EVS24
Stavanger, Norway, May 13-16, 2009

Powertrain 2020 – Challenges and opportunities for OEMs and suppliers

Michael Valentine-Urbschat[1], Dr. Wolfgang Bernhart
[1]*Roland Berger Strategy Consultants, Mies-van-der-Rohe-Straße 6, 80807 Munich,*
michael_valentine-urbschat@de.rolandberger.com

Abstract

Automotive OEMs and suppliers should prepare themselves for a major shift in powertrain technology. Stricter emission requirements and rising gas prices mean that new solutions are needed. And these solutions are within grasping distance – thanks to breakthroughs in Li-Ion batteries and an increasingly developed charging infrastructure. When will cars start having batteries? The exact point in time is hard to predict, but few doubt that it will come. We present an overview of current developments in technology and their potential impact on both OEMs and suppliers.

Keywords: ELECTRIC VEHICLES, TECHNOLOGY, MARKET, OEMS, SUPPLIERS

1 The final rise of the electric car

When GM cancelled its EV1 program in the US in early 2003, all hope of a successful market launch for electric cars seemed dead and buried. The only viable prospect for zero-emission vehicles appeared to be hydrogen or fuel cell powertrains.

That changed, however, with the breakthrough in Li-Ion batteries used in mobile devices and rapid progress in their application in vehicles. Action taken by companies to create the required charging infrastructure, and the appearance of mobility services with a strong customer focus, such as those offered by Better Place, have substantially raised the chances of wide market success for electric vehicles in the coming years.

Numerous manufacturers of batteries are now busily increasing production capacity so that they can achieve the required volume production of Li-Ion batteries. These batteries mean that the first serious electric vehicles – e.g. the Mitsubishi MiEV – can travel distances of well over 100 km. At the same time, improvements of 50% in the energy density of Li-Ion batteries are widely expected, accompanied by a significant reduction in production costs. And if gasoline prices continue to rise, the differences in running costs will also shift in favor of electric vehicles in the medium term.

Initial test drives show that leading automakers – Mitsubishi, General Motors, Renault and Daimler among them – are planning to launch highly attractive electric vehicles somewhere between 2010 und 2012. This new generation of vehicles should quickly lay the old "golf cart" image of electric cars to rest. Electric vehicles' outstanding performance and their lightening fast torque control, even in the lowest speed ranges, will play a critical role in this, and companies are spending increasing amounts on development in these areas.

The pilot trial announced by RWE and Daimler, to take place in Berlin from 2009 onward, is an ideal platform for introducing such electric vehicles. By working closely with OEMs, infrastructure

providers such as RWE are hoping to offer end customers attractive solutions for recharging their batteries at a competitive price.

Based on intense research, which included interviews with major players among OEMs, suppliers, potential infrastructure providers, and launch customers, we expect electric vehicles (which include battery-electric vehicles, i.e. BEVs, as well as electric vehicles with range extenders, such as the GM Volt, or plug-in hybrids, i.e. PHEVs, with a significant range in EV mode) to grab a market share of more than 10% in the global market by 2020 – varying by region and mostly depending on the level of governmental and infrastructure support.

The major results of our study are presented in this paper.

1.1 Zero-emission vehicles are needed

The current European Commission target level for CO2 fleet emissions of 130 g by 2012 can be reached only at great effort and cost by the car manufacturers. However, to reach the proposed 2020 limit of 95 g CO2/km, which corresponds to 4.0 l of gasoline, zero-emission vehicles (ZEVs) are almost inevitable (see Fig. 1) – even given the latest ICE technological developments with high improvement potential, such as thermal recuperation. Besides the EU, the Japanese government is in advanced discussions for similar CO2 fleet emission targets. Front-runners such as California in the US are requiring manufacturers to introduce ZEVs by 2014, independent of their fleet emission levels – with a number of other US states following suit. In China, it is highly likely that individual municipalities will extend the "inner city" ban of gasoline two-wheelers to four-wheelers, as soon as they see a viable chance for their home car industry to grab a significant share of the EV market.

1.2 Battery-electric vehicles (BEVs) are the best solution on the horizon

On a "tank-to-wheel" basis, all ZEV options, whether hydrogen- or battery-driven, have zero CO2 emissions. The key difference lies on the upstream "well-to-tank" side. Here the difference depends on the projected processes for creating, distributing and storing hydrogen on the one hand, and the CO2 emission levels of the different power plants to generate the electricity on the other hand. Almost all available studies show a significant advantage for battery-electric vehicles over hydrogen-driven cars. And even assuming modern coal-fired power plants as the source for electricity, there is an up to 25% reduction in CO2 emissions in comparison to gasoline-driven cars on a "well-to-wheel" basis.

Hydrogen options still suffer from the big questions on the infrastructure and system cost side. How can we afford a completely new production and distribution system? Who will pay

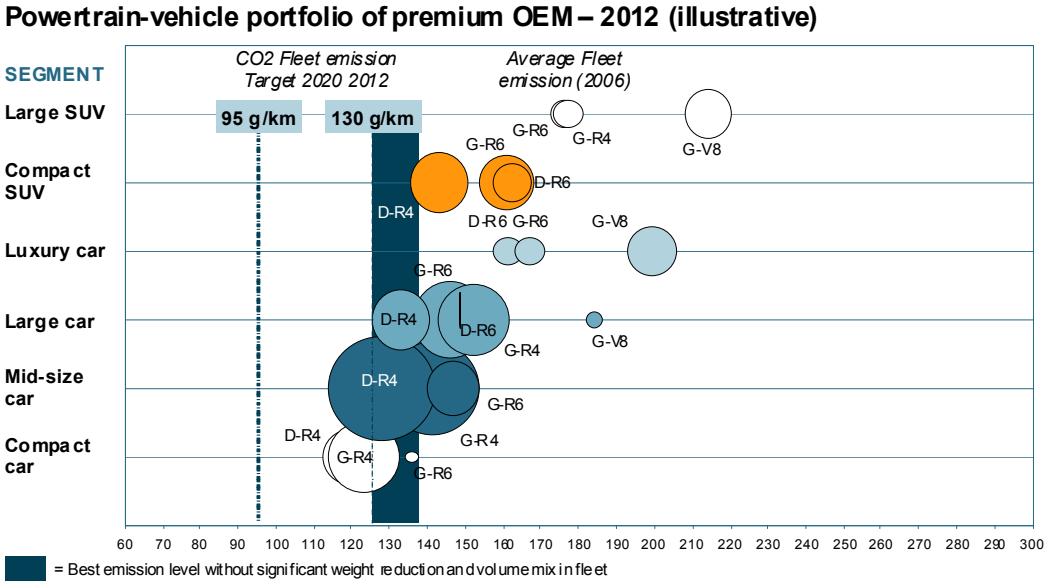

Figure 1: OEM fleet emissions after 2012 (Europe)

for it without making the hydrogen on an oil equivalent basis too expensive for the end consumer? And can the complex onboard system with storage, electricity production, and system control be price competitive with the alternatives? These types of open questions have led most key players to the conclusion that hydrogen powertrains will not be available in the foreseeable future, i.e. before 2020.

1.3 Li-Ion batteries finally become reliable, affordable and provide an acceptable driving range

The key concern for battery-electric vehicles to be ready for the mass market was always the availability of a battery technology that could provide the energy for an "attractive driving range" while at the same time addressing car safety issues and cost targets to be competitive with gasoline cars. With the announced introduction of Li-Ion batteries in the first cars by 2009, the safety and reliability issues appear to be resolved. Based on our research and numerous interviews with experts and key players in the field, we expect the first generation of mass-manufactured Li-Ion batteries for EVs in 2010/11 to enable an electric driving range of about 150 km at a cost of approximately 400 EUR/kWh, i.e. about EUR 8,000 for a 20 kWh battery pack. We expect further significant cost reductions for the batteries over the next 10 years with target costs as low as 200 EUR/kWh by 2020.

At the same time, further improvements in the energy density of Li-Ion batteries can be assumed, extending the electric driving range by at least 50% in the year 2020 (see Fig. 2).

So even by the year 2020, we do not see BEVs having the same driving range as ICE cars thereby limiting their use mainly to city and near-city driving. The two alternative solutions for "range extension" – fast charging or battery- exchange within a few minutes – will not be successful within the first years due to technical and customer acceptance reasons. Since EV market penetration will start in the big cities, we do not regard this issue as a problem for the market success of those cars. And within the next 5-10 years there will most likely be the necessary technical breakthroughs to either increase the battery capacities significantly or make fast charging a viable solution without hurting the battery life or creating other disadvantages.

On the supply side, today's key players from Asia in the field of NiMH hybrid car batteries or Li-Ion batteries for mobile devices will continue dominating the market. Yet despite this, a number of new players with significant capital backing in the US and Europe may have a chance to enter the Li-Ion battery market for EVs. Due to the planned application of more common materials for key

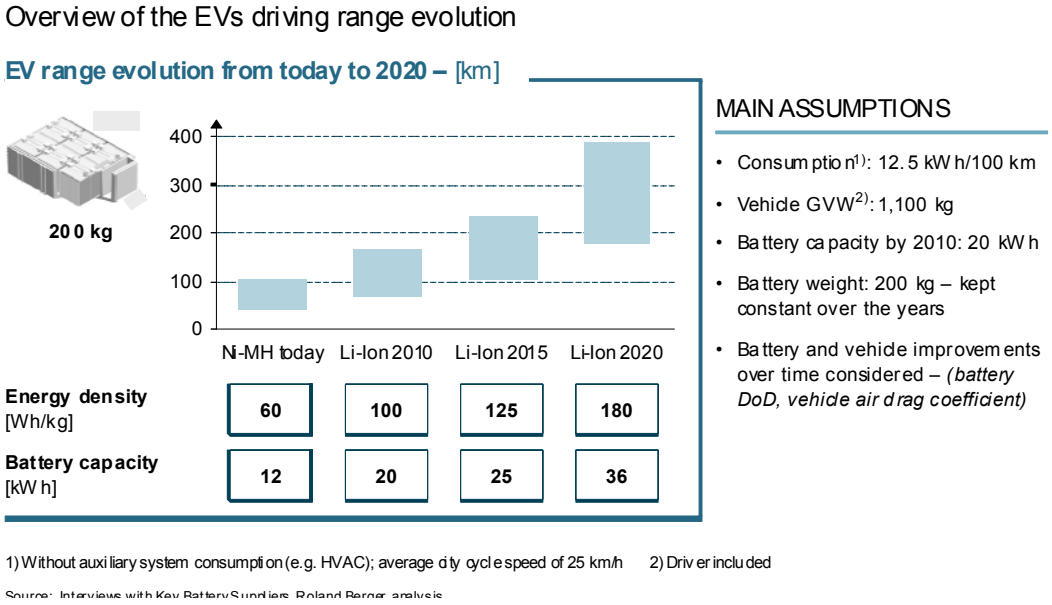

Figure 2: Expected Li-Ion battery performance

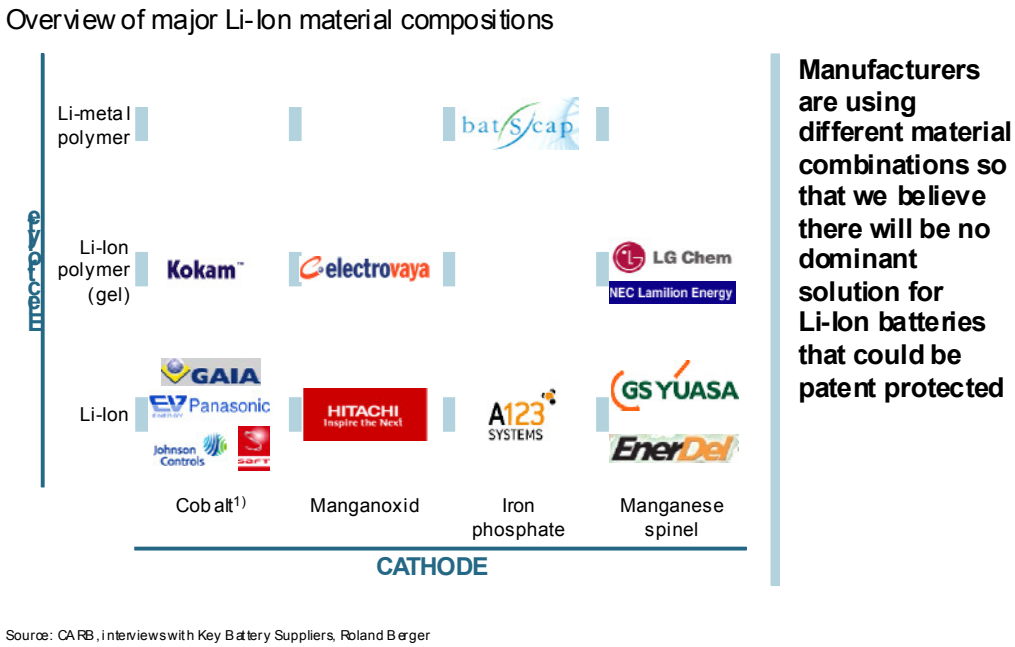

Figure 3: Key Li-Ion battery suppliers

components of the Li-Ion battery, we do not anticipate a shortage of raw materials; nevertheless, there is a risk of increasing material prices in general which may slow down the above-mentioned efforts to reduce the cost of the battery packs. Since there are still a number of competing chemical set-ups for the cell technology (see Fig. 3), we also do not foresee a similar IP dominance as in the NiMH battery field (with Cobasys from the US controlling the market for those batteries today).

1.4 Lower lifecycle costs and comparable performance characteristics will make electric vehicles very attractive

To what extent customers accept EVs depends heavily on the total cost of ownership and the comfort/performance level these cars provide. While an EV is much more expensive than an ICE vehicle with comparable functionality (due to the battery), the higher purchase price will most likely be compensated for by much lower consumption costs (annual gasoline costs versus electricity costs) and therefore lower total costs of ownership over the vehicle life. We expect a lifecycle cost advantage for BEVs and PHEVs for certain driving patterns with increasing gasoline prices, tax penalties and subsidies and cost reductions to be expected on the battery side.

However, a key issue will be whether new business models can be established to provide this cost advantage to the customer already at "day one", so that the initial purchase price disadvantage of EVs will not hit customers in the pocket. Innovative new players like Project Better Place are already creating possible business models for this area; i.e. selling the

customer "EV miles" on a very competitive price basis similar to a mobile operator model.

Having seen and driven quite a number of concept cars with the latest EV powertrain technology, we assume that the new generation of EVs coming to market in the next few years will be very competitive with current ICE-based cars in terms of performance and comfort. The old image of "golf carts" will disappear quickly and may even be reversed by the year 2020 as a result of the very attractive torque and response characteristics of e-motors.

1.5 Tax and other benefits will support the successful market launch of EVs

In the future, we expect EVs to be the only viable solution for avoiding city congestion or emission charges as in London, and may even be the only

cars allowed in certain mega-cities at all. The enormous market success of electric two-wheelers in China (having grown to more than 50% of annual sales within 7 years) is an impressive example of what government regulation can do to promote a new technology.

Tax incentives, already being discussed in many countries, will be used as another very important means to overcome the initial cost disadvantage of EVs and make the market launch of those cars even more successful. Israel and Denmark are setting the first prominent example by announcing purchase tax advantages of 62% and 180% for buying EVs, respectively.

CO2 taxes are already very high in some Western European countries, where Plug-in vehicles also have advantages in terms of their certification: Even with an electric range of 25 km they enjoy an additional certification advantage of around 30% in the New European Driving Cycle (NEDC) compared to "conventional" full hybrid models (which in any case already have relatively low fuel economy values). This gives plug-in vehicles a significant tax advantage for end customers, despite their higher costs.

1.6 A recharging infrastructure for EVs will be available at market launch

Another important factor driving customer acceptance is the availability of a recharging infrastructure at the beginning of the EV market launch. Some argue that EVs with range extender, such as the upcoming GM Volt, may not need a recharging infrastructure; however, we expect those cars to succeed in the market only with abundantly available recharging spots at public parking areas (see Fig. 4) so that city driving is conducted mainly in EV mode with all the cost and emission benefits. In addition, more people without an electric outlet in their garage could be reached, and the new "EV age" will be provided with much broader public awareness.

We see a number of utilities and other players in various countries already looking at the major revenue potential in this field combined with low incremental costs, since existing power plant capacity can be used and no grid upgrade is necessary in the first few years. The infrastructure rollout will start in the big cities with a significant proportion completed before the major market launch of the new EVs, as already announced by first players in this field. We see this happening in the next few years in all major car markets, from Los Angeles to London, Paris to Berlin as well as the megacities in Asia. With major cities and municipalities eager to provide their contribution for solving the "climate challenge" and making their city a front-runner in the field, there will be a self accelerating race of business partnerships and announcements in the coming years.

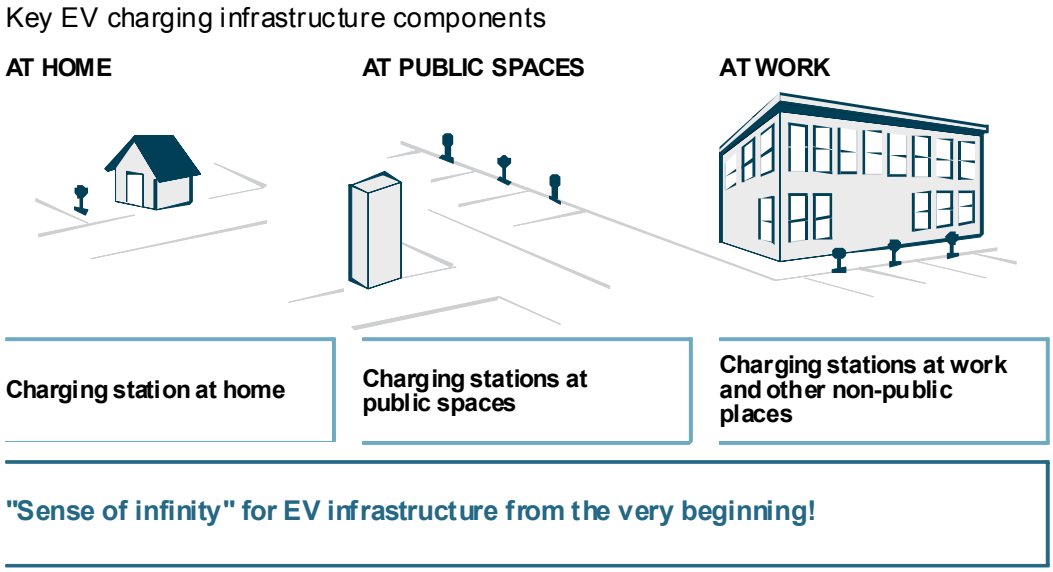

Figure 4: Set-up of expected EV infrastructure

1.7 A significant number of electric cars will be launched over the next few years

Pure battery-powered EVs (BEVs) are the dominant concept for the smaller, "city-like" car concepts and segments and are on the agenda of all major players. Some are already announced, such as the Mitsubishi MiEV and various cars from the Renault-Nissan alliance, while others are very close to the decision-making point.

Only Toyota and GM have announced the launch of PHEVs and EVs with range extender, but we assume other major car manufacturers will soon follow suit. These vehicle concepts are more complex and expensive than pure EVs, but provide a viable basis for all car segments since they do not have any range disadvantages in comparison to ICE cars.

The slow OEM reactions to this new trend in recent years have brought a number of viable new players to the market such as Think! and Miles for city cars, and Tesla and Fisker for sports cars. We also see the Chinese car manufacturers, notably BYD and Geely, regarding EVs as a major opportunity to close the gap in propulsion technologies to their global competitors.

2 Potential market development

To gain a picture of the potential market development, we analyzed a wide range of data on customer segmentation, driving profiles and running costs, as well as possible developments in energy and battery prices. We split electric vehicles into two groups: in one group, we put hybrid vehicles with an additional option for charging by connecting the battery to the power supply (so-called "plug-in hybrid electric vehicles" or PHEVs), including electric cars with range extenders; in the other group we put pure electric vehicles (EVs). We then looked at two possible scenarios. The **first scenario** is one of **aggressive growth,** with a significant drop in production costs for Li-Ion batteries and a continuing increase in energy prices on the scale seen in the last six to eight years, accompanied by ongoing expansion of the charging infrastructure. In the first scenario we also include increasing regulation of CO2 and other emissions, such as that already announced by the European Union. In the **second scenario** we consider **moderate growth** with the cost of batteries falling less sharply and moderate growth in energy costs, accompanied by much lower penalty taxes and duties. Below, we show how the market might develop in the major regions of the world where electric vehicles are sold, for each of the two scenarios (see Fig. 5).

In both scenarios, Western Europe will lead the way in terms of sales. This is mainly due to strict emissions requirements and tax penalties/benefits to be expected.

The trickiest area for forecasting market share is China. If the Chinese government decides to promote electric vehicles as a matter of policy, the country's share of such vehicles could be much higher than the level currently predicted.

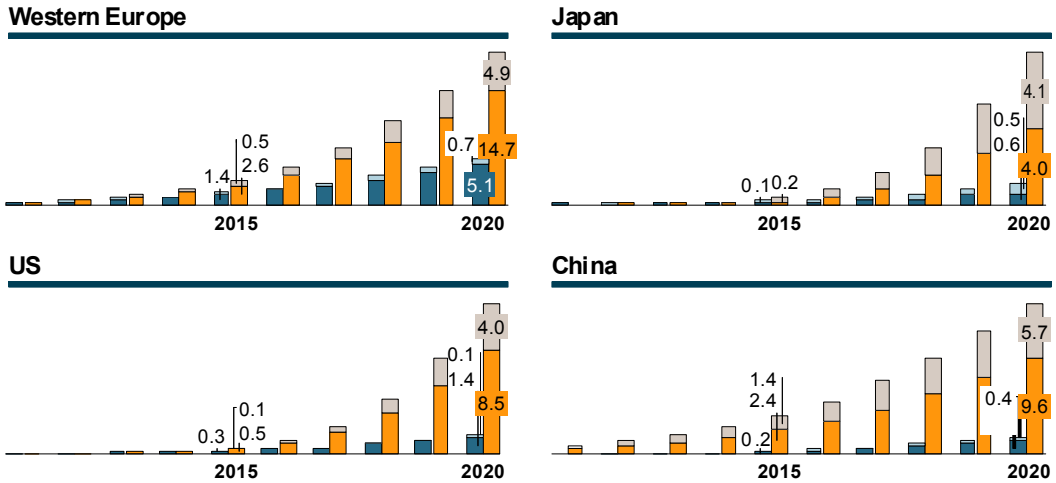

Figure 5: Global distribution of electric vehicles (% of vehicles sold)

3 Technology of the future

Fig. 6 shows the main powertrain configurations for hybrid and electric vehicles currently under development. Pure electric vehicles will remain the preserve of city cars/second vehicles (including "fun cars") for the foreseeable future. This means vehicles mainly in the A and B segments, but with all body types, from sports cars to mini vans. The reason here is the limited range of pure electric powertrains, due to the energy density and cost of batteries despite the advances in technology.

Cars with range extenders produced as serial hybrids show greater potential. This type of configuration will appear in vehicles of the compact segment and above – such as the upcoming GM Volt – and also small delivery trucks for city use.

Plug-in hybrids using parallel or power-split hybrid systems will mainly feature in the upper medium and premium classes, and in SUVs. This is because of their high system costs.

Where does that leave us? Well, the vast majority of passenger vehicles will still have combustion engines, albeit with much lower capacity and fewer cylinders than today on the whole. As far as range extenders are concerned – leaving aside ideas such as Wankel engines and gas turbines, now largely dismissed – we may see the emergence of very simple engines in which all the ancillary components are electrified. Optimized for fuel consumption and emissions, such engines can be produced much more simply and cost-effectively. Simple, low-consumption, low-emission, low-cost engines will play an even more significant role in growth markets in developing countries.

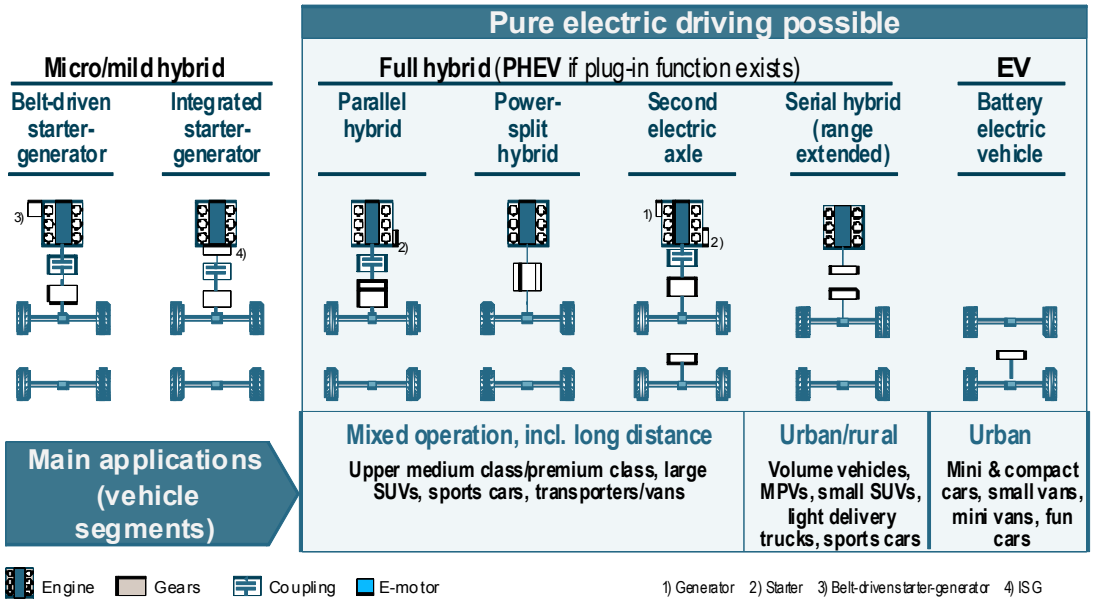

Figure 6: Powertrain configurations for electric driving

4 Opportunities for new players

As electric powertrain concepts come to the fore, the "competence edge" of established OEMs will erode away (see Fig. 7). Although established OEMs generally have much greater competence in overall vehicle design – something that new players may have to buy in – they have no advantage over newcomers when it comes to key new areas of development, such as battery technology or the design of electric motors. Indeed, in some cases they lag behind in precisely these areas. The problem is that established OEMs often have plants that are built around mass production. These plants offer no cost advantages for new powertrain configurations, at least in the case of pure electric vehicles. Worse still, their focus on traditional technology, and the supposed need to make use of existing infrastructure can prove a serious drawback when it comes to introducing new concepts.

Chances exist for newcomers to the market, such as Western niche players Think!, Tesla and Pininfarina, or low-cost manufacturers based in emerging markets. The former group is likely to maintain a niche role in the long term too. By contrast, manufacturers from emerging markets – China, in particular – face much wider business opportunities from the shift toward electric. Two good examples are BYD AUTO from Shenzhen and Tianjin Qingyuan. Both companies are pursuing a strategy of taking over the market via niche segments, a strategy successfully employed by other Chinese companies in the past.

BYD's core business is the manufacture of rechargeable batteries. There were good reasons why Warren Buffet's company Berkshire Heathaway acquired a 10% stake in BYD, listed on the Hong Kong stock exchange, in September 2008: In less than 15 years, BYD had moved from being a newcomer to a global leader in rechargeable batteries. The basis of the company's success is its high degree of vertical integration, which stretches as far as producing its own electrolytes and tools. In this way, the company benefits from all the advantages of its low-cost location in terms of costs and flexibility, while focusing on related research activity. BYD AUTO has been successfully producing passenger vehicles for the Chinese market for the last two years or so. It is now concentrating on producing plug-in hybrids and pure electric vehicles, initially for export to Israel. In addition to a research group in the area of batteries that numbers several hundred people, BYD claims to have around 1,000 employees working on alternative powertrain technology, in line with its aim to achieve long-term market leadership.

Tianjin Qingyuan is a joint venture between the partially state-owned Chinese CATARC (China Auto Technology & Research Center) and a number of Chinese manufacturers. These companies include the Tianjin Lishen Battery Company, whose Li-Ion batteries (LiFePO4) are used to produce a pure electric-driven compact car with a range of well over 100 km and a sales price of under USD 30,000. In 2007, Tianjin Qingyuan

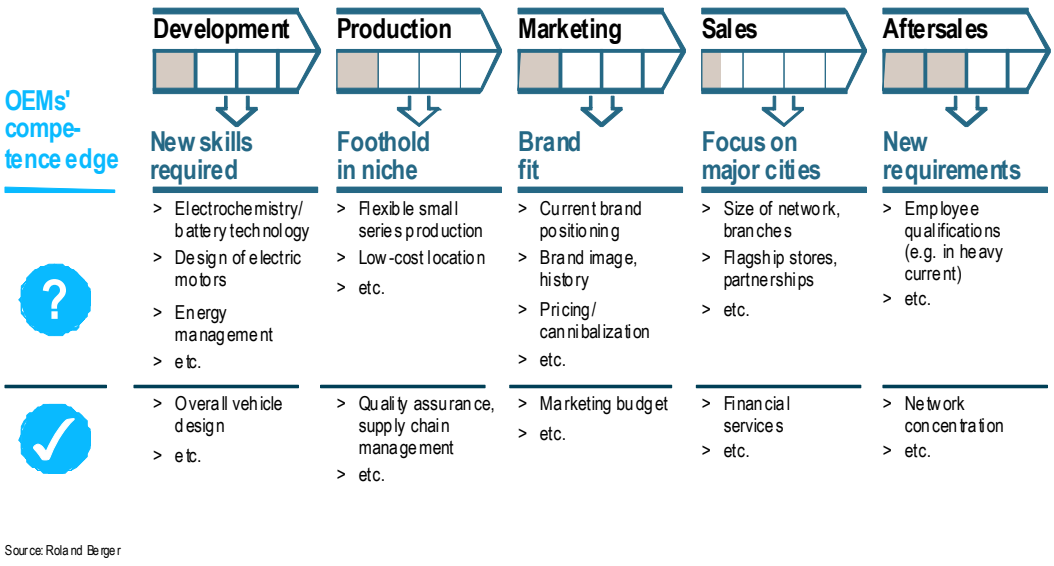

Figure 7: "Competence edge" of established OEMs

exported around 1,100 such vehicles (mostly with NiMH batteries), mainly to the United States. The company's medium-term goal is to achieve a leading position as a supplier of complete electric powertrains. It is also building a local supplier base for electric powertrains with the support of government agencies.

5 Challenges for OEMs

Established OEMs can't simply close their eyes to the challenges. They must develop and implement strategies aimed at exploiting the opportunities – strategies that are resilient even to changes in the overall market situation.

5.1 Manage complexity – reduce costs

OEMs must develop a broad technology portfolio, from new combustion processes and exhaust gas treatments to full electrification of the powertrain. They must introduce this technology in parallel across a wide range of vehicles. Of course, that means considerably more complexity and thus greater costs for established OEMs – with customers largely unwilling to pay a premium for the improvements in fuel consumption they have come to expect.

The spiraling number of different technologies and seemingly endless combinations of technical solutions with specific market requirements threatens to create a level of complexity for OEMs that is impossible to manage economically. What should the OEMs do? The answer is to streamline their technology portfolio rigorously. At the same time, they must pursue a global component strategy that meets the various regional requirements with a single set of modules. Partnerships and collaborations are increasingly important, too. As the level of hybridization grows and the influence of the powertrain application on the vehicle's handling characteristics becomes stronger, the arguments for companies going it alone to develop basic engines rapidly evaporate. And the same goes for hybrid and electric vehicle components, such as those used in electric motors.

6 Opportunities for OEMs

New vehicle concepts offer opportunities for new business – such as an affordable city car, or vehicles targeting specific customer groups. This is particularly the case with pure electric vehicles or those with range extenders, which offer much more creative freedom for innovative vehicle packaging.

Such cars have limited chances of market success, however, if they cost 50% more than comparable conventional vehicles. Even in cities with a high congestion charge, such as London, customers are easily put off by a high initial purchase price. The battery is the main extra cost element. Here, alternative financing models can be effective, such as those developed by "Project Better Place."

OEMs can develop their own attractive financing models too. They can do this by collaborating with energy providers, for example. Here, they should take re-utilization options for batteries and opportunities for additional business into account in their business plans right from the beginning. The following are some examples of activities that could generate additional revenue and profit streams:

- Operating a recharging infrastructure at vehicle-owners' homes, workplace parking lots, public parking areas and garages in cooperation with B2B partners, such as the operators of parking garages, shopping malls, etc.
- Operating "fast charge stations" and marketing the relevant system components
- New mobility concepts in which batteries are leased to the consumer or form part of a wider offer

Despite these developments, it remains uncertain how fast electric powertrains will come into general use. Given the current credit crunch, for many players the most attractive option may seem to be to wait and see. But this means losing precious time. Now is the moment for OEMs to examine critically what pieces of technology will truly make them stand out from their competitors. They need to streamline their development portfolios, focus their R&D team and have the courage to drop developments that are going nowhere. On top of this, they must build

partnerships that will generate economies of scale and thereby reduce their costs.

7 Implications for suppliers

For suppliers, the increasing electrification of the powertrain brings both risks and opportunities. On the one hand, simpler motors used as range extenders and the growing number of pure battery-electric vehicles mean substantially lower market volumes for specific mechanical components. At the same time, however, new growth chances are appearing, for example in hybrid and battery components.

Suppliers should look at the different potential market penetration scenarios and weigh up the implications for their product portfolios. They must ask themselves the following questions:

- How will the electrification of the powertrain influence the market potential of our current and future product portfolio? Where will there be growth, where will there be decline, and what customer requirements can we anticipate?
- Which technologies will be winners? Where are the opportunities, and where are the threats? How should we balance our project portfolio in R&D? Are our priorities in terms of funding, resources and timing right?
- Where are our strengths and our weaknesses? Can we – and should we – increase our competences in certain areas? Can we get access to strategic competences by making acquisitions now?
- Can we do it alone or do we need partners, and what should our partnering strategy look like? Are our R&D footprint and cost structures appropriate for coping with the coming challenges?
- Do we have the right organizational setup – not just for the long term, but also in the short term to make change happen?

Authors

Michael Valentine-Urbschat
Principal

Masters Degree in Mechanical Engineering and MBA from INSEAD. More than 10 years of management experience in the aviation and automotive industry – focus on powertrain R&D. 5 years as CEO of a small Venture Capital Boutique for high-tech start-ups in Germany. Since 2007 Principal at Roland Berger Strategy Consultants in Munich, Germany.

Dr. Wolfgang Bernhart
Partner

Master Degree in Mechanical Engineering, PhD in Production Technology. More than 15 years of experience in the automotive consulting business. Since 2007 Partner at Roland Berger Strategy Consultants in Stuttgart, Germany.