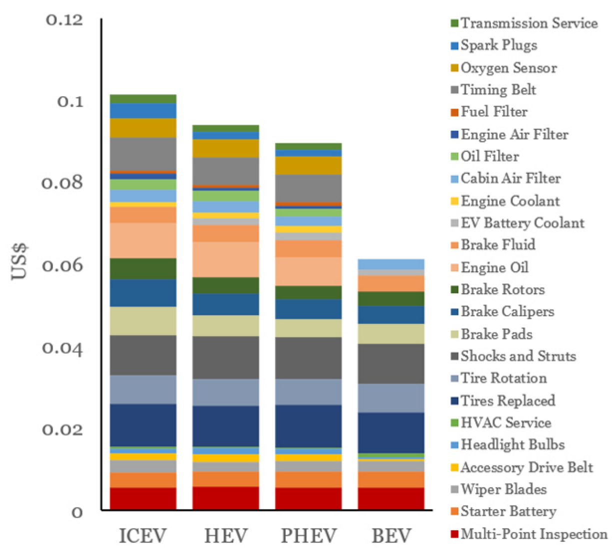
| EV Model | Nissan Leaf S Plus | Tesla Model 3 | Ford Mustang Mach-E | Audi E-Tron Quattro |
|---|---|---|---|---|
| Energy Required to Charge Battery (kWh) | 65 | 70 | 78 | 97 |
| Cost to Charge Battery (US$) | 9.72 | 10.47 | 11.67 | 14.51 |
| Range (Miles) | 226 | 272 | 224 | 226 |
| **Charging Cost per Mile (US$¢)** | **4.3** | **3.85** | **5.21** | **6.42** |

Figure 4 Average cost of fuelling an EV vs ICEV based on US prices (December 2022) by vehicle category US prices (December 2022) by vehicle category[xxx]




**Maintenance Costs:** Maintenance costs on average for EVs are generally in the range of US$¢ 6-6.2/mile, whereas for ICEVs can be up to US$¢ 10.1/mile. EVs have fewer moving parts, require fewer oil-changes, have lower wear on brake-pads because of regenerative braking, and dispense with some components such as the exhaust, radiator, carburettor, spark plugs, gearbox, clutch and so on. While the difference may appear minimal, over the lifetime of the vehicle it makes a considerable impact. For example, if a vehicle is driven 200,000 miles over its lifetime, that would represent US$ 8,000 saved with an EV, representing significant savings.

Figure 5 Maintenance cost per mile of typical light-duty vehicles[xxxi]




**Charging Infrastructure:** The cost of charging or fuelling an EV depends on several sub-factors. These include:

1. Electricity Source: Charging from the utility grid can sometimes be more expensive than choosing an electricity alternative, such as rooftop solar, community solar, community choice aggregation (CCA), or green power plan (GPP). Costs are typically less annually if the EV is charged from a community solar scheme, but CCAs and GPPs can be costlier than the utility. For owners of rooftop solar systems, an EV can essentially be charged for free once the cost of the solar system has been paid off.

Fact Box 1 A V2G Concept could enable additional savings for EV owners[xxxii]

In the GCC and Middle East countries, a vehicle-to-grid (V2G) concept could enable EVs to communicate to the power grid through smart grid systems to sell demand response services, by delivering electricity into the grid. In this way the EV can not only facilitate energy storage during its recharge time, allowing for better integration of renewable energy, but can also allow the restoration of the stored energy from the vehicle into the grid, providing significant economic benefits to the EV owner.

**2.** Battery Size: A larger battery will consume higher energy to be charged, however, depending on an EV's range, the charging cost per mile could still be less, since the vehicle would be required to charge less frequently. For example, while the popular Nissan Leaf would cost only US$ 6.73 to charge, in terms of mileage this would come out to US$¢ 4.5/mile. On the other hand, the Tesla Model 3 will cost about US$ 10.47 to charge, but the cost per mile is much lower, at US$¢ 3.85 due to the higher range of the car, reducing frequency of charging. The Tesla Model 3 is one of the more efficient EVs available on the market in terms of kWh required to drive one mile; a higher efficiency EV will have a lower charging cost per mile.

**3.** EV Charger: EV chargers typically come in three levels, and the level used can impact the amount of energy stored in the battery. Typically, a higher voltage charging level equals less energy loss. For example, Level 1 charging (120-volt chargers, using a regular outlet, mainly in the US) and Level 2 charging (via 208- or 240-volt standard home EV chargers, mainly in Europe and other countries) require converting AC electricity into DC that the EV battery can store and use[xxxiii]. This conversion causes energy loss because of the heat produced by it.

Level 3 charging (400-volt chargers typically available in public charging infrastructure) provides DC electricity (bypassing the Level 1 and Level 2 limitation of AC to DC conversion within the vehicle, which is time-consuming, by converting AC to DC in the charging station itself), so no in-vehicle conversion loss occurs. Level 3 charging has an efficiency of 90% and above, while Level 1 and 2 can be as low as 60%. Level 3 charging infrastructure is also pretty hefty, weighing in upwards of 250 kilograms, hence why it is mostly available in public EV charging stations on highways for longer distances or road trips. It can also potentially cost upwards of 200 times more than a Level 2 charging infrastructure, although it could charge more vehicles .

This is mainly why electricity sourced from public EV charging stations on highways using Level 3 charging infrastructure is pricier than direct charging at home from the grid (although at-home charging uses Level 1 and 2 charging systems, which have lower efficiency and more energy loss). However, even with the higher cost from Level 3 charging systems, the overall price to charge an EV on a long-distance trip is still far below what an ICEV would pay for gas on the same road trip.

4. Timing of Charging: Certain locations may charge different electricity rates during the day to charge an EV. In the US, time-of-use rates or time-varying rates are imposed by state utilities when the cost of electricity and the electricity demand is high – such as in the middle of the afternoon on a hot day[xxxv]. While it typically costs less to charge an EV at night if a utility uses time-of-use rates, it could lead to higher peak net electricity demand (i.e. the highest electric power demand minus power provided by solar and wind) as EV ownership expands.

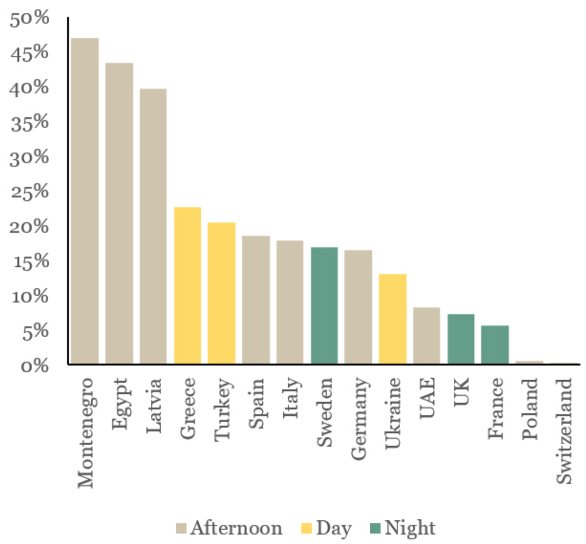
This could be mitigated by expanding daytime charging infrastructure to use excess solar power more efficiently as it would enable drivers to tap solar power when it is immediately available, instead of requiring power grid operators to invest in more energy storage to store daytime solar power for night-time charging.

This can be particularly helpful in countries with large solar resources that do not have the requisite energy storage to support night-time charging. In countries with a hybrid generation mix, daytime charging would eliminate the problem of lower carbon savings from night-time charging, as the grid would likely be fuelled by fossil fuels at that time. The increase in remote working can also help alter consumer behaviour by allowing people to charge their EVs from home during the day, although they could also charge at work if charging points are available[xxxvi].

Performance specifications meanwhile continue improving rapidly, with the range of some of the latest EV models coming in at >500 miles (about 800 km), such as California-based Lucid Motors' Lucid Air Grand Touring, which has an estimated 516 miles of range .

Other competitors include the Mercedes EQS 450+ AMG Line, which clocks in at 453 miles, and Tesla's Model S (Dual Motor All Wheel Drive) with 405 miles[xl]. These are comparable to similarly-sized ICEV counterparts such as the Porsche Macan, which has a range of 359 miles, or the more affordable Honda Civic (446 miles) and the Toyota Corolla Hatchback (462 miles) models.

Figure 6 Variation in carbon emissions depending on time of day for charging an EV in different countries[xxxvii]




A common misconception with EVs is that their silence equals lower speed and performance when compared to ICEVs that have a deep sound of revving engines. However, the opposite is true: EVs can accelerate faster than ICEVs and have more than enough speed for typical daily use.

The reason for this is that electric motors are simpler than ICE motors. EVs can provide full torque from 0 kilometres, resulting in instant acceleration[xli]. To compare, a traditional ICEV will take longer to get the engine-generated power to the wheels and might need to rev up in order to reach maximum torque. The power also has to go through to more moving parts, like the gearbox, which can make ICEVs less efficient.

However, most OEMS have to compromise between acceleration and top speed as EVs operate on a single-gear speed. Most EVs therefore opt for a balanced approach, which means lower top speeds compared to multi-gear, ICEVs. Regardless, the top speeds of some of the most popular EVs are eclipsing maximum speed limits allowed in most parts of the world, making them fast enough for any normal usage[xlii] .

Almost all of today's BEVs and PHEVs use Li-ion batteries, although the exact chemistry varies from that of consumer electronics batteries. This means an almost complete reliance on lithium ("white gold") as there is currently no commercially available substitute at scale.

~80% of lithium's increase in demand to 2030 is projected to come from EVs, with the remainder from battery storage and consumer electronics. Most of future BEV demand is slated to be met by adoption of higher Nickel-Cobalt-Aluminium (NCA) chemistries, which will drive demand for lithium hydroxide faster than lithium carbonate.

Demand for battery-grade lithium hydroxide could potentially be 6 times that of carbonate in 2030. Taking refinery assets currently under development, this could lead to an oversupply in lithium carbonate conversion capacity, but a deficit in battery-grade lithium hydroxide, causing producers to substitute hydroxide with carbonate in the production of medium nickel chemistries, such as Nickel-Manganese-Cobalt (NMC).

Demand for nickel, cobalt, and graphite (other minerals that go into an EV battery) will also see demand surge by up to 25 times in an aggressive Net Zero scenario. Copper demand for grid lines (to meet EV charging requirements alongside electrification of other sectors) will also double[xlv].

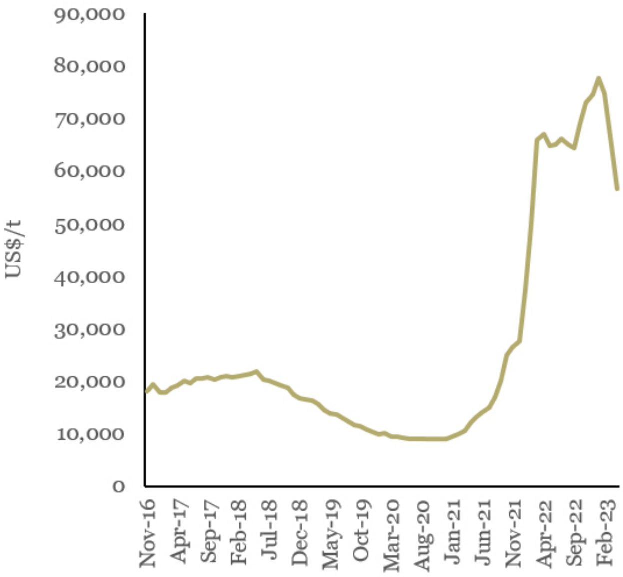
Developing new assets to meet this demand is a challenging process. Ore grades in copper mines have started deteriorating, meaning more waste rock has to be moved and processed, raising costs and carbon footprints. Lithium mining meanwhile is monopolised by a few large producers such as China, who is also the source of 80% of all rare earths (REEs), used in many EV motors. Tesla has announced it will eliminate REEs from its motors to avoid this problem, although possibly sacrificing some performance or gaining some weight.

This has created a supply-chain dependence and the potential for bottlenecks, raising prices. In the US and Europe, attempts to promote domestic mining are limited by environmental opposition and high costs.

Table 4 Demand of lithium for EVs by Scenario[xliii]

| Global EV Stock by Scenario | Moderate Climate Action (such as APS), 2030 | Net Zero Emissions by 2050 Scenario, 2030 | Net Zero Emissions by 2050 Scenario, 2050 |
|---|---|---|---|
| ***Millions*** | **270** | **350** | **700**[xliv] |
| Lithium Demand of Li-ion EV Batteries (Mt) in given year | 0.5 | 2.1 | 4.3 |
| Mines Required to Meet Lithium Demand | 63 | ~263 | 538 |
| Type of Lithium of Future EV Demand | Lithium Hydroxide | Lithium Hydroxide | Lithium Hydroxide |
| Supply of Lithium Hydroxide (based on Refinery Assets under development) | *Deficit by 2025* | *Deficit* | *Deficit* |
| Supply of Lithium Carbonate | Surplus | Surplus (?) | Surplus (?) |

Figure 7 Prices for battery grade lithium hydroxide[xlvi]




The rising inelasticity of lithium supply caused prices to surge to dramatically last year due to a combination of higher commodity prices, volatility, and supply chain constraints. Another reason was the rise in prices of associated battery metals, such as nickel, to which lithium prices can also be exposed. Russia's invasion of Ukraine created a lot of pressure, since Russia supplies 20% of global high-purity nickel. In the aftermath of Russia's invasion, nickel prices climbed to US$ 100,000/t, posing a serious problem for Europe, whose main source of nickel for EV battery development is Russia.

Prices have now started reversing after a two-year tear (Figure 7), offering a potential boost for consumers and OEMs that got hit by rising battery costs last year. Lithium hydroxide is currently trading at US$ 57,000/t, a more sustainable level for battery manufacturing requirements, albeit still some 6 times higher than prices in January 2021[xlvii].

The falling prices are mainly due to a slowdown in demand for EVs, particularly in China and other jurisdictions (such as certain EU states) that have started unwinding incentive schemes to promote EV uptake, as well as continued uncertainty that is making traders cautious.

Still, prices are high enough to motivate investment into lithium-processing facilities (such as Albemarle's US$ 1.3 B lithium-processing facility in South Carolina[xlviii]), although the exposure of the metal to the volatility of other commodities such as oil and gas, as well as monopolised trade has increased interest of OEMs in alternative battery chemistries.

Table 5 summarises key new chemistries under consideration by major OEMs of the world. While most of these have significant energy and performance advantages over the incumbent Li-ion, they are mostly in demonstration and/or prototype phase, meaning supply chains for their scalability are either non-existent, or extremely nascent at best.

Some also suffer from specific chemical constraints, such as K-ion (potassium ion) batteries, which with their superior energy density and lower costs could be a highly viable alternative, but metal reactivity and the lack of electrode materials strong enough to handle the stresses of potassium ions make it unlikely to enter the EV market anytime soon.

The only lithium battery chemistry currently available on the market to compete with ternary Li-ion batteries (NCM/NCA) is perhaps lithium iron phosphate (LFP), which is swiftly becoming the more common battery chemistry for new EVs due to a growing preference by OEMs for its lower cost and significant energy-density improvements over the last decade.

LFP-powered BEVs now have ranges of up to 376 miles, 3 times what an LFP could have achieved a decade ago[xlix]

Better safety and stability, and lower cost and stable supply of associated raw materials, alongside improvements in auxiliary technology, could cement LFP as the mainstay of EV battery chemistries in contrast to ternary ones. All major OEMS, including Tesla, Volkswagen, Rivian and BYD, are scaling investment into LFP, with Tesla, one of the earliest large-scale users of the chemistry, producing 50% of its EVs in Q1 2022 with LFP batteries[l].

Table 5 Key new battery chemistries for EVs[li]

| Battery Chemistry | Li-Ion (NCA) | Lithium Iron Phosphate (LFP) | Lithium-Nickel-Manganese Oxide (LNMO) | Sodium Ion (Na-ion) | Potassium Ion (K-ion) | Zinc Air (Zn-air) | All Solid State Batteries (ASSBs) |
|---|---|---|---|---|---|---|---|
| Nominal Voltage (V) | 3.6-4.0 | 3.6 | 3.7 | 2.3-2.5 | 2.0-3.9 | 1.3-1.4 | Up to 10 |
| Cycle Life | 2000+ | 8000+ | 1000+ | 5000+ | ~n/a~ | 1500+ | 9000+ |
| Specific Energy (Wh/Kg) | 200-250 | 90-120 | 150-220 | 100-120 (now 160) | ~260 | 400-450 | 500 |
| Advantages | High energy density, faster charging capability | Flat discharge voltage, high power | Good thermal stability, high nominal voltage | Abundant resource, lower costs, safer | Abundant resource, inexpensive | Flat discharge voltage, environmentally friendly | Non-combustible, high energy density, fast charging |
| Disadvantages | Lower cycle life, environmentally unfriendly, rising costs of raw materials, safety concerns | Low capacity, low profitability (from recycling) | Degrades all current electrolytes due to high stress | Low energy density, nascent supply chains | Metal reactivity, lack of electrode materials for potassium ions | Low cell voltage, caustic electrolyte | Heavy, require cooling systems, high costs, interface resistance |
| OEMs | *Legacy battery chemistry, first embraced by Tesla* | Tesla, Volkswagen, GAC, Rivian, BYD | | BYD | | | Nissan, Volkswagen |

The rise in government policies towards reducing oil use and emissions in line with national climate targets and global commitments such as the Paris Agreement has inevitably put the spotlight on the transport sector as the largest consumer of oil.

As a result, the passenger vehicle sector is not considered to be a growth sector for oil, despite the rise in people buying ICEVs for the first time in developing countries. A decline in demand for oil from the sector is inevitable as EVs continue making a larger share of total global vehicle sales, and sales of ICEVs are phased-out from key economies of the world.

Almost all Net Zero and carbon-constrained scenarios project EVs to make up over half of the passenger vehicle fleet by 2040 and continue to dominate the fleet moving forward (Figure 8).

Among non-carbon-constrained scenarios (typically BAU scenarios by major oil and gas companies or oil and gas producing governments' projection scenarios) EVs make up a smaller share of the total passenger vehicle fleet, with some estimates pinning them as low as 20% of the passenger fleet by 2050.

Figure 8 EV sales as a percentage of total passenger vehicle sales[lii]

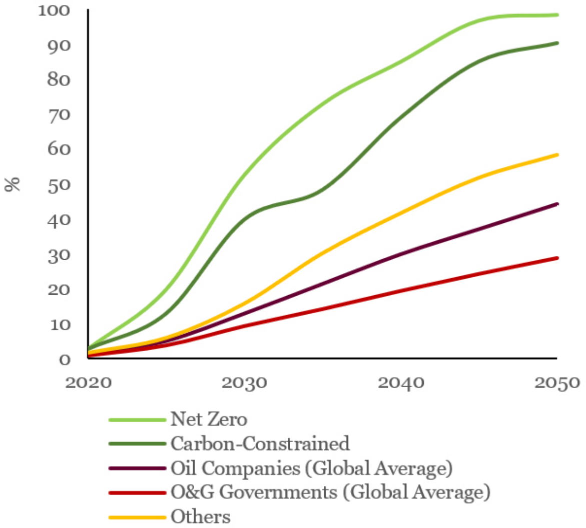
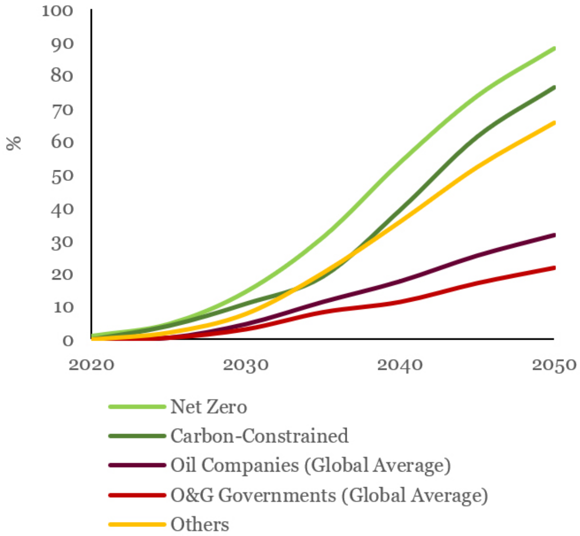



Figure 9 EVs' share of total passenger fleet[liii]



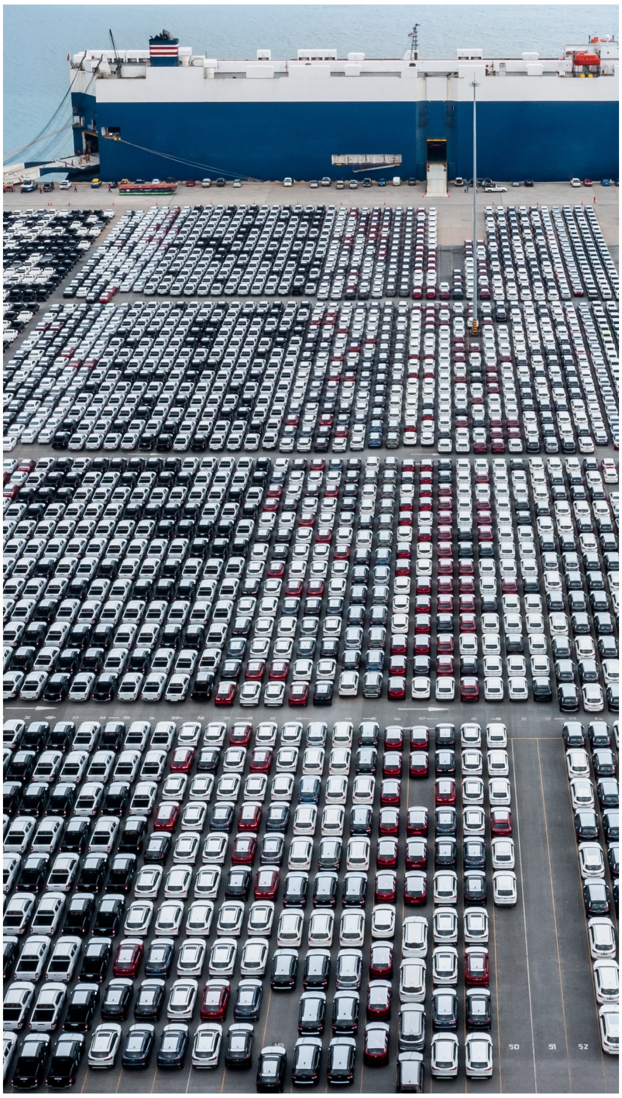



Figure 10 Oil demand displaced by EVs by region and scenario[lv]

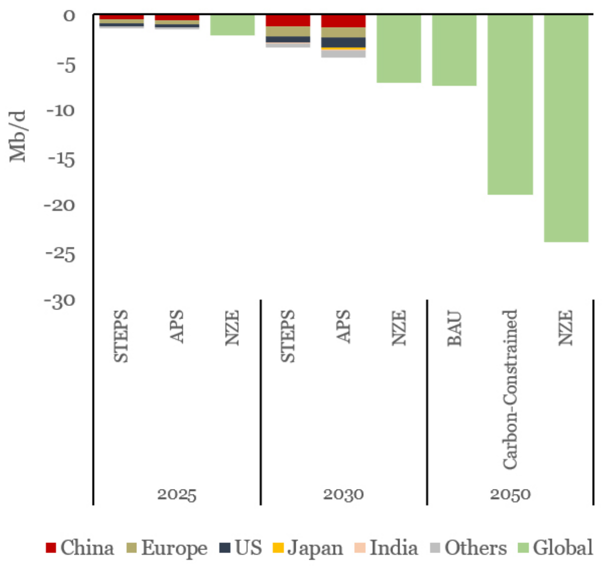
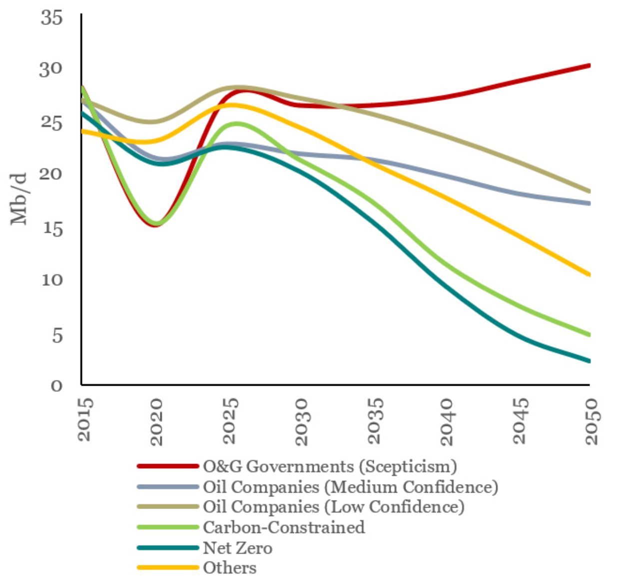



Figure 11 Forecast of global oil demand within the passenger sector resulting from EV sales projections, Mb/d[lvi]




In terms of oil demand displaced, moderate climate scenarios, such as the IEA's Announced Pledges Scenario and the Stated Policies Scenario, see the increased penetration of EVs into the global passenger vehicle stock displace some 3.5-4.6 Mb/d of oil by 2030, a significant amount (around 4% of current total oil consumption).

Under the Net Zero Emissions by 2050 Scenario, they displace some 7.3 Mb/d of demand by 2030[liv], thereby becoming a key input into peak oil demand forecasts. Longer-term, oil demand displaced by EVs reaches nearly 20 Mb/d under most carbon-constrained scenarios, and about 25 Mb/d under a Net Zero scenario. Because of their lower cost per mile, EVs are likely to be driven more and to be favoured for high-use segments such as taxis.

However, a decline in passenger vehicle oil demand does not necessarily mean that total oil demand itself will decline. Declines in the sector could be offset by strong-enough growth in petrochemicals, industry, fertilisers, and perhaps other transport segments like aviation, shipping and trucking, but might not be able to offset all displaced demand.

Still, the decline in oil demand for the passenger vehicle segment will not start seeing a meaningful decline till at least the mid-2030s (Figure 10), due to:

- The continued prevalence of ICEVs, at least in developing countries (especially in Africa and South Asia) where a larger number of people are purchasing these vehicles for the first time (and with an estimated vehicle lifetime of 15 years);
- The regulatory hurdles in successfully phasing out fossil fuelled-cars, even with international and national-level mandates to stop all sales of ICEVs by 2030-2035;
- Higher scepticism towards EVs in major O&G jurisdictions of the world, such as the Middle East, where fossil fuels are cheap and subsidised (even when market prices are high) and EV infrastructure limited, affecting adoption;

- Raw material supply constraints overtaking the pace at which alternative, cost-effective battery chemistries develop market and supply chains beyond mere demonstration;
- EV costs taking longer to turn competitive with ICEVs, especially in the absence of subsidy rewards or tax incentives as these are a burden on governments, and;
- The slow rollout of EV charging infrastructure at scale, and larger than standard gas stations, as EVs take an hour or more to recharge, especially if Level 1 or 2 charging is employed (in most developing countries).

Still, even the more sceptical jurisdictions of the world, such as oil and gas exporters in the Middle East, have begun to acknowledge the shift in the transport sector due to the advent of EVs, with some, such as Saudi Arabia, attempting to create "carbon space" that enables continuation of their primary business (i.e. oil export) by investing in battery development and EV manufacturing (such as through a US$ 905 M integrated battery chemicals complex in Yanbu), as well as joint ventures with Lucid Motors to build EVs, and a stake in Tesla.

The UAE has also established its first EV manufacturing company, indicative of a "dual strategy" approach that decarbonises domestic operations while securing a dominant position in emerging, low-carbon energy sources. There is also interest in sourcing some of the key materials for EVs: Saudi Arabia is expanding copper mining, while all the GCC countries other than Kuwait are important producers of aluminium.

# CONCLUSIONS


Despite the forecasted prevalence of ICEVs for the next 7-10 years, EVs have made radical changes to the transport sector and are slated to continue doing so, with ~16% of new car sales in 2023 set to be electric. Their increasing competitiveness on costs and performance as well as continually increasing international pressures to mandate their use to meet climate targets means they will demand leading oil and gas companies to transform their business models to take into account the very material possibility of rapid oil demand decline post-2030 as sales of ICEVs are phased-out.

At the same time, not all possible strides by EVs (low-to-zero GHG emissions, higher efficiency, no pollution, lower lifetime costs) will be achieved at the same time, or at least will take time to do so. Barriers of infrastructure, regulation and consumer familiarity can hold them back even when they reach commercial maturity. Some tasks, such as reaching full automation of driving, are still more challenging than first thought, even though they could revolutionise transport as currently known.

The implications of e-mobility reach well beyond the energy sphere, and will have widespread ramifications for industry, society, the environment and geopolitics. 2022 already presented a teaser in terms of supply chain disruptions, bottlenecks, and inelasticity of supply. Meanwhile, the growing dominance of China in EV and EV battery manufacturing will continue shifting the locus of global supply chains, raising the potential for strategic competition with the EU and US. Legacy car makers in these jurisdictions will have to compete against a myriad of start-ups, many of whom are specialists in the EV space, in order to retain their market shares.

Major oil and gas exporters will have to watch developments carefully, invest at strategic points, and make their own economic decisions robust to new emergent transport paradigms.

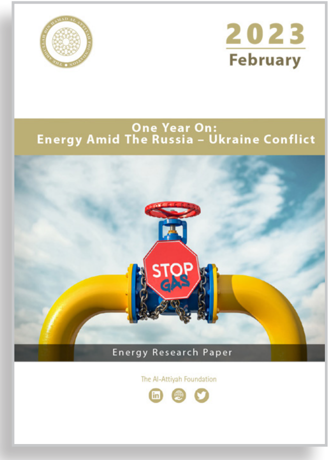
i. Qamar Energy Research, based on data from IEA, "Global EV Data Explorer", https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer and BloombergNEF, "Five Key Charts to Watch in Global Commodities This Week", March 2023, https://www.bloomberg.com/news/articles/2023-03-26/five-key-charts-to-watch-in-global-commodities-this-week?sref=IUPsko0S
ii. EV Volumes, "Global EV Sales for 2022", https://www.ev-volumes.com/
iii. Qamar Energy Research, based on data from IEA, "Global EV Data Explorer", https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer and BloombergNEF, "Five Key Charts to Watch in Global Commodities This Week", March 2023, https://www.bloomberg.com/news/articles/2023-03-26/five-key-charts-to-watch-in-global-commodities-this-week?sref=IUPsko0S
iv. BloombergNEF, "Five Key Charts to Watch in Global Commodities This Week", March 2023, https://www.bloomberg.com/news/articles/2023-03-26/five-key-charts-to-watch-in-global-commodities-this-week?sref=IUPsko0S
v. Qamar Energy Research
vi. Reuters, "A Reuters analysis of 37 global automakers found that they plan to invest nearly $1.2 trillion in electric vehicles and batteries through 2030", October 2022, https://www.reuters.com/graphics/AUTOS-INVESTMENT/ELECTRIC/akpeqgzqypr/
vii. EV Volumes, "Global EV Sales for 2022", https://www.ev-volumes.com/
viii. IEA, "Global EV Outlook 2022", May 2022, https://www.iea.org/reports/global-ev-outlook-2022
ix. Reuters, "A Reuters analysis of 37 global automakers found that they plan to invest nearly $1.2 trillion in electric vehicles and batteries through 2030", October 2022, https://www.reuters.com/graphics/AUTOS-INVESTMENT/ELECTRIC/akpeqgzqypr/
x. Qamar Energy Research, with data from Reuters, "A Reuters analysis of 37 global automakers found that they plan to invest nearly $1.2 trillion in electric vehicles and batteries through 2030", October 2022, https://www.reuters.com/graphics/AUTOS-INVESTMENT/ELECTRIC/akpeqgzqypr/
xi. Transport & Environment, "First ever comparison of car taxation in Europe reveals large discrepancies in approaches to EV incentives", October 2022, https://www.transportenvironment.org/discover/first-ever-comparison-of-car-taxation-in-europe-reveals-large-discrepancies-in-approaches-to-ev-incentives/
xii. GOV.UK, "Introduction of Vehicle Excise Duty for Zero Emission Cars, Vans and Motorcycles from 2025", November 2022, https://www.gov.uk/government/publications/introduction-of-vehicle-excise-duty-for-zero-emission-cars-vans-and-motorcycles-from-2025/introduction-of-vehicle-excise-duty-for-zero-emission-cars-vans-and-motorcycles-from-2025
xiii. Heycar, "2023 Electric Car Tax rates and VED bands", March 2023, https://heycar.co.uk/guides/electric-car-tax-rates
xiv. Institute of Transport Economics, Norwegian Centre for Transport Research, "The price of carbon implicit in the Norwegian road, fuel and vehicle taxation system", https://www.toi.no/getfile.php/1354320-1602769940/Publikasjoner/T%C3%98I%20rapporter/2020/1794-2020/1794-2020-Summary.pdf
xv. ACEA, "2022 Tax Guide", https://www.acea.auto/files/ACEA_Tax_Guide_2022.pdf
xvi. ACEA, "2022 Tax Guide", https://www.acea.auto/files/ACEA_Tax_Guide_2022.pdf
xvii. Bloomberg, "China's Provinces Offer EV Sweeteners as National Subsidies Fade", March 2023, https://www.bloomberg.com/news/articles/2023-03-07/china-s-provinces-offer-ev-sweeteners-as-national-subsidies-fade?sref=IUPsko0S
xviii. Bloomberg, "China's Provinces Offer EV Sweeteners as National Subsidies Fade", March 2023, https://www.bloomberg.com/news/articles/2023-03-07/china-s-provinces-offer-ev-sweeteners-as-national-subsidies-fade?sref=IUPsko0S
xix. Electrek, "Here's every electric vehicle that currently qualifies for the US federal tax credit", March 2023, https://electrek.co/2023/03/31/which-electric-vehicles-still-qualify-for-us-federal-tax-credit/
xx. Plug In America, "Inflation Reduction Act (IRA) EV Incentives, Explained", https://pluginamerica.org/inflation-reduction-act-ira-ev-incentives-explained/
xxi. Reuters, "Factbox: Electric vehicle subsidies under pressure in some Tesla core markets", January 2020, https://www.reuters.com/article/us-tes-

la-results-subsidies-factbox-idUSKBN1ZS1H9
xxii. Electrek, "Here's every electric vehicle that currently qualifies for the US federal tax credit", March 2023, https://electrek.co/2023/03/31/which-electric-vehicles-still-qualify-for-us-federal-tax-credit/
xxiii. Qamar Energy Research, with data from IEA, "Global EV Outlook 2022", May 2022, https://www.iea.org/reports/global-ev-outlook-2022, and Bloomberg, "Electric Vehicle Sales Top $1 Trillion in Wake-Up Call for Carmakers", February 2023, https://www.bloomberg.com/news/articles/2023-02-14/electric-vehicle-sales-top-1-trillion-in-wake-up-call-for-carmakers?sref=IUPsko0S
xxiv. Qamar Energy Research, with data from https://news.energysage.com/electric-vehicle-charging-cost-vs-gas/
xxv. Qamar Energy Research
xxvi. Data from EIA
xxvii. Qamar Energy Research, with data from EIA and Global Petrol Prices
xxviii. Qamar Energy Research, with data from https://www.eia.gov/petroleum/gasdiesel/
xxix. Qamar Energy Research, with data from https://news.energysage.com/electric-vehicle-charging-cost-vs-gas/
xxx. Qamar Energy Research
xxxi. Qamar Energy Research, with data from US DOE, Office of Energy Efficiency & Renewable Energy, "Battery-Electric Vehicles Have Lower Scheduled Maintenance Costs than other Light-Duty Vehicles", June 2021, https://www.energy.gov/eere/vehicles/articles/fotw-1190-june-14-2021-battery-electric-vehicles-have-lower-scheduled
xxxii. Qamar Energy Research
xxxiii. Energy Sage, "How much does it cost to charge an electric vehicle? EV vs. gas fuel comparison", https://news.energysage.com/electric-vehicle-charging-cost-vs-gas/
xxxiv. Chargie, "Level 2 vs. Level 3 EV Charging Stations: What's the Difference?", July 2022, https://chargie.com/resources/level-2-vs-level-3-ev-charging-stations-whats-the-difference/
xxxv. Energy Sage, "How much does it cost to charge an electric vehicle? EV vs. gas fuel comparison", https://news.energysage.com/electric-vehicle-charging-cost-vs-gas/
xxxvi. See also the Al-Attiyah Foundation Special Report: November 2022 Issue on "The EV Revolution: Optimism versus Reality"
xxxvii. Qamar Energy Research, with data from https://www.reuters.com/business/cop/is-your-electric-car-eco-friendly-you-thought-2021-11-10/
xxxviii. Car and Driver, "Longest Range Electric Cars for 2023, Ranked", March 2023, https://www.caranddriver.com/features/g32634624/ev-longest-driving-range/
xxxix. Move Electric, "The 10 electric cars with the longest range", January 2023, https://www.moveelectric.com/e-cars/10-electric-cars-longest-range
xl. Energy Sage, "How much does it cost to charge an electric vehicle? EV vs. gas fuel comparison", https://news.energysage.com/electric-vehicle-charging-cost-vs-gas/
xli. Qamar Energy Research, with data from Wallbox, "How Do EVs Compare To Gas Cars?", https://blog.wallbox.com/how-do-evs-compare-to-gas-cars/
xlii. Wallbox, "How Do EVs Compare To Gas Cars?", https://blog.wallbox.com/how-do-evs-compare-to-gas-cars/
xliii. Qamar Energy Research, with data from IEA, BNEF, and Wood Mackenzie
xliv. Wood Mackenzie, "700 million electric vehicles will be on the roads by 2050", February 2021, https://www.woodmac.com/press-releases/700-million-electric-vehicles-will-be-on-the-roads-by-2050/
xlv. EVs currently also use four times more copper than a traditional vehicle, due to more wiring, which will also add to overall copper demand
xlvi. Qamar Energy Research, with data from https://www.benchmarkminerals.com/
xlvii. Qamar Energy Research, with data from https://www.benchmarkminerals.com/
xlviii. Live Mint, "Lithium Prices Are Down, Cheaper Batteries and EVs Could Follow", April 2023, https://www.livemint.com/industry/energy/lithium-prices-are-down-cheaper-batteries-and-evs-could-follow-11680623562924.html
xlix. NPP, "Why Lithium iron phosphate battery market share will overtake the ternary lithium battery", December 2022, https://npplithium.com/lithium-iron-phosphate-battery-market-share/
l. NPP, "Why Lithium iron phosphate battery market share will overtake the ternary lithium battery", December 2022, https://npplithium.com/lithium-iron-phosphate-battery-market-share/

li. Qamar Energy Research
lii. Qamar Energy Research, with data from CGEP, "Forecasts of Electric Vehicle Penetration and its Impact on Global Oil Demand", December 2022, https://www.energypolicy.columbia.edu/publications/forecasts-electric-vehicle-penetration-and-its-impact-global-oil-demand/
liii. Qamar Energy Research, with data from CGEP, "Forecasts of Electric Vehicle Penetration and its Impact on Global Oil Demand", December 2022, https://www.energypolicy.columbia.edu/publications/forecasts-electric-vehicle-penetration-and-its-impact-global-oil-demand/
liv. IEA, "Global EV Outlook 2022", May 2022, https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf
lv. Qamar Energy Research, with data from IEA, "Global EV Outlook 2022", May 2022, https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf and CGEP, "Forecasts of Electric Vehicle Penetration and its Impact on Global Oil Demand", December 2022, https://www.energypolicy.columbia.edu/publications/forecasts-electric-vehicle-penetration-and-its-impact-global-oil-demand/
lvi. Qamar Energy Research, with data from CGEP, "Forecasts of Electric Vehicle Penetration and its Impact on Global Oil Demand", December 2022, https://www.energypolicy.columbia.edu/publications/forecasts-electric-vehicle-penetration-and-its-impact-global-oil-demand/

# PAST ISSUES

Have you missed a previous issue? All past issues of The Al-Attiyah Foundation's Research Series, both Energy and Sustainability Development, can be found on the Foundation's website at www.abhafoundation.org/publications

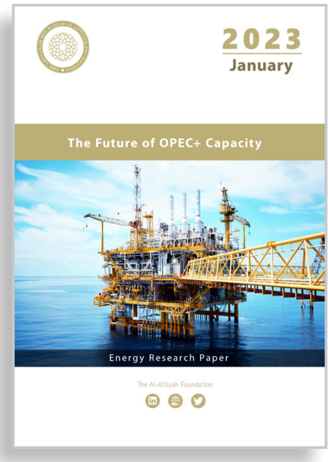



February – 2023

## One Year On: Energy Amid The Russia – Ukraine Conflict

The Russian invasion of Ukraine in February 2022 has created shockwaves in global energy markets, with fossil fuel supply shortages, changing energy trade flows, and economic uncertainty. After an initial global energy crisis, much adjustment has happened, but serious risks remain.

(QRCODE)

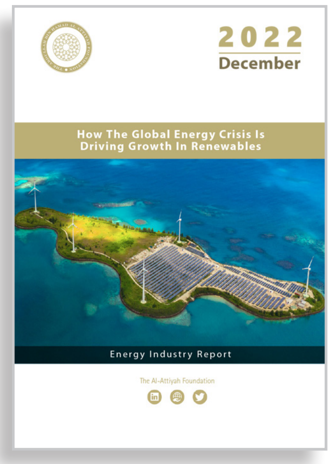



January – 2023

## The Future of OPEC+ Capacity

OPEC+ has faced three volatile years:2020, the year of the pandemic and demand plunge; 2021, the year of tight markets and inflation amid pandemicinduced supply bottlenecks; and 2022, the year of geopolitical risk and record-high energy prices.

(QRCODE)




December – 2022

## How the Global Energy Crisis Is Driving Growth in Renewables

The current global crisis and the greater focus on energy security is not slowing the energy transition. It has led to an upward revision of long-term renewable output.

(QRCODE)

**Our partners collaborate with The Al-Attiyah Foundation on various projects and research within the themes of energy and sustainable development.**

Qatar Foundation
Unlocking human potential

KAHRAMAA
Qatar General Electricity & Water Corporation

World Petroleum Council

QATAR UNIVERSITY

HAMAD BIN KHALIFA UNIVERSITY

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

UİP-ICP
ULUSLARARASI İŞBİRLİĞİ PLATFORMU
INTERNATIONAL COOPERATION PLATFORM
İSTANBUL

ISAG
Istituto di Alti Studi in Geopolitica e Scienze Ausiliarie

MITSUI & CO.

earthna

GORD
Gulf Organisation for Research & Development

United Nations Global Compact

NATIONAL COUNCIL ON U.S.-ARAB RELATIONS

GULF TIMES

The Al-Attiyah Foundation


Tel: +(974) 4042 8000,
Fax: +(974) 4042 8099
www.abhafoundation.org

Barzan Tower, 4th Floor,
West Bay.
PO Box 1916 Doha, Qatar

AlAttiyahFndn
The Al-Attiyah Foundation
Al-Attiyah Foundation