IMCO
Investment Management Corporation of Ontario

IMCO ELECTRIC VEHICLE RESEARCH REPORT

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EXECUTIVE SUMMARY

Electric vehicles (EVs), which were merely an interesting concept not so long ago, are now transforming the auto sector due to the soaring market value of industry participants and the increasing number of players in the EV ecosystem. The green nature of these vehicles compared to traditional internal combustion engine (ICE) vehicles makes EV adoption a clear first step in achieving net-zero emissions, increasingly a global concern. A key question we have sought to answer in this report is how much of this attention on EVs is hype and how much is supported by fundamentals? Furthermore, what impact will the transition to EVs have on IMCO and the sectors in our investment universe? Our main findings are listed below.

1. **The EV future is real:** Our work has helped cement our belief in the EV future. EV adoption has progressed faster than initial forecasts, with penetration essentially going from 0% of new car sales in 2008 to about 10% as of November 2021. Policy support, emissions regulations, progress on key technologies and consumer interest all support more adoption in the future, with auto executives and other industry stakeholders projecting about 30% of new car sales will be EVs by 2030. That said, there is still considerable uncertainty about the pace of EV adoption.

2. **The transition to EVs will require massive amounts of capital expenditure:** The future is clearly electric, but the key constraint preventing faster EV production (and therefore adoption) is the large legacy ICE manufacturing footprint. More than 130 years of innovation and capital have been spent designing and perfecting the auto assembly lines of VW, GM, Ford and their ICE peers. These factories and their associated supply chains cannot simply be converted to EV production overnight. As a result, billions need to be spent to build entirely new plants for EV production. More substantially, billions more will be needed to convert existing factories to partial or full EV production lines. To this end, the automakers have announced at least $300 billion of capital expenditures related to EV manufacturing over the next decade.

3. **The outlook for traditional automakers is unclear:** By now, most major automakers have announced their plans for the EV transition. But how exactly they'll do so is highly uncertain as the divergence of strategies, the existing position in EVs and, ultimately, consumer preferences have yet to fully play out. For example, GM and Ford have announced billions in EV-related investment but still believe the majority of their cars sold in 2030 will be ICE vehicles. Tesla, in contrast, believes it can sell more EVs in 2030 (20 million) than the combined total cars sold by GM and Ford in 2019 (13 million). The amount of capital directed towards EV startups such as Rivian and Lucid (approximately $65 billion in market capitalization) also signal potential challenges for ICE automakers.

4. **Global auto suppliers appear better positioned than ICE automakers:** The average car has 16 major component systems, so it's important to remember that while four major components face elimination in EVs, the value of the other 12 components remains largely the same — or even more valuable. Most global auto suppliers provide at least three major components, reducing their exposure to potentially obsolete ICE-specific components. That said, some auto suppliers are better positioned than others for the transition given their component exposure.

5. **Large investments in EV charging infrastructure will be required:** While EV manufacturers have announced and begun executing billions of dollars of investment for an EV world, there's still a significant need for investment in charging infrastructure to support continued adoption. Governments, municipalities, homeowners and businesses are expected to invest almost $200 billion USD in charging infrastructure and other EV-related support over the next 10 years.

6. **There are risks and opportunities beyond the automotive sector:** The transition to EVs will bring about both challenges and opportunities across sectors. *Power utilities* stand to benefit from EVs. Electricity consumption will increase from EV adoption, albeit at a gradual pace, giving utilities time to adapt their business models and grow capacity. Utilities can also benefit from developing new business divisions in the EV charging space, taking advantage of their extensive know-how in project management and engineering. *Real estate* property managers will need to be mindful of how the transition to EVs will impact the value of their properties. There are opportunities to attract and retain clientele by making properties EV-ready through investments in EV charging capabilities in both residential and commercial buildings. Expensive retrofits may also be necessary in older properties. Shopping centres, for their part, can offer EV charging to attract customers and increase the amount of time they spend at their properties and shop. Finally, properties specifically geared toward on-the-go fleet and industrial charging will become increasingly prominent. *Oil* demand, meanwhile, should lessen as global car and commercial vehicle fleets become dominated by EVs. This will be particularly acute from 2030 onward. *Metals and minerals* demand, on the other hand, especially for lithium and nickel, will increase due their roles in battery production. Evolving chemistry mixes, increased supply and battery recycling could help meet the demand.

Overall, our work has helped us better understand and believe in the electric vehicle future. With the involvement of IMCO's various asset classes, all of which have exposure to the EV future in one way or another, our work is the backbone along which we can prepare for this transition and take advantage of opportunities as they arise.

INTRODUCTION

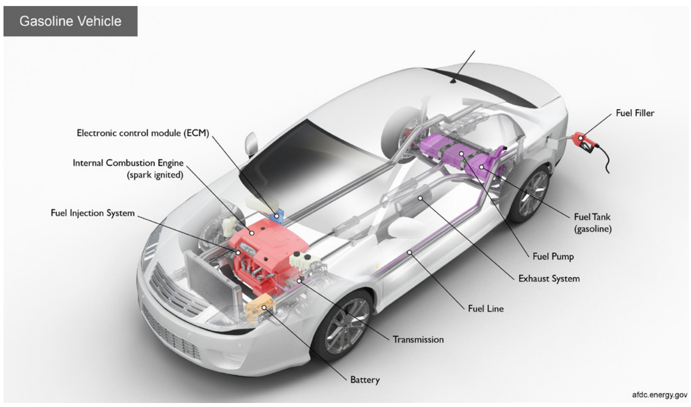
A single company, Tesla, has disrupted the 130-year-old auto industry ecosystem, one that's worth about $10 trillion or approximately 11% of global GDP. Tesla's vision to accelerate the transition to electric-powered vehicles started in 2003 and was first met with resounding skepticism from many different stakeholders, especially the leading internal combustion engine ("ICE") automakers. Fast forward 19 years and we are at an inflection point where approximately $300 billion in EV manufacturing-related investment has been announced over the next five to 10 years by ICE automakers in response to investor demands, regulatory pressure, competitive tension and, most importantly, strong consumer interest in adopting EVs. Electric vehicles are now expected to represent at least 30%-50% of all new cars produced and sold by 2030. In addition, some believe EV penetration may ultimately be significantly higher by 2030 and that almost all new cars sold by 2040 will be EVs, particularly in advanced economies. These projections have strong implications for the core ICE value chain but also many knock-on effects for the broader auto ecosystem.

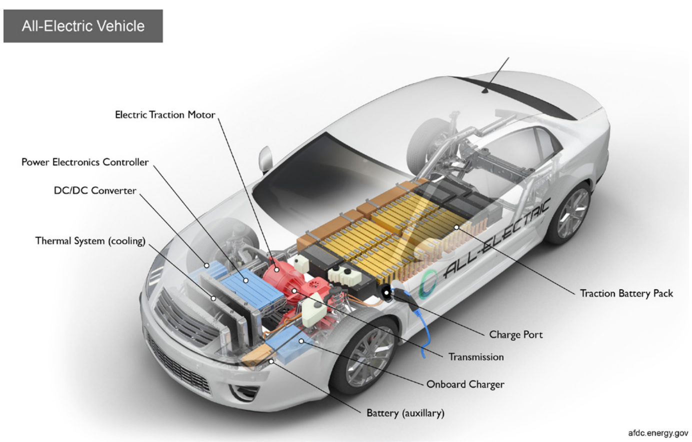
It's also worth noting the advent of autonomous vehicles, which are in many ways tied to the rise of EVs given the electrification and computerization of these cars. If proven commercially viable, autonomous driving technology could completely disrupt the auto ecosystem, albeit with a much more uncertain timeline. Industry participants and analysts' projections for mass adoption of autonomous vehicles range from a few years from now to decades away, signalling the still uncertain roadmap for autonomous driving. That said, the combination for EVs and autonomous driving represent a once-in-a generation disruption of one of the largest industries in the world.

This research report is a cross-asset class collaboration investigating the investment impacts of the EV future. It was commissioned by IMCO's Research Committee and sponsored by our fundamental equity team.

WHAT ARE THE DIFFERENT TYPES OF VEHICLES?

Internal combustion engine (ICE) vehicles are the most prominent vehicle technology today. They contain an engine where fuel is injected into a combustion chamber and combined with air. Gasoline and diesel are transportation fuels typically used to power ICE vehicles, but there are also alternative fuel options with varying levels of CO_2 emissions associated with them.





Electric vehicles (EVs) are vehicles that contain an electric motor that is powered by a battery pack. Along with lower emissions from using electric power, a key feature of electric vehicles is their use of regenerative braking, which converts the friction from braking into stored energy. There are three different sub-categories of electric vehicles:

- *Hybrid electric vehicles (HEVs)* contain both an internal combustion engine and a battery pack, which is used to provide additional power to the vehicle. The battery is charged through regenerative braking and by the internal combustion engine. The presence of battery power can allow for a smaller engine. These vehicles cannot be plugged in.
- *Plug-in hybrid electric vehicles (PHEVs)* are similar to HEVs, except their batteries can also be recharged from an external electricity source via a plug. These vehicles typically operate on electric power until the battery is nearly depleted, then switch over to using the power of their internal combustion engines.
- *All-electric vehicles (EVs)* have only an electric motor and a large traction battery pack. These vehicles must be plugged into an outlet or charging equipment regularly to operate. These are the only electric vehicles that do not use any type of fuel to operate.

While all types of electric vehicles can potentially reduce emissions compared to typical ICE vehicles, all-electric vehicles have the greatest potential to contribute to emissions reductions. When the source of electricity generation is also green, this effect is even greater. Their reduced level of emissions is why EVs are such a game-changer when it comes to combating climate change.

At the same time, today's EVs also have drawbacks, including the longer time it takes to repower them compared to ICE vehicles and shorter driving ranges. Hybrid-electric vehicles and plug-in hybrid electric vehicles are not as affected by these issues, and therefore represent a step towards lower emissions for those not prepared to deal with the disadvantages of EVs.

The table below compares the emissions levels of the major passenger vehicle types, as well as some of their other characteristics.

TABLE 1: Comparison of Selected Vehicle Types.

	Internal Combustion Engine Vehicle	Hybrid-Electric Vehicle	Plug-in Hybrid-Electric Vehicle	All-Electric Vehicle
Fuel Economy (average)	29 mpg	45 mpg	60 mpg equivalent	107 mpg equivalent
Driving Range (max)	640 miles	690 miles	640 miles	370 miles
Fuel costs (per mile)	10-15 cents	5-10 cents	5-10 cents 2-4 cents (battery)	2-4 cents
Greenhouse Gas Emissions (per year)	4.1 – 14.7 metric tonnes	2.8 - 9.0 metric tonnes	2.5 – 7.0 metric tonnes	1.8 – 3.5 metric tonnes

Source: US Congressional Research Service. Data is for 2019 US vehicles.

In addition to electric vehicles, there are other vehicle types that have been proposed as alternatives to the traditional ICE vehicle. We discuss some of their advantages and drawbacks below.

Flexible fuel vehicles (FFV) are ICE vehicles that are designed to draw power from fuels other than gasoline and may have lower emissions associated with them. There are more than 21 million flexible fuel vehicles on the road in the United States today, but many drivers don't know they're driving an FFV, or do not choose to drive them using alternative fuels. The most common fuel used in these vehicles is ethanol, a corn-based fuel that is associated with lower greenhouse gas (GHG) emissions than gasoline. However, there are many drawbacks to operating a vehicle on ethanol, including lower range (due to lower energy content), as well as the high costs associated with the fuel's production.

Fuel cell electric vehicles (FCEVs), like EVs, use an electric motor. In the case of FCEVs, the electricity is produced using a fuel cell powered by hydrogen rather than drawing electricity from a battery. FCEVs produce no GHG emissions, but the production of hydrogen requires energy that can be derived from both "clean" and "dirty" sources. FCEVs are less efficient than EVs when considering production and transportation/transmission of the hydrogen and are therefore not necessarily a winner in terms of reaching climate change objectives. Nonetheless, hydrogen is still seen as having some promising characteristics for the greening of larger vehicles and in shipping and aerospace, where there are more difficulties with full electrification.

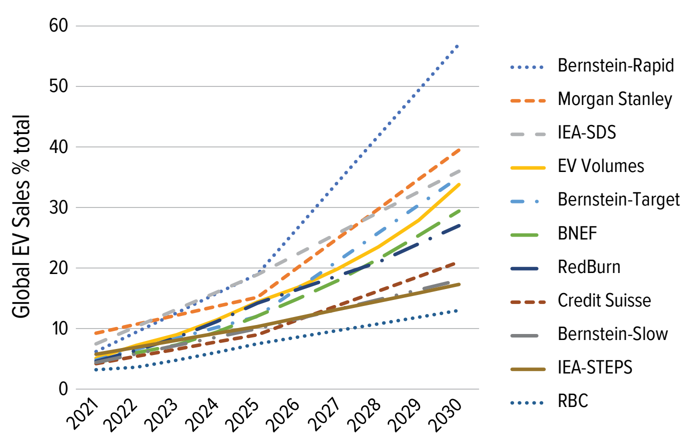
WHAT HAS BEEN DRIVING EV ADOPTION?

Electric vehicles have been around since the early days of cars, with the first EV hitting the road in 1890s. But for various reasons, EVs failed to take off as an alternative to ICE vehicles. This changed in the late 1990s and early 2000s with the introduction of popular hybrid electric vehicles and Tesla's ambitions to produce a fully electric vehicle. These early efforts resulted in the production of the game-changing Roadster, a luxury vehicle that could achieve almost 400 kilometres of range on a single charge. Both traditional automobile manufacturers and incumbents responded in turn with their own EV strategies.

However, price, model availability, range, and charging concerns have all been limiting factors in the widespread adoption of EVs. Governments have used policy measures to help consumers overcome these hurdles; the most common have been tax rebates or purchase incentives. These incentives helped lower the price of EVs for consumers, facilitating greater adoption, but EVs still largely remained a fringe or luxury product. One notable exception is Norway, where generous tax incentives and priority lanes for EVs helped the country become a leader in EV adoption. Nonetheless, the Norwegians were largely global outliers.

In recent years, this has started to change. Global EVs sales have grown from less than 1% of automobile sales in 2015 to 10% of sales in the last months of 2021. The world is moving quickly from early-stage adoption of EVs to more generalized adoption. By some estimates, sales of EVs could reach 50% of total global vehicles sales sometime between 2030 and 2040 if the trend continues. However, projections vary significantly (Chart 1). In this section, we explore some of the key drivers of EV adoption so far that form the basis of our views on where EV adoption is heading in the future.

CHART 1. EV adoption forecasts (Dec. 2021)

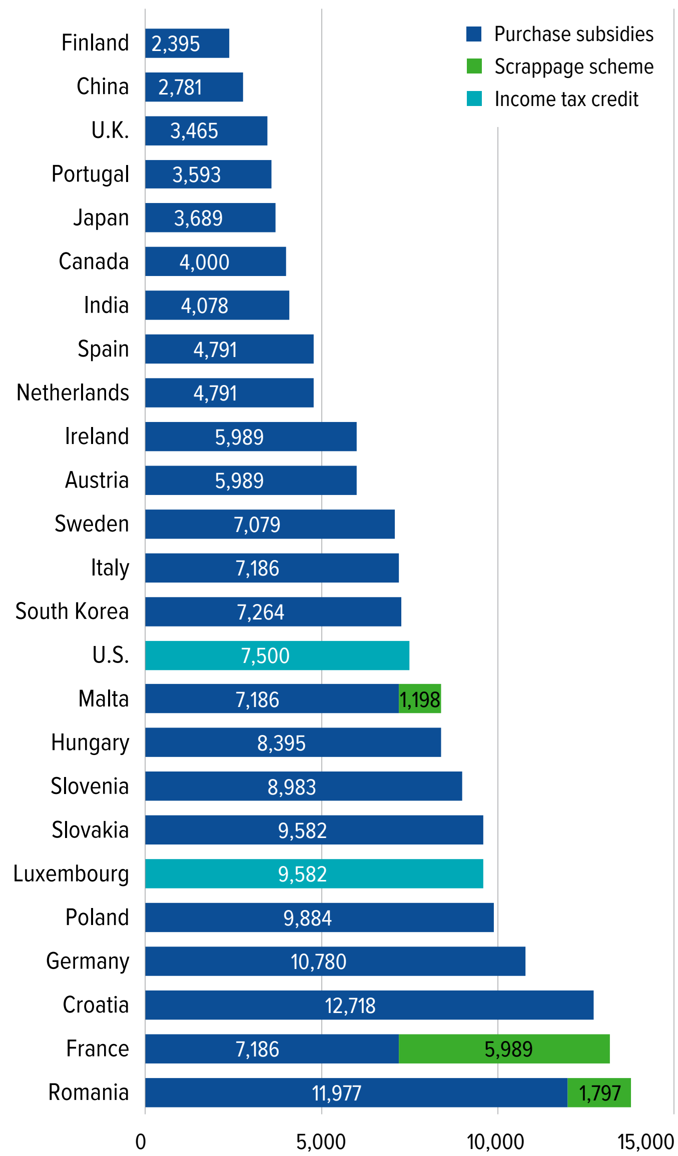


Source: IMCO's compilation from forecasters listed above.

Policy support

Most major global car markets have adopted some form of financial support to encourage car buyers to purchase EVs. (Chart 2) However, as the price of EVs comes down, these incentives are largely expected to be rolled back. An exception is the U.S., where President Joe Biden has proposed increasing the current $7,500 USD tax credit by 50% for American-manufactured vehicles, as well as a bonus for any EV that's been produced by unionized labour. This would certainly help promote more EV adoption in a country that is behind in terms of EV sales.

CHART 2. BEV Direct Purchase Incentives in USD



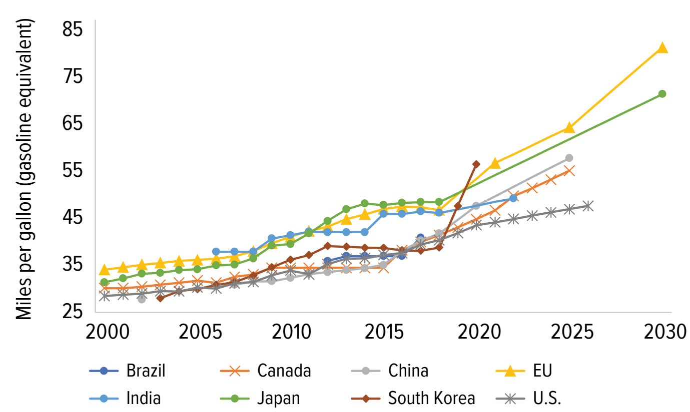
Source: BloombergNEF, October 2021

EV sales quotas, where car manufacturers are penalized for failing to reach specific EV sales targets, have also been used to spur EV adoption; however, they've been criticized for shifting EV sales from regions without quotas to those with quotas. In Canada, for example, both British Columbia and Québec have sales quotas, making it harder for dealers and consumers in other provinces to find EVs. For this reason, their overall impact on EV adoption may be limited.

Fuel efficiency standards have arguably been the most successful policy encouraging the shift to EVs. In the last few decades, major car markets around the world have been tightening their fuel efficiency standards. To meet these targets and avoid hefty fines, car manufacturers have the option of either improving the efficiency of their existing ICE vehicles or selling more electric vehicles, which are already much more fuel-efficient. Generally, they have been doing both, but it's clear that EVs are a necessity in an environment of tightening standards and net-zero greenhouse gas commitments around the world.

Globally, fuel efficiency standards and regulations vary (Chart 3). Europe, which is among the jurisdictions with the tightest emissions standards globally, is considering tightening them further. A current proposal would bring Europe's CO_2 emissions reduction target from 37.5% currently to 55% by 2030, implying EV adoption of about 60%. China is also tightening its standards gradually, with current standards implying EV adoption of around 18% in 2025. The U.S., for its part, has some of the laxest fuel efficiency standards among major car markets after former president Donald Trump rolled back the targets of Barack Obama's administration. However, Biden has proposed a return to Obama's targets by 2026. If successful, that would imply a massive increase in EV sales in the U.S., up from 4% currently to 25% by 2026, according to Bloomberg Next Energy Finance (BNEF).

CHART 3. Passenger car fuel economy standards



Source: International Council on Clean Transportation, Dec 2021

ICE phase-out ambitions that have been adopted by more than 20 countries, as well as net-zero emissions pledges that suggest broader EV adoption, further signal government commitments to the EV future, making it hard for automakers to ignore (IEA 2021).

Beyond policies incentivizing the purchase and sale of EVs, some other key factors cited by consumers as hurdles to EV adoption are also set to improve:

1. **Model availability.** Regardless of policy fluctuations, automakers are now gearing towards the new EV reality. By the end of 2020, there were more than 400 EV models available globally. About 450 new EV models will be launched through 2022, according to a McKinsey study, including SUVs and pickup trucks. This rapidly increasing availability of EV models across car segments will support adoption more broadly.
2. **Cost.** The cost of EVs, which has already fallen significantly, is expected to drop further as battery technology and manufacturing costs improve. Once battery costs fall beyond $100/kWh, which they are on track to do, BNEF estimates there will be price parity between EVs and ICE vehicles, eliminating the need for subsidies to incentivize buyers. At an equal sticker price, consumers will see significant lifetime savings from EV adoption since the cost of recharging an EV is much lower than the price of gasoline.
3. **Range.** Consumers expect EVs to have better range, even though the range of virtually all EVs is sufficient to cover the daily miles travelled in different geographies (Deloitte, 2021). Still, EV range continues to improve and may even surpass that of ICE vehicles. For example, Mercedes recently announced a concept EV with a 1,000-kilometre range. Range anxiety also appears to ease following EV adoption. This suggests some consumer concerns can be overcome by experience and greater education.
4. **Charging.** Greater availability of charging infrastructure and policies to support the rollout of charging stations have also helped relieve range anxiety for consumers.

Overall, the convergence of tightening emissions regulations, greater model availability and improving range, price and charging solutions point to a very real EV future. Automakers and their suppliers are clearly watching these trends carefully and making large investments to become EV-ready. This makes us confident that the EV trend is real and will endure.

WHAT ARE SOME OF THE RISKS TO THE EV FUTURE?

While there is a growing consensus on the timing and evolution of the EV transition, there are still highly divergent outlooks among key industry participants and investors. Furthermore, the prospect of autonomous driving further complicates the auto industry outlook because autonomous driving is potentially an even more disruptive factor than the EV transition. Without making a speculative bet, it is challenging to identify how the disruption facing the auto industry will ultimately play out and more importantly, who the winners and losers will be.

To help prepare for potential divergent futures, we believe it makes sense to use a scenario analysis to create a framework that will enable us to draw conclusions on these two important questions.

While there are many potential scenarios, we believe identifying a single metric and timeline is most helpful to clarify our thinking. We believe 2030 new car sales is the key metric for forecasting since new car sales are the driver of the entire auto ecosystem, and 2030 is a date most participants have identified as sufficiently far enough away to measure material progress and sufficiently close enough to allow for forecasting. Longer term auto production investment plans help to this end.

Below (Table 2) is our initial take on potential divergent states of the world and the impact on the auto ecosystem. It's meant to be illustrative and our best estimate of leading scenarios proposed by industry participants. The "Base Case: Cruising to the EV Future" scenario can be best described as the consensus view. It implies a gradual transition to EVs between now and 2030, with EV penetration hitting 30%-50% by 2030. While this is clearly disruptive, this timeline still implies an adjustment period is available to existing auto participants who take the opportunity and threat seriously.

The underlying view of our research best aligns with the "Base Case: Cruising to the EV Future" scenario. However, the three other scenarios shown below are meant to describe alternative scenarios that could lead to very different investment implications. Each has its proponents in the auto ecosystem.

TABLE 2. Divergent futures for the auto ecosystem

BASE CASE: Cruising To The EV Future

- Driven by continued investor demands and carbon regulations, car companies continue to invest in converting ICE production to EV.
- Governments continue to financially incent EV investment and gradually increase restrictions on ICE production.
- Consumers increase adoption of EVs inline with progress on cost parity on full range of ICE available models
- Progress on autonomous tech does not change car ownership culture implying transportation-as-a-service remains a niche market
- *2030 global car sales: Trend 90 million per year*
- *2030 EV Sales Penetration: ~30-50%*
- *Car ownership culture: unchanged*

RED LIGHT: EV & Autonomous Bubble Pops

- Tesla's share price collapses due to production challenges. Entire EV start-up ecosystem crashes alongside Tesla
- Investor financing dries up for EV start-ups reducing pressure on ICE producers to convert more of the production to EV
- Economics and low gas prices disincentivize EV adoption
- Mass consumer market show little appetite for expensive and limited model EV's despite government incentives
- EV conversion remains a priority for governments but also accept reality that it will be 2040-2050 before EVs become dominant.
- Autonomous far-off and no change in car culture in sight
- *Global car sales: Trend 90 million per year*
- *2030 EV Sales Penetration: ~10-20%*
- *Car ownership culture: unchanged*

THE FUTURE IS NOW: Autonomous Ubiquity

- One or more autonomous providers announces and demonstrates level 5 self-driving in 2023/2024
- Commercial licenses for robo-taxi networks are approved in multiple countries/regions rapidly
- Initial consumer reaction to step-change technology announcements is to purchase autonomous enabled vehicles as an potential income generator
- By 2025, transportation-as-a-service becomes a Netflix like phenomenon where car ownership culture is displaced by "car subscriptions"
- New car sales crash in 2025-2030 period
- As much fewer cars are needed, autonomous networks can sole-source EVs completely removing the need for ICE vehicles much faster than anyone expects
- *2030 global car sales: Collapse – 40 to 50 million per year*
- *2030 EV Sales Penetration: ~70-100%*
- *Car ownership culture: Car subscriptions instead of ownership becomes dominant by 2025 or 5 years earlier than Radical New Future scenario*

RADICAL NEW FUTURE: War on Carbon X iPhone Moment

- Apple announces next-gen self-driving EV with no steering wheel in 2025
- Global climate change activists gain mass support as climate event frequency intensifies
- Governments and technologists implement a global auto policy that effectively bans ICE vehicle sales
- High prices combined with government restrictions drive consumers to stop buying new cars and instead subscribe to on-demand vehicle platforms or transportation-as-a-service.
- Oil prices collapse causing major geopolitical and economic shocks globally.
- *2030 global car sales: Collapse – 40 to 50 million per year*
- *2030 EV Sales Penetration: ~70-100%*
- *Car ownership culture: Car subscriptions instead of ownership becomes dominant by 2030*

HOW DOES THE AUTO ECOSYSTEM FARE?

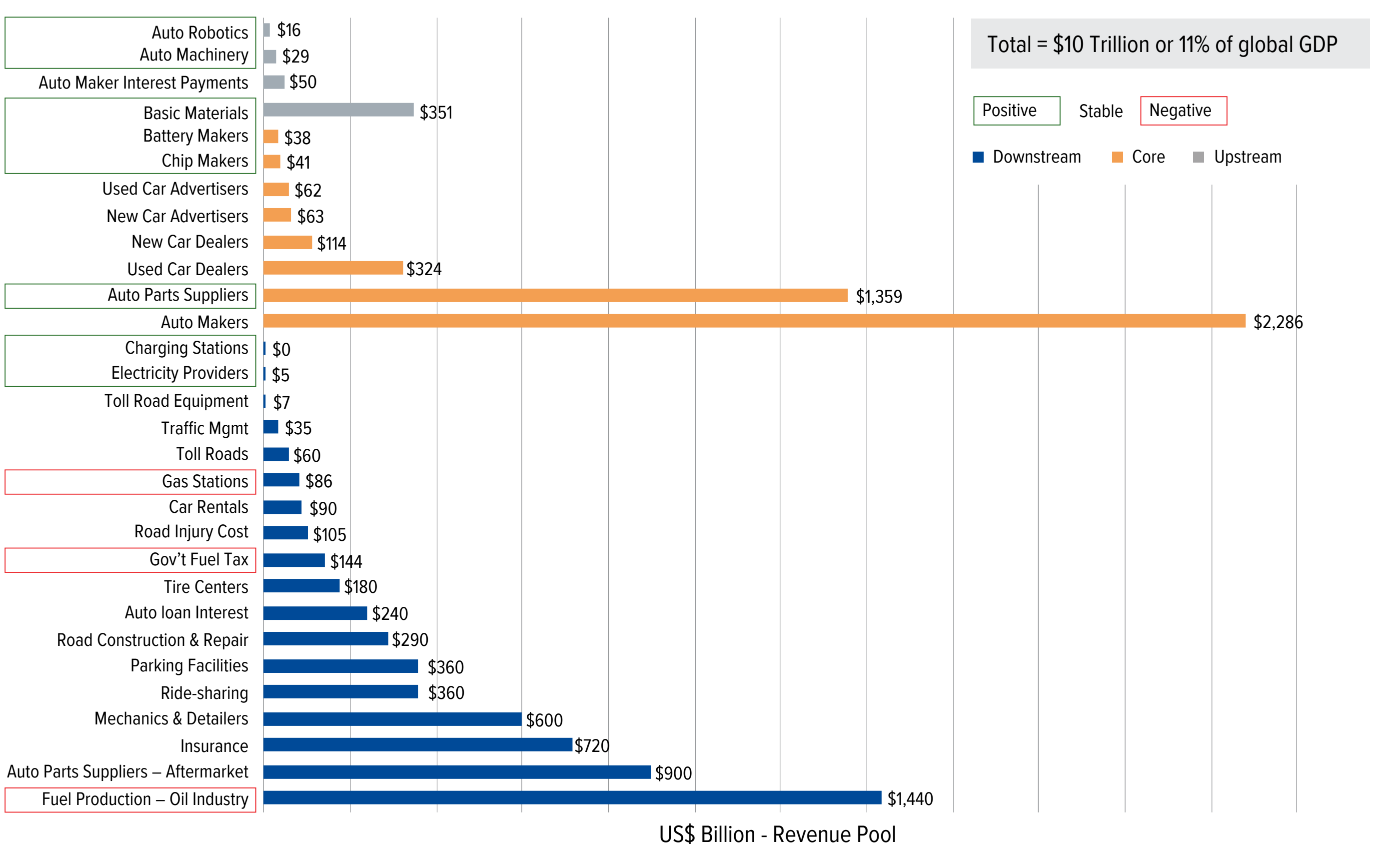
One of the main challenges when projecting the future of the auto industry is identifying key parts of a highly complex and global ecosystem. Using a first principles approach and triangulating with publicly available information, we estimate the auto ecosystem earns about $10 trillion in revenue each year, which equates to approximately 11% of global GDP. The ecosystem can be broken down into: (1) upstream activities that support the use of cars (e.g., basic materials, industrial equipment); (2) core activities that include the making of car parts and assembled cars as well as marketing and selling cars; and (3) downstream activities that generally happen concurrent or after a car is purchased (e.g., insurance, gas stations, repairs, etc.,).

As shown in Chart 4 below, the EV transition will likely have significant impacts on multi-billion-dollar and in some instances multi-trillion-dollar markets. In our "Base Case: Cruising to the EV Future" scenario, we see positive outlooks for some markets (auto robotics, batteries, auto suppliers, utilities), negative outlooks for others (oil industry, gas stations) and relatively stable outlooks for most of the ecosystem. That said, those negatively positioned, such as the oil and gas industry, can adapt to the transition by expanding adjacent offerings and converting parts of their business to the electric economy (investing in renewables, installing chargers, etc.).

The "Radical New Future" and the "Future is Now" scenarios, where there is rapid adoption of EVs and widescale adoption of transportation as a service, put many more parts of the auto ecosystem at risk. This is driven by the collapse in automobile sales. While most analysts expect the autonomous future to be further off than 2025 or even 2030, it's important to remember that could change quickly. If an autonomous player (like Tesla, Apple or Google) releases a game-changing self-driving vehicle, as we saw the iPhone do for mobile phones in the past, we could see a rapid disruption in auto OEM (original equipment manufacturer) market share and a (potentially material) change in overall car sales that would create extremes in terms of winners and losers. Finally, the "Red Light" scenario considers the possibility that EV adoption fails to continue to accelerate at such a rapid pace. This might occur if market factors cause less investment in the EV auto ecosystem, for example, leading to less capital available to finance the EV transition.

CHART 4. Analysis of winners and losers from EV adoption

Global Auto Ecosystem - Revenue Pools (US$ billions)



Source: IMCO estimates.

AUTOMAKERS HAVE A DIFFICULT TRANSITION AHEAD

In the inevitable electric future, the key constraint preventing faster EV production from automakers (and therefore adoption) is the large legacy ICE manufacturing footprint. More than 130 years of innovation and capital have been spent designing and perfecting the auto assembly lines of VW, GM, Ford and their ICE peers. These factories and their associated supply chains cannot simply be converted to EV production overnight. As a result, billions need to be spent to build entirely new plants for EV production and, more substantially, billions more must be spent to convert existing factories to partial or full EV production lines. To this end, automakers have announced at least $300 billion of capital expenditures related to EV manufacturing over the next decade. Disruptors like Tesla, however, can produce cars more efficiently because they don't have the burden of legacy manufacturing footprints and instead start from a clean slate with assembly plants purpose-built for EV production.

By now, most major automakers have announced their plans for the EV transition. But how exactly they'll do so is highly uncertain as the divergence of strategies, existing position in EVs and ultimately consumer preferences have yet to fully play out. For example, GM and Ford have announced billions in EV-related investment but still believe the majority of the cars they sell in 2030 will be ICE vehicles. Tesla in contrast believes it can sell more EVs in 2030 (20 million) than the combined total cars sold by GM and Ford in 2019 (13 million). The amount of capital directed towards EV star-ups like Rivian and Lucid (approximately $65 billion in market capitalization in 2021) also signals potential challenges for the ICE auto makers.

GLOBAL AUTO SUPPLIERS APPEAR BETTER POSITIONED TO ADAPT THAN ICE AUTOMAKERS

The average car has 16 major component systems, so it's important to remember that while four major components face elimination or significant changes (engine, transmission system, fuel system, and exhaust), the value of the other 12 components remains largely the same (body, glass, wheels, interior, airbags/seatbelts, steering, suspension, axles) or even more valuable in EVs (electronics, climate control and cooling, audio & telematics, braking). Three new major components (battery, electric transmission, power electronics) bring new participants to the auto parts industry, although none of them are set up to compete as global Tier 1 auto parts suppliers for non-battery related components. Most global auto suppliers provide at least three major components, reducing their exposure to potentially obsolete ICE-specific components. That said, some auto suppliers are better positioned than others for the transition given their component exposure.

Batteries are the most important major new component in EVs. Today's EVs are generally powered by lithium-ion batteries, with many players seeking to dominate this market. Suppliers are investing heavily to build out new manufacturing capability, which is set to triple from 540GWh/year of capacity in 2020 to 2,015GWh/year by 2025 (BNEF 2021 EV Outlook). This would imply investment of about $185 billion (BNEF). While there are many participants working on "next-generation" batteries that could one day supersede the existing battery technology, it appears these technologies are at least five to 10 years away based on consensus views. Beyond the technical challenges related to next-gen batteries, such as solid-state lithium-ion, the major challenge appears to be cost-effective production. As the EV industry pushes towards cost parity with ICE vehicles, next-gen batteries that may provide better performance (e.g., range and durability) but will be significantly more expensive to produce are unlikely to be a central part of automaker plans for many years.

CHARGING WILL BRING ABOUT A WHOLE NEW INDUSTRY

While EV manufacturers have announced and begun executing billions of dollars of investment for an EV world, there remains significant needed investment in EV-related infrastructure to support continued EV adoption. The consensus view is that governments, municipalities, homeowners and businesses will invest massively in charging infrastructure and other EV-related infrastructure, with almost $200 billion USD expected over 10 years. Government subsidies are also helping to support this industry.

The EV-charging industry is a clear necessity for the EV future. However, there are many ways EV users can charge their vehicles. Home charging is likely to be preferred by those EV users who have access to it. But many apartment dwellers and homeowners rely on street parking, meaning they will have to use public charging to meet their needs. Public chargers can be either fast (30 minutes to two hours) or slow (eight hours or more for a full charge). Some EV users may prefer to use faster public charging to meet their regular needs, recharging their battery while they do their weekly grocery shopping, for example. Others will prefer parking their vehicles overnight or while they work at a slow charging station. On-the-go charging for longer trips will also be needed, although perhaps not as much as previously since most EV users will be routinely leaving their destinations with a full battery. But those future charging locations may look very different, as more space will be required to accommodate 20-minute vehicle charges and the customers waiting to recharge. Given the uncertainties of EV user preference between charging options and locations, the ultimate and ideal mix between home, on-the-go and slow versus fast public charging is harder to predict. This means that businesses positioning themselves to take advantage of the trend face challenges. Lower usage of public charging infrastructure due to lower EV usage is another difficulty. For the next 10 years, the installation, hardware and turn-key setup side of the charging business will carry less risk since those businesses aren't exposed to final usage and asset ownership. From 2030 onward, higher predicted usage rates will help support public, fast-charging business models.

Multi-family units are another challenge in this space, where large investments and co-ordination are needed. The commercial vehicle and fleet sectors, which we do not cover here, also provide other important opportunities in the charging space.

RISKS AND OPPORTUNITIES BEYOND AUTO SECTOR

The transition to EVs will bring about both challenges and opportunities across sectors. Here are a few:

1. *Power utilities* stand to benefit from EVs. Electricity consumption will increase from EV adoption, albeit at a gradual pace. This means utilities should have time to adapt their business models, and the need for capacity upgrades are relatively far off. At the local level, however, some grid and transmission upgrades will be needed more quickly given potential areas of concentration for EV adoption. Regulatory co-ordination and changes in electricity pricing models would also be helpful to accelerate the EV transition. Utilities could benefit from developing new business divisions in the EV charging space, taking advantage of their extensive know-how in project management and engineering.
2. *Real estate* property managers will need to be mindful of how the transition to EVs will impact the value of their properties. There are opportunities to attract and retain clientele by making properties EV-ready through investments in EV charging capabilities in both residential and commercial buildings. Expensive retrofits may also be required for older properties. Shopping centres, for their part, can use EV charging to attract customers and increase the amount of time they spend shopping. EV charging is also becoming a necessary amenity to provide to office building tenants and can be an important factor to achieve sustainable office building certifications (ex. LEED). Finally, properties specifically geared toward on-the-go, fleet and industrial charging will become more and more prominent.
3. *Oil* demand should lessen as the global car and commercial vehicle fleets become increasingly dominated by EVs. This will be particularly acute from 2030 onward.
4. *Metals and minerals* will also be impacted due to their role in battery production. Demand for lithium and nickel will shoot up so quickly that there is a risk of global supply bottlenecks. Availability of these materials is also an issue, with much of the global supply and manufacturing concentrated in a few countries. Evolving chemistry mixes, increased supply and battery recycling could ease this problem.

CONCLUSIONS

As the world grapples with climate change, the case for electric vehicles grows stronger and stronger. The EV future is a lot closer than we initially suspected. The implications of this transition for the automotive industry, and the automotive ecosystem more broadly, are profound. Nonetheless, there is still a lot of uncertainty, and we must be prepared for multiple possible scenarios. Our research on EVs, which was a cross-asset class collaboration, has helped IMCO better prepare for this future, allowing us to identify risks and opportunities for our current and future investments.

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