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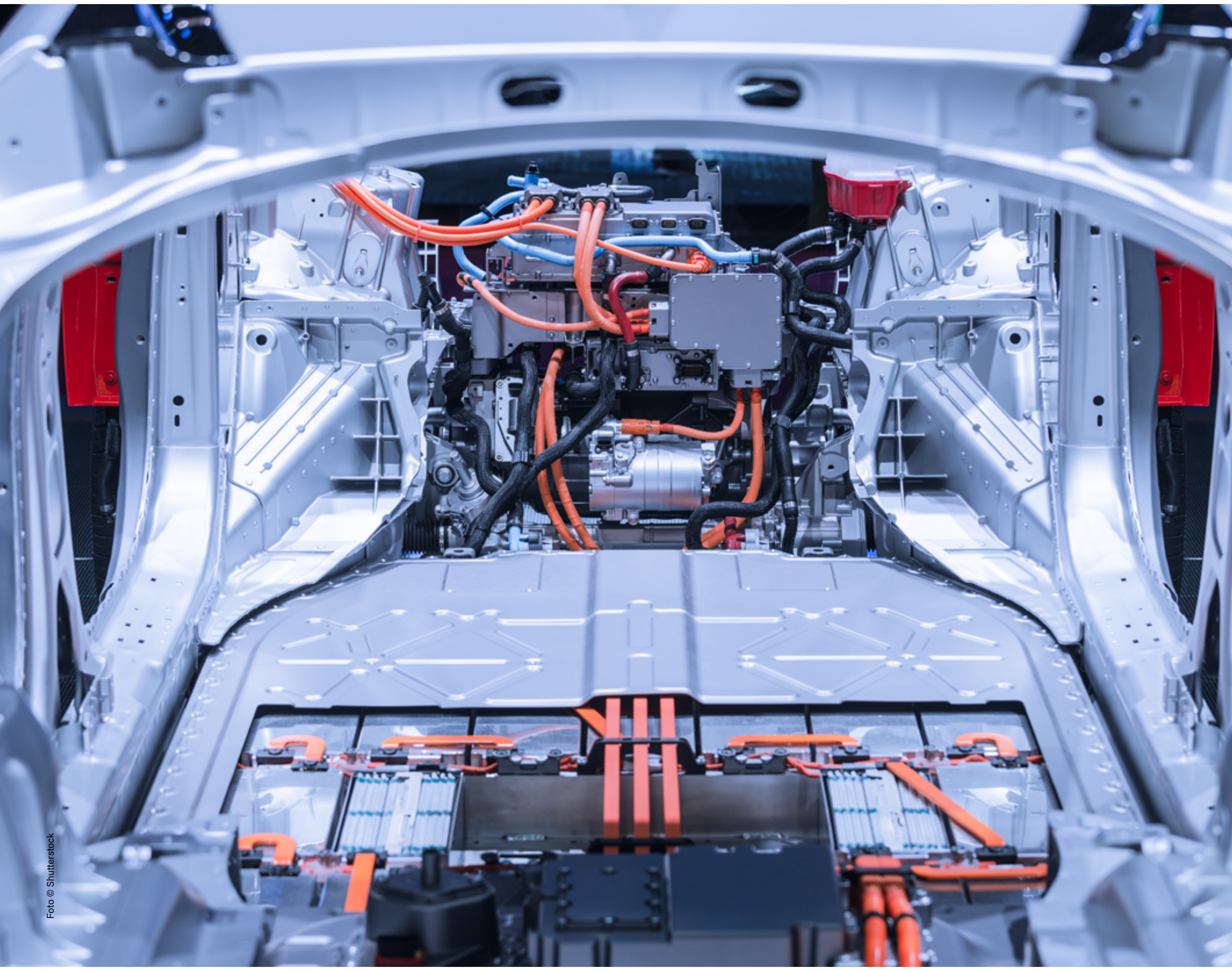

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Rewiring the Automotive Industry: a first step into a bigger revolution

The automotive industry is one of the largest markets in the world, worth almost 6 trillion dollars when including vehicle sales, fuel, and repairs. At the same time, it significantly contributes to the unsustainable depletion of resources and the emission of pollutants, representing a quarter of global oil demand and over 10% of global CO_2 emissions among others. Today, virtually every piece of this massive value chain is being turned upside down by the disruptive return of battery electric cars. In this newsletter, we set out to pick up the threads of the main environmental issues related to automobiles and dig deeper into the risks and opportunities of the electrification trend at a key inflection point.

From horses to batteries on wheels: a brief history of passenger vehicles

For almost 5,000 years, starting from 3,000 BC until the early 20th century, road transportation predominantly relied on animal power. But in the 1800s, things changed. Innovations in technology, vehicle design, and manufacturing emerged, and eventually led to Ford's Model T, a game-changer that replaced animal-powered vehicles. However, before gasoline engines emerged as the winner, three technologies competed in the 1800s:

i. **Steam Engines:** similar to steam locomotives, these engines hinged upon an onboard boiler to generate high-pressure steam, subsequently harnessed to rotate the wheels
ii. **Battery Electric Vehicles (BEVs):** analogous to their contemporary counterparts, these vehicles utilized electricity stored within a battery to power an electric motor, which in turn drove the wheels
iii. **Internal Combustion Engines (ICEs):** in this approach, fuel combusted within a confined chamber generated the pressure to propel the piston which was connected to the wheels

Steam engines were the first technology to be applied to passenger vehicles, emerging as early as the late 1700s. Electric cars followed suit around the 1830s, while internal combustion engine vehicles entered the market last, making their debut in 1886.

Irrespective of the technology, each vehicle type required time to mature into commercial viability. Innovations such as the lead-acid battery and the assembly line played pivotal roles in mitigating technical limitations and driving down costs. By the late 1800s, all three solutions were available on the market, albeit not at accessible prices, and each with distinct drawbacks: steam engines suffered from prolonged startup times, BEVs exhibited limited range, and ICEs necessitated manual cranking for ignition. In 1900, out of the few hundred vehicles in the United States, steam-powered automobiles constituted 40%, electric vehicles 38%, and gasoline-powered vehicles 22%. However, the initial two decades of the 1900s witnessed unprecedented advancements in internal combustion engine technology, characterized by the introduction of the electric starter to replace manual cranks, noise reduction through mufflers, and enhanced efficiency. Ford's adoption of this technology and the implementation of assembly line production, democratized access to ICE vehicles. Consequently, by 1930, steam and electric car makers had either shut down or switched to gasoline engines. The success of ICEs was followed by a century of incremental improvements, increasing penetration, and growing sales.

Figure 1: Thomas Edison with an electric car, 1913

For decades, battery electric vehicles were largely abandoned, until the confluence of three distinct trends triggered a resurgence of interest in the technology: dramatic cost reductions in lithium-ion batteries driven by the growing adoption in consumer electronics, concerns about air pollution and climate change and the exponential growth of solar and wind power that could provide clean power for charging. The launch of the Tesla Roadster in 2008 marked the birth of a new generation of BEVs powered by lithium-ion batteries. Fast forward 15 years, from around 20'000 vehicles sold in 2010, global BEVs sales are projected to surpass 10 million units (ca. 13% of market share) this year, a growth rate of over 60% per year. This adoption trajectory stands unparalleled in the annals of the automotive industry. The pivotal question emerges: does this powertrain shift denote a singular turning point within the industry, or is it an integral facet of a broader revolution fueled by considerations of environmental sustainability?

Cars and the environment: key issues and solutions

The automotive industry, which includes passenger cars and light commercial vehicles, employing 7% of all workers in Europe directly or indirectly and ~60 million people globally. When including fuel and repairs for a global fleet 1.3 billion vehicles strong, the total value of this market is over 6 trillion dollars. However, because of its scale and intricate supply chain, the automotive industry and its fuel related adjacencies, exert significant environmental pressures. At Ambienta we categorize those impacts in two distinct categories: those arising from resources consumption and those related to pollution.

A. Resources:

i. **Energy:** internal combustion engines only convert 15-40% of the energy in the fuel into useful energy, with the remainder released as heat. A quarter of the

100 million barrel/day of global oil demand comes from passenger vehicles, but far more than half of that is completely wasted.

ii. **Materials:** cars represent a significant share of the demand for various materials, particularly steel, representing ~10% of global demand, but also copper, glass, plastics, and others. Consumers' preference shift towards larger SUVs has escalated material consumption, effectively counteracting the progress made through lightweighting.

b. Pollution:

i. **Air Pollution:** despite advancements in exhaust gas treatment systems, even modern internal combustion engines continue to generate air polluting emissions. The European Environment Agency estimates that over a third of nitrogen oxides (NOx), ~20% carbon monoxide (CO) and around 10% of particulate matter, among other pollutants, is emitted by road transport. These particles, according to the UN, cause around 7 million deaths per year and a variety of health issues including aggravated asthma, reduced lung capacity, pneumonia and bronchitis. That's as many people died from Covid since 2020, every single year.

ii. **Greenhouse gases (GHGs):** the direct release of CO_2 from tailpipes accounts for 7-8% of global GHG emissions. When including emissions from oil extraction and refining, as well as those related to the materials used in the manufacturing of the vehicle, the figure is well above 10%.

Solutions: As we write, the electrification of vehicles represents just one bit of a broader yet less visible technologically enabled transformation that is reshaping the automotive value chain. Innovations originating outside the car industry have pushed the competition beyond its traditional boundaries of propulsion and comfort, challenging competences of OEMs as well as operations. Several trends have emerged at the crossroads of technological innovations, growing consumer awareness of environmental and health issues and political agendas. At least four stand out for the profound impact on the way we build, sell and use cars as well as the potential of steering the industry towards a considerably more sustainable trajectory.

a. **Car sharing:** cars are utilized for only 5%-10% of the time, parked idly for the remaining 90%-95%. Vehicle sharing can reduce the number of vehicles needed, with studies suggesting that each shared vehicle can substitute 5-15 cars. Moreover, shared fleets tend to exhibit a lower average age compared to private counterparts, thus being typically more efficient. However, despite the clear environmental benefits and a growing fleet with over 500'000 vehicles globally, examples of very successful and profitable business models are lacking. The confluence of factors such as intense competition from alternative urban shared mobility modes – think scooters, electric bikes, and ride-hailing services –, the surge in remote working and heightened hygiene concerns following the pandemic, has undermined the expansion of an exceptionally sustainable approach to individual mobility which was in hype five years ago.

b. **Autonomous driving:** Autonomous driving offers environmental benefits akin to car sharing, as both aim to slash individual car ownership by boosting vehicle utilization rates. Following an initial hype driven by unrealistic time-to-market expectations, a fatal 2018 accident involving an Uber self-driving vehicle and a cyclist prompted a shift towards prioritizing safety considerations, slowing down progress. Nonetheless, progress has been substantial since then: Waymo and Cruise vehicles are already transporting paying customers to their destinations autonomously in select cities, Tesla continuously updates its Full Self Driving software and Baidu has secured a driverless taxi license in Shenzhen, China. These operators have ambitious expansion targets and their safety records, despite concerns, are well above that of human drivers. While technology itself, despite ongoing refinement, no longer stands as the primary barrier to autonomous driving adoption, untested business models and the regulatory and insurance framework remain as challenges. Though not yet mature enough for direct investment in our strategies, the ramifications of this trend in the value chain necessitate thoughtful consideration when contemplating investment horizons spanning 5 to 10 years.

c. **Lightweight materials:** The automotive industry has long embraced the utilization of lighter materials to curtail both material and energy consumption. Practices like integrating high-strength steel and aluminum have effectively countered the augmented size of vehicles, a phenomenon accentuated by consumer preferences. Notably, in Europe, the shift towards SUVs has propelled the average car weight upwards by 100 kg over the past decade, and lighter materials mitigated the increment which would have otherwise been twice as high. Other materials on the other hand, such as carbon fibers, have failed to achieve mass-market adoption and are primarily

Figure 2: Phoenix's Mayor riding in a Waymo autonomous vehicle, December 2022

used in low-volume sports cars due to challenges in scaling and automating production to drive down costs. The lightweighting trend is set to accelerate with electrification: to offset the increase in weight of the battery, BEVs typically incorporate 40-90% higher content of aluminum than ICEs. Ambienta's rationale for investing in Phoenix in 2019, a company specializing in the production of extrusion dies for aluminum components, was firmly rooted in the recognition of this very opportunity.

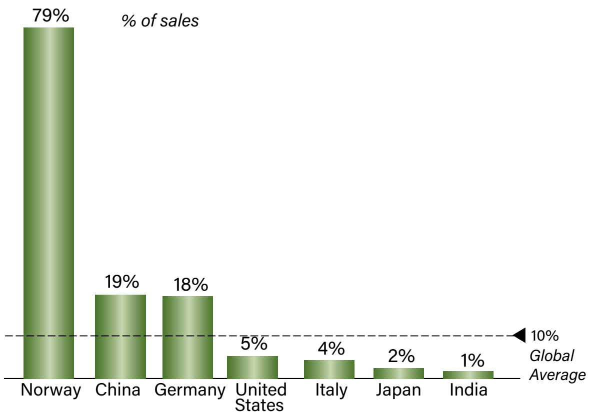
d. **Electrification:** to effectively eliminate direct CO_2 emissions and significantly curtail air pollutants, transitioning away from the conventional combustion engine is the only viable option. Two distinct alternatives exist: the first entails direct electrification through batteries and electric motors, while the second involves indirect electrification via green hydrogen and fuel cells. While some OEMs, particularly in Japan, continue to pursue indirect electrification, the market is clearly favoring direct electrification: in 2022 a mere 15'000 hydrogen fuel cell cars were sold, a fraction of the over 7 million BEVs. The rise of the electric car is driving and will continue to drive profound changes across the entire automotive value chain, which we explore in the next section.

Electrification: Reshaping the Automotive Value Chain

The trajectory of BEV adoption is unmistakably exponential, surging from just 1% of total passenger car sales in 2018 to nearly 10% in 2022. The global average data however hides profound regional differences, from Norway's 80% to Japan's 2%. A combination of government incentives, investment in charging infrastructure, consumer habits and cost of electricity are the main reasons for these wide variations.

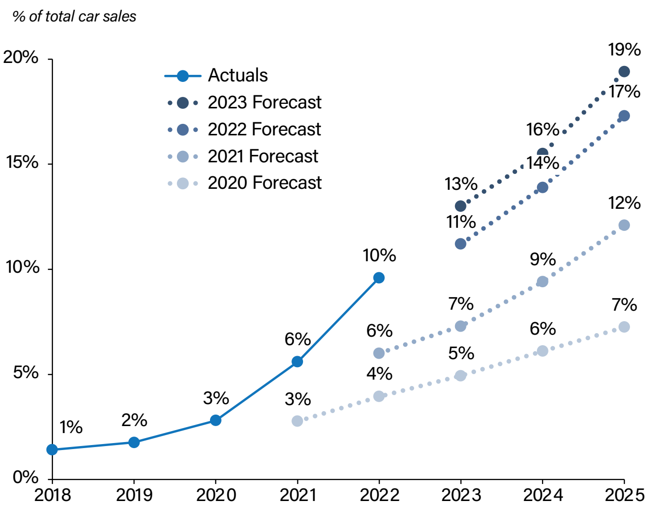
The explosive growth of BEVs surprised most analysts who, as usual, were projecting linearly growing adoption. We pointed to an upcoming boom in sales back in 2017 during one of our Annual General Meetings, but just 2 years ago, most forecasts expected BEV sales in 2022 to be 4%, less than half of the final figure. Graph 2 illustrates how actual penetration rates consistently outpaced expectations, prompting a constant upward revision of forecasts. While indications suggest a slight deceleration in the growth rate for 2023, we believe that the most widely cited estimations of 35-45% penetration by 2030 remain excessively conservative, premised on a linear extrapolation of the trend (IEA, BNEF, and UBS in Graph 3). Declining ICE sales volumes will threaten OEMs' economic incentive in continuing to develop and promote new models, accelerating the technology transition consistently with the adoption patterns in other industries in the past.

Graph 1: Battery Electric Vehicle Penetration by Country



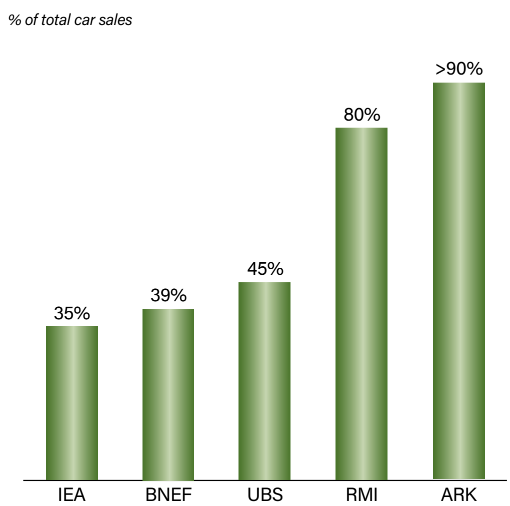
Source: Ambienta Analysis on UBS and BNEF data

Graph 2: Global BEV Penetration



Source: Bloomberg New Energy Finance

Graph 3: Global BEV Penetration Forecasts in 2030



Sources: 2023 BEV outlooks from International Energy Agency, Bloomberg New Energy Finance, UBS, Rocky Mountain Institute, ARK Invest

This exponential growth is enabled by the continuous improvements of the technology that will overcome what until today have been barriers to adoption. Nonetheless, the transition will bring social and economic consequences that cannot be ignored.

a.Overcoming Barriers to Adoption

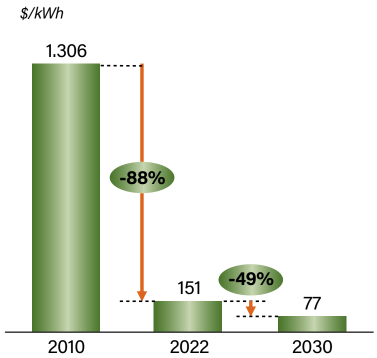
BEVs' rapid growth is supported by swift improvements in performance that have recently reached tipping points for mass market adoption, eroding barriers to adoption.

i. **Cost:** while historically cost competitiveness was driven by generous government incentives, BEV prices are catching up. In 2012, a Tesla Model S was priced at 57'000 $, while the average US vehicle was priced at around 31'000$. Today, a Tesla Model 3 starts at 40'200$ compared to the national average selling price of 46'400$, and sells at a very competitive 32'700$ with incentives. Price parity has already materialized in China, where average BEV prices are 30% below gasoline. These remarkable cost reductions have been underpinned by a trio of influential factors:

   1. **Cost of batteries:** over the past 10 years battery costs have plummeted by 80% as shown in Graph 4, diminishing at a rate of ~20% for every doubling in capacity.
   2. **Advances in power electronics:** the adoption of Silicon Carbide-based inverters improves vehicle energy efficiency, enabling a reduction in battery size for the same range, driving down costs.
   3. **Vehicle design for manufacturing and scale:** BEVs have an inherently simpler architecture, with ~30% fewer parts than ICEs. With growing production, the reduction in manufacturing complexity is starting to make a difference in the assembly costs. At the 2023 investor day, Tesla disclosed that the cost to produce a Model 3 was cut by 30% between 2018 and 2022. We anticipate these cost reductions to continue and eventually make BEVs cheaper than ICEs in all segments. Decades of optimization have refined ICEs' architecture for mass production, while battery technology, power electronics, and BEV designs are still in their nascent stages, poised for improvements with every successive model and the expansion of scale.

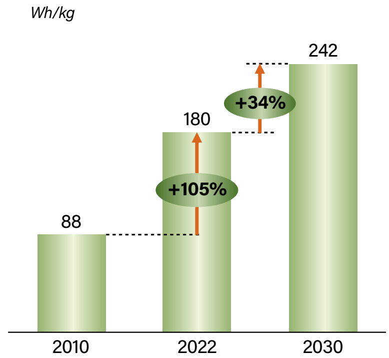
ii. **Performance:** range and charging times are the key performance indicators that consumers look at when comparing ICEs and BEVs. The energy density of batteries has doubled since 2010 (see Graph 5), and range has followed. In the US in 2022 there were 14 models with over 300 miles (~500 km) of range, up from only 3 in 2019. That's more than enough to cover most real driving needs considering that around 60% of trips in the US are under 6 miles. Improvements are set to continue if not accelerate in this field as well: CATL is already putting in production cells with twice the energy density of Tesla's and further benefits are set to come from solid state batteries. Vehicles with the option of 1'000 km range or less than 15 minutes charging times are likely to be on the road before the end of the decade, finally putting an end to the much debated "range anxiety".

Graph 4: Average Batttery Pack Prices



Source: Bloomberg New Energy Finance

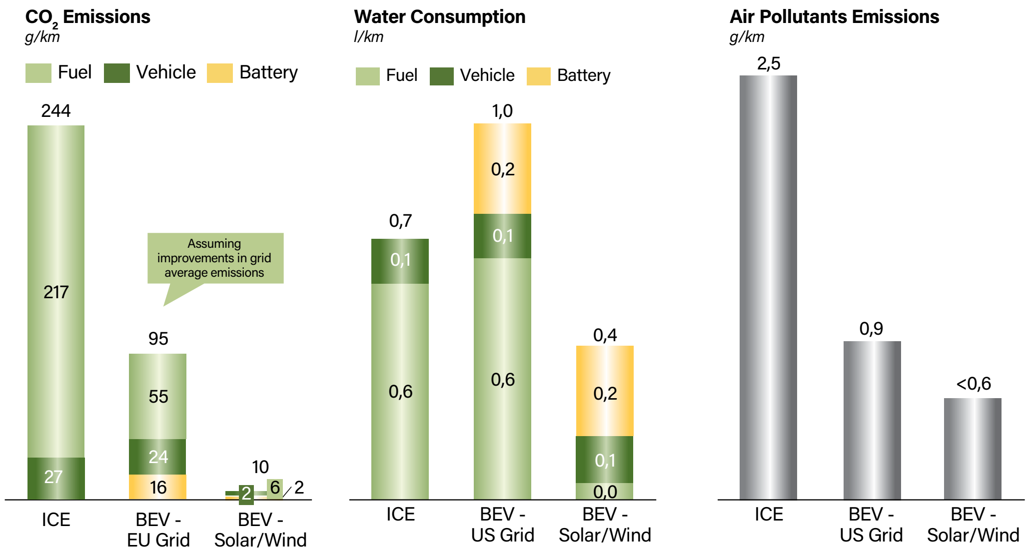
Graph 5: Average Batttery Pack Energy Density



iii. **Infrastructure:** to cope with the lower range and longer charging times than ICEs, BEVs users need to rely more on charging infrastructure. While it still represents a barrier to adoption in some countries, the charging network is being rolled out at a rapid pace: as of Q2 2023, public charging points in Europe exceeded 500'000 units, tripling in just three years. Furthermore, the need for public charging might have been vastly overestimated. Germany has recently debated whether to reduce its public charging targets since the observed ratio of home charging to public charging has been of 10:1. If the trend continues, by 2030 Germany would need half of the 1 million public charging point currently targeted.

iv. **Environmental impact:** a popular counterargument in certain geographies is that EVs environmental benefit are poorer than claimed if not worse than ICEs. Arguments like CO_2 emissions savings being overstated, water consumption being huge due to lithium production, batteries end of life being a terrible pollution issue, and so on. Even if we recognize complexities inherent in lifecycle assessments, we believe there is growing those arguments are flawed by unrealistic assumption and poor understanding of market dynamics. For instance, calculating the CO_2 emissions over a BEVs lifetime based on the present emission factor of the power grid is an unrealistic premise. The power sector CO_2 emissions factor has consistently declined by 1% annually at a global level over the past decade, propelled by the integration of renewable energy sources - an undeniable and accelerating trend. Not assuming batteries will be recycled is another flawed hypothesis: even though batteries contain potentially polluting materials, those are worth thousands of euros and already today nearly 100 companies in North America and Europe are engaging in lithium-ion battery recycling. In the case of water, arguments against BEVs focus on the water consumed in extracting lithium from brines but fail to point to the fact that oil production is even more water intensive: when looking at the water consumption per km over the life of the vehicle, the impact of the battery is 1/3 of that of the fuel for an ICE vehicle (see Graph 6). Generating electricity from fossil fuels also needs large amounts of freshwater for cooling, which is why today grid-charged BEVs are more water-intensive than ICEs. But when powered by renewable electricity, BEVs decidedly outperform ICEs across all environmental metrics (see Graph 6). As mounting evidence in favor of environmental sustainability accumulates, we anticipate that arguments against the environmental impact of BEVs will gradually disappear.

Graph 6: Environmental Impact Comparison



Sources: Ambienta analysis on data from US Department of Energy, US Congressional Research Service, Argonne National Laboratory; "The Underestimated Potential of Battery Electric Vehicles to Reduce Emissions"

b. Impacts on the Value Chain, Challenges and Opportunities

The outlined trends are driving transformative shifts along the entire automotive industry value chain, explored below.

i. **Earthquake in key raw material markets:** currently the most used raw material by passenger cars is, by far, oil. Accounting for ~25% of global oil demand, cars consume 1 billion tons of oil every year. The second most used material in cars, steel, is used 5x times less. As BEVs do not need oil, every 50 million BEVs on the road destroy around 1 million barrels per day of oil demand. At the end of 2022 there were less than 20 million BEVs growing 50% per year. This trend would bring by 2030 more than 300 million BEVs on the road, displacing over 6% of global oil demand. The actual impact is likely to be much higher given that most utilized vehicles (taxis, ride-hailing vehicles, rental fleets) are switching to BEVs faster than private vehicles. In China for example, ride hailing vehicles are already around 40% electric compared to 5% for the overall fleet, and Sinopec, China's largest oil refiner, recently forecasted peak gasoline demand to be already this year, two years earlier than previously announced. On the flip side, demand for the materials needed for batteries, lithium, nickel, manganese, cobalt, are growing at breakneck speeds, creating investment opportunities in extraction and refining. The current dominant role of China represents a clear concentration risk, with over 50% of lithium refining and over 75% of battery cell production. Mining and material reserves however are not concentrated in China: over 50% of lithium for example is mined in Australia, and the largest lithium reserves are in Chile. Therefore, China does not have any natural advantage in terms of control of the materials but has built an edge by building and scaling the refining and processing capacity. Western governments have realized the strategic importance of raw materials supplies and are incentivizing the development of local battery supply chains thus creating interesting opportunities for companies and investors.

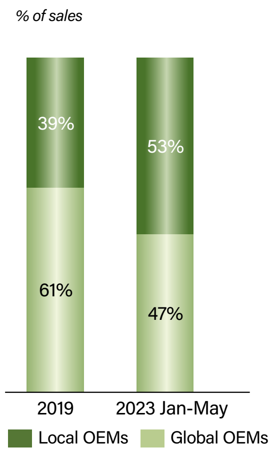
ii. **Global manufacturing shifting to Asia:** for a hundred years, automotive OEMs have consolidated without new meaningful entrants. But over the past 10 years, a century of investments in improving the

Figure 3: BYD's pop-up store for its Italian launch in Piazza Duomo, Milan, August 2023

combustion engine was devalued as BEV technology opened the road to new entrants. And the newcomers have taken full advantage of the opportunity: BYD has surpassed Volkswagen's sales in China and is now aggressively entering the European market; Tesla's Model Y was the best-selling car globally in Q1 23 surpassing the Toyota Corolla. Even in their home markets, legacy Western OEMs are now facing a serious threat from lower-cost Asian manufacturers. As Carlos Tavares, the CEO of Stellantis, has warned, "The price difference between European and Chinese vehicles is significant. If nothing changes, European customers from the middle class will increasingly turn to Chinese models." The European Commission has promptly responded, recently announcing an investigation on the support the Chinese government is handing domestic BEV manufacturers and threatening increased import tariffs.

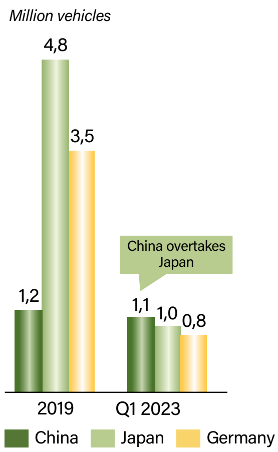
iii. Social costs: the transition to electric vehicles will undoubtedly cause a major dislocation of jobs. Yet, when viewed within the broader context of the energy transition, numerous sources anticipate a positive net employment impact, even within the automotive industry as a reduction in jobs in vehicles assembly is more than offset by new jobs in charging and power generation installation and maintenance. Nonetheless, two key issues remain. Firstly, jobs created will require a different skillset than jobs made obsolete, and therefore efforts to retrain the workforce will be necessary to fill the skill gap. Secondly, a disparity in geography is likely to emerge between the locations where new jobs are generated and those where jobs are lost. As Chinese OEMs emerge as the likely new winner of the BEV transition, Western governments should plan how to attract local manufacturing of these brands to retain jobs or retrain toward installation and maintenance. Prolonging subsidies for legacy jobs, apart from offering short-term political consensus, seems counterproductive in comparison to embracing the transition and supporting the jobs of the future.

Graph 7: China- Domestic Car Sales By OEM Origin



Source: Automobility

Graph 8: Car Exports By Country



Source: AlixPartners

Investment opportunities

As is often the case in fast-growing industries, investing in the electrification of cars can be tricky, with the opportunity to have outsized returns on one side but the risk of spectacular failures on the other. Disproportionate valuations for unprofitable, unproven businesses seldom generate attractive risk-return profiles in the long run while might be amazing short-term trades. Vehicle charging businesses, for example, have been hot but debatable investments in the past couple of years, as stock prices of the main listed players are down 70-90% and profitability still not in sight. Hydrogen related stocks followed a similar path, declining also 70-90% after the 2020-2021 hype which we warned against in our *dedicated newsletter*.

Further complicating investment considerations is autonomous driving: as the uptake of this technology is highly dependent on regulation and public perception, it's difficult to predict the outcome. In a country like China, the largest auto market in the world, a top-down decision to promote self-driving taxis could disrupt the traditional business of making and selling vehicles to consumers. Model variety, aesthetics, brand equity, and dealership networks all drastically lose value when the vehicle becomes part of a remotely operated fleet, and the lowest total cost of ownership is the only metric that matters. This dynamic would favor a swift adoption of BEVs as they are cheaper to operate than ICEs, but it would also have a negative effect on the overall number of vehicles sold by drastically increasing the utilization of vehicles. Long-term investors with 5+ years horizon need to take these considerations into careful account. There are a few ways to invest in the electrification trend across geographies and different steps of the value chain, but according to Ambienta's research, not all offer a balanced risk return profile. Due to the size of the industry, opportunities are more frequently found in our public market strategies than in our private equity funds.

- **Power semiconductors:** marginally used on internal combustion vehicles, power semiconductors become critical for the performance of BEVs, and their content gradually increases in hybrids, plug-in hybrids and BEVs. Therefore, regardless the speed and the extend of the electrification trend, their market will expand faster than the overall automotive market. High barriers to entry in terms of capital, technology and access to customers have resulted in a highly consolidated industry with a few dominant players like Infineon, STM, OnSemi and Texas Instruments. All these players also supply chips that enable autonomous driving and would therefore see a further increase in content per vehicle in case of greater adoption of this technology. Here we believe investors can find the most attractive opportunities in terms of risk/returns.
- **Batteries:**
  - **Cells and packs suppliers:** batteries are the most expensive component of a BEV. They are mission critical components with high barriers to entry and a highly concentrated market with the dominant suppliers, CATL, BYD and LG Chem, holding 2/3 of the global battery market. However, due to geopolitical risk and the lack of upside from a potential uptake of self-driving, we see a less attractive opportunity in this space
  - **Materials suppliers:** further up the battery value chain, miners and refiners of battery materials offer another interesting investment opportunity. Lithium in particular is seeing and will continue to see a strong demand growth as BEVs gain market share, but volatile material prices have a direct impact on stock prices. Major pure-play lithium mining players include Albemarle and the upcoming Livent-Allkem merger.
- **Electrical equipment suppliers:** another category of companies with rising content per vehicle, cables and connectors producers that are already supplying ICEs are seeing the value and importance of their products grow on BEVs. Similarly, electric motors and their subcomponents, which were already used on vehicles for secondary applications (window lifting, power steering, etc.), become a core component when used for traction. Public companies in this space include Amphenol, Aptiv and TE Connectivity and the recently listed Eurogroup Laminations, an example of a successful private equity project in this sector. Here we believe are the most interesting untapped opportunities for private market investors.
- **OEMs:** picking the winning OEM is not easy. New entrants in car manufacturing focused on electric vehicles are rapidly gaining market share and are demonstrating a significant cost advantage thanks to vertical integration, as evidenced from Tesla's industry leading margins and BYD's very competitively priced products. The new players, including the Chinese such as XPeng, Nio and Li Auto, are also leading when it comes to autonomous driving, but valuations are demanding. Legacy OEMs on the flip side have very attractive valuations, but we believe that not all will survive the next 5-10 years.

Conclusion

Passenger cars carry a range of environmental concerns, notably contributing to over 10% of global CO_2 emissions when factoring in both fuel and materials supply. The swift electrification of the automotive sector offers a clear positive impact on curtailing energy consumption, mitigating air pollutants, and reducing CO_2 emissions. The inflection point of battery electric vehicle (BEV) performance has been crossed, paving the way for an inevitable wave of mass adoption. However, it's crucial to recognize that not all businesses linked to BEVs will translate to sound investments.

The imperative to identify sustainable competitive advantages across the BEV supply chain, particularly in the context of a complex global macroeconomic landscape and trade tensions, remains paramount, consistent with Ambienta's research-driven approach. While we celebrate the growth of BEVs, we continue to observe the evolution of autonomous driving and other industry trends, anticipating the emergence of the next wave of revolutionary change.

ABOUT AMBIENTA *Ambienta is a European environmental sustainability investor across private equity, private credit and public markets. Operating out of Milan, London, Paris and Munich, Ambienta manages over €3.0 billion in assets with a focus on investing in private and public companies driven by environmental megatrends and whose products or services improve Resource Efficiency or Pollution Control. In private equity Ambienta has completed 66 investments to date. In public equity markets, Ambienta has pioneered one of the world's largest absolute return funds entirely focused on environmental sustainability and manages a full suite of sustainable products ranging from low-risk multi-asset funds to equity long-only. Ambienta has also recently established a private credit strategy with the same environmental sustainability focus as the other asset classes.* ***www.ambientasgr.com***