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The Second Dawn of Electrification: An Electrified Future for Personal Transportation

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Arm has engaged Strategy Analytics as a partner in the preparation of this report to validate the hypothesis that the emerging market for electrified vehicles will soon change to a mass market, with profound implications for the entire automotive value chain. Tomorrow's electrified vehicle will use fewer, higher-performance compute units and have strong synergies with automated driving trends. These models will be at the forefront of the trend to separate hardware and software.

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The electrified vehicle market has seen many false dawns. In the late 19th century, the first six holders of the land speed record were all electrically-powered. Around 100 years later, the GM EV1 offered the promise of a new generation of mass-market electric vehicles – only for the promise to disappear again. However, by 2027, Strategy Analytics expects that electrified vehicles of all types will make up approaching 40% of global light vehicle output. Things are thus very different this time around, argues Ian Riches, VP – Global Automotive Practice at Strategy Analytics, and an electrified future for vehicle transportation is now well within reach.

Market Evolution

It's still the case that pure battery electric vehicles (BEVs), which have no combustion engine in them, are still very much in the minority. In 2019, less than 2% of light vehicle production was accounted for by these models. Hybrids, of all types, had much greater volumes, with full-hybrid models such as the Prius the most common type, accounting for over 3% of total output in 2019. These full hybrids are joined by mild hybrids (around 2.5% of 2019 volumes) and plug-in hybrids (just under 2% of volumes) giving a total of around 8% of global light vehicle volumes being hybridized in 2019.

- Mild hybrids (MHEVs) are models where the electric drivetrain is typically less than 20kW in output, and is used just for torque assist rather than powering the vehicle on its own. Many newly-launched models use a 48V system.

- Full hybrids (FHEVs) are models where the electric drivetrain is sufficiently strong to power the vehicle on its own for very short periods (limited by the size of the battery), but are not capable of being plugged in to re-charge. The battery is charged either directly by the engine or via energy recuperation whilst decelerating.

- Plug-in hybrids (PHEVs) have the same powerful electric motors as full hybrid models, but can also be plugged in to recharge. They typically offer an electric-only range of around 50km.

Strategy Analytics now sees the full hybrid market as near its peak in terms of penetration rate. Most OEMs are not developing new full-hybrid models, instead focusing development on more cost-efficient mild hybrid models, plug-in models that offer electric-only operation or pure battery electric vehicles. Essentially, full-hybrid models are now not the most cost-effective way for carmakers to meet forthcoming emissions and fuel economy targets. Mild hybrid models can offer some of the gains but at a substantially lower cost. Plug-in models offer much greater improvements in efficiency on government tests. The latest testing standard used in Europe, South Korea, India and Japan is the "Worldwide Harmonized Light Vehicle Test Procedure", or WLTP. This aims to more closely replicate real-world fuel economy and emissions that its predecessor, the New European Driving Cycle (NEDC) did. Based on this new standard:

- The current Toyota Prius full hybrid offers WLTP CO2 emissions of 104 to 107 g/km, depending upon specification.

- The Ford Puma 48V mild hybrid offers WLTP CO2 emissions of from 125 g/km – compared with 132 g/km for the non-hybrid model. This may seem a small improvement – but the price increase for the mild hybrid model (less than £300 in the UK) is also very modest. The low-cost of the technology means that it is offered on the majority of the model line-up.

- The new Skoda Octavia iV PHEV offers WLTP CO2 emissions of around 30 g/km, as well as significantly more power and performance than the Prius.

Both mild hybrids and plug-in hybrid models will see growth over the coming years, as OEMs seek to meet both consumer demand and emissions targets. Some vehicle segments (especially larger models) could see gasoline mild hybrids becoming the default base-model option, as diesel is gradually displaced from the market.

Plug-in models offer consumers an excellent blend of the flexibility and range of a combustion-engined model alongside sufficient EV range for many daily driving tasks. They will remain a popular choice for many consumers for as long as the recharging infrastructure means that it is more time and effort to recharge a battery electric vehicle than to fill a combustion-engined vehicle with gasoline.

Their key drawback is cost – as they require two drivetrains. As battery technologies improve, allowing lower-cost and longer-range BEVs, Strategy Analytics expects to see PHEV consumers who have regular and easy access to recharging infrastructure start to move across to BEV models.

This leaves hydrogen-powered fuel cell vehicles, which Strategy Analytics expects to still have a very small part of the light duty vehicle market in 2027. The key challenge here is the infrastructure, and who will pay for the hydrogen filling stations that will be required. There will be some global hot-spots for this technology (e.g. Tokyo) – but it will likely remain niche. For medium and heavy-duty commercial vehicles, which typically refuel at a company depot (e.g. buses), the outlook is more promising. These depots could be incentivized to switch from the diesel they offer today to hydrogen.

By 2027, Strategy Analytics thus expects global production of electrified light-duty vehicles models to have reached around 40 million units, as shown in the Figure 1 below.

Growth of all xEV technologies will be significantly held-back in 2020 due to the shutdown of many global economies as countries deal with the COVID-19 coronavirus crisis, but Strategy Analytics expects a strong recovery in 2021.

The 2027 market for electrified models is thus expected to comprise of around:

- 13.0 million MHEVs, which will be 48V-based.

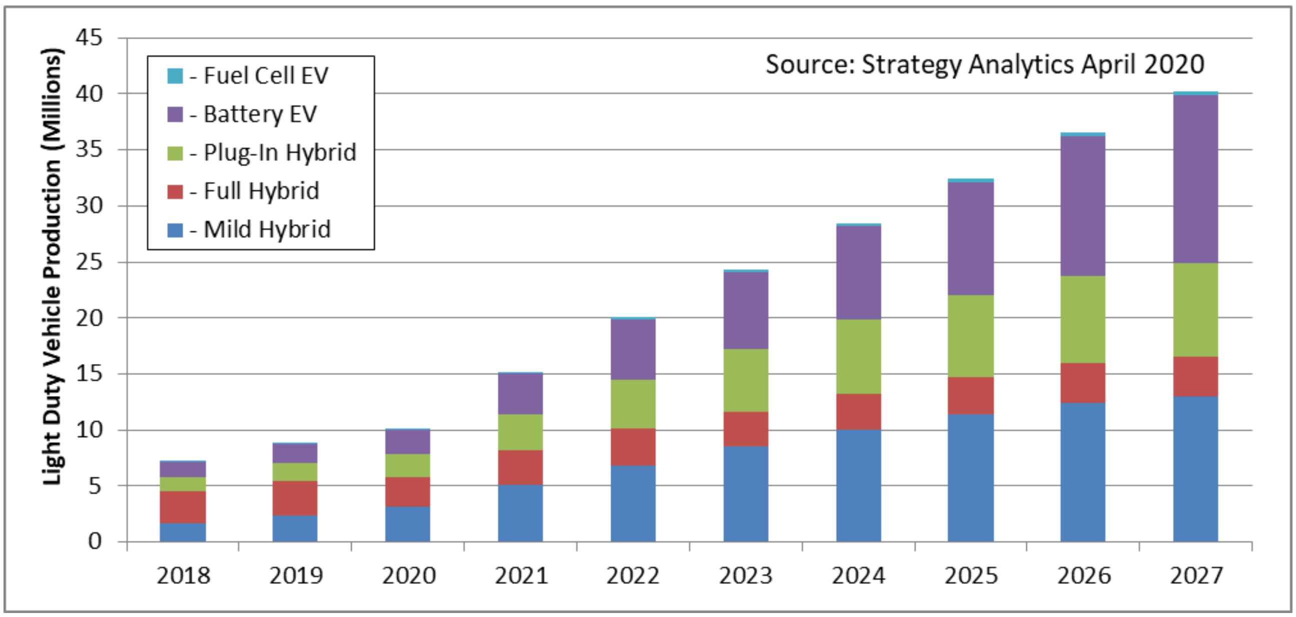
- 3.6 million FHEVs. This market segment is static and will then likely soon start falling off as OEMs and consumers move to other electrified model types. However, the full hybrid will still make sense for anyone with very limited or no access at all to recharging infrastructure

- 8.4 million PHEV models. Looking longer-term, Strategy Analytics expects plug-in hybrids to peak in mid 2030s, at a relatively low level. It could be argued that the plug-in hybrid only exists because the affordable 500km+

range electric car, along with suitable recharging infrastructure, does not yet exist. Reasonable projections for battery technology suggest that this is feasible in the mid-2030s, if not before. Therefore, for the vast majority of consumers there will be no need to purchase a PHEV. The BEV of the future will offer everything that they need.

- 14.9 million BEVs, making them the most popular electrified vehicle type. This is especially expected to be the case in China.

Figure 1 Global Production of Electrified Light Duty Vehicles



So What's Driving the Electrification Trend?

One of the key factors driving the electrification trend is regulation. For years, carmakers across the globe have needed to meet ever-tightening targets for fuel economy and exhaust emissions, and these will soon be impossible to meet without a significant portion of their fleets becoming electrified.

In recent years, these limits on the polluting-impact of combustion engines have been strengthened by governments announcing or accelerating plans to stop the sale of gasoline and diesel models. One example is that in February 2020, the UK government announced plans to ban the sale of new gas, diesel and hybrid vehicles from 2035, five years earlier than planned.

Incentives are also playing a key part in helping the market to develop. As the world recovers from the economic impact of COVID-19, Strategy Analytics expects that many governments will offer incentives to help restart the car market. After the financial crash of 2008 these were typically "cash for clunker" type scrappage schemes. Forthcoming schemes are, in the opinion of Strategy Analytics, highly likely to focus on "cash for combustion", where consumers are encouraged to move out of their gasoline- and diesel-only models into electrified ones.

Some car makers may seek respite from forthcoming exhaust emission and fuel economy targets, but Strategy Analytics expects strong resistance from most governments to such an approach. Any state support for car makers is highly-likely to be heavily tied to supporting the continued roll-out of electrified models.

One key exception to this general rule could be the USA. It has low and falling gasoline prices and the current administration does not see climate change as the threat that much of the rest of the world perceives it as. However, as powerful as the USA is, it accounted for less than 20% of global light vehicle volumes in 2020. China accounted for almost 30% of sales. Although we may see some program cancellations and delays of xEV models from US-centric carmakers. Strategy Analytics believes that their need to compete globally and remain relevant in China will ensure that electrification very much remains on the agenda, even in the USA. It's worth remembering that the USA remains Tesla's largest single market. As its model range expands to lower price points and to include the pickup trucks and crossovers favored by many Americans, the US domestic automakers will come under increased competitive pressures.

Alongside these impacts of government and regulation, consumer attitudes towards subjects such as global warming are now changing. Movements such as those spear-headed by Greta Thunberg are now appealing to an ever-wider mass of consumers, and corporations and industries which are deemed to be dragging their feet when it comes to going carbon neutral are increasingly at risk of protest and boycott. Offering an affordable and wide range of electrified models is thus becoming a vital part of the corporate responsibility and brand image of car makers. In addition, many commentators have noted the rapid air quality improvements that have been gained during COVID-19 lock-downs, in part due to the reduction in combustion-engined traffic. Many consumers and governments alike will be reluctant to give up these gains.

What Will the Impact of Electrification be on the Supply Chain?

As well as the electrification of the powertrain, the car is also undergoing a more hidden revolution. The paradigm for many decades, ever since the application of the first electronics in vehicles, has typically been for one function (e.g. HVAC, transmission control or park assist) to be implemented by a single dedicated electronic control unit. However, today's vehicles can feature well over 100 individual control units, and thus a new networking architecture is seen by many as vital. We can no longer go on adding new control units ad infinitum, and the centralization of features into larger domain or zone controllers is now starting to occur.

It is increasingly software, not hardware which is defining vehicle capabilities and functions. Car makers are thus looking to either develop or buy-in these software modules separately from the hardware blocks on which they will run.

However, architectural change for car makers is both expensive and risky. Strategy Analytics is thus typically seeing the boldest moves being made on new electrified-only platforms. This is especially the case for the many new and emerging carmakers, which have no desire to be hampered by what they see as outdated ways of architecting a vehicle. The electrified vehicle is thus at the vanguard of introducing these new architectures – together with the new ecosystems and ways of working that they require - into the automotive mainstream. As the electrified vehicle accelerates in its deployment, so will more centralized architectures.

There is, of course, another revolution coming for automotive –albeit one still at a very early stage in terms of market deployment. Over the longer-term, it is certain that vehicles will become more and more automated, be it for all or part of their operations. The electric vehicle has huge synergies here as well:

- Currently, refueling a gasoline or diesel model is not a task that can be easily automated. With wireless recharging, a fleet vehicle such as a robotaxi could easily take itself to and from a charging station with no need for human intervention.

- In addition, the new centralized architectures that are finding their way on to electrified models are exactly the solutions required to help enable automated driving. Complex tasks such as sensor fusion and path planning are most easily undertaking in a powerful centralized module that has access to all of the vehicle data.

- It is expected that many first-generation autonomous vehicles will be geo-fenced robotaxi-style models. They will only operate in certain areas, where safe operation can be guaranteed. Any range limitations brought about by an electrified powertrain are thus not as much of a concern, as the use case of these vehicles will not be to travel large distances in a single journey.

- The lower maintenance requirements that are typically seen with an electrified powertrain have many advantages when the vehicle is used as a robotaxi.

Facing the Challenges Ahead

It is thus clear to Strategy Analytics that the coming years will see most automotive growth centered around ever-more electrified models, built on ever-more centralized architectures. This brings huge opportunities to the automotive industry, but also huge challenges.

Many automakers are now starting to regard their gasoline and diesel platforms as “legacy”. It is entirely possible that some of these platforms never get updated with the kind of centralized architectures required to support automated driving. As the new, more centralized architectures start to dominate, this will accelerate the separation of hardware and software. Strategy Analytics expects to see the T1 business models that have existed for the past few decades come under increasing threat, with those that remain successful being the ones that transition successfully to a new more software-centric way of working, where the value of the software created is much more directly monetized than it is today.

Strategy Analytics also expects to see a rise in the use of techniques such as virtualization, which allow multiple operating systems and functions to run safely on a single piece of hardware. This is already happening in the infotainment and cluster space, with consumer-grade operating systems such as Linux sitting alongside more safety-oriented OSes for the cluster, each in its own virtual machine. The use of hypervisors and virtualization can be one solution to easing the problem of code migration.

Despite, or rather because of, this more software-centric future, the correct selection of technologies and partners for in-vehicle processing power will be ever-more vital. The user-experience of even the best software can be ruined by running it on poor hardware. One or two less-than-optimal sourcing decisions amongst the over 100 in-vehicle controllers deployed today will have either negligible, or a highly-limited impact. Getting the compute platform strategy wrong for a domain controller will likely affect multiple and highly-visible areas of the vehicle's operation.

Cars will thus need to be designed and built to be still delighting their passengers many years after leaving the factory, with headroom for new features to be added. It's not just a simple case of specifying the most "powerful" device available on a crude measure such as MIPs, but rather understanding the true nature of the task at hand and the way in which it may evolve in the future. Only then can correct decisions be made.

As well as the architectural challenges that electrified vehicles are bringing, the technology that enables electrification is also bringing its own issues. This is especially the case when it comes to batteries.

Time and again, consumer research has shown that vehicle range is one of the key concerns that purchasers have when it comes to BEVs. 2019 survey work undertaken by Strategy Analytics in the US, China and Western Europe showed that in all three regions, the top concerns of consumers were:

- There are not enough public charging stations
- The battery could run out and I would be stranded
- I might not be able to take long trips

All of these outranked concerns over the price of battery electric vehicles.

Continued development of battery packs is thus vital to the long-term success of BEV models. Improvements in density - both in terms of how much energy can be stored per unit mass and per unit volumes - are ongoing, and the results can already be seen in the market:

- The recent Nissan Leaf e+ 62 kWh variant uses the physically same cells, but with a 55 percent increase in energy density, and enabling the same pack design as the regular 40 kWh variant. Only slight changes were needed, such as raising the vehicle ride height.

Further boosts to battery pack performance are being sought using artificial intelligence and machine learning. This is being applied both in battery pack development, as well as the battery monitoring systems that will be embedded into future production vehicles and the cloud services that will support them:

- A team of researchers at Stanford University, in cooperation with the Toyota Research Institute[i] has recently developed a method of machine learning that is claimed to significantly reduce the amount of time it takes to test batteries. The technique reduced the time taken to test for the optimal charging profile by 98%.
- In 2019, Beijing-based mobility provider DiDi Chuxing equipped a test fleet with Bosch's "Battery in the Cloud" solution[ii]. This is designed to work alongside in-vehicle battery management systems, and has been claimed to cut down on wear and tear of the battery by as much as 20%.

- Work done in a collaboration between the University of Cambridge, A*STAR and Nanyang Technological University in Singapore has concluded[iii] that data-driven machine learning will "be a promising technique for real-time battery modelling in the future."

Conclusions

The future of the car is certainly an electrified one. Governmental and societal pressures mean that 2030 will see around 40% of light vehicles produced being electrified, with that percentage increasing to 95%+ by 2050.

This change will not be without consequences for the automotive industry. Much of the value of today's powertrain will migrate into the hands of battery pack, motor and inverter vendors. Especially in the case of battery packs, it is not the typical T1 suppliers who always dominate in these areas, and new alliances and acquisitions between combustion engine specialists and xEV innovators will surely need to be made.

- Although many larger OEMs have invested heavily in this area to develop their own expertise and capabilities, not all carmakers have either chosen, or been able to afford to follow this path. The support of expert xEV-centric suppliers will remain vital to many automakers.

These new electrified platforms will also typically be at the vanguard of offering automated driving features, as well as pushing innovative and centralized networking architectures into the mass market. As electrification accelerates, so too will the demand from carmakers to separate hardware and software, bringing further challenges to traditional T1 vendors.

The move to centralized processing, with more virtualization and machine learning, will also place more focus on the automotive processor vendors. With the eventual need for a smaller number of more highly powered processors, the selection of these platforms will undoubtedly see higher-level and more strategic decision-making than is commonplace for today's relatively low-value automotive microcontrollers.

- For most carmakers, Strategy Analytics believes that vehicle architectures will evolve over the coming years, rather than making a "big-bang" leap from decentralized to highly-centralized in one go. Maintaining a common processor architecture during this evolution will make migrating software between domains and applications much easier.

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[i] https://news.stanford.edu/2020/02/19/machine-learning-speed-arrival-ultra-fast-charging-electric-car/
[ii] https://www.bosch-presse.de/pressportal/de/en/bosch-extends-the-service-life-of-electric-vehicle-batteries-193216.html
[iii] Ng, M., Zhao, J., Yan, Q. et al. Predicting the state of charge and health of batteries using data-driven machine learning. Nat Mach Intell 2, 161–170 (2020). https://doi.org/10.1038/s42256-020-0156-7